APPENDIX Y

Pipeline Stream Crossing Construction Mode Determination
Pipeline Stream Crossing Construction Mode Determination
1. **Introduction**

The purpose of this document is to identify the modes of pipeline stream crossing construction to be used on the Alaska Stand Alone Pipeline (ASAP) project. The document attempts to outline in detail the various aspects of pipeline construction, including: specific modes; pipe protection, insulation, and buoyancy control; cover depth criteria; bank protection measures; and mitigation measures. As a supplement to this document, a *Pipeline Stream Crossing Construction Mode Determination Manual*...
(Attachment A) has been developed to guide the Engineer in crossing mode selection at each site and document supporting information and considerations used by the Engineer in crossing mode selection. A Mode Determination Support Table will be developed to identify all relevant information, pertinent decision variables, and engineering notes that were the basis for crossing mode determinations. The table and associated data will be incorporated into an ArcGIS geodatabase.

While the following sections highlight some standard project considerations, the Engineer and Contractor should establish and implement appropriate mitigation plans and Best Management Practices (BMPs) to ensure a successful waterway crossing that minimizes potential impacts and will provide a reasonable level of protection to the aquatic and terrestrial habitat.

2. **Pipeline Stream Crossing Construction Modes**

This document discusses in some depth stream crossing construction modes and considerations relevant to mode selection, design, planning, construction, and mitigation. Economics are always a key consideration in mode determination, though little discussion is dedicated to this matter here. It can be said that cost will generally increase in the order of open cut, isolated open cut, drilling, and aerial span crossings. However, site conditions may incur higher costs for trenching beyond the cost of trenchless methods. This is typically concurrent with increased levels of difficulty and risk associated with site conditions and the specific limitations of each crossing mode.

All instream construction activities impact waterway ecosystems with the disturbance of the stream bed and banks, typically resulting in short term pulses of suspended sediments. This episodic sediment loading may result in acute impacts to adult and juvenile fish and possibly chronic impacts to eggs and fry if the associated habitat falls within the zone of impact. All instream activities should be conducted in a manner that reduces sediment loading of the waterway and limits the extent of downstream impacts. Open cut methods, where surface water is present, yield the largest potential sediment loading concentration of instream methods. Open cut activities should be performed during annual low flow conditions and as expeditiously as possible. Isolated methods more effectively mitigate increased sediment loading than do open cut methods while eliminating the risk of frac-out (i.e. release of trenchless drilling fluids into the watercourse). Isolation methods employ measures to minimize silt-laden return flows downstream of isolation, both during construction and the decommissioning of isolation structures.

While horizontal directional drilling (HDD) is commonly identified as the most environmentally sensitive method of crossing a waterbody below grade it is not without its own risk of impacting the aquatic ecosystem. Frac-out has significant impacts both to the environment and the project budget and schedule. Under the right conditions, drilling can be a safe, expedient, and cost effective way of crossing a waterbody. However, past case histories discussed in subsequent sections suggest that the occurrence of drilling success is less than that experienced when implementing trenching methods.

Below is a discussion of various crossing modes and general BMPs to be considered.

2.1 **Trenching**

Crossing a waterbody by way of trenching involves the physical removal of surface materials to achieve the required burial depth of the pipeline. This excavation of a trench can be performed in both wet and dry conditions, though the amount of water will typically dictate the trenching method of choice. Once
the pipeline is in place, the trench is backfilled and the stream restored to pre-construction conditions. The greatest concerns of trenching include deleterious impacts to aquatic and riparian habitats, and destabilization of stream banks resulting in accelerated thermal and mechanical erosion. Below is a list of general BMPs for trenching followed by discussions and considerations of open cut and isolated open cut trenching modes. This section will conclude with a summary of case histories of trenched crossings, with the goal of presenting real world expectations and caveats to be considered during mode selection, planning, construction, and mitigation activities.

General BMPs include:

- Locate extra work areas (e.g. fabrication and staging areas) at least 50 feet from water’s edge when practical, and no less than 30 feet from the water’s edge when approved.
- Locate fueling and fuel storage at least 100 feet from streams and waterbodies. When conditions require refueling within 100 feet of waterbodies, the Contractor must implement a preapproved spill prevention and cleanup plan.
- Limit extra work area sizes to that needed to construct the stream crossing.
- Ensure all established erosion and sediment control measures are implemented across the work area.
- Store as much instream spoil on the banks as is practical (additional temporary workspace may be required). When placing spoils in the active channel, deposit spoils in long piles oriented parallel to flow to minimize erosion, avoiding areas of highest water velocity.
- Construct berms or other sediment barriers to prevent saturated spoils on banks from flowing back into the waterbody. If working at a dry crossing, berms will not likely be required unless groundwater and saturated spoils are encountered.
- Retain a 30 foot buffer from the stream bank of undisturbed vegetation during initial clearing, except where needed, for equipment crossing. Sediment control measures will be in place prior to construction within the 30 foot vegetation buffer.
- Limit clearing of vegetation between the waterbody edge and extra work areas to the project right of way (ROW).
- Salvage and store vegetation layer to aid in bank reclamation following construction.
- Grading of stream banks for trenching equipment will be limited to the trench line.
- Grading of work areas will be directed away from the waterbody to minimize runoff entering the waterbody.
- Temporary or permanent vehicle crossings may be constructed, as required.
- Maintain natural stream flow rates at all times.
- Retain undisturbed native soils (hard plugs) between the stream and overbank trench. These will remain in place during instream excavation to prevent diversion into the open trench. Trench plugs will be removed immediately prior to pipe placement and backfilled once the pipe is in place.
- Install trench breaker (soft plug) adjacent to waterbody where consolidated soils or organic materials are prone to washing out.
• If necessary, install soft plugs and dewater trench in a manner that does not cause erosion and inhibits silt-laden water from entering the waterbody.

• When performing instream blasting, implement blasting methods that minimize overall shockwave, deploy air bubble curtains to dampen shockwave, limit blasting to times of least environmental/biological impact, displace fish from blast area using approved methods, use confined explosives, and avoid using ammonium nitrate based explosives.

• Install approved instream sediment controls, such as sediment mats or geotextile blankets, as necessary.

• Complete fabrication (welding, coating, weighting) and testing of instream pipe string well in advance of completing instream trenching activities.

• Utilize “push-pull” or “float” techniques to place pipe in trench whenever conditions allow.

• Place pipe in trench and backfill immediately. Restore stream channel to approximate preconstruction profile using clean gravel or native materials for the upper 1 foot of backfill.

• Backfilling generally consists of replacing the excavated material, however, clean gravel may be used as backfill when excavated materials increase potential downstream sedimentation, increase scour potential, or do not provide sufficient groundwater flow around the pipe. Where surface material has been segregated, in the case of an armor layer overlying fine grain materials, subsurface material will be replaced in the stratified order it was removed.

• Prior to backfilling, the trench will be dewatered as necessary. The pump intake shall be suspended above the trench bottom and water discharged over a well vegetated upland area with appropriate energy dissipation; splash pup, splash plate, plastic liner, non-woven sediment filter bag, or straw bale dewatering structure. Dewatering activities will be performed such that no silt-laden water is discharged to the stream.

• Backfill from the center of the stream towards the bank to direct silt-laden water toward the plugs where it can be pumped and discharged. Lower bucket into water before releasing backfill.

• It is the Contractor’s responsibility to meet the necessary water quality standards and requirements set forth by regulatory agencies.

• No backfill crown will be placed in the waterway. Ensure that the channel profile and gradient are returned to preconstruction conditions.

• Ensure backfill is well compacted on approach slopes and stream banks.

