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An Aiming Protocol for Fish-Counting Sonars using River Bottom Profiles from a Dual-Frequency Identification Sonar (DIDSON)

by

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and

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April 2009

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye to fork	MEF
mideye to tail fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY MANUSCRIPT NO. 09-03

AN AIMIMG PROTOCOL FOR FISH–COUNTING SONARS USING RIVER BOTTOM PROFILES FROM A DUAL–FREQUENCY IDENTIFICATION SONAR (DIDSON)

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ABSTRACT

Counting migrating fish in rivers using sonar relies on carefully positioning the transducer to maximize fish detection. A side-looking sonar used to ensonify adult salmon (*Oncorhynchus spp*.) is typically deployed nearshore with the beam directed perpendicular to the current along the river bottom. Relying on reflections from the river bottom or targets to aim the transducer may result in an aim that poorly detects fish. A better method is to profile the river bottom, model the sonar beam in relation to the river bottom contours, and select a tilt angle that places the sonar beam along the river bottom across the desired sampling range. We devised an aiming protocol using river bottom profiles obtained from dual-frequency identification sonars (DIDSONs) at several Alaskan rivers. The DIDSONs were deployed nearshore with the multiple beams positioned vertically in the water column and aimed cross-river. Our profiling methods worked well at sites with a linear bottom or a steep to flat slope change but were limited when the secondary slope was steeper. The accuracy of DIDSON profiles was improved by using small range windows, centering the bottom image in the beam, and marking the top edge of the bottom image. We selected optimum transducer tilt angles based on the river bottom's topography and size of the sonar beam. The aiming protocol increased our confidence in fish counts obtained using side-looking sonars.

Key words: river bottom profiles, dual-frequency identification sonar, DIDSON, aiming protocol, side-looking sonar, profiles, transducer tilt angle, fish counting, *Oncorhynchus*, salmon

INTRODUCTION

When side-looking sonar systems are deployed in rivers for the purpose of counting adult migrating salmon (*Oncorhynchus spp.*), one of the most critical components for obtaining good detection is selecting an aim that aligns the beam along the slope of the river bottom. Migrating salmon tend to swim along the river bottom to take advantage of the reduced flow velocities (Brett 1995; Hinch and Rand 2000; Hughes 2004; Webb 1995). Riverine sonar sites are typically selected to meet the criteria of a single channel, linear river bottom, laminar flow, fine substrate materials, and adequate current flow to prevent fish from milling or traveling offshore (Mesiar et al. 1990). Fish have been counted with sonar systems ranging from single-beam echocounters (Bendix counters[1]) to more modern split-beam and multi-beam sonars (Brazil 2007; Faulkner and Maxwell 2008; Gaudet 1990; Mesiar et al. 1990; Miller et al. 2007; Trevorrow 1997; Westerman and Willette 2007; Xie et al. 2005).

The alignment of the sonar beam with the river bottom is important regardless of the type of sonar used. For single and split-beam systems, a narrow beam must fit between the river's surface and bottom boundaries. At sites where fish are bottom-oriented (typical of rivers with strong current flows), it is critical that the beam is positioned directly above the river bottom but below the surface. Using narrow-beam, split-beam systems, we have observed substantial losses in fish detection with the beam aimed even 1/2° too high above the river bottom. With multi-beam sonars, excess energy from the wider vertical beam can often be aimed down into the river bottom without altering fish detection rates. The wider beam is less sensitive to small changes in the tilt angle of the transducer. The Alaska Department of Fish and Game (ADF&G) operates several sonar sites in rivers to estimate migrating salmon populations, primarily sockeye salmon (*O. nerka*). Inseason daily estimates of salmon passage are used in the management of several commercial fisheries. At the sites described in this study, either Bendix counters (single-beam, echo-counting sonars; Gaudet 1990) or DIDSONs (Dual-frequency IDentification SONars; Belcher et al. 2002) are used to estimate salmon passage rates for commercial fisheries management. The DIDSON is still in the transition phase at some of these sites but will soon

[1] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

replace the aging Bendix counter (Brazil 2007; Faulkner and Maxwell 2008; Westerman and Willette 2007). We developed a methodology, an aiming protocol, for accurately aligning the DIDSON sonar beam with the river bottom using river bottom profiles obtained from DIDSONs and absolute tilt information from pitch and roll sensors.

Aiming a transducer for the purpose of ensonifying migrating fish often depends on interpreting information from received echoes visually displayed on oscilloscopes and/or echograms. With no other information available, it is easy to assume that this method is adequate. For the Bendix counter, an aim is typically selected by tilting the transducer up or down until voltage spikes received and displayed on an oscilloscope from the river bottom are below the threshold and flattened across the sampling range. This is the ideal circumstance. Normally, high amplitude echoes from bottom obstructions require the sonar technician to raise the beam to avoid generating 'false' counts. Once an aim is selected, it is tested by dragging a target through the beam at close range and observing the returning voltage spikes on an oscilloscope. For split-beam and multi-beam sonars, technicians often select a tilt angle based on observing echoes or images reflected from artificial targets and/or the river bottom. These methods can be deceptive. In certain situations, we have measured larger amplitudes from target echoes when the transducer was tilted at an extreme downward angle where multiple bounces of the beam were possible compared to an angle where the echoes returned along a single path. Testing the aim with targets at close range creates the tendency to tilt the transducer too far down (Maxwell and Smith 2007). Positioning targets at multiple ranges to fully test the aim is difficult in rivers under the best conditions and is made more difficult by swift currents, ice floes, and floating debris. Trying to keep a target stationary long enough in the beam to separate it from non-target reflections is often challenging. Using the DIDSON profiling method, the information needed to select an optimal transducer tilt angle, can be obtained from nearshore, without the use of a boat.

The DIDSON is a high-resolution, multi-beam imaging sonar with acoustic lenses designed to focus the returning energy and sharpen the resulting video-like images (Belcher et al. 2002). The DIDSON field of view is 29° with a 14° vertical beam. For fish counting, the multiple narrow beams are positioned horizontally showing the river bottom as a mostly static background with fish moving across (Figure 1; sample fish images can be viewed at http://www.soundmetrics.com). Positioning the narrow beams vertically, rather than horizontally, provides detailed information in the vertical dimension that can be used to image the river bottom's profile (Figure 2). This level of detail is not available from traditional bathymetry methods. River bottom profiles obtained from the DIDSON compared well with profiles generated from actual range and depth measures or other bathymetry methods (Maxwell and Smith 2007). The error in DIDSON profiles comes from a combination of horizontal and vertical beam spreading and the manual marking of targets. The calculated depth of the river bottom from DIDSON images depends on which beam the image is observed in, not its position in the beam. This limits the accuracy of the calculation to one-half the beam spacing. However, Maxwell and Smith (2007) observed that the error was less than the potential beam-spreading error would suggest. In certain situations, the river bottom topography limits the use of a DIDSON for creating profiles. A slope change in the cross-river direction from flat nearshore to steep offshore creates shadow zones where returning echoes are either not able to reach the transducer or require multiple bounces to reach it. Under these circumstances, an accurate profile cannot be created. However, the bottom images can be assessed, and because fish-counting sonars have this same limitation, the profiles can be used to determine that a new site be selected.

To determine the optimal sampling aim for our fish-counting sonars, we recorded river bottom images using the DIDSON, and extracted range and depth points allowing us to create a river bottom profile. A rotateable sonar beam was overlaid onto the profile and used to determine the optimal tilt angle for the fish-counting sonar.

OBJECTIVES

Our primary study objectives were to:

1. Describe the river bottom profile at each sonar site.
2. Identify environmental features, i.e. turbidity, bottom structure, water depth, that may reduce fish detection.
3. Select the optimal transducer tilt angle for each site based on information from the river bottom profiles.
4. Develop an aiming protocol using the DIDSON profiling methods that can be used by sonar technicians.

METHODS

STUDY SITES

We profiled the river bottom at ADF&G sonar sites along the Copper, Kasilof, Kenai, Nushagak, and Yentna Rivers (Figure 3). The Copper River sonar site is approximately 100 m downriver of the Million Dollar Bridge below the outlet of Miles Lake. At this site, the river is one main channel approximately 360 m wide and is influenced by Childs Glacier downriver and Miles Glacier upriver. The natural substrate on the south bank is made up of large cobble and boulders. A concrete substrate (30 m long, 5 m wide, 13% grade) was constructed in 2001 to provide a uniform bottom to aim the sonar beam along. On the north bank, the sonar was deployed on the natural substrate of sand and small cobble. From 1991 to 1995, the U.S. Geological Survey measured suspended sediment levels at the Million Dollar Bridge with a range of 0.5–2.2 kg/m^3 with corresponding discharges of 1,119–10,394 m^3/s (Brabets 1997). In 2002, turbidity measures off the south bank exceeded the 1,000 Nephelometric Turbidity Units (NTUs) maximum limit of a Global Water turbidity meter (Maxwell and Gove 2004).

The Kasilof River sonar site is located 12.6 km (7.8 mi) from the river mouth. At this site, the river is a single channel approximately 58 m wide and the bottom substrate is a mixture of large cobble and boulders. Water level gradually rises through the summer. The turbidity, measured with a secchi disk, is typically < 0.46 m.

