Physical Models of Knik Arm and Port of Anchorage, Alaska

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Port of Anchorage Expansion and the Corps' Mission

The Port of Anchorage, Alaska, is located on the eastern bank of the Knik Arm of Cook Inlet. Figure 1 is an aerial view of the Port during low tide. The Port serves 80% of Alaska's populated area, and it handles over 90% of consumer goods sold in the railbelt. Development, operation, and maintenance of navigation channels and berthing areas at the Port of Anchorage are the responsibility of the Alaska District, U.S. Army Corps of Engineers (USACE). Shoaling at Anchorage Harbor has required annual dredging ranging between 1,500,000 and 2,100,000 yd^3 over the last five years.

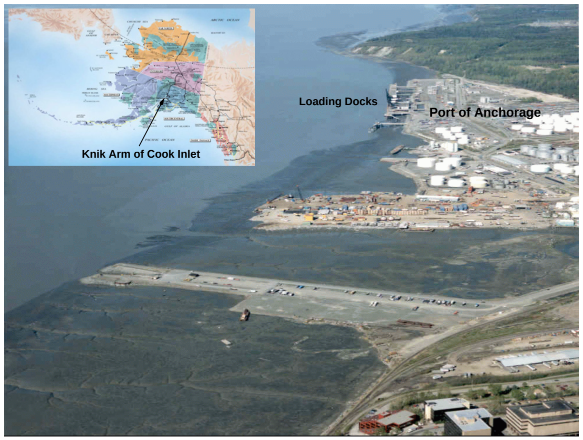

Figure 1. Port of Anchorage, Knik Arm, Cook Inlet, Alaska.

Planning is underway for a significant expansion to the Port of Anchorage with construction to be phased as illustrated in Figure 2. In addition to the engineering and construction challenges involved in this port expansion, Port authorities and USACE Alaska District engineers need to understand how the expansion could alter the tidal flow regime in this highly dynamic region where the tide range varies by as much as 30 feet. A key aspect for USACE engineers is estimating dredging requirements to meet navigation needs of the Port.

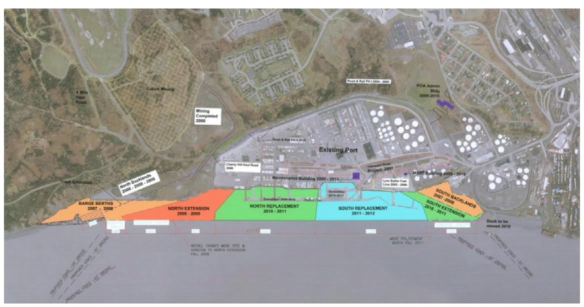

Figure 2. Proposed Port of Anchorage expansions.

Changes to the flow magnitudes and patterns caused by Port expansion and the construction sequence could impact shoaling patterns which, in turn, could affect operations at the Port of Anchorage. Physical model and numerical model studies sponsored by the Corps of Engineers Alaska District and conducted at the U.S. Army Engineer Research and Development Center (ERDC) in Vicksburg, Mississippi, are intended to give an assessment of flow modifications and changes to sedimentation likely to occur when these proposed engineering improvements are constructed.

The bathymetry of Cook Inlet and Knik Arm surrounding the Port of Anchorage has been constructed at small scale in two physical models. These models reproduce the spring tide cycle along with the large-scale gyres created by the predominant headlands. With the models engineers can assess differences to the flow regime caused by Port expansion. The physical models are also being used to improve a numerical flow model that drives a sophisticated numerical simulation of sedimentation in the Knik Arm of Cook Inlet.

Knik Arm Tidal Flow Physical Models

Two small-scale models of the Knik Arm have been constructed for these studies. The first model, termed the *"Large-Area Model"* covers a reach of Cook Inlet measuring approximately 19 statute miles. The red box on Figure 3 in the next column shows the region covered by the Large-Area Model, and Table 1 below presents the model scale ratios and key parameters as determined using Froude scaling laws. The model is geometrically distorted with a horizontal scale 4 times larger than the vertical scale.

Table 1. Large-Area Model Scales and Parameter Values.

