IODP proposal 992-Full: Understanding megathrust earthquake hazards and post-LGM climate change along the southern Alaska margin through scientific drilling

USGS science for a changing world

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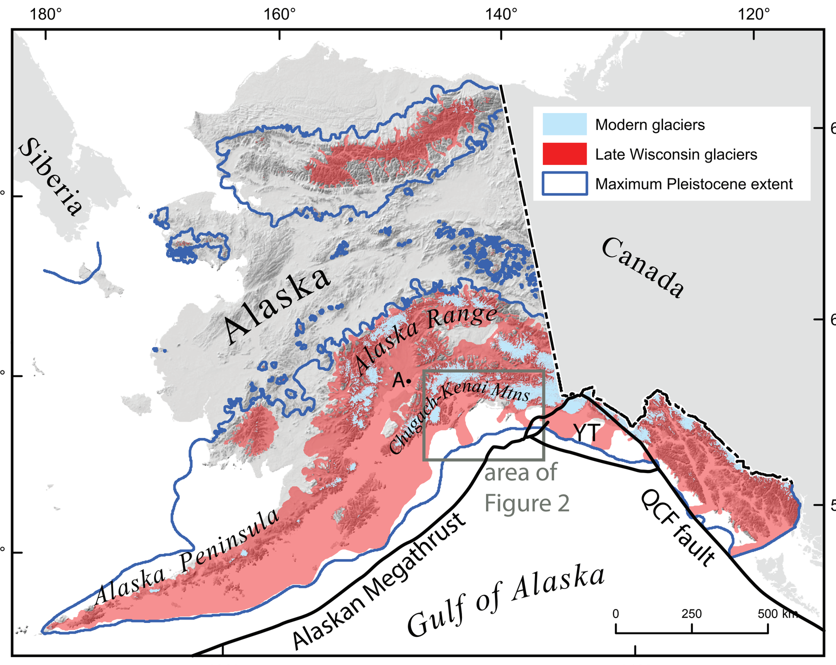
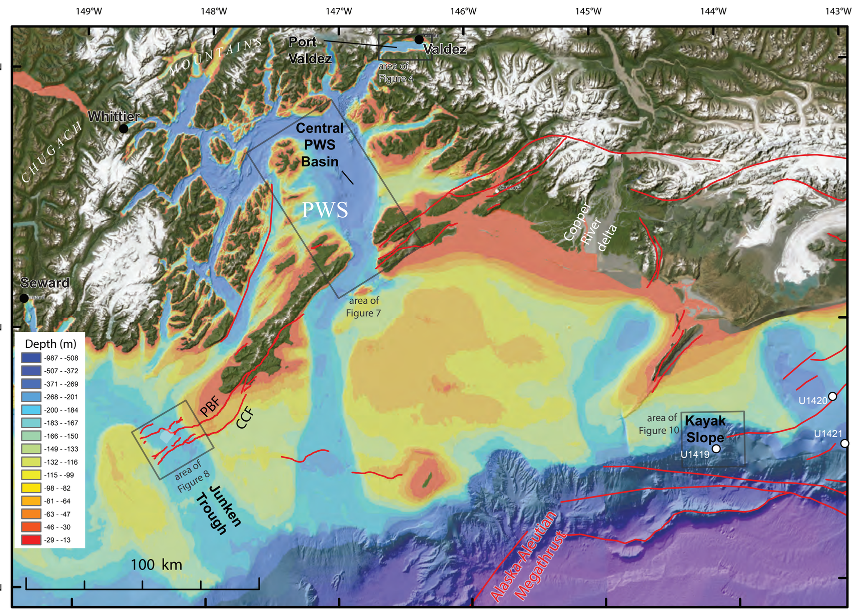
Introduction