The Kenai River sonar site is located 30.6 km (19 mi) from the river mouth. At this site, the river is a single channel approximately 120 m wide. The bottom substrate is a mixture of cobble with occasional boulders. Water level gradually rises through the summer peaking in late July or early August. Turbidity measured at this site in 2002 was 21 NTUs along the north bank and 28 NTUs along the south bank (Maxwell and Gove 2004).

The Nushagak River sonar site is located approximately 40 km upriver from the terminus of the Nushagak commercial fishing district and 4 km downriver from the village of Portage Creek. Located within tidal influence, the main river channel is approximately 300 m wide at the study area. During high tide, a reduction in current occurs but no flow reversal. Overall, the water level drops as the season progresses. The bottom substrate is mostly sand and fine gravel. The turbidity level was not measured at this site, but at times, the water is clear enough to see fish swimming in the shallow water near the banks.

The Yentna River sonar site is located 9.7 km (6 mi) from the river mouth. At this site, the river is a single channel approximately 250 m wide. The water level fluctuates throughout the summer. The bottom substrate is a mixture of gravel and cobble. The turbidity, measured with a secchi disk, is typically 0.10-0.12 m.

DATA COLLECTION

Standard and long-range DIDSONs were used to record river bottom profiles at the sonar sites. The specifications for each DIDSON by frequency are listed in Table 1. A Hydroacoustics Technology Inc. (HTI) Model 661H single-axis rotator or a Remote Ocean System (ROS) dual-axis rotator with remote controller and relative feedback was used to adjust the position of the DIDSON transducer. We used H-shaped mounts made from aluminum poles held together with slightly larger diameter aluminum poles welded into T-shapes (Figure 2). The rotator was attached to a hanging bracket on the mount, and the transducer was affixed in the vertical configuration to a metal plate mounted to the rotator. Although many sonar systems are coupled with automated rotators that include feedback, the feedback is only relative. At some of the sites, the DIDSONs were modified to include an internal attitude sensor. Where an internal sensor was not available, a BioSonics, Jasco, or Geomechanics attitude sensor was attached and aligned with the angle of the transducer. Each sensor was calibrated with a bubble level on shore to obtain a zero attitude point. The sensor provided absolute tilt and heading information in one-second intervals.

At the Copper River south bank site, a DIDSON was deployed on the concrete substrate. At all other sites, DIDSONs were deployed on the natural substrate. Each DIDSON was deployed at a fixed location nearshore and aimed perpendicular to the river current with the multiple beams positioned vertically. The transducer was tilted so that the river bottom within the range of interest appeared in the beam's center. To ensure the best range resolution for each recorded image, a profile was compiled from a series of images. We recorded short range images using a more downward transducer aim and raised the aim successively higher to record farther ranges. The DIDSONs display threshold was set as low as possible without distorting the raw image, and the intensity was adjusted to provide the best contrast. The number of recorded frames per second was set as high as the incoming signal from the ethernet would allow without losing frames. Focus and receiver gain were automatically set. We measured the water temperature and the transducer's water depth and distance to shore. Sound speed was calculated from the water temperature based on equations from Simmonds and MacLennan (2005) and entered into the DIDSON initialization file to obtain correct range measures. For each new aim, we recorded the transducer's tilt angle and lens depth (distance from the river surface to the center of the lens). All site measurements are included in Appendix A1.

Error in DIDSON profiles comes from the increasing diameter of the individual beams in the vertical and horizontal planes as they spread out from the transducer, and user error from marking the profiles. Both sources of error were addressed by Maxwell and Smith (2007). Marking error and beam spreading error were minimized by marking the brightest region (highest amplitude) on the image. Echoes within this region should be closest to the beam centers.

DATA ANALYSES

Converting the river bottom images into range and depth values was accomplished within the DIDSON software using the 'Mark Depth Profile' function. To use this function, points along the edge of the bottom image were marked by the user, and the depth (*D*) of each selected point was calculated based on the following equation, which is diagrammed in Figure 4:

$$D = s + r \bullet \sin[(\theta + t) \bullet \frac{\pi}{180}] \qquad (1)$$

where:

s = distance from the center of the lens to the river surface (m);

r = range from the center of the composite beam's two-dimensional view-field to the target (m);

t = tilt angle of the transducer (degrees); and

θ = angle from the central axis of the composite beam's two-dimensional view-field to the target (degrees).

Range measures were based on echo-return time and the sound speed, which was calculated using water temperatures measured at each site (Simmonds and MacLennan 2005).

The extracted range and depth polar coordinates were converted to rectangular coordinates and plotted in Microsoft Excel with a model of the DIDSON beam overlaid. Placement of the model beam was based on the distance to shore, lens depth, and water depth at the DIDSON transducer positioned horizontally for fish counting. The vertical angle of the model beam was 14º for all sites except the Kenai River's north bank where a concentrating lens narrowed the DIDSON's nominal beam angle to approximately 8º. We extended the model beam to the desired sampling range and used Excel macros to control the tilt angle. We selected the tilt angle that best aligned the beam with the river bottom throughout the sampling range and positioned the central axis of the beam just above the river bottom. Small changes were allowed to the selected aim to reduce interference from the surface and bottom boundaries.

At a few of the sites, we tested the final aim with an artificial target, a 10.16 cm plastic sphere filled with 4.4 mm copper-plated steel shot (bb's). Acoustically, the target was roughly the size of a sockeye salmon (-32 dB; Smith and Maxwell 2007). The target was lowered to the river bottom approximately 2 m from the transducer and raised to the surface to test the detection limits at close range. Ideally, target work should be performed at multiple ranges; however, this was difficult at most of our sites.

Appendix A2 contains an aiming protocol designed to be used by technicians that outlines the process of generating river bottom images from the DIDSON, and processing the images to determine the optimal transducer tilt angle for the sampling sonar system. A sample form for recording the measurements is included in Appendix A3.

RESULTS

River bottom profiles were generated along both banks of the Copper, Kasilof, Kenai, Nushagak, and Yentna Rivers across multiple field seasons. A transducer aim was selected that aligned the sampling sonar beam with the river bottom and placed the beam's maximum energy (the beam center) where the majority of adult salmon migrate. The optimal transducer tilt angles selected for each site are listed in Table 2.

COPPER RIVER

At the Copper River, bottom profiles were recorded throughout the field season as the water level rose, and the transducers were moved inshore.

Off the south bank, five DIDSON profiles were combined to create an overall profile of the concrete substrate and the river bottom beyond (Figure 5). On May 11, the long-range DIDSON was deployed near the offshore edge of the substrate where the detection range extended to 63 m. When deployed at the substrate end, the standard DIDSONs high-frequency profile image showed an initial, smooth 4-m segment followed by an intermittent rocky region (Figure 6). The smooth segment was likely part of the ice shelf that the DIDSON was deployed on, since the actual substrate did not extend that far offshore. In each successive profile, a standard DIDSON was positioned farther up the substrate, and the ice shelf was no longer present. The image profiles were straight and smooth along the concrete substrate. Bottom images from the standard DIDSON were limited in range to approximately 19 m, except the July 10 image, which had a maximum range of only 13 m. The plastic sphere target, deployed 2 m from the face of the transducer to test the aim, was visible on the river bottom.

Off the north bank, the long-range DIDSON profiles from 2004–2007 showed a gradually decreasing slope out to approximately 67 m (Figure 7). The May 19 image, recorded when the water level was lowest, had a range of only 16 m. On June 6, after the DIDSON was moved inshore following increases in water level, the river bottom was visible out to 32 m. The maximum visible range of a bottom profile was 40 m. The combined bottom profiles from all four years were similar out to 20 m. Beyond 20 m, the 2006 and 2007 slopes began to drop off more steeply.

KASILOF RIVER

At the Kasilof River, a standard DIDSON was used to record bottom images of the north bank site in 2005 and both banks in 2007.

The DIDSON images from the north bank showed a flat, gradual slope out to 12 m (Figure 8). The bottom signal then became weak or absent out to 17 m, which indicated a change to a nonreflective substrate or a depression. A dip in the bottom occurred at 22 m. The north bank had a narrow water column and a fairly linear slope which required a transducer tilt angle close to level when the beam was aimed.

The south bank DIDSON images showed a flat, gradual slope out to 20 m with weak bottom signal from 10-17 m (Figure 9). The linear, flat south bank slope was similar to the north bank, but the water column was narrower. Strong surface reflections required the beam center to be aimed into the river bottom. Target tests were not performed.

KENAI RIVER

In 2004, a long-range DIDSON was used to record river bottom images of the sites along both banks of the Kenai River. From 2005-2007, a long-range DIDSON was used on the north bank and a standard DIDSON on the south bank.

The north bank DIDSON images showed a linear river bottom with a smooth slope out to 31 m and a second slightly steeper slope out to 90 m (Figure 10). The shallow slope and narrow water column required a transducer tilt angle close to level.

