KNIK ARM HYDRAULIC STUDIES: PRELIMINARY DATA ANALYSES - A SUMMARY OF FINDINGS -

Prepared for

PND Incorporated
1506 West 36th Avenue
Anchorage, Alaska 99503

Prepared by

URS Corporation
2700 Gambell Street
Anchorage, Alaska 99503

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Preliminary Data Analyses

Prepared by

URS Corporation
2700 Gambell Street, Suite 200
Anchorage, Alaska 99503

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By

J. Colonell, P.E., Ph.D.[1],
O. Smith, P.E., Ph.D.[2],
J. Aldrich, P.E., P.H.[3],
and P. Mineart, P.E.[4]

[1] Senior Principal Engineer/Oceanographer, URS-Anchorage
[2] Professor of Coastal & Arctic Engineering, University of Alaska Anchorage
[3] Principal Engineer/Hydrologist, URS-Fairbanks
[4] Senior Engineer, URS-Oakland CA

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KNIK ARM HYDRAULIC STUDIES: PRELIMINARY DATA ANALYSES

1. Purpose and Scope of this Report

In April 2004 the Knik Arm Bridge and Toll Authority (KABATA) selected PND Inc. to provide Conceptual Engineering Services for the initial evaluation of Knik Arm Crossing alternatives. To provide additional river and coastal engineering expertise to the conceptual engineering team, PND Inc. contracted with URS to provide input on several aspects of the Knik Arm Crossing studies:

- Technical review and consultation on Knik Arm hydraulic studies that were conducted by Dr. Orson Smith, P.E., during summer 2004,
- Preliminary assessment of oceanographic and hydrodynamic effects of/on the most updated concept of a crossing structure, based on results of summer 2004 studies, and
- Recommendations for additional studies that will be needed for evaluation of environmental effects and development of engineering design criteria

URS's responsibilities on the first item were handled through frequent but informal communications between Dr. Smith and Dr. Jack Colonell, P.E. The second and third items are the subject of this report, which essentially is a summary of analyses and conclusions derived from technical memoranda prepared by Dr. Smith, Mr. Jim Aldrich, P.E., and Mr. Phil Mineart. Some parts of these memoranda have been incorporated verbatim in this report, prepared as a joint effort of the four engineers named above.

Presented in this report are results of preliminary analyses of design considerations that stem from the dynamic hydraulic behavior of Knik Arm. The methods applied to obtain these results are those that are widely accepted and used by bridge designers, but none are believed to be the best possible representation of Knik Arm hydraulic conditions; computational results are considered to be very preliminary. Means to improve these analyses are recommended. Also addressed briefly in this report are probable effects of the current design concept on Knik Arm oceanography. Lastly, recommendations are included for additional work to address data gaps and refine hydraulic analyses.

2. Knik Arm Crossing Design Considerations

2.1 Current Design Concept

A representative design concept of the bridge has been developed by PND, Inc. This representative crossing was selected for preliminary test case conditions only and is not indicative of the actual bridge recommendation. The representative bridge concept is located about 3 miles northeast of the Port of Anchorage, north of Cairn Point. The width of the unobstructed tidal waterway at this location is about 13,000 feet (2.5 miles) at an elevation of 10 feet above the mean lower level of low water (MLLW). The bridge concept was estimated at approximately 7,000 feet (1.3 miles) in length, with embankment approaches that would extend into the tidal waterway on each side of the bridge. This bridge length represents the minimum bridge length currently under consideration, roughly matching the existing natural conditions constriction at Cairn Point; the goal here being not to further restrict tidal flows in Knik Arm as compared to naturally occurring conditions. The bridge was assumed to have spill-through abutments, 26 standard piers, and two fender piers. The distance between the spill-through embankments was about 6,800 feet at an elevation of 10 feet above MLLW. The first standard pier was about 188 feet from the east end of the bridge. Additional standard piers were located at 265 foot intervals, with the last pier being about 188 feet from the west end of the bridge. Each pier consisted of two vertical four-foot diameter piles and two four-foot diameter batter piles. The waterway between piers 13 and 14 (near the center of the inlet arm) was designated as a navigation channel; with a fender pier located on the west side of standard pier 13 and on the east side of standard pier 14. The width of the navigation channel was assumed to be 250 feet. The top width of the bridge was assumed to be 42 feet and the top width of the road embankment was estimated at 107 feet. The side slopes on the bridge approach embankments and at the abutments were assumed to be 2H:1V.

