SCUBA TECHNIQUES USED IN RISK ASSESSMENT OF POSSIBLE NUCLEAR LEAKAGE AROUND AMCHITKA ISLAND, ALASKA

Stephen Jewett, Max Hoberg, Heloise Chenelot, Shawn Harper
Institute of Marine Science, University of Alaska Fairbanks, Fairbanks, AK 99775-7220

Joanna Burger
Division of Life Sciences, Consortium for Risk Evaluation with Stakeholder Participation (CRESP), and Environmental and Occupational Health Sciences Institute (EOHSI), 604 Allison Road, Rutgers University, Piscataway, New Jersey 08854-8082

Michael Gochfeld,
CRESP and EOHSI, UMDNJ-Robert Wood Johnson Medical School, Piscataway, New Jersey 08854

Abstract

Amchitka Island, in the Aleutians, had three underground nuclear tests (1965 to 1971) ranging from approximately 80 kilotons to 5 megatons. Initial surveys (1960s-1970s) did not report radioactive contamination in the marine environment. The U.S. Department of Energy (DOE) is moving to closure and Long-term Stewardship of Amchitka Island. Therefore, it is necessary for a reassessment of Amchitka's marine environment with respect to possible current or future transfer of radionuclides to marine ecosystems, particularly to sensitive or endangered species, and to foods harvested by Aleut and commercial fishermen. The Amchitka Science Plan was compiled by CRESP, a multi-university consortium of researchers, as a guideline for the reassessment. One of the overall objectives of the Science Plan is to evaluate possible contamination of marine organisms of concern to subsistence hunters and fishers in Native Communities, the U.S. Fish & Wildlife Service, the Alaska Department of Environmental Conservation, DOE as well as other stakeholders, and to provide a baseline for future monitoring.

An assortment of marine organisms was collected at Amchitka and at a reference site (Kiska), including representatives of various trophic levels, sedentary/sessile plants and animals, and subsistence/commercial species in the intertidal and subtidal zones. A team of scuba divers from University of Alaska Fairbanks collected shallow (< 30 m) subtidal organisms during July 2004. This paper details the rationale and methods used by the divers to log nearly 93 hours of bottom time collecting thousands of samples of water, sediment, kelp, invertebrates, and fishes for radionuclide analyses.

Introduction

Amchitka Island, situated in a tectonically and seismically active area in the western Aleutians, was the scene of three underground nuclear test shots: *Long Shot* (~80 kilotons) in 1965; *Milrow* (~1 megatons) in 1969; and *Cannikin* (~5 megatons) in 1971 (Figs. 1 and 2). Amchitka Island is unusual among US legacy sites of the Cold War in a number of ways:

- Underground nuclear explosions of exceptional size including the largest (*Cannikin*) ever;
- Location within an actively deforming plate boundary characterized by intense earthquake activity;
- Remote location and difficulty of access;
- Proximity to Asia;
- Location within an important international fishery;
- Protected status as a National Wildlife Refuge with endangered species; and
- Part of the marine environment that supports the subsistence lifestyle of indigenous people and significant commercial fisheries.

Many concerns over earthquakes, pollution, and marine resources were voiced at the time of the testing. Initial surveys did not report evidence of radioactive contamination in the marine environment, and residual radionuclides were considered confined to the test cavities (Merritt and Fuller 1977). At present, the U.S. Department of Energy (DOE) is moving to closure of contaminated sites and longterm stewardship. Therefore, it is necessary to reassess the marine environment with respect to possible current or future transfer of radionuclides and other contaminants to the sea, to foods harvested by Aleut fishers and hunters, foods of commercial interest, and selected representatives of marine food webs. It is also necessary to develop plans for the scope and frequency of the monitoring that will be needed in the long term stewardship program.

The cause for stakeholder concern is that residual radionuclides from nuclear tests may migrate through the fractured and faulted rock, carried by groundwater, and enter the marine food chain potentially causing ecological and human health effects. As a result of this concern, Alaska Department of Environmental Conservation (ADEC) and DOE requested that the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) take the lead role in organizing and implementing the *Amchitka Independent Assessment Science Plan* (hereinafter referred to as *Science Plan*) (Burger *et al*. In Press). CRESP is a multi-university consortium of researchers dedicated to assisting DOE in the planning and prioritizing of its massive environmental management responsibilities, through the involvement of stakeholders at each step of the risk management process. Members of the Amchitka CRESP team are from U Maryland and New Jersey-Robert Wood Johnson Medical School, Rutgers U., Vanderbilt U., U. Pittsburgh, U. Alberta, and U. Alaska Fairbanks. The Amchitka CRESP team mobilized to implement the Science Plan with a three-phase field expedition in 2004.

Approach and Rationale

Since the potential exists for radionuclides from the test shots to be carried into the marine environment by freshwater through seeps along faults and fractures, research is needed to determine the location where these discharges may occur. To address this need a physical oceanographic survey (Phase I) was conducted from the 49-m F/V *Ocean Explorer* during June 12-23 by UAF Physical Oceanographer Mark Johnson and a group from the Naval Undersea Warfare Center, Keyport, Washington. Twelve transects were established adjacent to *Cannikin* and *Long Shot* and perpendicular to shore at depths ~30-90 m (Fig. 3). These transects covered an area determined in part by the location of fault lines nearest to the blast sites and extending in a parallel direction offshore. Due to the presence of extensive canopy-forming kelp, depths < 30 m could not be surveyed by the *Ocean Explorer*. The team used a multibeam echosounder to construct the bathymetry, a side scan sonar with sub-bottom profiler to map the substrate, and a Conductivity-Temperature-Density (CTD) instrument to determine whether there is fresher-than-expected water near the ocean floor. Bottom water and sediment samples were also collected for radionuclide analyses. No physical oceanographic transects were established off *Milrow* due to inclement weather, time and budgetary constraints. Another task conducted on land simultaneously during Phase I was magnetotulleric and audiomagnetotulleric testing of the subsurface on Amchitka by Physicist Martyn Unsworth, U. Alberta. This task was carried out along the cross-island transects contiguous to the nuclear test shots, to characterize the Amchitka rock mass and to identify the depth and location of the most likely groundwater pathways from the island to the sea.