Off the steeper south bank, high-frequency bottom images from the standard DIDSON indicated a rockier bottom at this site. A ridge, most likely created from a large boulder, rose 0.2 m off the river bottom at 8 m (Figure 11). The river bottom dropped steeply out to 9 m, flattened and remained fairly smooth out to 55 m, and gradually rose beyond. During all years, the river bottom was visible at the maximum range setting. In 2004, the 78-m profile showed an increase in slope beyond the thalweg. The 2007 profile was shallower from 15-29 m compared to profiles from previous years. A transducer tilt angle was used that optimized sampling of the initial, nearshore slope. In Figure 12, north and south bank DIDSON profiles were combined to show a cross section of the river with the DIDSON beams overlaid. With the selected aims, the plastic sphere target was visible along the river bottom nearshore and at several ranges offshore.

NUSHAGAK RIVER

River bottom images were recorded using a long-range DIDSON off the Nushagak River's right bank site (facing downriver; north bank) from 2005–2007 and a standard DIDSON off the left bank from 2004–2007.

Off the right bank, the profiles dropped steeply out to 10 m, then flattened to a gradual slope that continued to the 70 m end range (Figure 13). The length of the initial slope was dependent on water level. As the field season progressed and the water level dropped, this segment shortened. Close to shore, the river bottom had rough, highly reflective features except between 7-10 m where areas of absent bottom indicated a weak signal return. The selected transducer tilt angle raised the central portion of the beam higher off the bottom which allowed for a longer range on the secondary offshore slope. The sonar deployment location changed in 2007 to a site approximately 50 m downriver, closer to the sonar tent. The slope at the new site was less steep with a more gradual slope decline in the nearshore region (Figure 14). The river bottom profile showed a shallower water column throughout the ensonified range and a flatter overall slope. The bottom image was visible out to 76 m. The DIDSON sampling beam covered the majority of the water column out to the end range.

Off the left bank, the slope gradually declined out to the maximum viewing range (40 m) in the 2005 profile (Figure 15). In 2006 and 2007, the profile changed and the slope began to flatten from 10 m out to the end range. No obstructions or weak signal returns from the bottom were observed. The target was detected nearshore on both banks along the river bottom.

YENTNA RIVER

The Yentna River bottom images were recorded using a standard DIDSON from 2005-2007. No distinguishing rocks or depressions were observed in the profiles.

The steep slope along the north bank was fairly consistent out to 15 m then flattened (Figure 16). The bottom slope dropped 2 m in depth from the transducer to 7 m offshore.

Off the south bank, the smooth linear slope dropped steeply (2.5 m) out to 10 m then became less steep (Figure 17). The selected tilt angle optimized the sampling of the nearshore slope, while limiting the effective range of the secondary slope. Target tests were not performed.

DISCUSSION

The DIDSON-based profiling method allowed us to observe the effects of aim changes on the relationship between the transducer beam and the river bottom and surface. In many cases, because of the DIDSON's wide vertical beam, it was not possible to place the maximum energy (center axis) of the beam near the river bottom. At sites where the water column was narrow, it was often necessary to push the central axis of the beam into the static river bottom to avoid interference with the river's surface. The deeper water columns at the Kenai and Copper River south banks and both sides of the Yentna Rivers allowed us to place the central axis of the beam just above the river bottom. The entire beam fit within the confines of the river boundary layers. At the shallow water sites of the Kenai River north bank, and the Kasilof River, much of the excess DIDSON beam energy was aimed into the river bottom. The optimal aim at these shallow water sites was close to level, with selected aims ranging from -1° to -1.5°. The south bank profile of the Kasilof River, although relatively flat, required that the beam be aimed further into the river bottom because of strong surface reflections. At these shallow sites, the DIDSON beam covers the entire water column from river bottom to surface. We would expect few or no fish to pass undetected over the beam at these sites. Conversely, the Yentna River had the steepest slopes, with selected aims of -13° and -16.2°. Here, there was more opportunity for fish to pass over the beam if conditions caused them to rise up off the river bottom and into the top portion of the water column.

At the Copper River site, high turbidity levels limited the range of the sonar. Compared to the other rivers profiled, the Copper River was the most turbid. Higher turbidity levels occurred in July, when the water was high, and the current was stronger. At the start of the field season, in May, we used a long-range DIDSON to profile the south bank because the lower frequency allowed a longer detection range. As is typical that time of year, the water level was at the lower edge of the concrete substrate, and we were able to generate a profile that extended as far beyond the substrate as possible. The river bottom at the offshore end of the substrate is gradually eroding. In Figure 6, a DIDSON image shows a 1-m wide hole just beyond the base of the substrate. It is unknown whether fish swim into this hole and pass by undetected during the early season when the water level is low. The north bank river bottom may have undergone significant changes starting in 2003. The Million Dollar Bridge was undergoing repairs from 2003 until the end of June 2005 to raise a collapsed span on the north bank. The repair project included building a work pad in the river around the bridge abutment just upriver from the north bank sonar site. The work pad created a large back eddy that extended downriver and significantly changed the flow pattern redirecting the current offshore. The work was completed; however, remnants of the pad remain, and the current is slowly degrading it. Before the pad was put into place, it was assumed the majority of salmon traveled close to shore. With the altered flow pattern, fish may have been pushed further offshore, beyond the range of the sonar. Early in the season, the sampling range was limited by the slope change; later, turbidity was the primary limiting factor.

At the Kasilof River south bank site, surface noise required aiming the beam into the static river bottom. Along the north bank, the beam was aligned along the river bottom. On this side of the river, the water was slightly deeper, and the surface intensity was weaker. Both sides of the Kasilof River might benefit from a narrower vertical beam that would better fit the water column. Fish detection was not affected by turbidity or a change in slope on either side of the river.

Along the Kenai River south bank, the steep to flat slope change has little effect on the DIDSON's ability to detect fish; however, the Bendix counter's range was limited to 7 m by this slope change. During the winter of 2007, flooding occurred on the Kenai River along with major ice jams. These events may have caused fill to occur in the offshore area of the south bank site; seen in the comparison of the 2007 profile to subsequent years (Figure 11). The north bank profile changes from a relatively flat to slightly steeper slope. This topography may create an unreliable profile. The change in slope is small; however, echoes from the river bottom along the secondary slope may be a mixture of direct and multi-path reflections. The shallow depth along this bank makes it easier for multi-path reflections off the surface to be detected by the transducer. Offshore fish detection may also be affected.

The Nushagak River bottom is dynamic and changes may have occurred between the years when the DIDSON profiles were created, which could account for some of the differences between the Nushagak's left bank DIDSON profiles. The turbidity is much less compared to the other rivers, and does not limit the range on either side of the river in this study.

The Yentna River profiles were very similar among years. Both banks are relatively similar to each other, with a steeply dropping slope nearshore, which flattens offshore. Fish detection could be affected by the steep slopes on both banks. The transducer's tilt angle creates an area in the upper portion of the water column that is not ensonified where possible fish may go undetected.

The accuracy of the DIDSON profiles can be improved by using small range windows, centering the bottom image in the beam, and marking along the top edge of the bottom image (Maxwell and Smith 2007). Because the range resolution on the screen depends on the number of pixels available to create the image, smaller range windows result in more accurate images. To keep the range windows small, we recorded multiple bottom images at each site by increasing both the start ranges and window lengths. Range and depth points from the multiple images were then combined to form a single profile plot. Tilting the transducer until the bottom image is centered within the DIDSON viewing window will also result in a more accurate profile. The source level of the individual beams is highest in the center beam, and considerably lower on the outer beams (pers. comm., Ed Belcher, President Sound Metrics Inc.) When the DIDSON's narrow beams are positioned vertically, the 14^{o} horizontal beam can widen the bottom image. The width of the bottom image depends on the upriver-downriver slope of the river bottom. Steeper slopes in this dimension create wider bottom images. For consistency, we only marked points along the top edge of the bottom image. The DIDSON vendors have developed a condensing lens that narrows the 14° beam to 1°. This should improve the accuracy of the bottom image in these situations.

Previously, bathymetry maps were created to assist in aiming the transducer but were only updated when funding allowed. Consequently, annual changes in the bottom slope went undocumented. Because of the ease of creating DIDSON profiles at sites where the DIDSON is used for sampling, annual profiling of the river bottom makes it possible to track trends and events that may alter the topography of the river bottom. Profiles should be recorded at the Copper River north bank site every year to examine changes in the river bottom from the gradual deterioration of the work pad at the bridge upriver. Along the end of the south bank concrete substrate, annual profiling is needed to monitor the scour occurring and detect potential ice shelves early in the season. At the Nushagak River, the bottom is fairly dynamic and annual profiles are advised. The Kasilof, Kenai, and Yentna River sites have more stable river bottoms; however, following a flood event, winter ice jams, or other potential bottom-changing events, updated profiles are essential. When developing a new site for sonar deployment, DIDSON images of the river bottom can assist in plotting an accurate profile, determining whether the bottom slope is adequate for sonar deployment, determining range limitations for sampling fish passage, and finding the best aim at a particular location.

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We would like to thank the field crews of the Copper, Kasilof, Kenai, Nushagak, and Yentna Rivers for their help with the logistics of this study. Chuck Brazil deployed the DIDSONs on the Nushagak River and assisted in collecting the profile data. Ed Belcher, Bill Hanot, and Joe Burch provided help and assistance with the operation of the DIDSON. Bill Hanot wrote the software program to create the river bottom profiles at our request. Lowell Fair provided editorial comment.