2.2 Tidal Flows

Dr. Smith (2004a) observed the currents in Knik Arm as a reversing tidal flow where inflowing river discharge does not significantly influence current speeds or directions. River and streams discharging into Knik Arm influence salinity and sediment load, but inlet currents are completely dominated by the extreme tidal ranges that exist there. While flows in most tide-affected rivers slow on flood tide and plateau at a non-tidal condition during ebb tide, Knik Arm tidal currents are reversing with near symmetrical speed variation in both directions. Tidal currents at the site regularly exceed 7 knots speed and are stronger on ebb (westward) flow than flood (eastward) flow. Maximum currents last about an hour before subsiding over time to near zero speed then reversing in a near symmetric fashion. The time between reversals (slack water times) is about 6.2 hours. Knik Arm and upper Cook Inlet experience a diurnal inequality in tidal flows. This means that of the two floods and two ebbs in each lunar day (24.8 hr), one flood flow and the consecutive ebb flow have a much greater velocity than the other flood and ebb flows.

2.3 Seabed Scour

The foundation design, shape, and spacing of bridge piers are central to the feasibility and cost of the entire bridge. Likewise, the length of approaches and design of abutments control the length of the bridge opening and structural need for piers. Confident predictions of scour across the bridge opening and around piers and abutments are fundamental and crucial to design of the entire bridge.

Scour from tidal currents at the Knik Arm Bridge will produce sediment transport conditions that are highly dynamic and variable. Scour resulting from the contraction of the waterway by the abutments will cause a general lowering of the bed within the bridge opening. The acceleration of the flow around the abutments and piers and the resulting vortices will result in the formation of scour pits around the piers and abutments.

Knowledge of underwater site conditions is not extensive at the site, but many critical natural parameters were addressed by KABATA-sponsored studies during 2003 and 2004. Further definition of sediment transport and related natural phenomena in the vicinity of the bridge will be a good investment toward prevention of mistakes and oversights in the design of the bridge that could lead to construction cost overruns and unnecessarily high maintenance expense.

3. Effects of Knik Arm Crossing on Local Oceanography

3.1 Hydrodynamic Effects

Effects of the roughly half-mile bridge approach embankments on flow speed and direction in Knik Arm are referred to as *hydrodynamic* effects (i.e. effects on water *movement*). As already described, the reduction of channel cross-section by the two embankments and the bridge support piles will cause the average flow speed to increase in the remaining channel cross-section. Velocity profiles collected by Dr. Smith (2004a) demonstrated that the maximum flow speed occurs during ebb of the spring tide[5]. Based on available bathymetric (below water topographic) data, it is estimated that the bridge approach structures will reduce the flow cross-section to about 86 percent of its present size at elevation 10 ft (re: MLLW).

Maximum surface currents measured by Dr. Smith (2004a) during ebb of the spring tide were as high as 7 knots (approximately 12 ft/s). At the locations of the bridge abutments, maximum surface currents were about 6 knots (10 ft/s). Near the seabed maximum currents were about one-half those observed at the surface. With the bridge approaches and ice-coated piers in place, these current speeds could be expected to increase by 16-20 percent. Except in the vicinity of structural components, where local flow accelerations could be larger, flow speeds throughout the entire cross-section could be expected to have similar percentage increases.

With sufficient "pinching off" of the flow by the approach structures and bridge support piles, flow could be impeded to the point that the tidal response of Upper Knik Arm would be altered. Changes in the timing and amplitude of the tide could affect the movement of water into and out of Upper Knik Arm.

No conclusions regarding potential effects of the embankments on overall flow patterns, or tidal response characteristics of Upper Knik Arm, can be drawn from the data provided by Dr. Smith (2004a). However, such information can be developed from an appropriately configured hydrodynamic model (Section 5.2) that incorporates the altered channel geometry.

3.2 Hydrographic Effects

Effects of the bridge approaches on distribution of water properties such as temperature and salinity are termed *hydrographic* effects. However, hydrographic effects occur only if the water body containing the structure has significant vertical or horizontal stratification of water properties. Temperature and salinity profiles obtained by Dr. Smith (2004a) showed that the hydrography of Upper Knik Arm during mid-summer 2004 not only lacked such stratification, but also was very strongly dominated by flows from the Knik and Matanuska Rivers.