A second survey (Phase II) was carried out from June 29 through July 19 aboard the *Ocean Explorer* to sample marine birds, intertidal organisms and the benthic environment (inside the 30-m depth by scuba divers). Divers from UAF focused on eastern Amchitka Island and Kiska Island, the Reference site situated approximately 80 km west of Amchitka (Fig. 4). Transects established for physical oceanography off *Cannikin* and *Long Shot* were extended to shore and transects established off *Milrow* and Kiska Island (Figs. 5-7) were sampled by divers. The rationale for positioning the *Milrow* transects was based on proximity to this test shot and known fault lines. Locations of the Kiska Island transects were based mainly on proximity to shore-based sampling sites on the east and west sides of the island. Divers collected sediment, water, algae and animals at about 5, 9, 18, and 27-m depths along the transects. Limited sampling occurred at the 27-m depth due to the need to adhere to no-decompression diving at this remote region.

Diving operations were conducted by two teams each consisting of two divers and a tender using an inflatable skiff. Dive sites along transects were determined with the aid of portable depthsounders (Speedtech Instruments Model SM-5) and GPS units (Garmin GPSmap 60CS with BlueChart electronic nautical charts). Dive teams worked adjacent dive sites simultaneously and they were in constant radio contact.

At each dive site divers descended to the anchor and sampled within a ~60-m radius of the anchor. Dive time at each site varied from 20-60 minutes, depending upon the depth. Each diver had a mesh bag ("goody bag") and dive knife for collecting organisms. One diver also had a spear for spearing fishes and octopus and containers for water and sediment. Water and sediment sampling in all shot site areas surrounding Amchitka Island was performed to fulfill the Radiological Health and Safety provisions of the overall Amchitka Expedition, Health and Safety Plan and to supplement the physical and biological data collected on the expedition. Typically two 1-L plastic containers of water were collected within 1 m of the bottom. Containers were filled at the surface and purged at depth and replaced with bottom water. Wherever soft substrate was encountered a 1-L plastic container was filled with surface (to 5 cm deep) sediment by plowing the open jar across the substrate. Digital still and video recordings were made of the diving activities.

Phase III of the CRESP expeditions was carried out in deeper waters around Amchitka and Kiska islands aboard the biennial NOAA Aleutian Islands bottom trawl survey. CRESP researcher, James Weston, collected designated fishes and other marine biota from the F/V *Gladiator* during July 18 and August 7.

Organisms targeted for collection included some subsistence and commercial species (Table 1), species previously tested for radionuclide analyses (Table 2), species trophically important, and species with various modes of mobility, longevity and feeding. Approximately 1500 g wet weight (composited) of each species was targeted per site. All samples including water, sediment and biota were screened for radioactivity in the field to insure that expedition personnel were not exposed to radiation in excess of HASP exposure guidelines. Organisms collected by divers are presented below mainly by feeding mode, but other life-history attributes are presented.

Primary Producers

The dominant primary producers were brown algae (kelp), mainly *Alaria fistulosa*. This canopy-forming subtidal species is an annual and can attain lengths up to 25 m (O'Clair *et al*. 1996). For kelp collections, 1 m of the plants' proximal (including holdfast and sporophylls) and distal ends were cut off and bagged. Five replicates were collected per site. Other species of brown algae collected less frequently included *A. nana, Laminaria bongardiana*, *L. yezoensis, L. saccharina*, *Agarum clathratum*, *Cymathere triplicata* and *Fucus gardneri*. The latter species was collected intertidally without diving.

Grazers

The dominant grazer or herbivore collected was the green sea urchin *Strongylocentrotus polyacanthus*. This urchin feeds mainly on kelp, including *A. fistulosa*, while it is the main food of sea otters, as well as occasionally eaten by Aleut residents of Atka, Alaska. Approximately 12 or more large urchins were bagged from each site. Another grazer included the gumboot chiton or giant Pacific chiton *Cryptochiton stelleri*, the largest chiton (to 33 cm long) in the world. These brick red organisms were typically pried off rocks by hand, unlike smaller chitons of other species that require tools to extract them. This chiton feeds on a variety of young kelps and it is eaten by Aleut residents from Atka. *Cryptochiton* can live to more than 20 years (O'Clair and O'Clair 1998). Although generally low in density, 2-6 individuals were collected at sites where possible.

Filter feeders

The dominant filter feeder or suspension feeder collected was Jingle Shell or Alaska Falsejingle *Pododesmus macroschisma*. Much of the carbon of this bivalve is derived from detritus sloughed off the blades of growing kelps (O'Clair and O'Clair 1998). It is mainly eaten by a variety of sea stars. The size of the jungles that were collected approximated 8-12 cm wide. It was pried off rocks using a knife and generally 6-12 individuals were collected per site. Another filter feeder taken was an unidentified spherical tan sponge with a size to ~10 cm in diameter. This sponge was relatively ubiquitous, but low in density. Some sponges are known to be long-lived, perhaps in excess of a hundred years (O'Clair and O'Clair 1998). Generally 6-12 individuals were collected per site. Other filter feeders collected were the Northern Horse Mussel *Modiolus modiolus* and Blue Mussel *Mytilus trossulus*. *Modiolus* was more common than *Mytilus*, however, both species were in low densities. *Modiolus,* which attains a larger size than *Mytilus*, required much time to dig out of rocky crevasses where they were secured by byssal threads and camouflaged by a variety of epiphytic organisms. Typically 4-6 individuals of each species were collected where possible.

Deposit feeders

The only deposit feeder collected was the sand dollar *Echinarachnius parma*. This organism was taken partially buried within the sand surface, however, only a few sites had sandy sediment. Because of the low density only 4-6 individuals were taken per site.

Predators/scavengers

The snail known as the Oregon Triton or Hairy Triton *Fusitriton oregonensis* was a common predator/scavenger invertebrate. This snail, which attains lengths up to 12 cm, was typically cryptic with various epiphytic organisms attached to their shell. *Fusitriton* feeds on a wide variety of invertebrates (O'Clair and O'Clair 1998). Typically 4-6 individuals of this snail were taken where possible. Another invertebrate predator/scavenger was the Giant octopus *Octopus dofleini*. This species feeds on a variety of benthic organisms and it is taken by sea otters and occasionally by subsistence harvesters at Atka. Although this species is not long-lived (<5 years), it can attain very large size - to 272 kg (O'Clair and O'Clair 1998); specimens collected by divers ranged up to 23 kg. This octopus typically required both divers to subdue by spearing and bag at depth.