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TABLES AND FIGURES

Table 1.–Dual-frequency identification sonar (DIDSON) specifications.

DIDSON model	Frequency (MHz)	Number of beams	Beam dimensions (°)	Beam spacing (°)	Maximum range (m)
Standard	1.8	96	0.3x14	0.3	12
Standard	1.1	48	0.4x14	0.6	40
Long-range	1.2	48	0.5x14	0.6	40
Long-range	0.7	48	0.8x14	0.6	100

Table 2.–Optimal transducer tilt angles and sampling ranges selected after evaluating the DIDSON river bottom profiles at ADF&G sonar sites.

River/Bank	Vertical Beam angle (°)	Tilt angle (°)	Sampling range (m)
Copper River			
North Bank	14	-5.6	35
South Bank	14	-8.2	20
Kasilof River			
North Bank	14	-1.5	30
South Bank	14	-4.0	30
Kenai River			
North Bank	8	-1.0	50
South Bank	14	-7.0	30
Nushagak River			
Right Bank (2005-06)	14	-6.2	50
Right Bank (2007)	14	-3.5	50
Left Bank	14	-5.4	30
Yentna River			
North Bank	14	-13.0	30
South Bank	14	-16.2	30

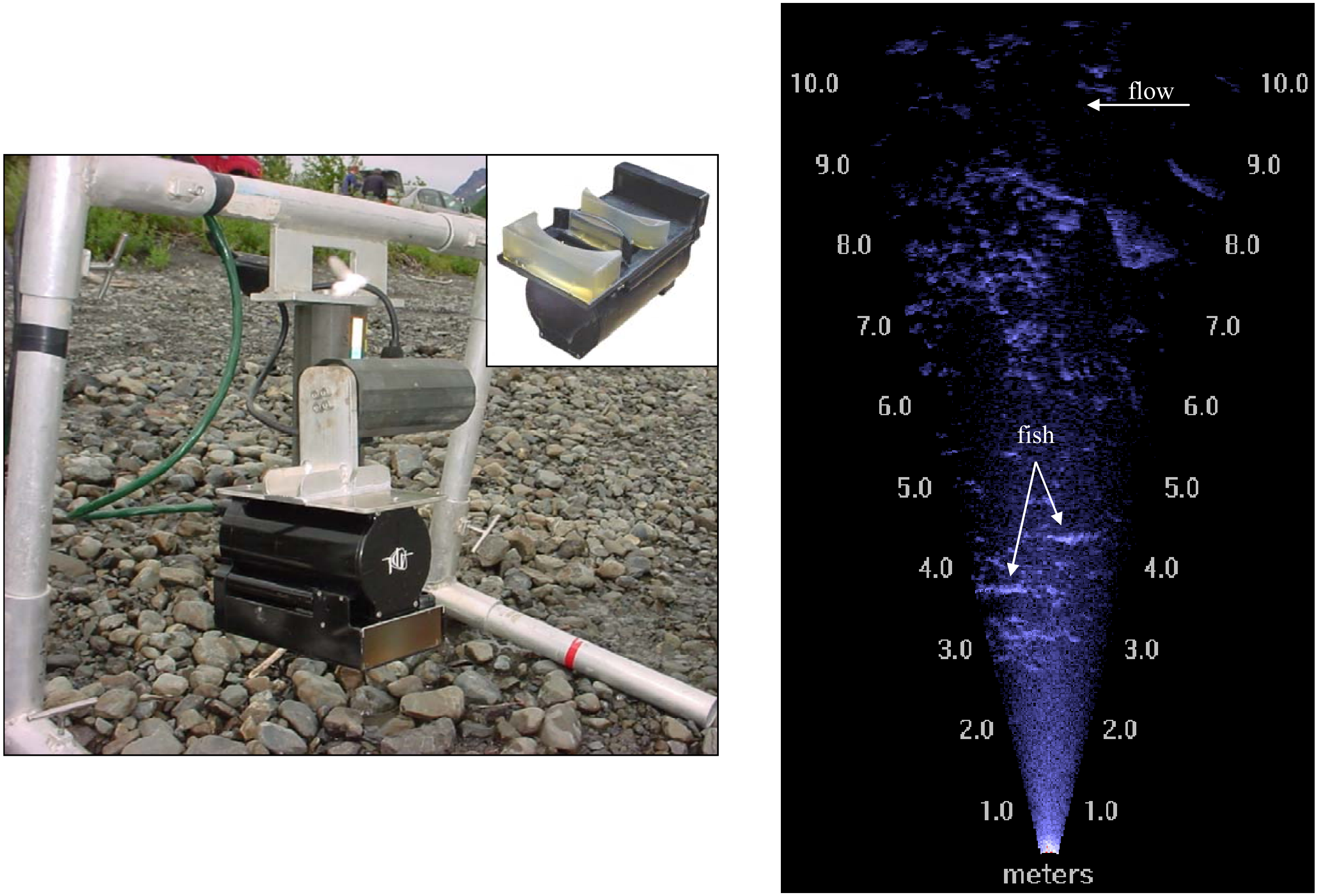

Figure 1.–The DIDSON positioned horizontally on an aluminum H-mount (left) for counting fish and a DIDSON image (right) showing migrating fish and bottom reflections along the Kenai River's south bank.

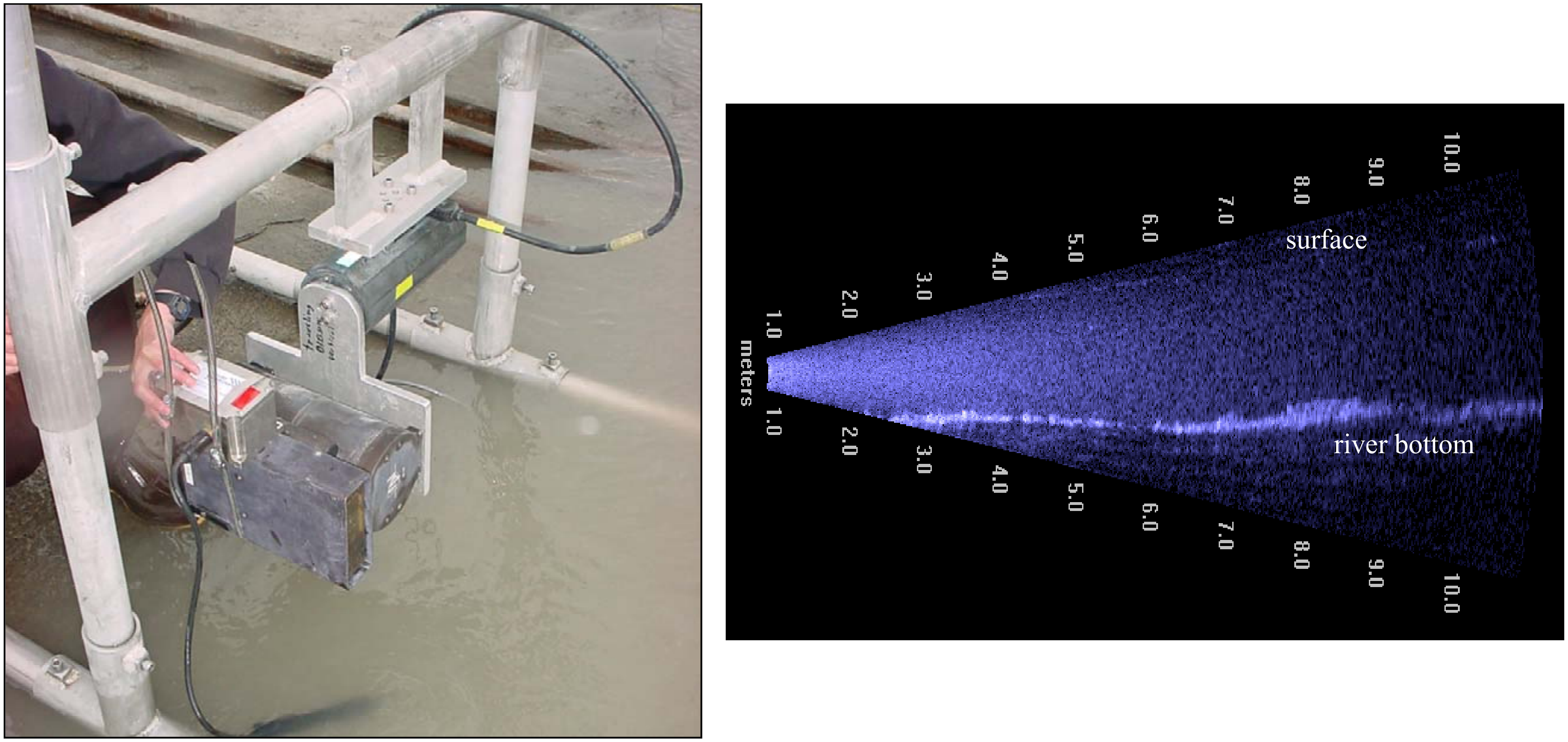

Figure 2.–The DIDSON positioned vertically on an aluminum H-mount (left) to record river bottom profiles and a DIDSON image (right) of the river bottom along the Kenai River's south bank sonar site.