Coastal structures, such as the half-mile bridge approaches under consideration for the Knik Arm Crossing, can affect both the mean and turbulent characteristics of the local flow field by deflecting the flow and creating fluid shear that increases the production of turbulence and the presence of vortices. These effects, in combination with the influence of the Knik and Matanuska Rivers, will likely obliterate any hydrographic effect that might be attributed to the bridge embankment approaches. Experience with similar structures in less dynamic environments

[5] "Spring" tide is the higher tide and the one with the larger range of the two fortnightly tidal cycles.

support this conclusion (e.g. Mineart et al. 1988; Niedoroda & Colonell 1990; Colonell et al. 1992). Nevertheless, this conclusion should be further verified by an appropriate numerical modeling effort (Section 5.2).

4. Preliminary Estimates of Seabed Scour

4.1 Methods

A preliminary estimate of scour depth at the proposed bridge during a combined 100-year river flood and tidal event was prepared for this report (Aldrich 2004, Smith 2004b). The objective was to provide an estimate of the scour depths that will need to be accommodated by the final design. Two types of scour were addressed: scour at the abutments (abutment scour) and scour at the piers (pier scour). Ultimately the bridge should be designed to withstand 100-year and 500-year storm events (Richardson and Davis 2001).

The depth of scour at the abutment was estimated with each of two methods: the ABSCOUR method (Maryland State Highway Administration 2004) and the HIRE method (Richardson and Davis 2001). The depth of scour at the piers was estimated as the total of the contraction scour within the waterway opening of the bridge and the local scour around the pier. Contraction scour was estimated using Laursen's "live-bed" equation (Richardson and Davis 2001). Local scour at the piers was estimated using the CSU equation (Richardson and Davis 2001). The possible increase in scour depth resulting from the presence of sand waves on the bed was added to both the abutment scour estimate and the pier scour estimate.

Although potentially important, long-term degradation of the bed was not addressed for this preliminary analysis of scour. Similarly, lateral migration of the thalweg (main stream of submarine water movement) was not considered. Thus, only the effects of flow contraction, local currents around the piers and abutments, and the height of potential bed forms, were addressed in this assessment.

Based on information presented by Dr. Smith (2004a) the median grain size (D_{50}) of the bed material was assumed to have a diameter of 0.00625 inches and the 95 percent finer (D_{95}) grain size was assumed to be 0.0095 inches. To compute the waterway opening at the bridge and, also, scour at the piers, all piers were assumed to have a 1-foot thick ice "collar" above the MLLW. Below MLLW the piers (likely constructed of concrete) were assumed to be free of ice. The maximum velocity within the waterway opening of the bridge was assumed to be 1.3 times the average velocity.

4.2 Results

Three pier scour scenarios were addressed, with results as listed in Table 1:

- Case 1 assumes a standard pile group configuration, with flow direction at an angle with the pile group.
- Case 2 assumes a standard pile group configuration with flow direction parallel to the pile group.

- Case 3 assumes that the standard pier and fender pier are close enough to affect the scour depth, but are not connected by ice or debris that would increase the effective size of the piers. The flow direction is assumed to be parallel to the pile group.

Table 1: Summary of Preliminary Scour Depth Computations

Method	Total Scour Depth (ft)				
	West Abutment	East Abutment	Pier Case 1 (Angle)	Pier Case 2 (Parallel)	Pier Case 3 (Fender)
ABSCOUR	25	69	23	21	31
HIRES	110	110	--	--	--

4.3 Discussion

The scour depth estimates presented above are considered to be very preliminary. The difference in the abutment scour estimates produced with the HIRE and ABSCOUR methods is indicative of the potential error associated with these estimates. It should also be noted once again that no attempt was made to include possible long-term degradation in the scour depth estimate or to include the possible effect of thalweg migration. Depending upon the specific conditions at this site, either of these processes could result in a significant increase in the scour depth.

For the conditions analyzed, there is probably less uncertainty associated with the pier scour estimates than the abutment scour estimates. However, a change in the pile diameter, pile group configuration, or type of pier could have a significant impact on the scour depth. Debris or ice floes hanging up on the pile could also significantly increase the scour depth.

The scour depth at the end pier adjacent to each abutment is likely to be affected by the scour hole formed at the abutment. Similarly, the scour hole at the fender piers and the closest standard pier are likely to be affected by the proximity of the piers to each other. The other standard piers appear to be spaced enough apart that the scour holes will not overlap.

Embankments with sloped faces called spill-through abutments are currently being considered for the proposed bridge approaches. Such abutments avoid the cost of vertical retaining structures. When used with short embankments, spill-through abutments also generally result in less scour depth than vertical wall abutments.