Fish predators collected by divers with spears mainly included Rock greenling *Hexagrammos lagocephalus*, Irish lords *Hemilepidotus jordani* and *H. hemilepidotus*, rockfishes *Sebastes ciliatus, S. melanops*, Pacific cod *Gadus macrocephalus,* and Rock sole *Lepidopsetta bilineata*. Typically less than six individuals of each of these species were taken at a site. The Rock greenling, known locally as "Pogie", is harvested by subsistence users at Atka; adults as well as eggs deposited on kelp and rocks are taken. This is a very territorial fish and relatively easy to approach and spear. Pacific cod are taken for subsistence and commercial purposes. The only species taken from the less encountered sandy substrate was Rock sole. This species feed mainly on benthic invertebrates, while the other fishes feed on benthic and pelagic invertebrates and fishes.

Results

Samples were collected for radionuclide analyses by divers at 50 transect sites, with 17 at Long Shot, 9 at Milrow, 12 at Cannikin and 12 at Kiska Island, the Reference (Table 3).

Opportunistic sampling also was carried out at Constantine Harbor (Amchitka) and Kiska Harbor. Dive sampling resulted in 136 dives for a total bottom time of nearly 93 hours. Samples included bottom water, sediment, four genera of brown algae, nine genera of benthic invertebrates, and six genera of fishes. Organisms were selected for analyses based on their importance in subsistence and commercial fisheries (Table 1), history of radiological baseline information (Table 2), mobility (Table 4), and life history traits. The CRESP team has initiated the processing of the specimens for testing at Idaho National Engineering and Environmental Laboratory (INEEL) and Vanderbilt U. Isotopes of interest for analysis in this study are the gamma emitters ^{137}Cs, ^{152}Eu, ^{60}Co; alpha emitters $^{238, 239, 240, 241}$Pu, $^{234, 235, 236, 238}$U, ^{241}Am; and beta emitters ^{90}Sr, ^{3}H, ^{99}Tc, ^{129}I. Of these, ^{137}Cs and ^{90}Sr are most likely to accumulate in muscle (soft tissue) and cause human health risks through consumption. The other isotopes that are expected to result from the test shots accumulate preferentially in either skeletal material (bones or exoskeletons) or specific organs, with a lesser distribution in muscle. Details of the sample preparations and radionuclide analytical results will be presented in a report scheduled for Spring 2005.

References

Bartell, S.M., Nobmann, E.D., and Ponce, R.A. 1999. *What People Eat*: *Atka, Alaska, 1998-1999.* Final Report submitted to University of Alaska and Aleutian/Pribilof Islands Association,Inc. Prepared by IDM Consulting, 3935 Apollo Drive, Anchorage, AK 99504. 59 pp.

Burger, J., Gochfeld, M., Kosson, D., Powers, C.W., Friedlander, B., Eichelberger, J., Barnes, D., Duffy, L.K., Jewett, S.C. and Volz, C.D. In Press. Science, policy, and stakeholders: developing a consensus science plan for Amchitka Island, Aleutians, Alaska. Journal of Environmental Planning and Management.

Kruse, G.H., Crow M, Krygier, E.E. et al. 2001. *A Review of Proposed Fishery Management Actions and the Decline of Steller Sea Lions Eumetopias jubatus in Alaska: A Report by the Alaska Steller Sea Lion Restoration Team.* Alaska Dept of Fish and Game Regional Informational Report 5J01-04, Juneau, Alaska.

Merritt, M.L. and Fuller, R.G. (eds.). 1977. *The Environment of Amchitka Island, Alaska.* Technical Information Center, Energy Research and Development Administration. Report, TID-26712.

O'Clair, R.M., Lindstrom, S.C., and Brodo, I.R. 1996. *Southeast Alaska's Rocky Shores: Seaweeds and Lichens*. Plant Press, Auke Bay, Alaska.

O'Clair, R.M. and O'Clair, C.E. 1998. *Southeast Alaska's Rocky Shores: Animals*. Plant Press, Auke Bay, Alaska.

Witherell, D. 2000. *Groundfish of the Bering Sea and Aleutian Islands Area: Species Profiles 2000.* North Pacific Fishery Management Council, Anchorage, AK.

Table 1. Marine species most commonly harvested for subsistence in Atka, Alaska (source: Bartell *et al*. 1999) and most commonly harvested commercially near Amchitka Island (source: Kruse *et al.* 2000; Witherell 2000).

Subsistence Food	**Commercial Food**
Sea Lion	Atka Mackerel
Pacific Salmon	Pacific Cod
Pacific Halibut	Walleye Pollock
Harbor Seal	Pacific Ocean Perch
Chiton	Sablefish
Pacific Cod	Pacific Halibut
Octopus	Turbot
Sea Urchin	Greenland Turbot
Dolly Varden	Brown King Crab
Rock Greenling ("Pogie")	

Table 2. Marine plants and animals collected for radiological analyses near Amchitka Island in 1965-75 (source: Merritt and Fuller 1977) and 2004 (present study).

1965-75

Mammals	**Fishes**	**Invertebrates**	**Algae**
Sea otter	Rattail	Sponge	Red - *Corallina*
	Cal. Smoothtongue	Jellyfishes	Red - *Constantinea*
	Dolly Varden	Blue Mussel	Red - *Porphyra*
	Salmon (5 spp.)	Weathervane Scallop	Red - *Halosaccion*
	Lantern Fish	Snails	Brown - *Alaria*
	Northern Lampfish	Squid	Brown - *Fucus*
	Pacific Cod	Octopus	Brown - *Laminaria*
	Walleye Pollock	Mysid	Brown - *Hedophyllum*
	3-Spine Stickleback	Krill	Brown *Thalassophyllum*
	Pacific Ocean Perch	Isopod	Green - *Ulva*
	Dusky Rockfish	Amphipod	
	Rock Greenling	Tanner Crab	
	Atka Mackerel	Horse Crab	
	Red Irish Lord	Red King Crab	
	Sculpin	Brown King Crab	
	Pacific Halibut	Basket Star	
	Turbot	Sea Urchin	
	Rock Sole		

2004

Mammals	**Fishes**	**Invertebrates**	**Algae**
	Pacific Cod	Sponge	Brown - *Alaria*
	Pacific Ocean Perch	Blue Mussel	Brown - *Fucus*
	Dusky Rockfish	Horse Mussel	Brown - *Laminaria*
	Rock Greenling	Rock Jingle	Brown - *Agarum*
	Atka Mackerel	Gumboot Chiton	Brown - *Cymathere*
	Red/Yellow Irish Lords	Oregon Triton	
	Pacific Halibut	Octopus	
	Rock Sole	Brown King Crab	
		Sea Urchin	
		Sand Dollar	

Table 3. Marine locations around Amchitka and Kiska islands where UA divers collected water, sediment, brown algae, invertebrates and fishes for radionuclide analyses, June 29 - July 19, 2004. X indicates where a sample was collected.