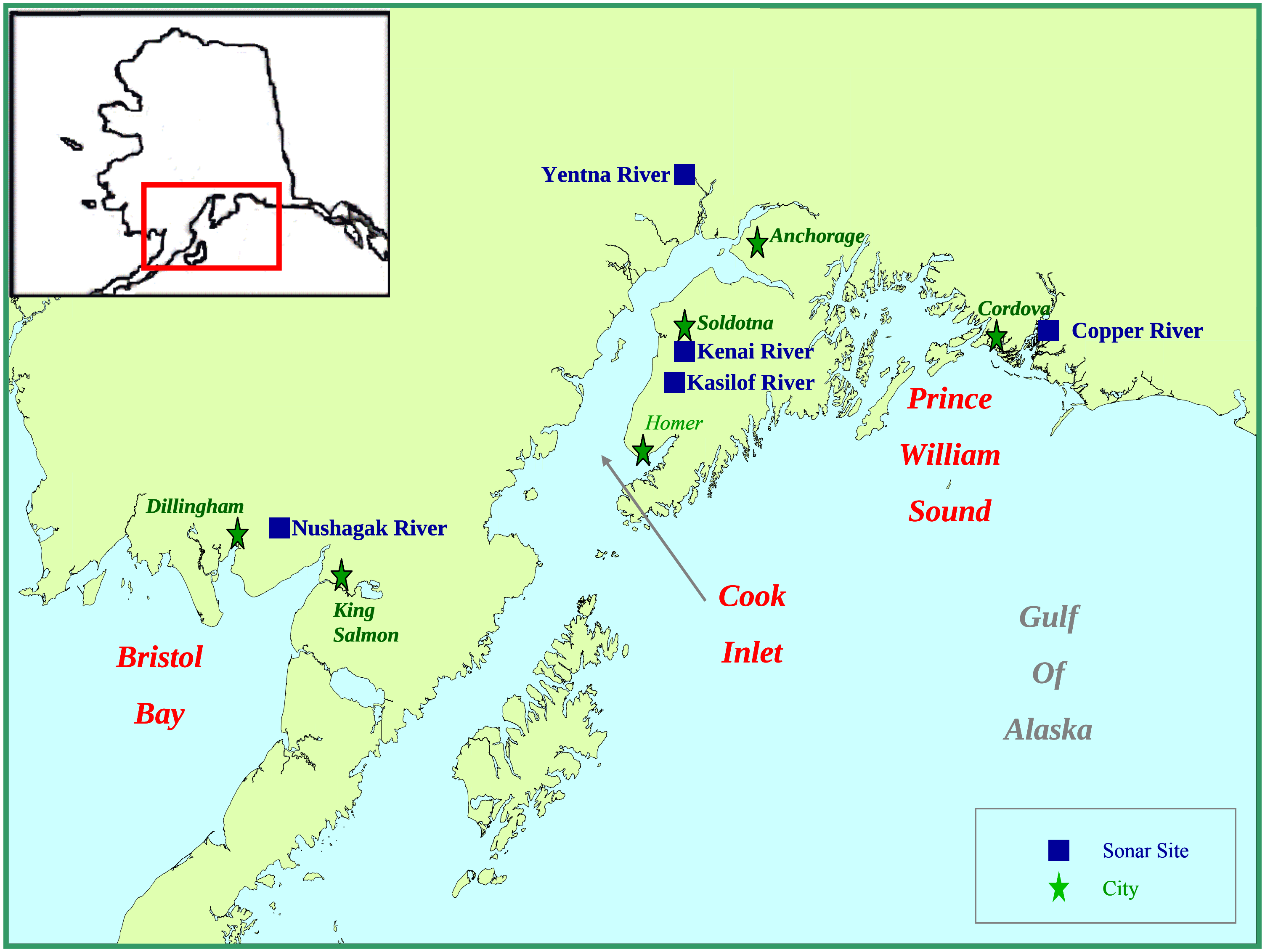

Figure 3.–The location of Alaska Department of Fish and Game sonar sites in Southcentral Alaska notated with a square and labeled with the name of the river.

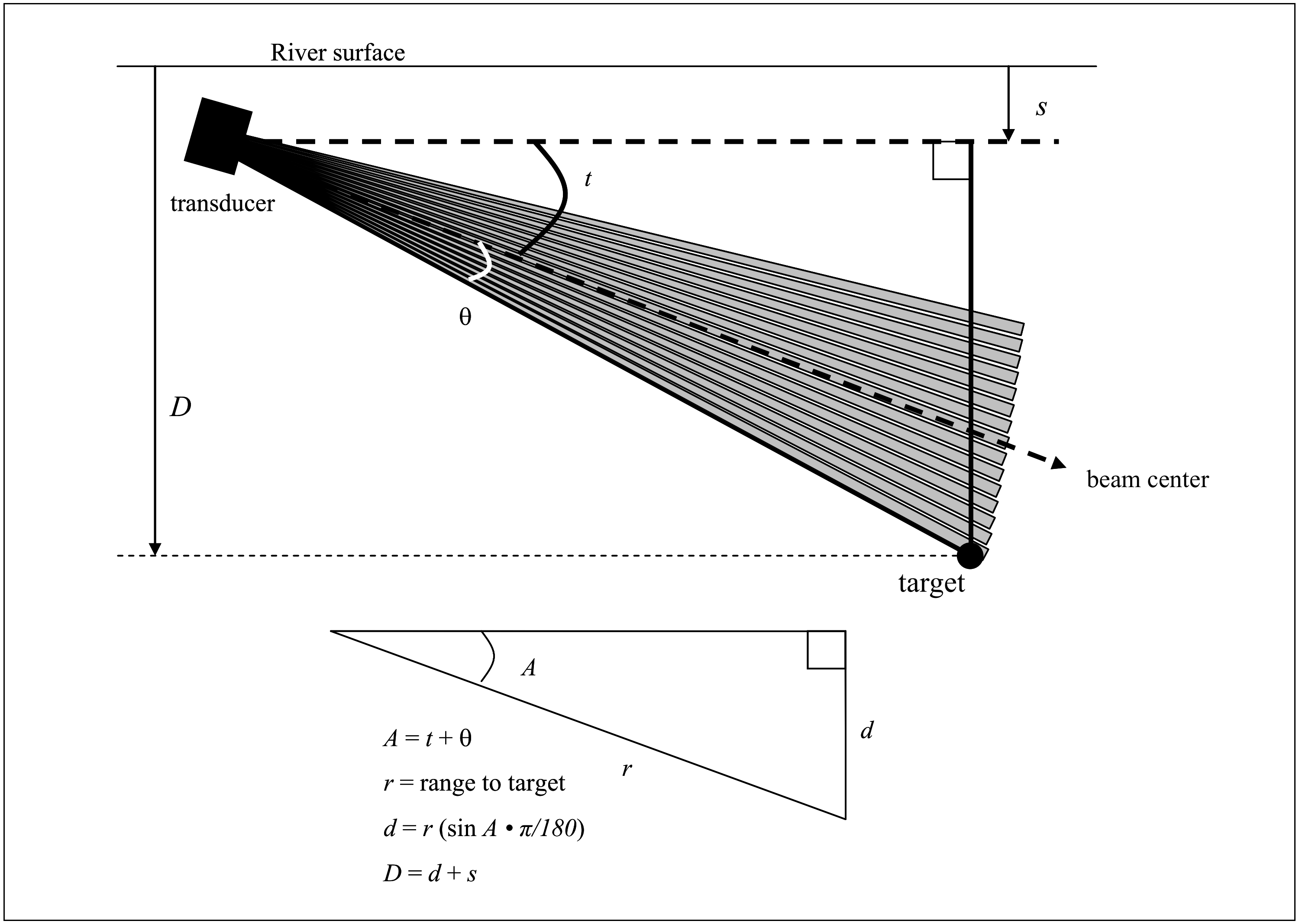

Figure 4.–A diagram of the depth calculation used by the DIDSON software in the Mark Depth Profile function where: t = tilt angle of the transducer (degrees), θ = angle from the central axis of the composite beam's two-dimensional view-field to the target (degrees), and s = distance from the center of the lens to the river surface (m).