However, because of the half-mile length of the embankments, preliminary computations suggest that the spill-through abutments might be subject to as much scour as would be experienced with vertical abutments. If sloped-face abutments are used, they will require erosion protection where the embankment comes in contact with the channel current. Armoring the abutments with an effective riprap layer will be more difficult due to the close proximity of the nearest pier to the abutment. The riprap layer necessary to protect the abutment might extend out to the pier, such that placement of an effective riprap layer around the pile is made more difficult.

If spill-through abutments are used, one means of reducing the scour at the abutment and the adjacent pier might be to use guide-banks (longitudinal dikes) at the abutments. Guide-banks would cause the flow through the bridge to be more uniform and, thus, the scour depths at the bridge to be less than without the guide-banks.

To compute the scour depth at the abutments using ABSCOUR, it was necessary to estimate the velocity of the flow in the tidal waterway upstream from each abutment. To do this, the tidal waterway was divided into three flow tubes. The velocity in each flow tube was estimated as a percentage of the average overall velocity based on several figures showing velocities measured by Dr. Smith (2004a). The use of better methods of estimating the velocity in the flow tubes would likely have a significant effect on the abutment scour estimates.

It should be noted that the bed material size used in the scour computations was based on surface samples, and was assumed to be uniform with depth. Sand wave height was assumed to be six feet. Both of these assumptions could have significant effects on the scour depth estimates.

Several additional analyses could be performed to refine the one-dimensional analyses used to prepare the scour depth estimates presented above. First the tidal basin model could be refined. The model used for this analysis assumes vertical sides and an effective surface area based upon data provided on 2 August 2004 by Dr. Smith (2004a). Rather than calibrating the model based on vertical sides, the model could be calibrated with tidal basin areas representing several elevations within the tidal variation. Second, a numerical analysis of the difference in velocity across the tidal waterway could be made using the August 2004 data and used to estimate the velocity in the flow tubes upstream of the bridge. Third, subsurface information that is available for locations near the crossing could be used to estimate the change in bed material size with depth. Fourth, several additional methods could be used to compute the scour depth at the abutments and piers and compared to the estimates using the above referenced methods.

Finally, it should be noted that a preliminary one-dimensional analysis was used to represent a three-dimensional flow situation. Coefficients were applied to account for the three-dimensional nature of the flow. The use of one-dimensional analyses to represent three-dimensional flow situations is valid where the scour depths are relatively small and/or relatively conservative assumptions and safety factors can be used in the design.

4.4 Recommendation for Conceptual Scour Design

This preliminary assessment of the depth of scour at the abutments and piers associated with a proposed Knik Arm Bridge was made in order to provide rudimentary scour depths for the conceptual design of the bridge. Until these analyses are refined, it is recommended that the *unprotected* scour depth during the 100-year event be assumed to be on the order of 30 to 90 feet at the abutments and on the order of 20 to 40 feet at the piers. Although scour depths were computed individually for the west and east abutments, and although it seems likely that the scour depth will be deeper on the east abutment, the computations are considered too primitive to differentiate between the two abutments. Thus, until more detailed computations can be performed, it should be assumed that the scour depth at either abutment could be as deep as 90 feet, or deeper if it is determined that long-term degradation or thalweg migration is likely. It is also recommended that the scour depth at the pier adjacent to each abutment is assumed equal to the predicted abutment scour depth, and that the scour depth predicted for Case 3 be assumed to occur not only at the fender pier but also at the closest standard pier.

5. Data Needs

5.1 Comprehensive Oceanographic Modeling

5.1.1 Modeling Needs

To address concerns about effects of the crossing components on the Knik Arm water body, as well as to provide better information for development of engineering design criteria, a comprehensive modeling effort will be required. While a physical model has unquestionable visual appeal, a more useful choice for a comprehensive effort would be a numerical model that has been applied in water bodies having characteristics similar to those of Knik Arm. However, physical modeling might be expedient for examination of certain aspects of pier and abutment design criteria.

In water bodies such as Knik Arm, tidal variations of water levels and currents are unsteady and thus are poorly represented by steady-state models. Unsteady flow in rivers, such as the advance of a flood wave, typically does not occur as fast or with such dramatic change in speed or direction as in Knik Arm, where flows completely reverse four times each lunar day (24.8 hr). Selection of a numerical model that can effectively simulate this change is critical to confident predictions of scour-related hydraulic effects, as well as overall hydrodynamic behavior. So-called "one-line," or one-dimensional, models that apply an average condition across the channel will not effectively address the significant flow variations that will exist near the bridge, but they may be adequate as a boundary condition some distance upstream and downstream from the crossing.