LOCATION	SITE NAME/a	COORDINATE	WATER	SEDIMENT	ALARIA	LAMINARIA	AGARUM	CYMATHERE	SPONGE	BLUE MUSSEL	HORSE MUSSEL	JINGLE SHELL	GUMBOOT CHITON	OREGON TRITON	GIANT OCTOPUS	SEA URCHIN	SAND DOLLAR	ROCK GREENLING	IRISH LORDS	ROCKFISHES	PACIFIC COD	ROCK SOLE
Constantine Harbor	RECON	N 51 24.885 E 179 17.892														X						
Constantine Harbor Doc	CONST DOC	N 51 24.445 E 179 17.504								X		X										
Long Shot Transect BL1	BL1-15A	N 51 25.388 E 179 13.738														X						
Long Shot Transect BL1	BL1-15B	N 51 25.421 E 179 13.9	X		X											X						
Long Shot Transect BL2	BL2-15	N 51 25.881 E 179 13.1	X													X						
Long Shot Transect BL2	BL2-30	N 51 26.071 E 179 13.698			X											X						
Long Shot Transect BL2	BL2-60	N 51 26.099 E 179 13.7	X													X						
Long Shot Transect BL3	BL3-30	N 51 26.512 E 179 13.3	X		X											X		X				
Long Shot Transect BL3	BL3-60	N 51 26.480 E 179 13.5	X									X	X			X		X	X			
Long Shot Transect BL4	BL4-15	N 51 26.820 E 179 12.261							X	X	X	X	X	X		X		X				
Long Shot Transect BL4	BL4-30	N 51 26.973 E 179 12.766			X							X	X			X		X				
Long Shot Transect BL4	BL4-60	N 51 26.981 E 179 12.9	X						X			X	X	X		X		X	X			
Long Shot Transect BL4	BL4-90	N 51 26.963 E 179 12.8	X	X		X			X			X	X	X		X						X
Long Shot Transect BL5	BL5-15	N 51 27.209 E 179 11.588							X	X	X	X				X		X	X			
Long Shot Transect BL5	BL5-30	N 51 27.278 E 179 11.886			X				X			X	X	X		X		X	X			
Long Shot Transect BL5	BL5-60	N 51 27.331 E 179 12.2	X	X													X					X
Long Shot Transect BL6	BL6-15	N 51 27.729 E 179 11.417							X		X	X	X			X						
Long Shot Transect BL6	BL6-30	N 51 27.760 E 179 11.724			X				X			X	X	X	X	X		X				
Long Shot Transect BL6	BL6-60	N 51 27.831 E 179 12.0	X			X			X			X	X	X		X		X	X	X		
Milrow Transect BM1	BM1-30	N 51 23.638 E 179 09.1	X		X																	
Milrow Transect BM1	BM1-60	N 51 23.524 E 179 08.9	X			X	X		X		X	X		X		X		X	X			
Milrow Transect BM2	BM2-15	N 51 24.193 E 179 09.613				X		X	X			X	X			X		X		X		
Milrow Transect BM2	BM2-30	N 51 23.999 E 179 09.2	X		X	X	X	X	X			X				X						
Milrow Transect BM2	BM2-60	N 51 23.785 E 179 08.8	X			X	X		X		X	X				X						
Milrow Transect BM3	BM3-30	N 51 24.116 E 179 08.9	X		X	X			X		X	X				X		X				
Milrow Transect BM3	BM3-60	N 51 23.696 E 179 08.0	X						X			X		X		X		X	X			
Milrow Transect BM4	BM4-30	N 51 24.527 E 179 09.1	X		X				X			X				X		X				
Milrow Transect BM4	BM4-60	N 51 24.199 E 179 08.5	X	X					X			X				X		X		X		
Cannikin Transect BC2	BC2-15	N 51 28.072 E 179 10.838							X		X	X				X						
Cannikin Transect BC2	BC2-30	N 51 28.289 E 179 11.341			X						X	X	X	X		X		X	X			
Cannikin Transect BC2	BC2-60	N 51 28.393 E 179 11.5	X						X		X	X	X	X	X	X		X	X	X		
Cannikin Transect BC4	BC4-30	N 51 28.197 E 179 11.007							X		X	X	X			X		X	X	X		
Cannikin Transect BC4	BC4-60	N 51 28.418 E 179 11.0	X			X			X		X	X		X	X	X		X				
Cannikin Transect BC4	BC4-90	N 51 28.578 E 179 11.0	X			X			X			X		X		X			X			
Cannikin Transect BC5	BC5-15	N 51 28.236 E 179 09.040		X		X					X					X		X			X	
Cannikin Transect BC5	BC5-30	N 51 28.356 E 179 09.067		X	X							X	X		X	X						
Cannikin Transect BC5	BC5-60	N 51 28.540 E 179 09.1	X	X													X					X
Cannikin Transect BC6	BC6-15	N 51 29.058 E 179 06.712		X	X	X		X								X		X				
Cannikin Transect BC6	BC6-30	N 51 29.136 E 179 06.804			X								X			X		X				
Cannikin Transect BC6	BC6-60	N 51 29.244 E 179 06.9	X						X		X	X	X	X	X	X		X	X	X	X	
Kiska Harbor Dock	KISKA DOC	N 51 58.708 E 177 32.828								X		X		X		X			X			X
Kiska Transect BK1	BK1-30	N 52 02.252 E 177 30.057			X							X	X			X						
Kiska Transect BK1	BK1-60	N 52 02.259 E 177 29.9	X						X			X	X			X		X	X	X		
Kiska Transect BK2	BK2-15	N 52 01.426 E 177 29.902							X		X	X				X		X				
Kiska Transect BK2	BK2-30	N 52 01.492 E 177 29.742			X	X	X				X	X	X	X		X		X	X			
Kiska Transect BK2	BK2-60	N 52 01.489 E 177 29.6	X						X		X	X		X		X			X			
Kiska Transect BK3	BK3-30	N 51 58.516 E 177 33.925			X	X											X					X
Kiska Transect BK3	BK3-60	N 51 58.342 E 177 33.7	X	X												X						X
Kiska Transect BK4	BK4-30	N 51 59.464 E 177 34.500																				X
Kiska Transect BK4	BK4-60	N 51 59.531 E 177 34.810		X													X					X
Kiska Transect BK5	BK5-15	N 51 59.108 E 177 34.601									X	X	X			X		X	X	X		
Kiska Transect BK5	BK5-30	N 51 59.317 E 177 34.581			X							X	X	X		X						
Kiska Transect BK5	BK5-60	N 51 59.087 E 177 35.0	X								X	X	X			X		X	X			

a = Site name: B=Biological, L=Long Shot, M=Milrow, C=Cannikin, K=Kiska, 1-6=transect #, -15=intertidal to 15 ft (~5 m), -30=30 ft (~9 m), -60=60 ft (~18 m), -90=90 ft (~27 m).