Southern Alaska is a preeminent location to address central IODP challenges, with sedimentation rates providing exceptional resolution of time-varying processes. The Prince William Sound region of Alaska experienced a Mw 9.2 earthquake in 1964 and is the best modern example of a glaciated subduction margin. We aim to develop a paleoseismic and paleoclimate record to address: 1) megathrust earthquake recurrence, the completeness of marine paleoseismic records, mechanical conditions governing tsunamigenic splay faulting, and submarine landsliding; 2) distal-proximal timing, synchroneity, and abruptness of Cordilleran Ice Sheet dynamics linking to nearby IODP Exp. 341 drilling, and extending the highest resolution site U1419 to ~150,000 years to compare deglacial dynamics across two glacial terminations, and understand the dynamics of Cordilleran ice growth. Seismic data indicate likelihood of collecting good stratigraphic sequences through Marine Isotope Stage 3 in Prince William Sound and to MIS 6 in Junken Trough and Kayak Slope, to test emerging hypotheses about abrupt climate and ice sheet change, and ice-ocean-sediment interactions in large marine terminating outlet glaciers. We propose drilling 10 holes in 4 areas. Our proposal is in for its second review.



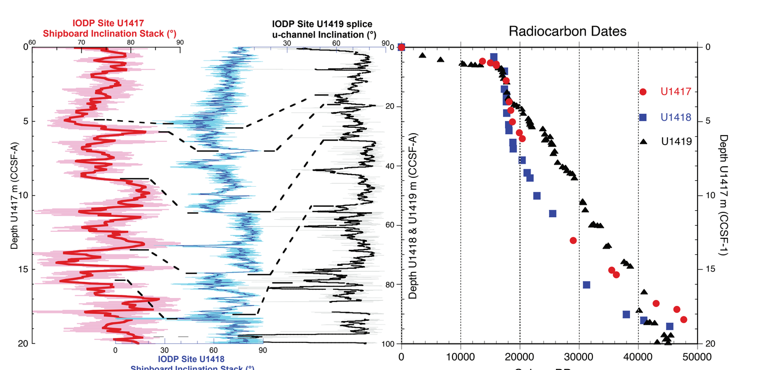
The glacial framework

Late Wisconsin (LGM) and Pleistocene maximum extent of glaciers in Alaska, from Kaufman et al. (2011). Modern glaciers, in light blue, also highlight regions of high topography. Inset box shows location of proposed drilling areas below. A, Anchorage; QCF, Queen Charlotte-Fairweather fault; YT, Yakutat terrane.



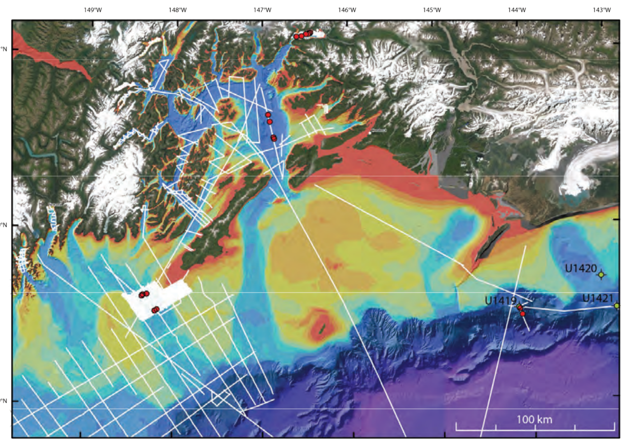
Four proposed drilling areas

Geographic setting of the Prince William Sound and four proposed drilling areas: (1) Port Valdez, (2) Central PWS Basin, (3) Junken Trough; (4) Kayak Slope. Red lines show active faults. PBF: Patton Bay fault; CCF: Cape Cleare fault



High-resolution stratigraphy

IODP Expedition 341 results showed exception resolution in the stratigraphic record due to an abundance of datable material and high sedimentation rates. Paleomagnetic and radiocarbon age model template developed from U1419 (Walczak et al., 2020); U1418 (Velle et al., 2022), U1417 (Stoner et al., unpublished data).