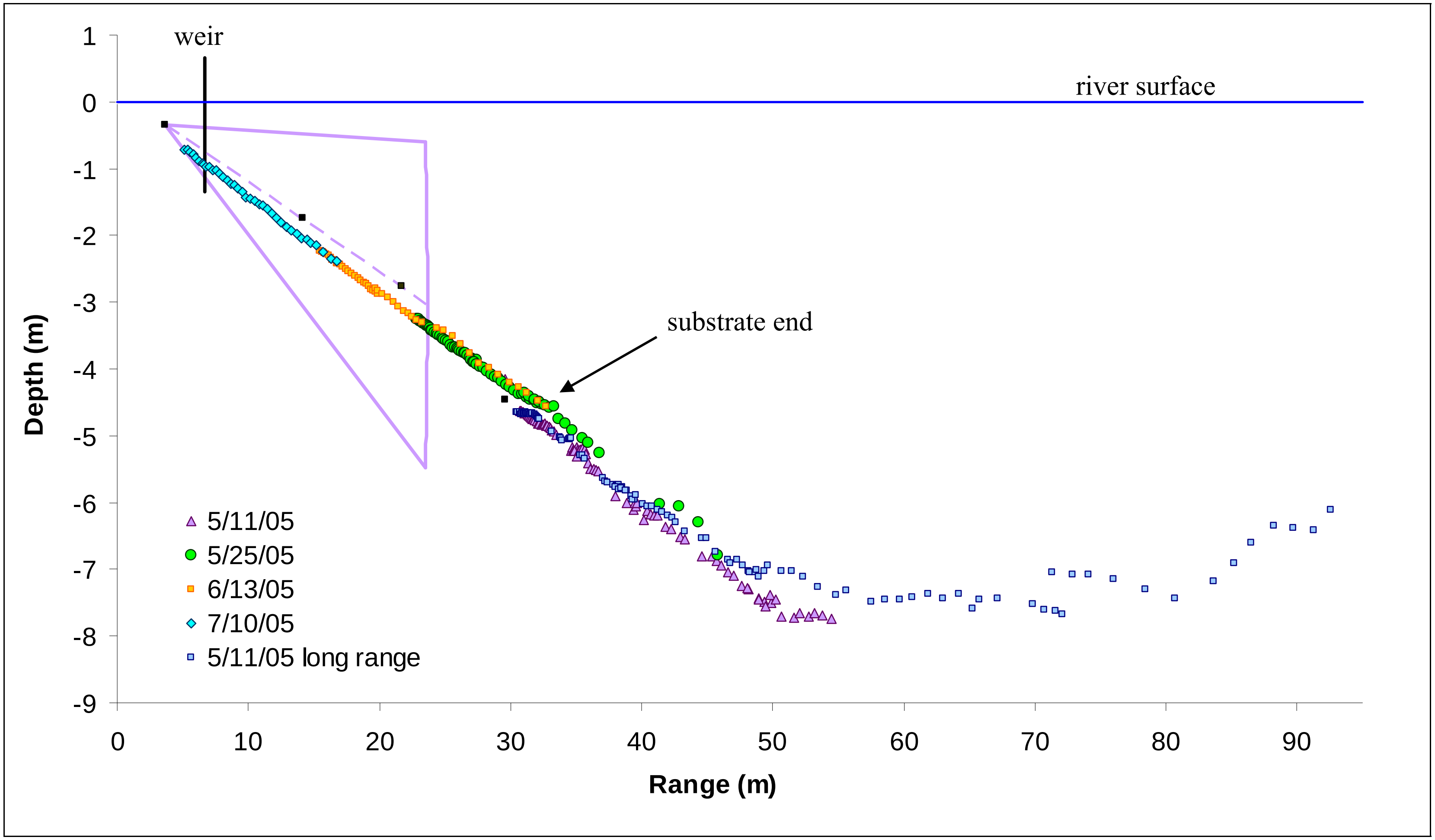

Figure 5.–Copper River south bank profiles created from DIDSON images of the concrete substrate and river bottom. Four standard DIDSON profiles and one long-range DIDSON profile from different positions along the substrate were combined to create an overall profile of the bottom. The transducer's position during each recorded profile is indicated by a black square. A 14° DIDSON beam is overlaid and angled 8.2° below level.

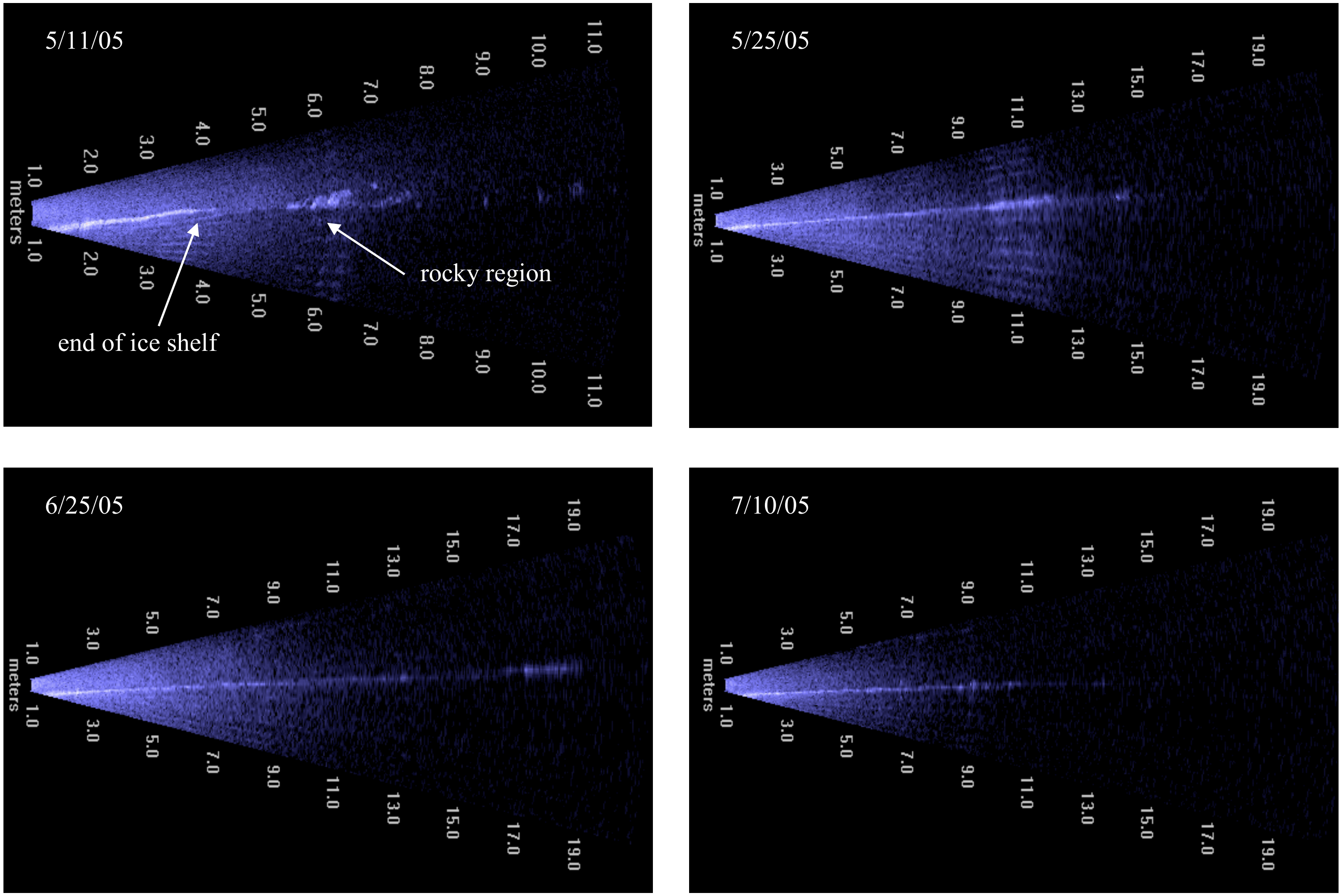

Figure 6.–Copper River south bank's concrete substrate displayed in DIDSON images. On May 11, an ice shelf was visible in the first 4 m of the image and a rough, rocky region farther offshore. On July 10, the range was limited to 13 m during a period of high water and increased turbidity.