• Stabilize banks and install temporary sediment barriers within 24 hours of completing instream construction. For isolated trenching, restore channel geometry and stabilize banks prior to returning flow to the watercourse. Grade banks back to preconstruction contours when practical, or to an approved stable angle of repose.

• All instream work will comply with construction timing windows and conditions permitted by the appropriate regulatory agencies and applicable permits. Ideally, all instream work will be completed within 24 hours on minor streams and 48 hours on intermediate and major waterways when conditions allow.
Vegetative stabilization techniques are preferred where feasible. If soil and/or flow conditions dictate use of riprap or non-native materials (e.g. geogrids) for bank stabilization their placement must comply with authorizing agencies.

Install permanent erosion and sedimentation control measures, including revegetation of riparian areas.

Clean-up water crossing work areas immediately following backfill and erosion control installation. When winter clean-up is impacted by frozen spoils complete rough clean-up prior to breakup and final clean-up after breakup.

1. **Open Cut**

Open cut will be the most common crossing method used for the project. This mode entails excavating a trench across a stream or river bed and pulling, carrying, or floating the pipe into position. Open cut methods can be used both in open water and dry conditions. Conventional excavation equipment, such as backhoes, dozers, mechanical ditchers, and draglines, are generally used to excavate the trench. Equipment may operate in the stream bed when approved, though most operations will occur with equipment being staged outside of the water’s edge if present at time of construction. Some stream beds may require blasting. All blasting operations will be controlled and monitored. The trench will be excavated and spoils placed outside of the stream bed, where conditions warrant. Larger river crossings may require that spoils be placed within the stream bed. Following excavation, prefabricated pipe strings will be lowered into the ditch, fitted with necessary buoyancy control, and covered with backfill. Backfilling will be accomplished from the center of the stream, working toward the water’s edge if present at time of construction. Following pipeline burial, the stream will be stabilized using approved restoration methods and temporary vehicle crossings removed. A general schematic of open cut trenching modes at small and large crossings are presented in Figure 1 and Figure 2, respectively, in Attachment B.

2. **Isolated Open Cut**

Isolated open cut crossing methods will be employed at locations where flow conditions make open cut technically impractical or where fish habitat sensitivity dictates. The isolated method is similar to open cut, but typically involves damming the waterway and redirecting flow to allow dry excavation. A brief description of preferred isolation methods are presented below:

* **Dam & Pump**

Dams will be constructed with materials that minimize sediment and prevent pollutants from entering the waterway, such as geotextile bags or clean gravel with liners. Pumps will be installed, operated, and continually monitored for sufficient flow to maintain natural flow volumes. A practical upper limit to consider for pumping is 35 cubic feet per second (cfs). On-site backup pumps will be in place to maintain natural flow volumes in the event of pump failure, ensuring adequate and redundant power supply for pumps. Pump intakes will be screened. Pump discharge should be located to minimize streambed scour and bank erosion. Channel morphology and flow conditions may allow for the use of pumps without the use of dams, commonly referred to as sump and pump; a channel having a pool-riffle or beaded sequence could have pumps placed in a natural pool or bead upstream of a riffle. Pumps will drawdown water surface elevations such that surface flow through the downstream riffle would terminate. Clean water will be discharged sufficiently downstream of the crossing site to prevent backflow into the...
excavation. If isolated pools persist between pump intake and discharge, fish salvage may be necessary. In either case, pumping is not a suitable isolation method for streams requiring fish passage. A general schematic of isolated open cut trenching using the dam and pump method is presented in Figure 3 in Attachment B.

**Flume**

The use of flumes can facilitate fish passage in relatively narrow, straight channels when necessary or when pumping cannot achieve required flow rates. Similar to the pumping method, dams will be constructed with materials that minimize sediment and prevent pollutants from entering the waterway, such as geotextile bags or clean gravel with impervious liners. The dam should be constructed to form an effective seal with the channel and divert stream flow through the flume without introducing sediment to the water. The flume pipe(s) can be installed after blasting, if required, but prior to trenching. The flume pipe(s) used will convey no less than the natural channel flow volume at the time of construction. A practical upper limit to consider for using a flume is 250 cfs. The flume pipe(s) will be oriented to avoid impounding water upstream and minimize streambed scour and bank erosion downstream. Flumes will be constructed to facilitate fish passage when required. A general schematic of isolated open cut trenching using the flume method is presented in Figure 4 in Attachment B.

**Diversion**

The diversion method employs existing conveyance paths to route flow around the excavation site. The diversion method may be used at waterways with more than one channel or active conveyance path such as in braided streams. Ideally, diverted flow will be isolated to channels that are normally active during ordinary high water conditions, rather than abandoned paleochannels or canals cut into the floodplain. Ensure that diverted flow can be conveyed within the diversion channel without changing the hydraulic nature of the channel; avoiding bed scour and bank erosion. An abandoned channel may also be used to convey flow, so long as steps are taken to minimize flushing of sediments and preconstruction flow conditions are restored to ensure the abandoned channel remains abandoned following construction. Diversion dams will be constructed with materials that minimize sediment and prevent pollutants from entering the waterway, such as geotextile bags or large grained materials with impervious liners. The use of flexible conduit may be necessary to convey water to a neighboring channel. Tie-ins will be completed following instream construction in areas that are isolated from stream flow at the time of construction. A general schematic of isolated open cut trenching using the diversion method is presented in Figure 5 in Attachment B.

General BMPs listed in the above open cut section apply to isolated methods where relevant. Additional BMPs for isolated open cut trenching methods include, but are not limited to:

- Multiple methods of isolation may be required to achieve suitable working conditions at an individual crossing.
- Pump intakes must be screened and located so as not to disturb the streambed.
- Additional erosion protection and/or energy dissipaters may be required downstream of the pump or flume outlet.
- Pumps, flumes, and dams will remain in place until after construction and restoration of streambed and channel banks is complete at the pipeline crossing.
- Any additional restoration of streambed and channel banks will be completed within 24 hours of dam removal when feasible.
The dam removal process will minimize silt-laden discharge to the greatest extent possible.

3. Case Histories & Lessons Learned

Attachment A of Pipeline Associated Watercourse Crossings (CAPP et al. 2005) provides a case history summary for various water crossing modes. It provides insight into common and not so common occurrences during stream crossing construction. Key aspects of the case histories for trenching mode construction are presented below.

**Open Cut**

When trenching with backhoes under open water conditions, a dramatic increase in suspended sediments and benthic drift were common. This impact was limited to the period immediately following construction, typically only 24 hours, with no long term negative impacts. Small stream crossings (<10 meters wide) were completed within 24 hours and medium streams (10-20 meters wide) were completed in 48 hours, with a few exceptions requiring plow-in trenching, blasting, and spoil transport to offsite storage areas. On large streams (>20 meters wide), hoes were typically used with instream construction times ranging 1-3 days for streams < 50 meters, with one stream of 885 meters wide requiring 60 days to complete. Longer construction times were typically the result of adverse conditions including; extreme widths, very sandy substrate, very steep and long approach slopes, and deep channels requiring construction pads for hoes.

In general, open cut methods were always successful with a range of difficulty and degree of success. Well-constructed, highly successful crossings were well planned, had sufficient equipment and experienced crews, and were completed in as little time as practical. Low success crossings were typically too soft or sandy, the Contractor was slow or disorganized, poor use of instream sediment control measures, undersized equipment under the poor advice of inspectors and government representatives, and flooding conditions during construction.