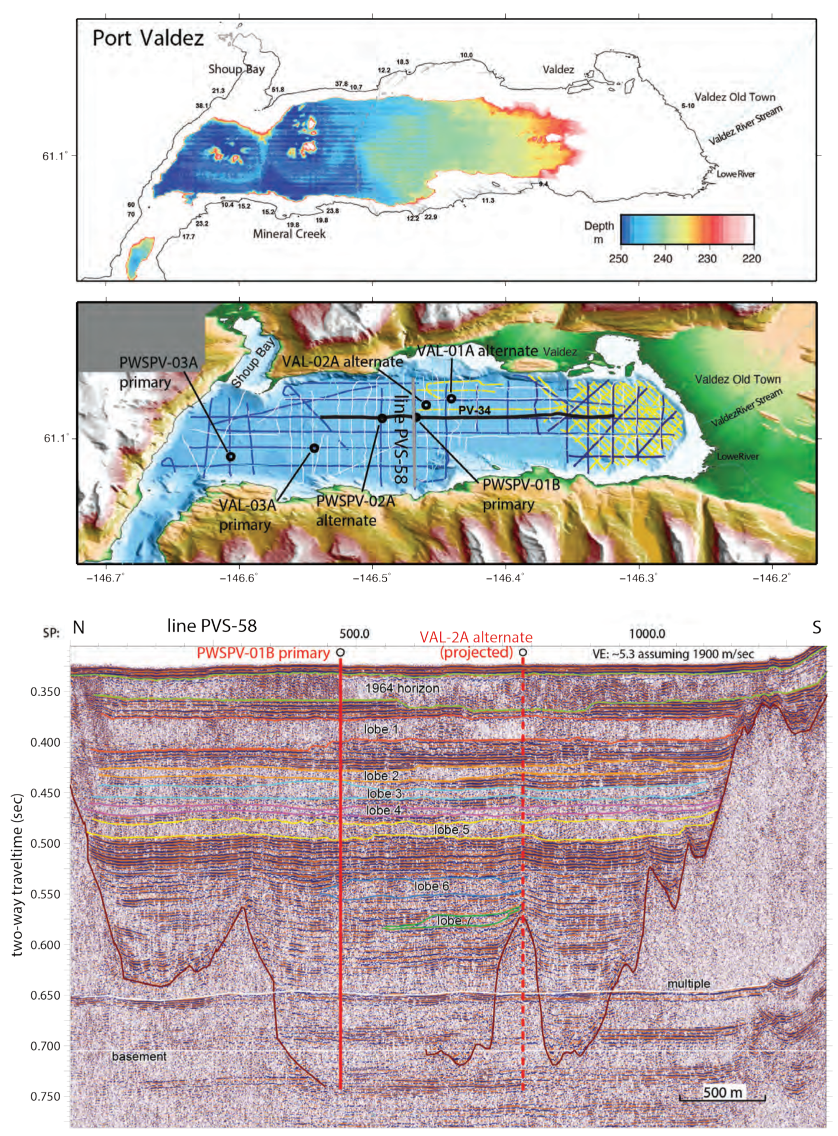
Seismic data

An abundance of seismic data provides context for proposed drilling. Seismic lines are shown by white lines, in the Prince William Sound region used to develop this proposal. Proposed drilling localities shown with red circles. IODP holes U1419, U1420, and U1421 are also shown with green symbols.