Table 4. Mobility traits influencing selection of screening marine species for radionuclide analyses.

Mobility	Importance	Species
Sedentary	Provides an indication of point exposure	Brown Algae, Sponge, Rock Jingle, Mussels
Locally mobile	Integrates exposure over a few meters of designated site	Gumboot Chiton, Oregon Triton, Sand Dollar, Sea Urchin, Rockfishes, Rock Greenling
Mobile	Provides an indication of local movement within a few km of designated site	Octopus, Brown King Crab, Irish lords,
Migratory	Provides an indication of regional exposure	Atka Mackerel, Pacific Ocean Perch, Pacific Cod, Walleye Pollock, Flatfishes

Figure 1. Location of Amchitka Island relative to the State of Alaska.

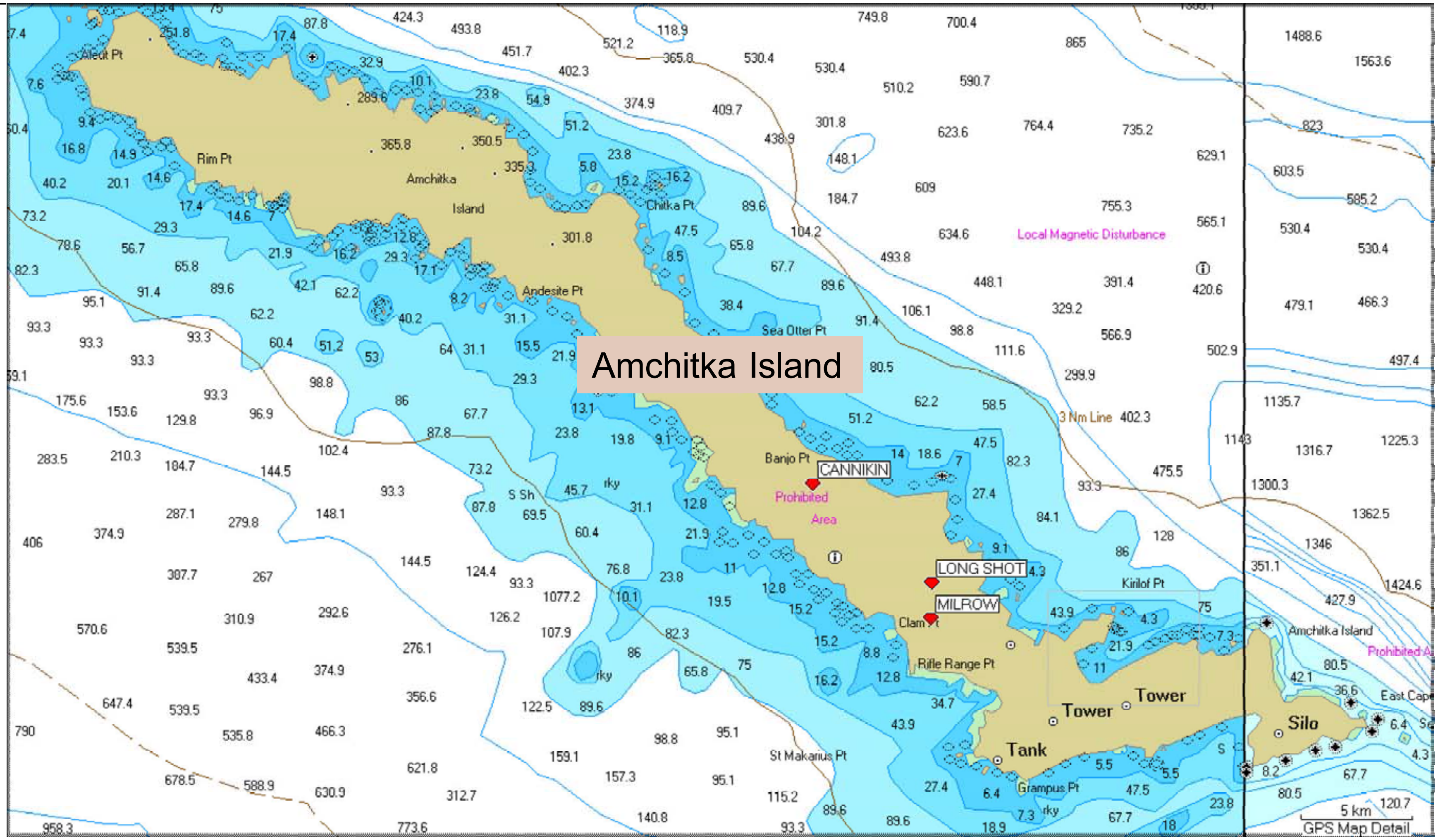

Figure 2. Location of three nuclear test blasts on Amchitka Island: Long Shot (~80 kilotons) in 1965; Milrow (~1 megaton); and Cannikin (~5 megatons) in 1971. Depth is in meters.