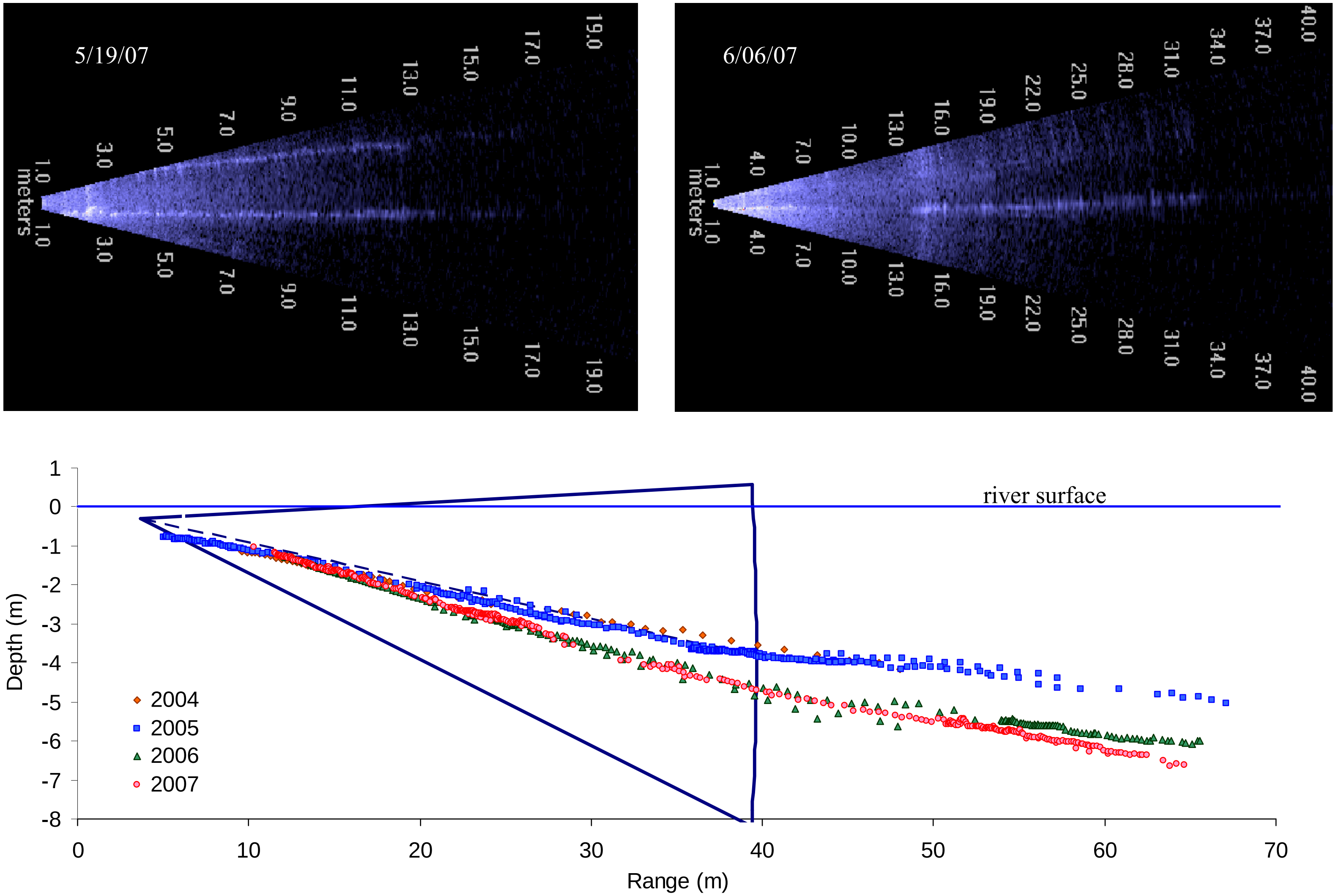

Figure 7.–Copper River north bank's river bottom displayed in DIDSON images (top) and the resulting profiles (bottom) overlaid with a 14° DIDSON beam angled 5.6° below level.

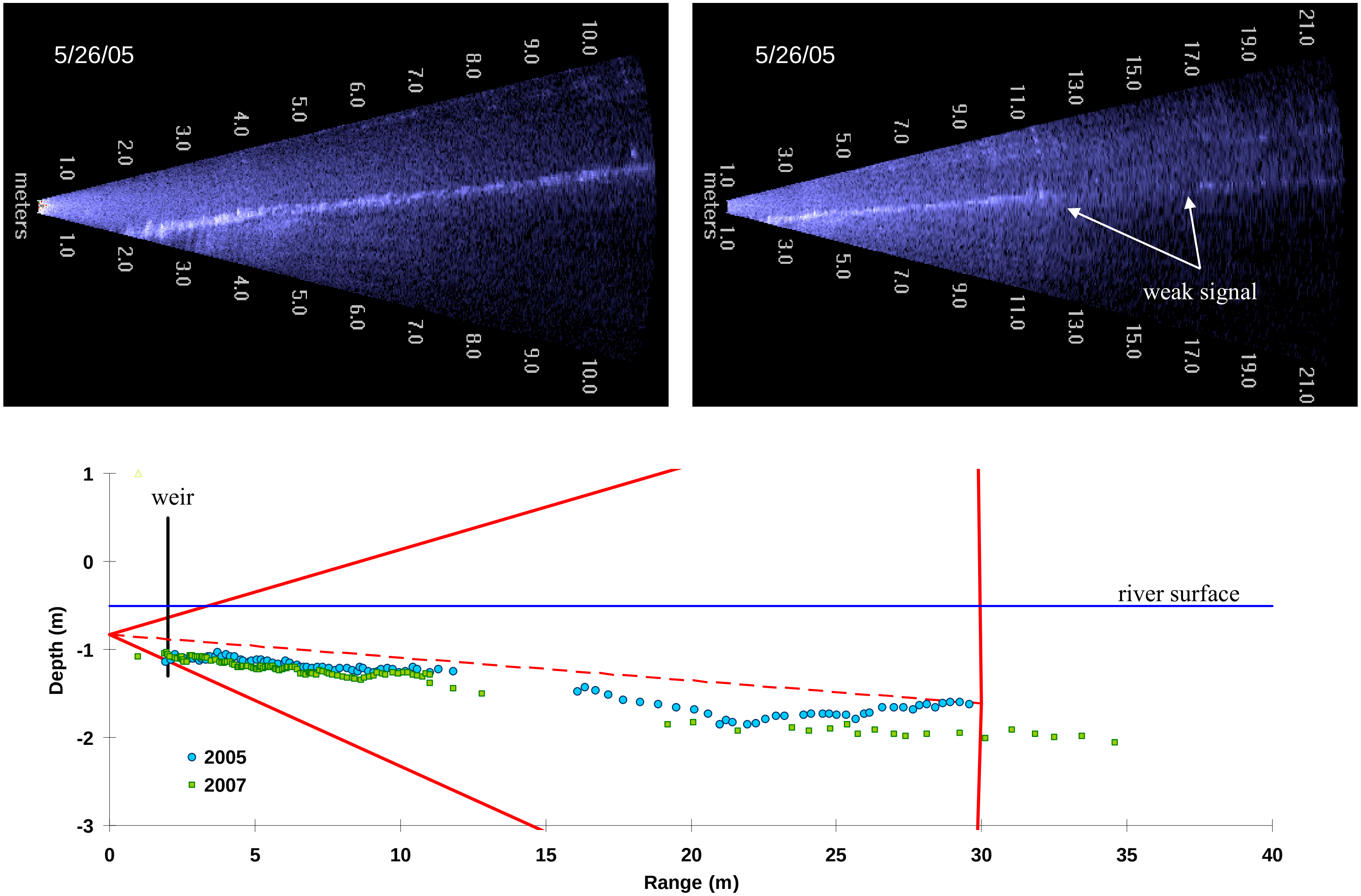

Figure 8.–Kasilof River north bank's river bottom displayed in DIDSON images (top) showing weak or absent echoes from 12-17 m (top, right). River bottom profiles (bottom) are overlaid with a 14° DIDSON beam angled 1.5° below level.

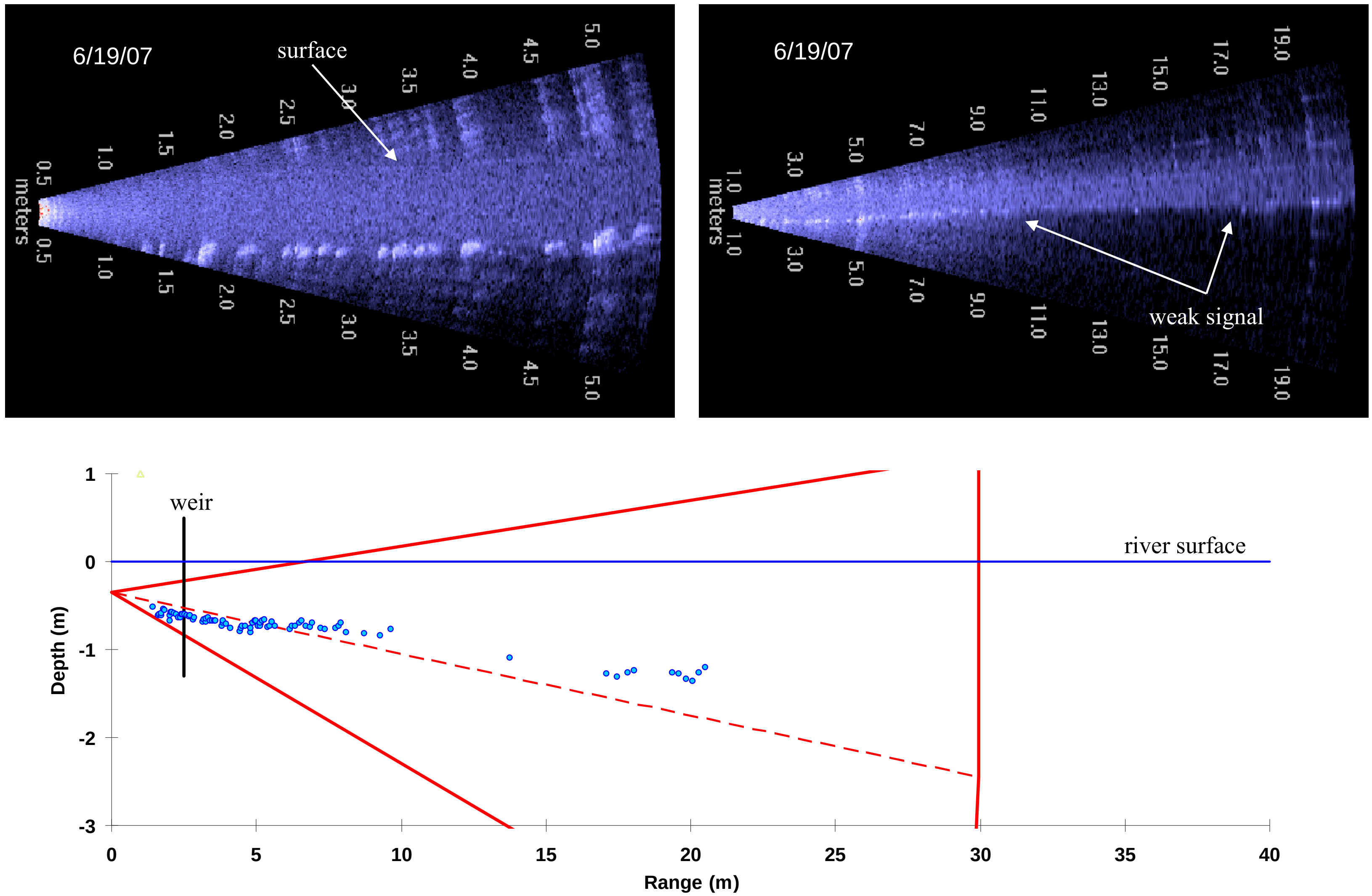

Figure 9.–Kasilof River south bank's river bottom displayed in DIDSON images (top) showing a rocky, uneven bottom and a distinct surface line (top, left) and weak or absent echoes from 10-17 m (top, right). The river bottom profile (bottom) is overlaid with a 14° DIDSON beam angled 4.0° below level.