A number of two-dimensional unsteady flow models are adaptable to Knik Arm conditions. Some of these models also account for wind stress, which may prove to be a significant factor during extreme weather conditions. Although the model code should be selected based on a detailed comparison of the options available, it will not be necessary to develop a special-purpose site-specific computer program. Trial simulations with more than one existing model code for the sake of comparison should prove to be an affordable investment and will assure maximum confidence in the interpretations of simulation results.

5.1.2 Numerical Modeling Approaches

One-dimensional Analysis

A one-dimensional model of Knik Arm, though not as precise as a model with more dimensions, probably would provide an adequate indication of the overall level of impact of the project, both in magnitude and area of effect, and would enable quick assessment of the maximum extent of environmental influences of the project. The shape of the Arm (long and narrow) fits well with a one-dimensional model and the transverse velocity profile data presented by Dr. Smith (2004a) suggest that the flow is generally parallel across the channel. A disadvantage of the one-dimensional model would be that local variations in horizontal velocity distribution would not be captured. Near the bridge embankments and possibly upstream and downstream of the large "hole" off Cairn Point, the flow would be converging or diverging, respectively. A two-dimensional model would be needed to capture these features. To the extent that the bridge affects this flow pattern, a two-dimensional model would be needed. However, depending upon schedule and budget, a one-dimensional model should be considered as a first approximation, possibly in conjunction with a two-dimensional model for analysis near the crossing alignment.

Two-dimensional Analysis

A two-dimensional model would require significantly more gathered data over the one-dimensional model. The major advantage would be that it would provide an estimate of the change in horizontal velocity distribution that may occur due to construction of the bridge embankments. The embankments will deflect the flow away from the banks and toward the center of the channel; however, data provided by Dr. Smith (2004a) indicate that the majority of the flow is already in the near the center of the channel so this effect may be minor.

A two-dimensional model would require detailed bathymetric data which appear to be available. If sediment transport is the ultimate issue, a two-dimensional model should provide adequate information for the sediment transport analysis; an assumption can be made as part of the sediment transport analysis of a uniform vertical velocity profile throughout the body of water. Then the calculation of friction on the seabed is not estimated directly from the depth averaged velocity but instead is calculated from the assumed vertical velocity profile. This method should work for Knik Arm since little stratification occurs.

Two-dimensional models generally provide adequate information to reasonably estimate hydrodynamics and sediment transport. Situations where this is not the case occur where density driven or buoyancy driven flows are important. Where vertical stratification is strong, such as in estuaries with large freshwater inflows (i.e., very large rivers) relative to the tidal flows, two layer flow can occur and a two-dimensional model will no longer adequately represent the actual flow conditions. However, this does not appear to occur in Knik Arm (neither the Knik nor Matanuska Rivers are large enough to establish such conditions).

Horizontal variations in density, as can occur in estuaries with large mud flats, can also affect flow patterns. These can be captured with a two-dimensional model that simulates density, but a three-dimensional model would provide better results. It needs to be noted that the advantages of a three-dimensional model in the above cases can only be obtained if salinity and temperature are also simulated. If the effects of salinity variability are negligible, the benefits of a three-dimensional model over a two-dimensional model are reduced.

Three-dimensional Analysis

A three-dimensional model is required when density stratification is important. Knik Arm does not appear to be either vertically or horizontally stratified so there does not appear to be any significant advantage of a three-dimensional over a two-dimensional model based on density-driven flows.

Another possible reason to select a three-dimensional over a two-dimensional model is to obtain better definition of velocity changes between deep and shallow areas where steep underwater slopes exist. In these locations there may be a significant vertical component to the velocity that is not accurately represented in a two-dimensional model. However, where underwater slopes are shallow the two-dimensional model should be adequate.

When estimating sediment deposition in deep holes a two-dimensional model may underestimate the fine material (silt) accumulation. In a deep hole the velocity near the bottom of the hole may be lower than predicted by the depth-averaged (i.e. two-dimensional) model as much of the flow may pass over the hole (depending upon its size). However, in Knik Arm the sediment appears to be mostly coarse material (sand) so this deficiency would not likely be an issue.