Proposed Drilling

1) Port Valdez area

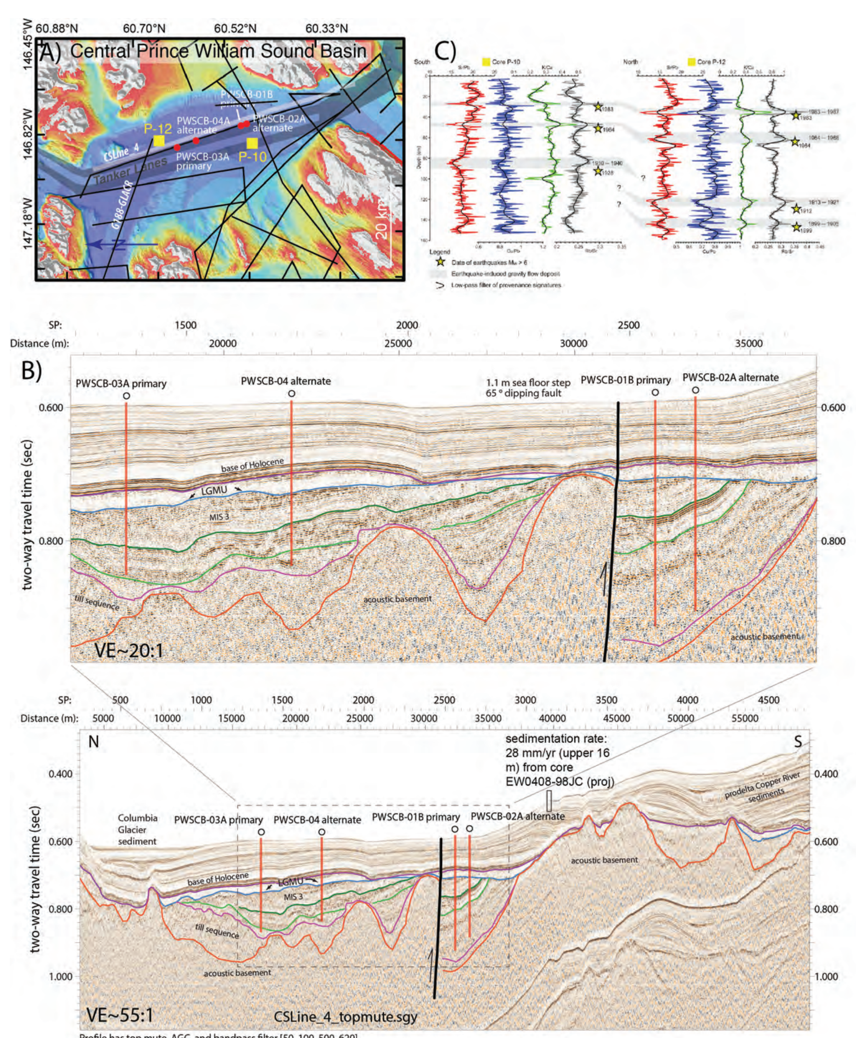
Goals are to: a) Develop a history and mechanistic understanding of large submarine landslides, compare the timing to terrestrial paleoseismic records, and test relationships between frequency and/or volume of landslides during neoglacial times (last 3-4 kya) relative to earlier Holocene; b) Analyze a Holocene climate record to examine the potential causes and impacts of Holocene climate states at high resolution.



The Port Valdez drilling locality with proposed hole locations. (A) high-resolution bathymetry of Port Valdez from 220-250 m depth highlights the landslide debris morphology, including main westward flowing 1964 slide, and blocks and low-angle circular lobes downslope of Shoup Bay. Tsunami run-up elevations in meters (black numbers) and inferred direction of wave movement (grey arrows) as indicated for the western portion of the fjord by Plafker et al. (1969). (B) Topography, bathymetry, and seismic tracklines. White, cyan and yellow lines indicate the location of older single channel sparker seismic and chirp data (e.g. Ryan et al., 2010). Dark blue lines show collocated sparker or boomer MCS reflection profiles and high-resolution chirp profiles collected in 2013. (C) Seismic profile PVS-58, showing repeated submarine landslide deposits. Line location shown in (B). X-axis is distance along line in meters. Individual landslide debris layers highlighted with colored shading. Green shading at top denotes 1964 event.