**Dam & Pump (Isolated)**

The dam and pump method was typically used on crossings less than 10 meters wide though there were cases of 15-75 meter wide crossings. Conventional sandbags were most commonly used to construct dams though larger one cubic meter bags were used on larger high energy water crossings. Alternative dam construction methods employed pea gravel bags and impermeable liners, gravel and rock with and without liners, and plate steel. In some cases, the work area could be isolated by pumping from existing upstream pools without the need for a dam (sump and pump method). Success was in nearly all cases dependent on the ability to create a good seal or maintain a dry work area. Plate steel dams were very successful when conditions allowed, with excellent success achieved from the sump and pump method without the use of dams. Sand bags worked well, though proper construction was imperative. Construction was typically completed in 24 hours or less, with longer work windows being the result of poor planning.

In general, dam and pump methods were successful, with all difficulties resulting from poor planning. Success is dependent on the identification of reasonable need for dams (using the preferred sump and pump method when conditions allow), construction of high quality impermeable dams, adequate stream flow calculations and oversizing of pumping capacity (150% of anticipated flows), storing spare equipment and fuel on site, and a contingency plan for possible problems.
**Flume (Isolated)**

Flumes were implemented on crossings exceeding 10 m in width and as wide as 200 m. Flumes were typically large diameter pipes with flange plates, usually with multiple pipes welded to each flange plate. The use of pumping was not uncommon to supplement flumes in downstream conveyance, and manage groundwater intrusion and seepage into the work area. Conventional and large sandbags with impermeable liners were typically used to construct the dams, though additional methods were used. In some cases, the temporary vehicle crossing was used as the upstream dam.

The success rate of flumes was rather low in comparison to other trenching methods, suggesting that their use may not be the best choice unless conditions are ideal. Problems with difficult and failed crossings included poor planning, implementation on sinuous channels, short flumes limiting ditch width and work area, poorly sealed dams, undersized equipment including flumes and pumps, organic banks and substrates, and steep approach banks that prevented threading of pipeline under the flume.

**Diversion (Isolated)**

Diversions were constructed by way of various methods, including sandbags, aquadams and median barriers, and instream cobble and gravel bar material. It was not uncommon to use pumps or flumes in conjunction with diversions to handle seepage and groundwater, as well as reduce conveyance down the diversion channel. Instream construction timing windows varied according to the size of the crossing, from 2-17 days. Of the diverted crossings that were monitored where flow was diverted through natural channels, none experienced increased suspended sediment as a result of diversion. Construction of canals for diverted flow resulted in excessive amounts of suspended sediment.

Generally, diversions were successful when planned and implemented appropriately. Difficulties were limited to inefficient diversion of water, erosion of the diversion channels (typically constructed or paleochannels), and placement of spoils with increased susceptibility to erosion.

### 2.2 Trenchless

Trenchless methods of crossing attempt to avoid or significantly reduce direct disturbance of waterways and bounding riparian habitat either by drilling under the waterway or spanning the waterway with a super structure (aerial span). They can be effective methods with relatively low environmental impact to water quality and stream bank integrity. Drilling may include a number of methods including the commonly implemented HDD method, horizontal directional boring (HDB), slick boring, ramming, direct boring, and micro tunneling. The use of HDD, HDB, micro tunneling, and slick boring allow for a controlled vertical curve drilling path of the pipeline that can target acceptable layers of substrata and predefined entry/exit points, while achieving adequate burial depth to account for scour and channel migration. Slick boring and micro tunneling typically require excavation of working bore pits or bell holes for the rig. Ramming and direct boring are non-steerable systems requiring a near straight drill path and bell holes on each side of the crossing excavated to the final burial depth. Below are discussions and considerations of trenchless drilling methods. Common types of aerial spans are also briefly discussed.

#### 1. Drilling

Under the appropriate conditions, drilling can be a cost effective crossing method with no direct impact on environmentally sensitive waterbodies. However, this method is considered high risk given the level of potential impact to the waterway in the event of frac-out, as well as potential increases in cost and schedule delays in the event of failure. A frac-out response plan that includes measures to terminate...
drilling, contain drill mud, prevent further migration into the waterway, and notification procedures should be developed and implemented, as needed. A contingency plan for crossing the waterway should also be developed prior to drilling in the event that the chosen drilling method is unsuccessful. This includes a plan for sealing the abandoned drill hole. General schematics of drilling methods using HDD and direct boring are presented in Figure 6 and Figure 7, respectively, in Attachment B.

General BMPs for trenchless drilling modes include, but are not limited to:

- It is the Contractor’s responsibility to notify the Engineer and Owner of any concerns regarding the drilling design or site conditions that may increase the risk of failure at any time prior to or during construction.
- The Contractor should provide a drilling execution plan that addresses all aspects of the drilling program at each site. Key components of the plan may include; details of each step in operations, detailed drawings, equipment specifications, workspace and water requirements, drilling fluid design plans, monitoring and reporting plans, and contingency plans including mitigation.
- Ensure drillers are provided with all available and necessary data for a clear understanding of subsurface conditions, including existing utilities, and engineering design criteria (i.e. No Drill Zone and proposed drill path) specific to the crossing prior to drilling.
- Ensure temporary workspace has been obtained for monitoring drilling and for pipe string prefabrication and testing.
- Setup drilling equipment away from the edge of the waterbody; do not clear or grade within the established riparian buffer zone.
- Excavate bell holes beyond the top of bank, a minimum of 100 feet from any waterway to preserve riparian habitat and contain any sediment or deleterious substances.
- Ensure only bentonite based drilling mud is used with no additives unless prior approval has been granted by appropriate regulatory agencies.
- Water from an approved source will be used to prepare the drilling mud slurry and will be obtained according to applicable permits.
- Drilling mud and slurry will be stored in approved enclosures to ensure it does not enter the waterway, neighboring wetlands, or off the immediate workspace.
- A mitigation plan for all trenchless drilling operations will be developed to address measures to be performed in the event of drilling fluid release onto the ground or waterway. Keep all material and equipment needed to contain and cleanup drilling mud release on site, readily accessible and in proper working order in the event of frac-out or a spill.
- Install appropriate erosion and sediment control structures downslope of drill entry and exit points to contain any release of drilling mud.
- Employ full time inspectors to monitor for any inadvertent drilling fluid release into the waterway and functionality of erosion and sediment control structures. A detailed monitoring plan will be established and approved by permitting authorities prior to drilling operations.
All excess drilling mud will be disposed of in a preapproved manner (e.g. hauled to an off-site disposal location).

All casings used to manage and monitor mud returns will be removed following construction.

The Contractor will provide an as-built report with drawings, as well as a compilation of monitoring reports at the end of construction.

2. Drilling (HDD specific) Case Histories

Attachment A of *Pipeline Associated Watercourse Crossings* (CAPP *et al.* 2005) provides a case history summary for various water crossings modes, including HDD. The lessons learned here can be applied with some consideration to boring and ramming methods. As with any crossing method, the feasibility of drilling is limited by site conditions, particularly soil conditions, available workspace, and geometric constraints. Case studies suggest that drill mud seepage can occur in all soil types, but is most likely in the presence of permeable zones having minimal cover between the drill path and the bed of the waterway. Higher incidents of drill mud seepage and drilling difficulties (i.e. loss of equipment, bore hole collapse, damaged pipes) were encountered at sites characterized by large grain sized material (gravels, cobble, boulders) than for sites characterized by fine grained and consolidated materials. Feasibility of HDD success decreased with increased subsurface grain size and pipe diameters. Mud seepage is typically isolated to point sources along the drill path. Seepage can be mitigated to some extent by reducing mud pressure and using corrective measures outside the waterway (e.g. containment berms and vacuum trucks). Of the 146 cases reviewed, the incidence of drill mud seepage was less than 14% for small and medium pipe diameters and approximately 85% for large diameter pipes (> 24 inches). Reported difficulties included loss of the borehole, pipe damage during pull-back, equipment losses via jamming or breakage, and inaccurate steering control. In response to difficulties, boreholes may have been abandoned for a second drilling attempt or alternative crossing methods.