Overall, there does not appear to be a strong reason to use a three-dimensional model over a two-dimensional model. There are no significant density gradients so the three-dimensional model's ability to calculate density driven flows is not required. However, some localized flow variations could require three-dimensional modeling; steep underwater slopes near Cairn Point, for instance, would be better represented in a three-dimensional model. If two-dimensional modeling predicts scour depths that continue to be of concern near either the piers or abutments, then it would be advisable to select a three-dimensional model, or even a physical model, to examine the local hydrodynamic and sediment behavior in the immediate vicinity.

5.2 Scour Prediction

The following actions will lead to more precise and confident prediction of scour at Knik Arm Bridge:

1. Establish a program to monitor scour and ice interactions around newly installed piles under a pier at Port Mackenzie near the proposed bridge site.
2. Repeat multi-beam hydrographic surveys of the area for the purpose of measuring recent short-term change in the bed geometry and for comparison to historical hydrographic data to determine long-term changes. Analysis of multi-beam hydrographic data will also allow patterns of bed forms (*i.e.,* submarine sand dunes) to be discerned.
3. Continue measurements of bed sediment characteristics with a view toward definition of patterns in the vicinity of the bridge and for application to estimate sediment transport budgets and scour at the bridge.
4. Develop a two-dimensional unsteady flow numerical model with capability to simulate tidal flows as they occur in Knik Arm and to simulate changes in tidal flow induced by construction of bridge abutments.
5. Continue measurements of tidal currents at the proposed sites of abutments and piers, and complete a transect across Knik Arm for the purposes of calibrating and verifying numerical simulations, as well as estimating sediment transport patterns and rates near the bridge site.
6. Investigate the probability of extreme ice conditions causing a jam that would accelerate flows through the bridge opening, and design the bridge supports to minimize this likelihood.
7. As the design advances with the above measures, test abutment scour and pier scour with small-scale mobile bed physical models to verify and extend the predictions of empirical formulae and numerical simulations.
8. Incorporate means to monitor scour in the design of piers, abutments, and other bridge features.

5.3 Physical Modeling of Scour at Piers and Abutments

Empirical predictions of scour at single vertical piers are more reliable than predictions for battered piles or piling groups. Mobile bed physical models all suffer from unavoidable scale effects, but patterns of scour and order-of-magnitude scour pit dimensions are readily achievable at a small, relatively affordable scale. Abutment scour appears to be a sensitive issue for the Knik Arm Bridge, due to the half-mile length of the abutments and speed of tidal currents at the site. Extensive bed protection well beyond the toe to the abutments may be required. Flow-training wing walls or other current-guiding structures adjacent to the abutments may be considered. The pattern of scour will change with these mitigative structures in place and will be qualitatively predictable by small-scale mobile-bed physical modeling. A number of agencies and institutions in the U.S. and Canada operate physical scale modeling facilities for tests of this type.

6. General Recommendations

6.1 Further Data Analysis

Analyses of data collected by Dr. Smith (2004a) have thus far been cursory efforts to address very specific concerns. There is an abundance of information in this data set that can be applied to many of the data needs identified above. We recommend that a comprehensive analysis of these data be established as the basis for additional field studies and to support numerical modeling of Knik Arm oceanographic processes.

6.2 Additional Hydraulic Field Studies

The amount of sediment transport, and associated parameters, should be measured on one or more spring ebb tides. To the extent possible, the discharge, suspended load, and bed load should all be measured simultaneously. These data are necessary to calibrate the sediment transport function of the two-dimensional model that would be used to estimate scour depth at the piers and abutments. Monitoring of scour and seabed dynamics will provide valuable insight, as well as full-scale “model” data, for design of Knik Arm crossing components.

6.3 Numerical Modeling of Knik Arm Oceanography

To ensure that the oceanographic modeling adequately addresses both engineering and environmental concerns, we recommend convening a panel of experts – engineers, scientists, and planners – whose charge would be develop the scope of this effort after due consideration of the genuine needs and concerns. In this way, all potential users of modeling results would be apprised of the capabilities and limitations of modeling, and their expectations managed accordingly. Subsequently, a detailed scope of work would be developed and suitably qualified provider of modeling expertise would be identified and authorized to proceed.

6.4 Physical Modeling of Local Hydrodynamic / Scour Processes

The potential need for physical modeling to augment development of engineering design criteria for scour protection was identified above. We recommend that a procedure similar to that described above for numerical modeling be used for developing an appropriate scope of work and the means for its expedient delivery to engineering designers.

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