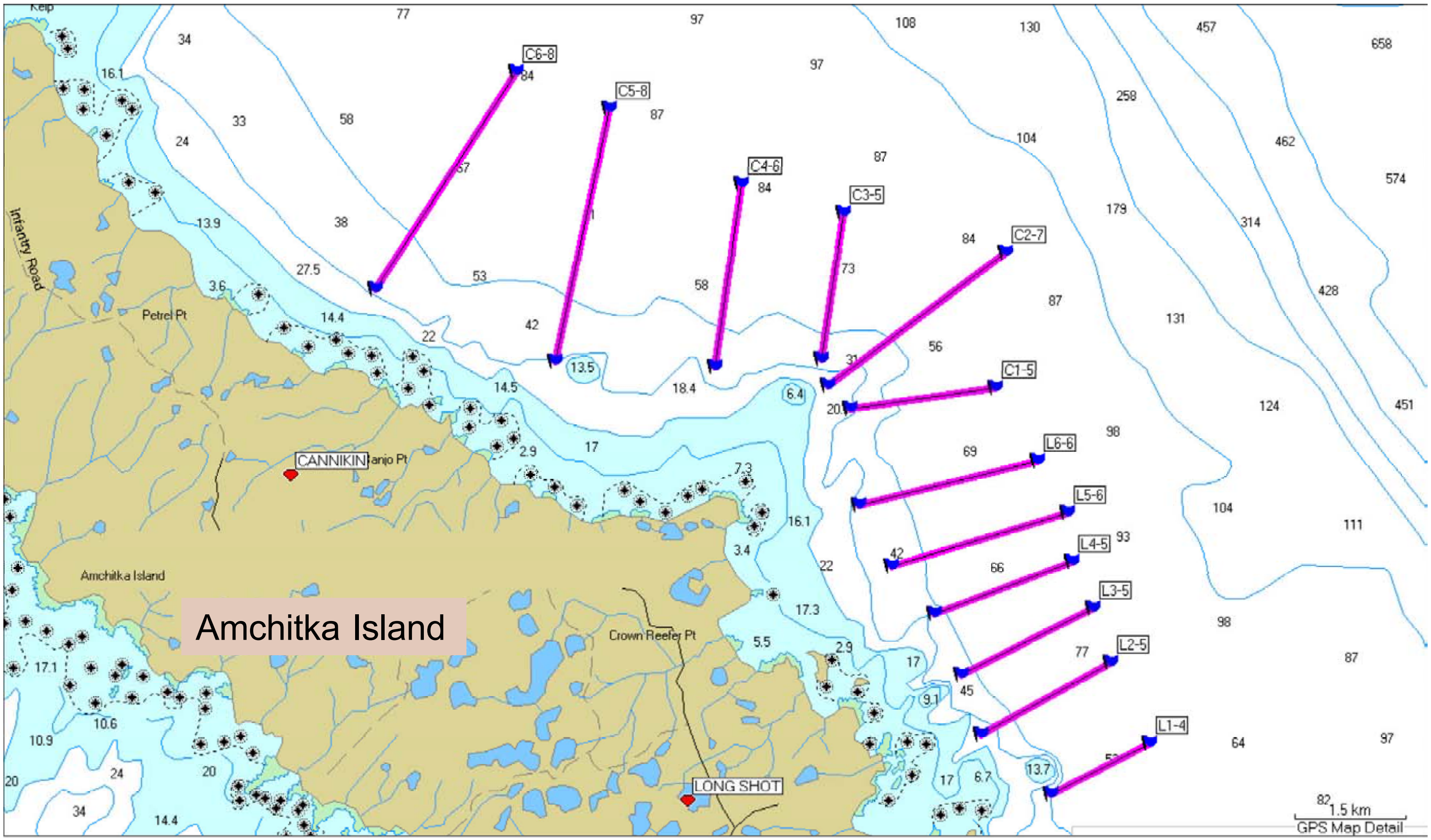

Figure 3. CTD transects established adjacent to Cannikin and Long Shot, June 2004 (Source: Dr. Mark Johnson, UAF). Depth is in meters.

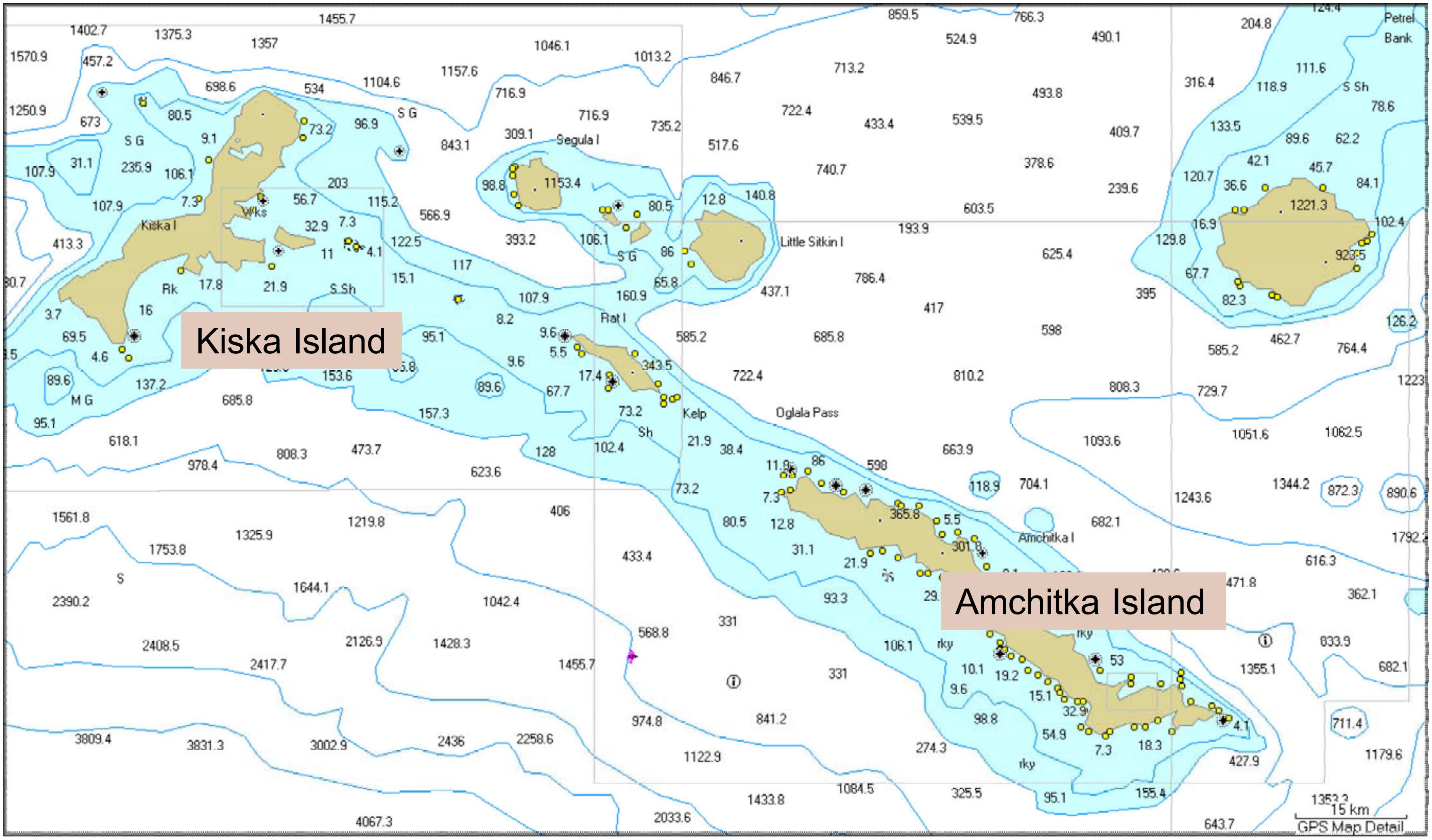

Figure 4. Map showing Amchitka Island and Kiska Island (Reference). Depth is in meters.