The purpose of the mode determination process is to identify the ideal crossing mode for site-specific conditions, such that failure and borehole abandonment will be mitigated to the greatest extent possible. Case histories for large diameter pipes suggest that trenchless drilling methods have a lower rate of success than trenching methods. As such, trenchless drilling methods should require a high level of consideration and substantiating support as a preferred choice over trenching methods.

3. Aerial

The aerial span method involves suspending the pipeline aboveground over the waterway. An aerial span can include one of the following approaches:

- Suspension from an existing structure
- Single-span bridge with no instream supports
- Multi-span bridge with at least one support in the waterway

Possibly one of the most costly methods of stream crossing, aerial spans are reserved for the most difficult crossing conditions, or where existing infrastructure can be easily retrofit to carry the pipeline. It is anticipated that the ASAP alignment will implement aerial spans at a limited number of crossings.
3. **Pipe Protection, Insulation & Buoyancy Control**

3.1 **Coatings**

All buried portions of the pipeline not exposed to high abrasion soils or high soil stress will be coated with fusion bonded epoxy having a minimum thickness of 14 to 16 millimeters and compatible with the cathodic protection system. Coating will be 3M Scotchkote Fusion Bonded Epoxy Powdered Coating 226N+ or equivalent.

Aboveground piping will be coated with fusion bonded epoxy and an insulation system or an epoxy primer and a suitable urethane top coat.

In high abrasion areas and at HDD crossings, the coating system will be supplemented with a proven abrasion resistant coating compatible with the cathodic protection system, such as POWERCRETE DD.

3.2 **Insulation**

To ensure proper cathodic protection, insulated pipe will not be used at stream crossings. Board insulation may be used at trenched stream crossings in an effort to minimize frost bulb formation beneath the crossing, and subsequent impacts to groundwater and below ice surface water conveyance.

3.3 **Buoyancy Control**

Depending on the overall length of waterway crossings and types of soils within these areas, buoyancy control may not be required. Commonly, where forces resisting flotation (pipe weight, overburden, soil strength) exceed 110% or more of the buoyant force (calculated using appropriate specific gravity) buoyancy control will not be required. Where the forces resisting flotation are, at minimum, less than 110% of the buoyant force, buoyancy control measures may be required.

Potential buoyancy control measures include increased pipe wall thickness, concrete coating, bolt-on weights, or saddlebag weights. Refer to the ASAP Pipeline Design Basis for more specific information on buoyancy control measures and selected negative buoyancy for pipeline design at stream crossings.

4. **Depth of Cover**

Project criteria for depth of cover at stream crossings are presented in Table 4.1. Depths are presented as the minimum allowable and are based on criteria established in the Right-Of Way Lease ADL 41899749 and CFR 192.327 and. Additional depth of cover may be applied to account for potential scour, channel migration, and/or buoyancy control.

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<th>Location</th>
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Section 3.13.2 of the Right-Of Way Lease stipulations states that minimum depth of cover will be at least twenty (20) percent of the computed scour depth, but will not be less than four (4) feet. To account for
uncertainties in scour estimates the selected minimum depth of cover will be five (5) feet at stream crossings.

Per 49 CFR 192.325, the pipeline must be installed with at least 12 inches of clearance from any other underground structure not associated with the pipeline. If this clearance cannot be attained, the pipeline must be protected from damage that might result from the proximity of the other structure. Owners of structures (such as foreign pipelines) may have their own criteria. Site-specific stipulations will be included in the Pipeline Design Basis, as required.

5. Approaches

Grading may be required for equipment access and staging. Approaches will be graded to allow required access of necessary vehicles and equipment. Approach slopes will be graded to a safe and reasonable slope for the soil types present. Surface water runoff will be controlled via permanent slope breakers and approved erosion and sediment control structures to minimize erosion and ponding. Methods of preparing and restoring approaches will be presented in appropriate mitigation plans under separate title.

6. Bank Protection

During construction every effort should be made to minimize impacts to the active floodplain and channel, thereby reducing the level of site reclamation. Stream banks pose a significant level of concern, particularly in the presence of fine grained soils and permafrost. Destabilized, unprotected banks can accelerate channel migration and/or direct flow along the pipeline ROW. To mitigate potential impacts to the pipeline and restore local hydraulic conditions and habitat, bank restoration and protection will be required for trenching modes.

All stream banks should be restored to as near pre-construction conditions as possible. The stream bank elevation should be re-established to tie into existing grade. If practicable, stream banks will be stabilized and temporary sediment barriers installed within 24 hours of completing the pipeline crossing.

Site conditions and material availability will dictate the method of bank stabilization. Ensure that erosion and sediment control measures are implemented and functional until long-term bank stabilization has been established. In thaw unstable soils where permafrost and ice lenses persist, incorporate thermal barriers as quickly as possible to inhibit thermal erosion and seepage into the pipeline ROW. Stream crossing design will not rely on bank armoring or river training works to maintain pipeline integrity without substantive reasoning, such as impractical overbank construction, presence of adjacent facilities, or environmental concerns. If conditions dictate (e.g. excessively steep, unstable banks or excessive flow velocities) engineered bank protection may be required. All engineered bank protection should be designed by the Project Engineer. Natural materials, with a preference toward bio-engineered techniques will be implemented in engineered structures wherever feasible. Such structures could include rootwad revetments, branch packing, log walls, live cribwall, boulder clusters, rock riprap revetments, gabion wall, spur dikes, etc.

7. Mitigation

Mitigation procedures will outline actions taken during the planning, design, and construction phases to minimize adverse impacts to aquatic and riparian habitats. The level of mitigation considered during
planning and design will depend on habitat sensitivity, selected crossing mode, and permitting requirements. Regulatory agencies and interested parties should be consulted during planning and design in sensitive habitats. Prior to permit applications the Engineer and Contractor should ensure that information requirements are clearly identified and that the required information be submitted as part of the application documentation. As part of mitigation planning and design, appropriate documentation should be developed. These may include; environmental protection plans, reclamation plans, erosion and sedimentation plans, habitat and restoration enhancement measures, possible compensation agreements, post-construction monitoring plans, and contingency plans. The erosion and sedimentation plan, as well as reclamation plan are often key components of permit application documentation.

Crossing construction procedures should be considered when developing appropriate mitigation plans. These may include: surveying, clearing, spoils handling, grading, temporary vehicle crossings, instream blasting, isolation construction, trenching, instream sediment control, subsurface drainage control, pumping discharge, pipeline installation, backfilling, clean-up, and reclamation. State and federal guidance for environmental monitoring procedures and standards should also be considered in developing appropriate mitigation plans.

Most of the mitigation procedures relating to mode construction activities have been identified above as BMPs. More detailed mitigation measures relating to site preparation and reclamation will be developed under separate title and implemented as needed.