(2) Central Prince William Sound Basin area

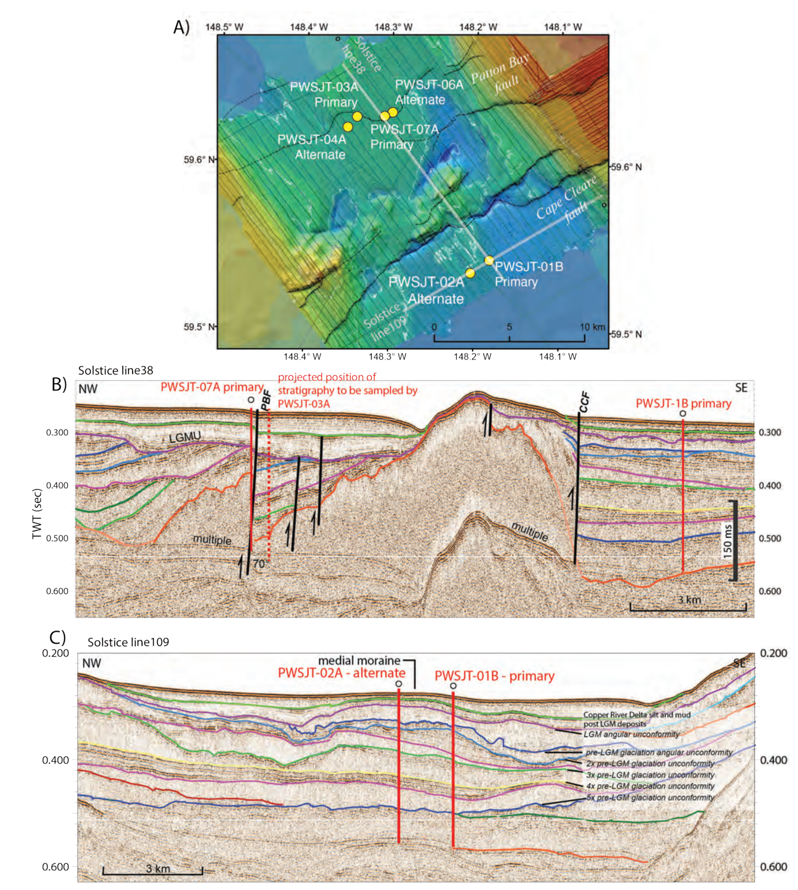
Goals are to: a) Collect a late Pleistocene climate and sedimentary record and establish timing of major ice stream deglaciation; b) develop a potential 10,000-year record of megathrust earthquakes; c) examine a high-latitude record of abrupt MIS 3 climate changes in an ice-proximal setting; d) establish slip rate and variability of a megasplay fault.



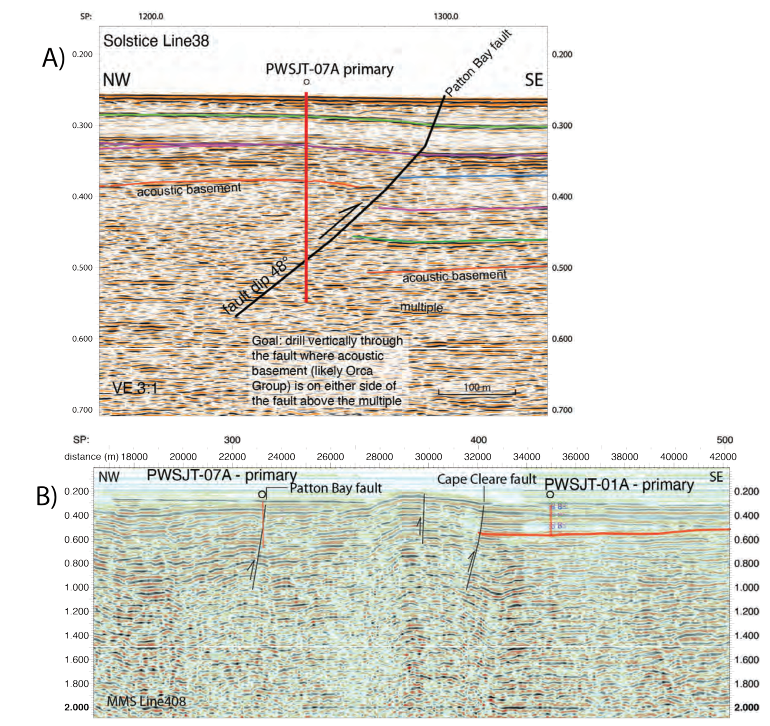
A) location map showing proposed drill sites with red circles. MCS lines in black, and tanker traffic lanes in grey. Yellow squares show locations of cores studied by Kuehl et al. (2017) shown in part (C). B) Minisparker seismic line CS4 modified from Finn et al. (2015). Blue horizon is the LGM unconformity, as evidenced by the angular unconformity associated with splay faults in the center of the region. Older sediment between the blue and violet lines is possible MIS 3. Green horizons are marker horizons within the unit. Between the violet horizon and acoustic basement is a probable till sequence. C) Downcore elemental ratios (from XRF) of key provenance ratios distinguishing Copper River and Prince William Sound sediment sources from Kuehl et al. (2017). Major excursions showing strong Prince William Sound provenance are seen at four depths in P-12 and three depths in P-10, indicating sediment gravity flows. A 210Pb age model is used to calculate age ranges for each of the correlative excursions interpreted as earthquake-generated sediment gravity-flow deposits. Thus, the entire top section may contain an earthquake record spanning Holocene time.