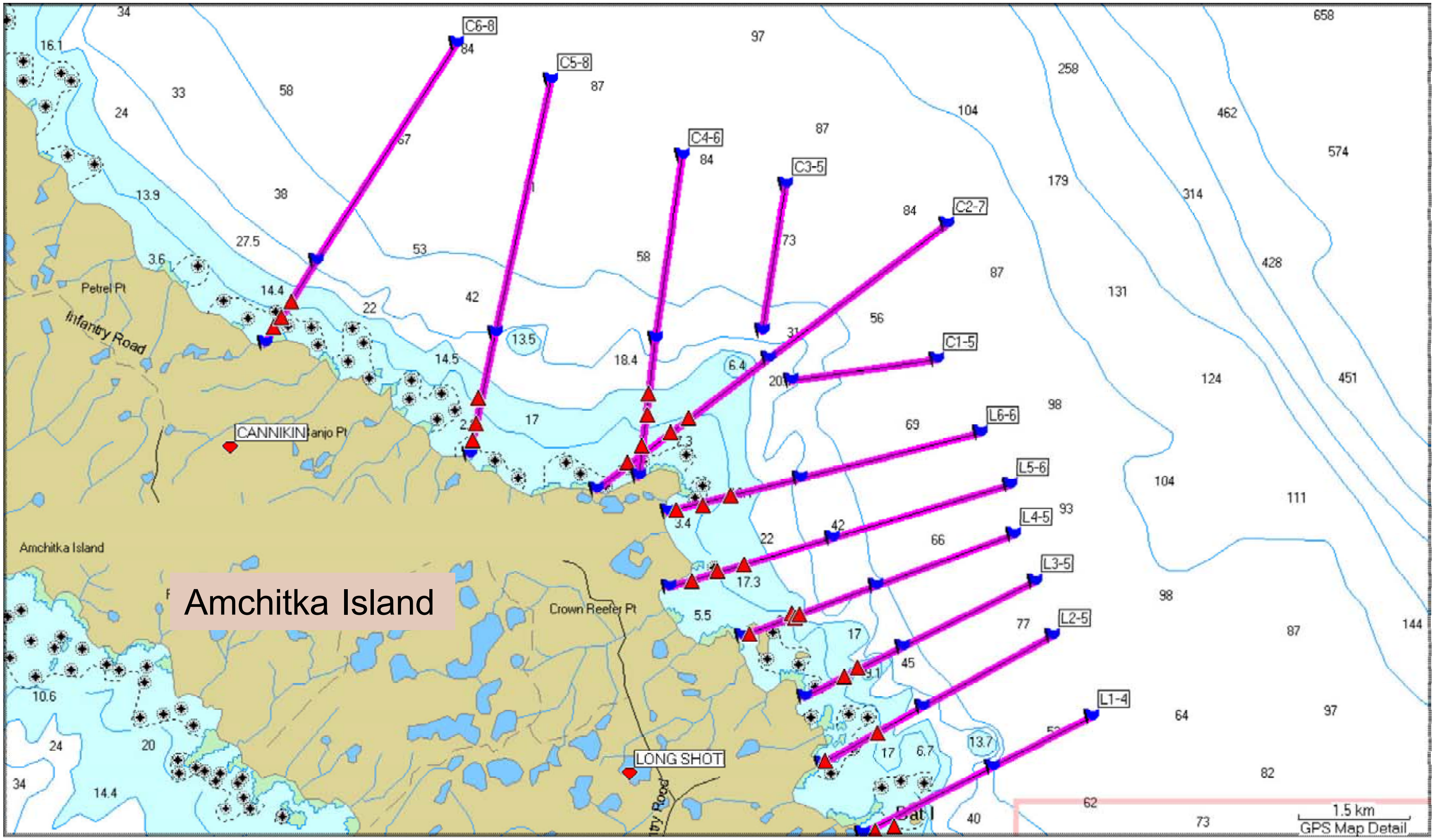

Figure 5. Dive locations (red triangles) adjacent to Cannikin and Long Shot where samples were collected July 2004. Depth is in meters.