8. **References**

Attachment A

*Pipeline Stream Crossing Mode Determination Procedure*
*Manual & Decision Tree*
ALASKA STAND ALONE PIPELINE/ASAP PROJECT

ASAP PIPELINE STREAM CROSSING CONSTRUCTION MODE DETERMINATION MANUAL

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## REVISION HISTORY

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# ACRONYMS AND ABBREVIATIONS

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<td>ADF&amp;G</td>
<td>Alaska Department of Fish &amp; Game</td>
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<td>ASAP</td>
<td>Alaska Stand Alone Pipeline</td>
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<tr>
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<tr>
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<td>Right-of-way</td>
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1. SUMMARY

1.1 STREAM CROSSING MODE DETERMINATION PROCEDURES

The purpose of the Alaska Stand Alone Pipeline (ASAP) Stream Crossing Construction Mode Determination Manual is to establish a procedure by which each stream crossing site and associated pipeline crossing mode can be efficiently and consistently evaluated by design engineers. A procedural method has been developed in support of preliminary stream crossing mode determinations and is presented herein. This mode determination procedure serves to identify the anticipated design complexity, magnitude of construction activity, and potential for environmental impact or pipeline integrity impact. Details of aerial photography, Light Detection And Ranging, and topographic survey; hydrologic, hydraulic, geotechnical analyses; and assessments of environmental and adjacent facilities concerns will serve as the basis for the mode determination and classification of relative difficulty. The relative difficulty of crossing mode should be evaluated to help identify primary and secondary mode options for each crossing, where relevant. The selection of crossing modes and identification of relative difficulty will be based on several categorical analyses that form the Pipeline Stream Crossing Mode Determination Decision Tree (Appendix A).

The Pipeline Stream Crossing Mode Determination Decision Tree will guide the user in identifying the most suitable crossing mode for each site based on site specific features and best engineering judgment. In some cases, site specific data may be absent or anecdotal, in which case, the user should err on the side of safety and apply best engineering judgment based on their understanding of local conditions and past experience.

Detailed analyses are presented for trenching and trenchless drilling modes. While decision variables are identified in these sections of the decision tree, they are intended to act as a guide in identifying common items of consideration to which the user can provide notes on site specific conditions and the weight those conditions might have on mode suitability, relative difficulty, and feasibility. Detailed analyses are intended to be used and reviewed by multiple specialists (e.g. geotechnical, construction, pipeline, civil, and water resource engineers) with a working knowledge of the crossing site.

This decision tree directs the user in identifying four modes of stream crossing construction: open cut, isolated open cut, trenchless drilling, and aerial span. There are multiple approaches to isolated open cut and trenchless drilling modes, as well as a variety of equipment that can be used. It is not the intent of this decision tree to specify the equipment or specific method of isolation or drilling, though engineering notes may provide a venue by which preferred methods and equipment can be identified. Case histories of stream crossings have shown that the success of construction is heavily dependent on planning, equipment selection, and experience of construction personnel. As such, the selected equipment and specific mode of isolation or drilling
will likely be a collaborative decision by the Contractor, Engineer, Owner, and regulatory agencies.

Section 2 provides a description of each decision variable presented in the mode decision tree. The user should review the following descriptions to aid in determining the best path within the decision tree and to stimulate a reasonable evaluation of site conditions for detailed analyses of mode selection and relative difficulties to be expected during the construction process. In general, the Stream Classification Support Book can be referenced for site specific conditions. Additional resources are referenced in italics that will provide supplemental information on site conditions relevant to the specific decision variable. While Section 2 does not assess the economics of crossing mode determination, Section 3 presents relative economic considerations that are likely to play a role in the final crossing mode determination.
The following subsections present the categorical analyses of the Pipeline Stream Crossing Mode Determination Decision Tree (Pipeline Stream Crossing Mode Determination Decision Tree) and a description of associated decision variables. The following should be used as a supplement to the Decision Tree, to help guide the Engineer through the determination process and identify the intent of each decision variable as it relates to the crossing site.

2. TRENCHING ENGINEERING/CONSTRUCTABILITY ANALYSIS

2.1 Dry?

Ephemeral channels that could convey flow during the design flood event may be dry during the construction period. These channels have been reviewed for potential scour and migration; particularly those located on alluvial fans, and may have a required burial depth exceeding the minimum permissible burial depth. If the channel is dry, it can be open cut (follow the “Yes” branch), otherwise additional analysis is required (follow the “No” branch).

2.1.2 Usable, Existing Support Structure?

If an existing support structure (i.e. bridge) is located within the alignment corridor and the pipeline could feasibly be suspended from the support structure, then follow the “Yes” branch. If not, follow the “No” branch.

2.1.3 Preferred With Owner Approval?

If suspension from an existing support structure is preferred over trenching and trenchless drilling modes by the engineer, and has been approved by the pipeline owner, then the preferred crossing mode will be aerial span (follow the “Yes” branch). Otherwise, additional analysis is required (follow the “No” branch).

2.1.4 Isolated/Open Cut Engineering Concerns?

At this point, dry crossings that can be open cut and existing infrastructure that has been approved for use in aerial spans have been evaluated and eliminated from consideration. The next step is to consider engineering and constructability concerns specific to the crossing sight as they relate to trenching modes. Go to Detailed Trenching Engineering/Constructability Analysis for guidance on evaluating trenching mode concerns specific to the crossing site. If the crossing poses possible engineering or constructability issues, follow the “Yes” branch. Otherwise, there are no
engineering or constructability concerns that would inhibit the use of trenching methods; follow the “No” branch to the Fish Habitat Sensitivity Analysis.

2.1.5 Trenching Impractical?

If the Detailed Trenching Engineering/Constructability Analysis proves that crossing the waterbody by means of trenching is impractical or is excessively difficult relative to other options, then trenchless modes will need to be considered; follow the “Yes” branch to the Trenchless Method Analysis.

2.2 FISH HABITAT SENSITIVITY ANALYSIS

2.2.1 Sensitive Fish Bearing (Anadromous) Stream?

If the stream has been identified by Alaska Department of Fish & Game (ADF&G) to be a sensitive fish bearing stream, including anadromous species, then the user should attempt to determine the impact of construction on fish habitat (follow the “Yes” branch), otherwise hydraulic conditions will dictate trenching feasibility (follow the “No” branch). Refer to the Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes to identify ADF&G classified sensitive fish bearing streams.

2.2.2 Habitat within Zone Of Influence?

The zone of influence represents the portion of the stream bed where trenching may occur and the area of the waterbody downstream of construction where 90% of the sediment discharged as a result of open cut trenching will be deposited. Refer to Stream Crossing Classification Support Book and/or site specific detailed studies for the potential Zone of Influence (ZOI). Identification of potential habitat can be determined using identifiers presented in the Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes; field sampling by ADF&G or Bureau of Land Management; and site specific conditions, such as bed material, depth, velocity, or gradient. The ZOI will vary depending on the crossing method (open cut vs. isolated open cut) and anticipated hydraulic conditions during construction.

If spawning and/or rearing habitat is likely present within the ZOI, the timing of construction should be considered to reduce impact, either by selecting a time when flow magnitude is at a minimum or when fish assemblages are least susceptible (follow the “Yes” branch). Otherwise, isolated open cut feasibility should be evaluated as this approach will significantly reduce downstream sediment loading and resulting ZOI extent (follow the “No” branch).

2.2.3 Construction Timing Window Minimizes Impact?

If sensitive fish habitat is identified within the ZOI, construction timing should be evaluated against seasonal flows and critical time periods for suspected spawning, rearing, or migration activity. If a construction timing window is selected that will minimize the impact of trenching
activity on sensitive fish species (i.e. winter season), follow the “Yes” branch. Otherwise, follow the “No” branch to evaluate the feasibility of an isolate open cut crossing mode.

2.2.4 Dry or Frozen to Bottom?

If the crossing is dry or ice is present and is frozen to the ground (grounded ice) at the time of construction, fish species will not be impacted, and the crossing can be open cut (follow the “Yes” branch). Predicted or observed fall flow depth and winter ice thickness will indicate the likelihood of grounded ice. If water is present (e.g. low water or non-ground ice) during the selected construction timing window, conditions should be evaluated as to the quality of local overwintering habitat (follow the “No” branch).