3) Junken Trough area

Goals are to: a) Constrain rates and progression of megathrust splay faulting that ruptured in 1964, b) evaluate mechanical properties and fault zone structure by drilling through a modern active splay fault; c) develop ice-proximal climate record through three glacial cycles.



Proposed drill sites shown in red. A) Multibeam bathymetry of the trough and seismic tracklines. Location of map shown in Figure 2. The Cape Cleare fault (CCF) and Patton Bay faults (PBF) have clear expression. B) Sparker MCS line showing along-strike trough structure. C) Sparker MCS line across trough, just south of the Cape Cleare fault. Note the presence of pre-LGM strata with parallel reflectors, which may be MIS 3 interglacial sediment, or sediment deposited between successive advances. Below this are additional glacial-interglacial sequences.

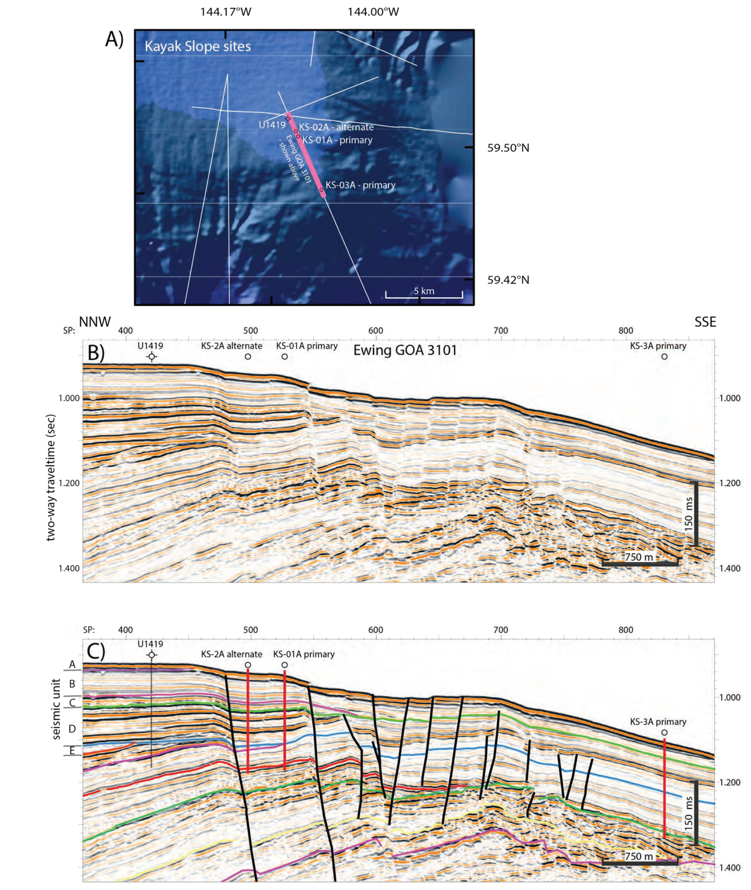


Proposed megathrust splay fault drilling sites at Junken Trough

Site PWSJT-07A, on an active strand of the Patton Bay fault, is the primary target. B) At depth, the fault has a ~48° dip assuming 1900 m/sec velocities. We infer acoustic basement (Orca Group) at 307 m, the fault zone at 540 m, and then TD for the hole would be at 601 m at the multiple. (C) 1975 MMS line 408 airgun data clearly show the fault extending to well below 2.0 seconds depth. It also shows every other fault we identify on the high-resolution seismics, which gives us confidence in its imaging. Thus, we see this as a rare opportunity to drill an active megathrust splay fault.

(4) Kayak Slope area

Obtain: a) a long (~150,000 yr) continental slope record of deglaciation and climate change extending the well-dated Quaternary record at nearby Site U1419, b) compare/contrast the LGM deglaciation to older transitions (MIS 5-6) and examine ice growth dynamics in the transition from the last interglacial to the last ice age. Compare with nearby Junken Trough, and with other global margins to determine ice stream synchronicity.