Model Scales		
Scale	**Scale Value**	**Model Equivalence**
Horizontal length scale	N_X = 800	1 ft = 800 ft
Vertical length scale	N_Z = 200	1 ft = 200 ft
Geometric distortion	$\Omega = N_X/N_Z$ = 4	–
Time scale	$N_t = N_X/\sqrt{N_Z}$ = 56.6	1 s = 56.6 s
Velocity scale	$N_V = \sqrt{N_Z}$ = 14.14	1 ft/s = 14.14 ft/s
Horizontal area scale	$N_{AX} = N_X{}^2$ = 640,000	1 ft^2 = 14.7 acres
Vertical area scale	$N_{AZ} = N_X N_Z$ = 160,000	1 in^2 = 1,111 ft^2
Discharge scale	$N_Q = N_X N_Z^{3/2}$ = 2,262,742	1 gal/s = 302,485 ft^3/s
Model Parameter Values		
Parameter	**Prototype Value**	**Model Value**
Maximum tide range	≈ 35 ft	≈ 2.1 in
Tide cycle period	12.42 hr	13.17 min
Total tidal prism	1.03(10)^{11} ft^3	805 ft^3 (6,022 gal)
Maximum flow velocity	≈ 10 ft/s (6 kts)	≈ 0.7 ft/s
Maximum discharge	7,170,000 ft^3/s	3.17 ft^3/s (1,422 gal/min)
Deepest elevation	-170 ft mllw	-10.2 in mllw

The second Cook Inlet model, termed the *"Small-Area Model"* focuses on a 6.5-mile reach of the Knik Arm centered on the Port of Anchorage as outlined by the blue box drawn on Figure 3. Model scales and equivalent key parameters for the Small-Area Model are given in Table 2. Geometric distortion is less for this model. Figure 4 shows how the large-area and small-area models are situated in the 60-ft-wide ESTEX flume.

Table 2. Small-Area Model Scales and Parameter Values.

Model Scales		
Scale	**Scale Value**	**Model Equivalence**
Horizontal length scale	N_X = 400	1 ft = 400 ft
Vertical length scale	N_Z = 200	1 ft = 200 ft
Geometric distortion	$\Omega = N_X/N_Z$ = 2	–
Time scale	$N_t = N_X/\sqrt{N_Z}$ = 28.3	1 s = 28.3 s
Velocity scale	$N_V = \sqrt{N_Z}$ = 14.14	1 ft/s = 14.14 ft/s
Horizontal area scale	$N_{AX} = N_X{}^2$ = 160,000	1 ft^2 = 3.7 acres
Vertical area scale	$N_{AZ} = N_X N_Z$ = 80,000	1 in^2 = 555 ft^2
Discharge scale	$N_Q = N_X N_Z^{3/2}$ = 1,131,370	1 gal/s = 151,252 ft^3/s
Model Parameter Values		
Parameter	**Prototype Value**	**Model Value**
Maximum tide range	≈ 35 ft	≈ 2.1 in
Tide cycle period	12.42 hr	26.33 min
Total tidal prism	1.03(10)^{11} ft^3	3,219 ft^3 (24,080 gal)
Maximum flow velocity	≈ 10 ft/s (6 kts)	≈ 0.7 ft/s
Maximum discharge	7,170,000 ft^3/s	6.34 ft^3/s (2,846 gal/min)
Deepest elevation	-170 ft mllw	-10.2 in mllw

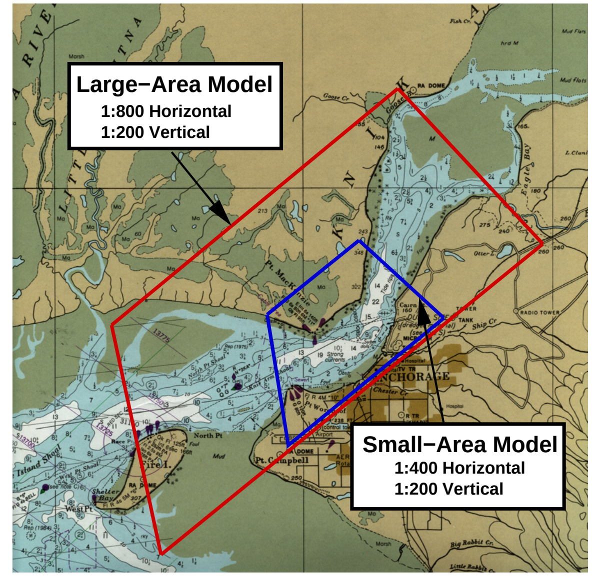

Figure 3. Coverage of Knik Arm physical models.

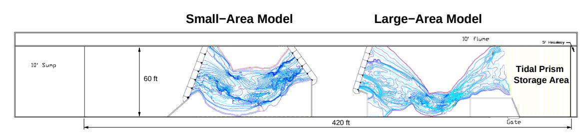

Figure 4. Location of Knik Arm models in ESTEX flume.

Physical Model Study Objectives

The objectives of the **Knik Arm Physical Model Study** include the following:

- Examine changes to the hydrodynamic flow regime likely to occur after each phase of the planned Port of Anchorage expansion.
- Assess project impacts to Corps of Engineers navigation, dredging, and port maintenance operations.
- Provide measurements for improving advanced numerical models of the complex flow and sediment transport regime in the Knik Arm.

Point of Contact

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