2.2.5 Overwintering Habitat?

If water is present other variables that limit overwintering habitat should be considered. Upwelling groundwater, volume, substrate, and flow all affect the suitability for overwintering habitat. It is likely that short of a winter site visit, adequate knowledge of these conditions will be limited or absent. An environmental specialist should be consulted for this determination. If under-ice water conditions are sufficient to provide overwintering habitat to sensitive species, follow the “Yes” branch. If it is determined that water is present but is not suitable as overwintering habitat within the ZOI, follow the “No” branch to consider the feasibility of open cut trenching without isolation.

2.2.6 Open Cut Feasible?

It is assumed that open cut crossings will be completed in 24 to 48 hours unless site-specific conditions make this window infeasible. Initial stream bed and bank stabilization, as well as temporary erosion and sediment control measures, should be completed within 24 hours of finalizing instream construction activities. If the crossing does not contain water, grounded ice is present, or hydraulic and environmental conditions are such that a trench can be open cut without isolation methods, follow the “Yes” branch. If open cut trenching is not feasible, follow the “No” branch to evaluate isolated open cut feasibility.

2.2.7 Isolation Feasible?

If open cut trenching is not feasible then the possibility of isolated open cut trenching will be considered. The primary metric for isolation feasibility is flow rate at the time of construction. The selected isolation methods, or combination of methods, will dictate the associated flow rate limitations.

In state designated fisheries, isolated crossing methods will typically be limited to waterbody widths of 30 feet to water’s edge at time of construction. Greater spans may be possible where stream flow, soil, and terrain conditions allow, and/or where permitted by authorizing agencies. The specific method of isolation (i.e. pump, flume, or diversion) will be left to the discretion of
the Contractor with approval of the project Engineer and Owner. All isolated crossings will be approved and permitted by the appropriate authorizing agency. Initial stream bed and bank stabilization must be completed prior to returning flows to the waterbody.

Pumping may be implemented where pumps can adequately transfer stream volumes around the work area. On-site backup pumps and screened intakes are required. Dams must be constructed with materials (e.g. sand bags or clean gravel with plastic barrier) that reduce sediment loads into the waterbody. Pumping operations should be established to minimize silt-laden outflow and reduce streambed scour. Dams and pumps will be monitored for proper operation during the construction period.

Flumes are preferred where sensitive fish species passage is required. Flumes must be placed prior to trenching, though blasting may occur prior to flume placement if required. Sandbag diversion structures or equivalent must be developed to form an effective seal and divert flow through the flume without inhibiting fish passage. Some modification of the stream bottom and banks may be required to achieve an effective seal. Orient flumes to reduce bank erosion and streambed scour.

Diversions may be used at waterbodies with more than one channel, such as braided channels. Sandbag diversion structures or equivalent must be developed to form an effective seal and divert flow away from the installation section and into the alternate channel. Tie-ins will be completed in areas isolated from flow, though groundwater pumping may be required. Pumping activities, if required, should conform to those of the dam and pump method.

If an isolated open cut crossing mode is deemed feasible during the proposed construction timing window, follow the “Yes” branch. Otherwise, trenchless crossing modes will need to be evaluated; follow the “No” branch to the Trenchless Method Analysis.

### 2.3 DETAILED TRENCHING ENGINEERING/CONSTRUCTABILITY ANALYSIS

Many factors unique to a specific crossing can increase the level of difficulty in design and construction of the pipeline. These factors are typically not specific decision variables that direct mode determination one way or the other, but rather highlight local conditions that require consideration and inform design, permitting, and construction efforts. In this section, design and construction engineers are encouraged to identify any site specific conditions that could impact trenching mode selection and identify the associated level of difficulty. Eight items of consideration are listed below. The Engineer is to provide notes/comments in the adjacent boxes if the associated item of consideration is a concern. Additional comments and relative level of difficulty should be provided if the Engineer is concerned about a condition or situation not categorized below or needs additional space to provide comments.
2.3.1  Steep Approach/Bank Slopes?

Do approach or bank slopes preclude safe and effective operation of trenching equipment (e.g. > 60 degrees)? Can an effective bank stabilization technique be implemented following instream construction? Bank materials, stabilizing materials (e.g. riprap or vegetative), channel morphology (e.g. crossing relative to bend, scour potential, migration potential), presence of permafrost or ice lenses, and tie-in to natural contours should all be considered. Ultimately, steep approach and bank slopes can inhibit effective trenching and storage of cuttings. Banks should be restored to their natural contour or the angle of repose of stabilizing material, though restoration and stabilization efforts will have to key into natural contours at upstream and downstream limits. Is this feasible?

2.3.2  Challenging Site Restoration?

Are conditions at the crossing such that implementing temporary and/or permanent restoration would be challenging or have an unusually high risk of failure? Do bank materials consist of unconsolidated fines, organics, or silts? What is the thermal regime of the banks? Does native vegetation provide a thermal balance and is it feasible to quickly restore this thermal balance following construction? Is permafrost or are ice lenses present? Will exposer and thaw of bank materials increase seepage down the pipeline corridor? Is the channel highly mobile (e.g. high migration potential)? Are expected velocities excessively high (e.g. ≥ 10 feet per second)?

2.3.3  Seasonal Restrictions?

Is the location positioned such that access to the site is limited to a particular season or operations window? This can be limited by equipment being used, mode of transport, road construction limitations/requirements (e.g. wetlands travel, spanning sensitive fish bearing streams), landowner restrictions, etc.

Seasonal flow volumes should also be considered to identify feasibility of open cut construction and isolation methods. Practical upper limits of flow isolation are 35 cubic feet per second (cfs) for pumps and 250 cfs for flumes.

Seasonal icing and ice thickness should also be considered. Crossing with extreme aufeis formation may pose significant challenges during construction. Fluming may not be practical if ice thicknesses exceed 5 feet as the flume needs to daylight at or near streambed elevation.

2.3.4  Excessive Migration/Setbacks?

Do the expected channel migration extents require excessive setbacks? Is burial depth achievable across the floodplain, both with respect to materials, depth, and right-of-way (ROW) extents? Would bank stabilization measures, such as riprap or vegetative revetments, be preferred?
2.3.5 Excessive Scour/Burial Depth?

Is the required burial depth achievable in the soils present? Can instream activities be completed within a reasonable construction window given the required burial depth? To what extent will bank stabilization or river training measures impact scour and the final design depth? Can these be avoided or minimized?

2.3.6 Adjacent Infrastructure?

Is there any existing infrastructure adjacent to or spanning the proposed crossing? Will the existing infrastructure result in shallow burial depth or increased exposure to scour or erosion? Does the infrastructure pose any ROW limitations? Does the infrastructure require enhanced engineering or additional construction/reclamation effort?

2.3.7 Impact to Local Hydraulics?

Will the pipeline adversely affect groundwater flow (e.g. increase aufeis potential)? Can impacts to groundwater be mitigated (e.g. high porosity gravel trench bed)? Will surface water hydraulics be impacted (e.g. because of stabilization efforts)? Can adequate flow rates be maintained to protect aquatic life, allow fish passage, and minimize impacts to existing downstream uses?

2.3.8 Challenging Soil Conditions?

Will local soil conditions result in increased effort or decreased success of trenching or restoration efforts? Do bank materials consist of thermally unstable unconsolidated fines, organics, or silts? Are subsurface materials dominated by cobbles and boulders? Is bedrock present and will it require blasting?

2.4 TRENCHLESS METHOD ANALYSIS

To this point, initial evaluations suggest that trenching modes are neither feasible (engineering/constructability analysis) nor suitable (fish habitat sensitivity analysis). As an alternative, trenchless crossing modes should be evaluated.