A) location map. B &C) Seismic images are time migrated stacks, with (B) being uninterpreted, and (C) is interpreted. Proposed drill holes are thick red lines. Site U1419 is thin red line at left. Seismic stratigraphy based on Jaeger et al. (2014) from U1419 drilling, with Seismic Unit A as Holocene, Unit B dates from ~15-36 kya, and Unit C is ~36-60 kya. .

Table of proposed drillsites

Site	Priority	Area	Latitude	Longitude	Water Depth (m)	Penetration	Site Time (d)
VAL-01A	Alternate	Port Valdez	61.11470	-146.44190	237	293	4.5
VAL-02A	Alternate	Port Valdez	61.11240	-146.46080	238	308	4.5
VAL-03A	Primary	Port Valdez	61.09670	-146.54470	246	312	4.5
PWSPV-01B	Primary	Port Valdez	61.10790	-146.46833	242	403	6.0
PWSPV-02A	Alternate	Port Valdez	61.10764	-146.49375	245	445	5.0
PWSPV-03A	Primary	Port Valdez	61.09381	-146.60730	251	391	6.0
PWSCB-01B	Primary	PWS central basin	60.52442	-146.87512	440	314	5.0
PWSCB-02A	Alternate	PWS central basin	60.51523	-146.86882	439	276	5.0
PWSCB-03A	Primary	PWS central basin	60.65210	-146.93627	445	251	4.5
PWSCB-04A	Alternate	PWS central basin	60.61235	-146.91828	442	239	4.5
PWSJT-01B	Primary	Junken Trough	59.54248	-148.18414	209	*274*	6.4
PWSJT-02A	Alternate	Junken Trough	59.53480	-148.20785	205	*259*	6.2
PWSJT-03A	Primary	Junken Trough	59.62614	-148.34294	195	*283*	6.5
PWSJT-04A	Alternate	Junken Trough	59.62044	-148.35329	194	*295*	6.6
PWSJT-06A	Alternate	Junken Trough	59.62928	-148.30101	197	413	7.5
PWSJT-07A	Primary	Junken Trough	59.62566	-148.30998	194	413	7.5
KS-01A	Primary	Kayak Slope	59.52154	-144.12280	713	183	4.7
KS-02A	Alternate	Kayak Slope	59.52461	-144.12517	710	202	4.7
KS-03A	Primary	Kayak Slope	59.03293	-147.42382	832	180	4.7
				Total site time estimate at primary sites:			55.8