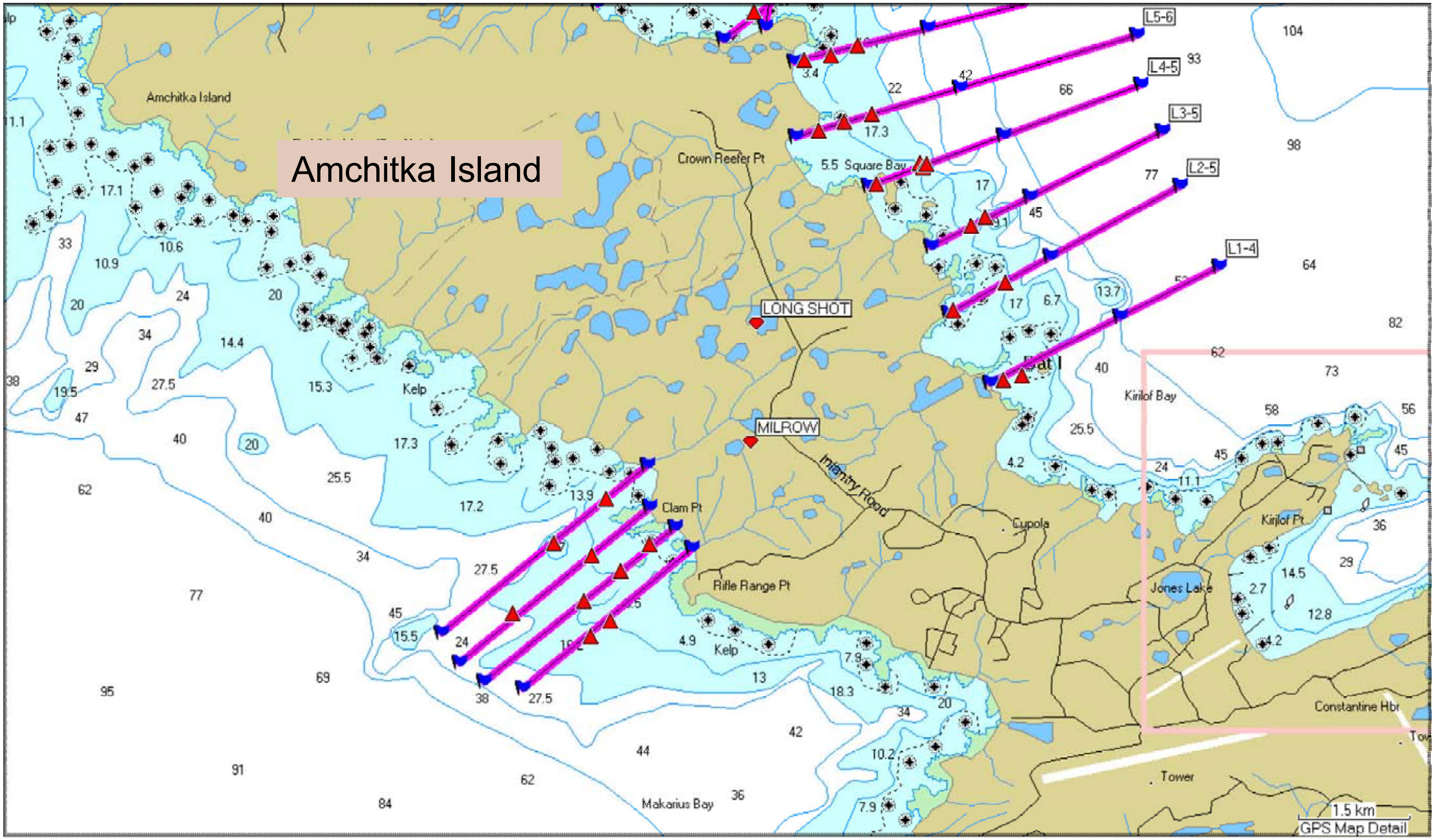

Figure 6. Dive locations (red triangles) adjacent to Milrow and Long Shot where samples were collected July 2004. Depth is in meters.

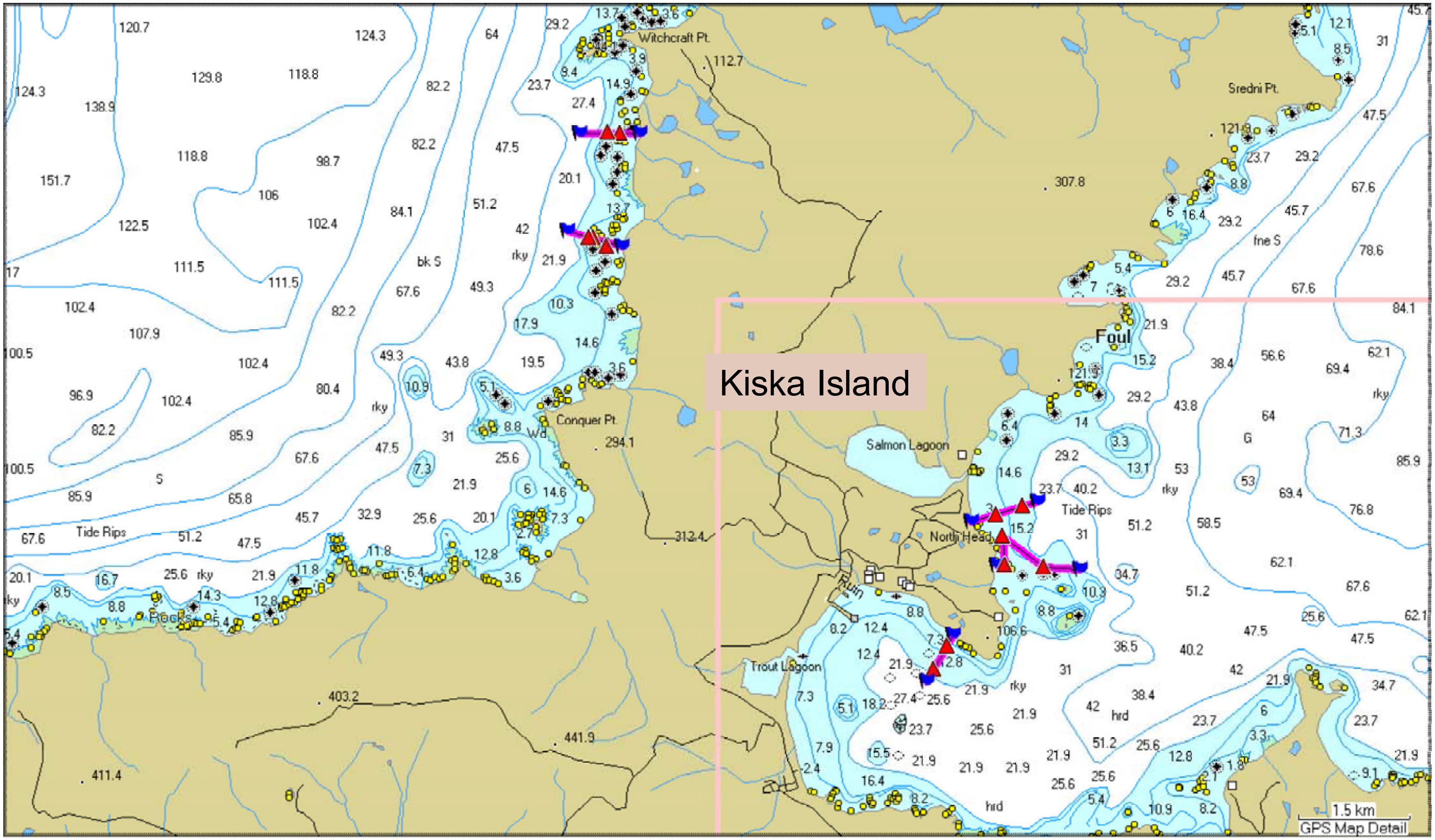

Figure 7. Dive locations (red triangles) off Kiska Island (reference site) where samples were collected July 2004. Depth is in meters.