2.4.1 Trenchless Drilling Feasible?

Trenchless crossing modes will fall into two categories; drilling and aerial span. Aerial span has been considered under the Trenching Engineering/Constructability Analysis section above, as an early alternative to trenching modes in the presence of a usable, existing structure and the approval of the Owner. In the absence of existing and usable infrastructure for aerial spans, the economics of trenchless drilling will often outweigh those of an aerial span, requiring either a rerouting of the pipeline to an existing structure or the design and construction of a new structure. To avoid elevated construction costs, trenchless drilling feasibility should be evaluated prior to considering aerial span as an alternative at this phase of mode determination. To evaluate
trenchless feasibility, refer to Trenchless Drilling Feasibility Analysis. While economics are not considered within the Pipeline Stream Crossing Mode Determination Decision Tree, they are a vital component in identifying a preferred crossing mode and are discussed in Section 3 below.

If the Trenchless Drilling Feasibility Analysis has determined that trenchless drilling is feasible, the option of aerial span as a preferred crossing mode should be considered by the Engineer (follow the “Yes” branch). Otherwise, trenchless drilling has been deemed infeasible and the use of an aerial span should be considered by the Owner (follow the “No” branch).

2.4.2 Aerial Span Preferred?

While trenchless drilling may have been deemed feasible, a preference for aerial span should be considered; particularly if it was determined that trenchless drilling would be excessively difficult or of excessively high risk. If aerial span is not the preferred crossing mode over trenchless drilling, follow the “No” branch. Alternatively, if aerial span is preferred by the Engineer over trenchless drilling, follow the “Yes” branch to evaluate the acceptance and approval of aerial span by the Owner.

2.4.3 Owner Approval of Aerial Span?

If an aerial span, either newly constructed or from an existing structure is preferred by the Engineer, and has been approved by the pipeline Owner then the preferred crossing mode is aerial span (follow the “Yes” branch). Otherwise, the Engineer should review alternative options for crossing the waterbody (follow the “No” branch).

2.4.4 Review Alternative Options

If trenching and trenchless drilling are initially deemed infeasible, impractical or of excessive difficulty and risk, but an aerial span design is not approved by the Owner, a detailed review of alternative methods including a review of trenching and trenchless method analyses should be performed. Provide notes/comments.

2.5 TRENCHLESS DRILLING FEASIBILITY ANALYSIS

Many factors unique to a specific crossing can increase the level of difficulty in design and construction of the pipeline. These factors are typically not specific decision variables that direct mode determination one way or the other, but rather highlight local conditions that require consideration and inform design, permitting, and construction efforts. In this section, design and construction engineers are encouraged to identify any site specific conditions that could impact trenchless mode selection and associated level of difficulty. Seven items of consideration are listed below. The Engineer is to provide notes/comments in the adjacent boxes. Additional comments and relative level of difficulty should be provided if the Engineer is concerned about a condition or situation not categorized below or needs additional space to provide comments.
Trenchless drilling can include but is not limited to Horizontal Directional Drilling (HDD), horizontal directional boring (HDB), slick boring, micro tunneling, ramming, and direct boring.

2.5.1 Limited Access/Workspace?

Are there any limitations to site access and required workspace? Suitable access to and from both the entry and exit sites must be available for required drilling, fabrication, and operations equipment. If temporary or permanent structures are used to cross the watercourse, selection of a suitable vehicle crossing mode should consider equipment loads, hydraulic and environmental impacts, as well as post-construction restoration. Access is also required for available water source(s) during installation, for monitoring the drill path, during cleanup operations in the event of a fluid release (e.g. frac-out), as well as cleanup and restoration activities following construction.

The entry side must accommodate and support heavy equipment, requiring satisfactory access and stable soil conditions. Pipe string fabrication and testing location will necessitate sufficient length and width to provide suitable workspace. This may require a false ROW that could complicate construction with additional cost and need for landowner consent. When considering boring or ramming, the Engineer needs to evaluate presence of existing infrastructure; required bell hole dimensions, orientation, and access; pipe layout space; and local terrain.

Required workspace should be specified by the contractor. For preliminary determination purposes of HDD operations, the Engineer can assume an entry site area of approximately 200 feet by 200 feet, and an exit site of 130 feet by 100 feet plus the required length and width for pipe string fabrication. Extra workspace outside of the ROW should have a setback of no less than 500 feet from the water’s edge at time of construction if possible.

2.5.2 Pipe String/Drill Hole Alignment?

Coincident with acquiring suitable workspace for pipe string fabrication and testing, are there any limitations that would hinder alignment of the pipe string and drill hole? Are there any terrain limitations, existing infrastructure (e.g. roads, railroads, buildings), or land access issues that would prevent alignment of the pipe string with the drill hole? Given the large size proposed 36 inch pipeline, there is little latitude for alignment shift or bending of the pipe string relative to the drill hole.

2.5.3 Entry/Exit Point Limitations?

Do the entry and/or exit points have any limitations? The selection of the drill entry and exit point locations must consider a number of requirements. The terrain must be cleared, graded, and stable enough for safe operations; sites should have negligible longitudinal or side slopes. The elevation difference between entry and exit points should not be excessive. Entry and exit points should provide sufficient space for safe and efficient operations, with consideration of: existing infrastructure, land use, sensitive environmental habitat, and cultural resources; elevation
differential between points (generally the entry point will be at an equal or lower elevation than the exit point); problematic soils near surface that may require isolation; rig size and layout requirements, including bell hole dimensions; pipe string layout and fabrication area; mud and returns pits; and bulk storage of materials. The resulting drill path between entry and exit points must be feasible and of the lowest risk possible, with special considerations of; avoiding No Drill Zones, maintaining reasonable pipe geometry, and limiting pipe length. Feasibility in this regard is largely dependent on subsurface conditions and required burial depths discussed in greater detail below.

2.5.4 Water Source Availability?

Is water for use in drilling operations readily accessible? Is there sufficient volume or are there any concerns regarding permitting sufficient volumes? Is the source water of sufficient quality?

The availability of a water supply for drilling operations should be considered. Water will be required for drilling fluids and pre-testing the pipe string when warranted. Unconsolidated soils and hydraulic fractures can greatly increase the water demand during drilling. Water is typically pumped from a neighboring waterbody or hauled to onsite storage tanks. Things to consider with respect to water availability are: physical location of waterbody relative to drill site, access to the water body, flow restrictions, regulatory approval, and construction schedule/season. It should not be assumed that the waterbody crossed by the drilling operation will be available for use, either because of volume limitations or environmental/fish habitat sensitivity.

2.5.5 Mud Disposal Proximity?

Post-drilling mud must be disposed of following drilling operations. Is a mud disposal site within close proximity or will hauling become a costly consideration? The haul distance to a mud disposal site can add significant cost and effort to operations.

2.5.6 “No Drill Zone” Limitations?

Are subsurface or local topographic conditions restricting in any way, such that they dictate the depth and location of the drill path? Are design data (i.e. burial depth and setback distance) achievable for the given subsurface conditions and local terrain? Is the required drill path complex, such as requiring compound curves?

The No Drill Zone is defined by vertical limits of potential drill paths between specified entry and exit points, intended to ensure the bore is maintained within suitable geologic materials while maintaining sufficient cover, reasonable pipe geometry, and avoiding potential groundwater concerns. The No Drill Zone is influenced by a number of factors, including: crossing area terrain with respect to entry and exit locations and minimum depth of cover, subsurface soil and bedrock stratigraphy and suitability for drilling, predicted channel scour and lateral migration, as well as potentially unstable slopes/landslide features and other geotechnical “problem” areas. Some issues of geotechnical concern may include the occurrence of cobbles and boulders, fissures that
could provide fluid migration path, high plastic clay soils and shale bedrock with potential for swelling, jointed/fractured bedrock units, etc. Other non-geotechnical concerns are sited in the entry/exit point limitations section above.

2.5.7 Groundwater Conditions?

Are groundwater conditions limiting in any way? Do they increase the chance of drilling failure (e.g. frac-out or borehole collapse)? Is the groundwater artesian, such that containment would be difficult in the event of aquiclude failure? Can a bell hole be constructed for boring or ramming operations without overwhelming groundwater intrusion or risk of flooding the bell hole?

2.5.8 Risk of Failure?

Trenchless drilling failure is dependent on a number of factors, each of which should be considered when determining the risk associated with a trenchless crossing mode. It can be assumed that planning, site knowledge, and equipment will not factor into the risk of failure, though these are common factors that lead to operations failure. Experience and ability of both the Engineer and Contractor should be considered with great scrutiny for unprecedented or uncommon crossings; either with respect to site conditions or required pipe geometry/length. Common problems associated with drilling that can influence risk of failure include: loss of drilling fluid into substrata increasing water needs; drilling mud seepage into the waterbody resulting in possible adverse effects on fish, habitat, and water quality; collapsed borehole; washout of cavities and surface settlement; lock-up/stuck drill stem; abandonment/loss of tools; and damaged pipe or coating.

Though the trenchless mode may have been completed successfully, additional risks should be considered following drilling operations. These may include unsuccessful of difficult restoration of disturbed riparian areas, exposure during flood events, damage because of third party activities (i.e. near neighboring infrastructure), subsidence at entry/exit points, limitations to pipeline accessibility for repairs.

2.5.9 Additional Concerns?

Are there any additional concerns not highlighted above? For example, regulatory roadblocks during the application and approval stage because of insufficient information, or increased restrictions because of limited information or environmental sensitivity. Inadvertent release of drilling fluids into the environment could lead to large regulatory fines and enhance cleanup/restoration operations, including long-term environmental monitoring. Are there any outstanding economic disadvantages?
3. ECONOMIC CONSIDERATIONS

While not specifically considered within the Pipeline Stream Crossing Mode Determination Decision Tree, design and construction costs are no less important in evaluating a preferred crossing mode. Ideally, the cost of construction and risk of impact should be related to the environmental value of the resources at risk. As such the Engineer should consider a balance between crossing mode cost and potential environmental impacts.

Direct costs are highly dependent on site conditions, crossing mode type, and contract agreements. The Canadian Association of Petroleum Producers has developed a relative cost comparison of various crossing mode techniques and stream crossing sizes (CAPP et al. 2005). An adaptation of that comparison is presented in Table 3.1. Care should be taken when considering relative costs presented in this table for the proposed large diameter ASAP.

Indirect costs vary between crossing mode techniques and activities, as well as general availability of resources, information, and site accessibility. A comparison of major indirect costs should not be overlooked, such as the money and time saved on erosion control and bank reclamation when drilling a stream crossing. However, drilling can incur additional costs through acquisition of extra temporary workspace, specialized equipment and trained personnel, water sourcing and mud disposal, and risk of failure which could require implementation of contingency plans, extension of the project schedules, and regulatory fines. Some of the key economic considerations for stream crossings include:

- Design and geotechnical investigation
- Availability of experienced contractors and ability to obtain competitive bids
- Permitting processes
- Extra temporary workspace
- Land surveying
- Clearing
- Grading
- Trenching or drilling
- Special equipment and materials
- Dewatering
- Instream mitigation measures
- Erosion and sediment control measures
- Bank reclamation, restoration, and stabilization
- Inspection and testing
- Access
- Operations and maintenance
- Habitat compensation
### Table 3.1: Relative Costs of Stream Crossing Modes (Adapted from CAPP et al. 2005)

<table>
<thead>
<tr>
<th>Technique</th>
<th>Small Stream Crossing &lt; 30 Feet Wide</th>
<th>Medium Stream Crossing 30 - 60 Feet Wide</th>
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<td>low</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Dragline</td>
<td>n/a</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>Dredging</td>
<td>n/a</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td><strong>Isolated Open Cut</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dam &amp; Pump/Sump &amp; Pump</td>
<td>low to moderate</td>
<td>moderate</td>
<td>n/a</td>
</tr>
<tr>
<td>Flume</td>
<td>low to moderate</td>
<td>moderate</td>
<td>n/a</td>
</tr>
<tr>
<td>Diversion</td>
<td>n/a</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td><strong>Trenchless</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HDD</td>
<td>low to high</td>
<td>low to high</td>
<td>low to high</td>
</tr>
<tr>
<td>Boring</td>
<td>low to moderate</td>
<td>moderate</td>
<td>moderate</td>
</tr>
<tr>
<td>Ramming</td>
<td>low to moderate</td>
<td>moderate</td>
<td>high</td>
</tr>
<tr>
<td><strong>Aerial Span</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Existing Bridge Attachment</td>
<td>low to moderate</td>
<td>low to high</td>
<td>low to high</td>
</tr>
<tr>
<td>Self-Supporting Bridge</td>
<td>moderate to high</td>
<td>high</td>
<td>high</td>
</tr>
</tbody>
</table>

**Notes:**

- Many site-specific stream characteristics can affect the cost of individual crossing modes including: width, depth, channel shape, flow volume, substrate composition, and approaches. Crossings should be evaluated on a case by case basis.
- Costs do not consider environmental suitability
- n/a = not applicable or practical
- Relative costs are based on the following assumptions:
  1. Drilling and blasting of bedrock is not considered
  2. Single, small diameter pipe
  3. All isolation open cut methods assume backhoe excavation
Appendix A  Pipeline Stream Crossing Mode Determination Decision Tree
Detailed Trenching Engineering/Constructability Analysis

**Isolated/Open Cut Engineering Concerns?**

- **Steep Approach/Bank Slopes?**
  - Yes
  - Notes: Relative Difficulty: Challenging

- **Challenging Site Restoration?**
  - Yes
  - Notes: Relative Difficulty: Challenging

- **Soil Conditions?**
  - Yes
  - Notes: Relative Difficulty: Steep

- **Impact to Local Hydraulics?**
  - Yes
  - Notes: Relative Difficulty: Excessive Scour/Burial Depth

- **Adjacent Infrastructure?**
  - Yes
  - Notes: Relative Difficulty: Excessive Migration/Setbacks

- **Seasonal Restrictions?**
  - Yes
  - Notes: Relative Difficulty: Excessive Scour/Burial Depth

- **Excessive Scour/Burial Depth?**
  - Yes
  - Notes: Relative Difficulty: Impact to Local Hydraulics

- **Adjacent Infrastructure?**
  - Yes
  - Notes: Relative Difficulty: Seasonal Restrictions

- **Soil Conditions?**
  - Yes
  - Notes: Relative Difficulty: Steep

- **Steep Approach/Bank Slopes?**
  - Yes
  - Notes: Relative Difficulty: Challenging

**Additional Concerns:**

- **Notes:** Relative Difficulty: Additional Concerns

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001-C-22-GRD-W-0055 EED, July 2016 - Attachment 12
FIGURE 1
OPEN CUT TRENCHING MODE AT SMALL CROSSINGS - TYPICAL
FIGURE 2
OPEN CUT TRENCHING MODE AT LARGE CROSSINGS - TYPICAL

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FIGURE 3
ISOLATED OPEN CUT TRENCHING MODE USING DAM & PUMP - TYPICAL

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FIGURE 4
ISOLATED OPEN CUT TRENCHING MODE USING FLUME - TYPICAL

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FIGURE 6
TRENCHLESS DRILLING MODE USING HORIZONTAL DIRECTIONAL DRILLING (HDD) - TYPICAL

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FIGURE 7
TRENCHLESS DRILLING MODE USING DIRECT BORING - TYPICAL

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