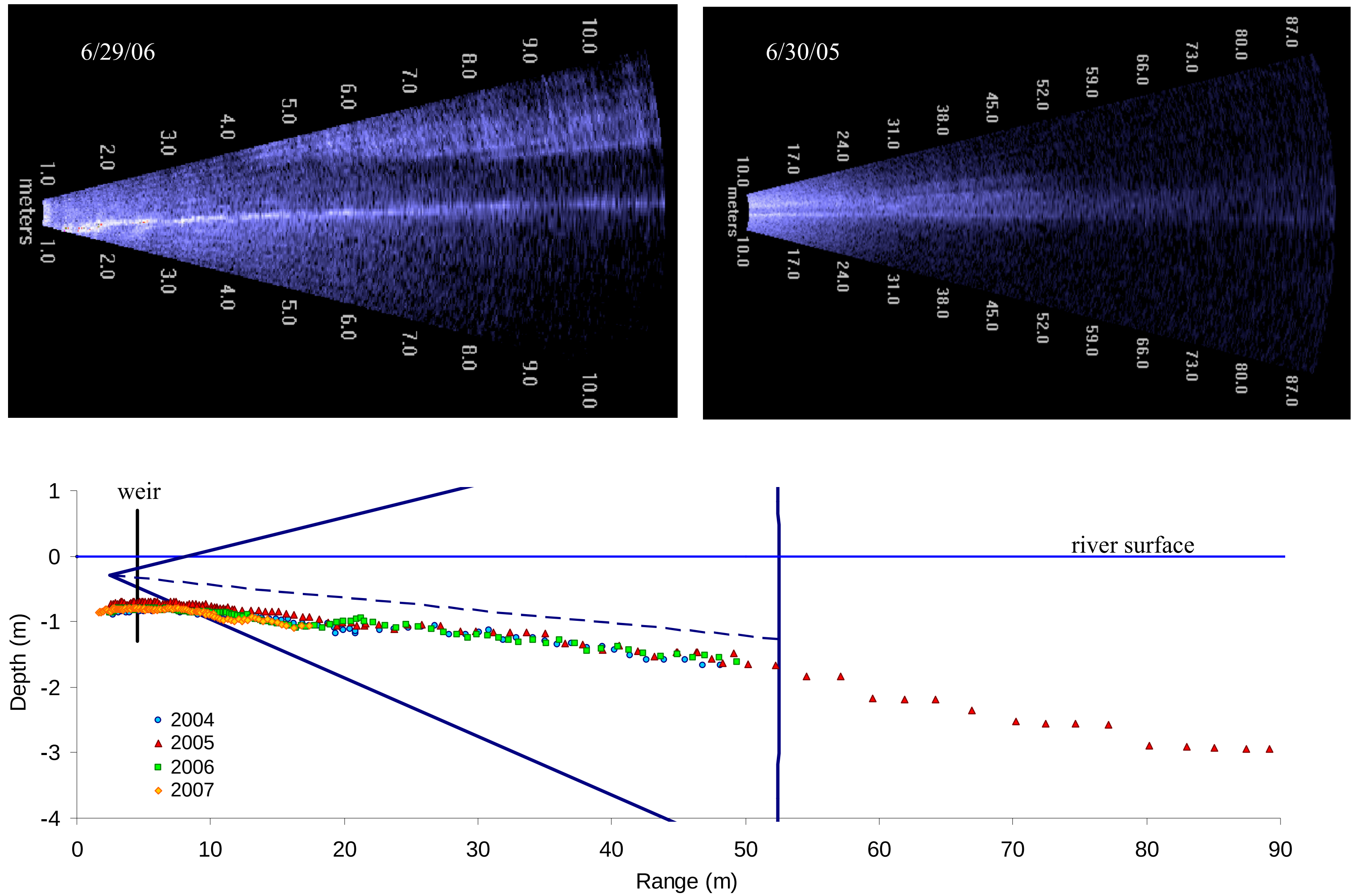

Figure 10.–Kenai River north bank's river bottom displayed in DIDSON images (top), and the resulting profiles (bottom) overlaid with an 8° DIDSON beam angled 1.0° below level.

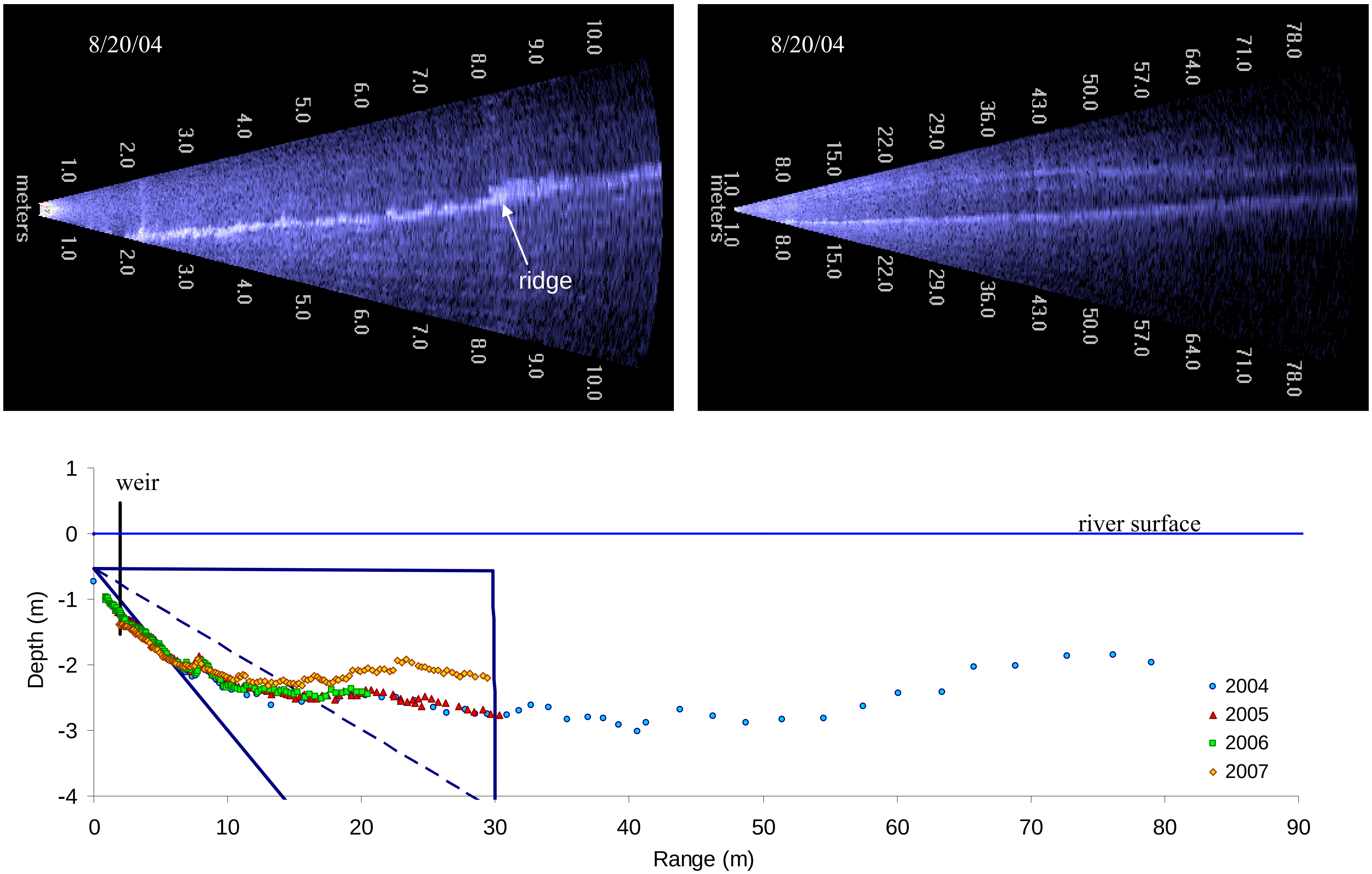

Figure 11.–Kenai River south bank's river bottom displayed in DIDSON images (top) showing a ridge at 8 m (top, left), and a distinct surface line across the range (top, right). The resulting profiles (bottom) are overlaid with a 14° DIDSON beam angled 7.0° below level.

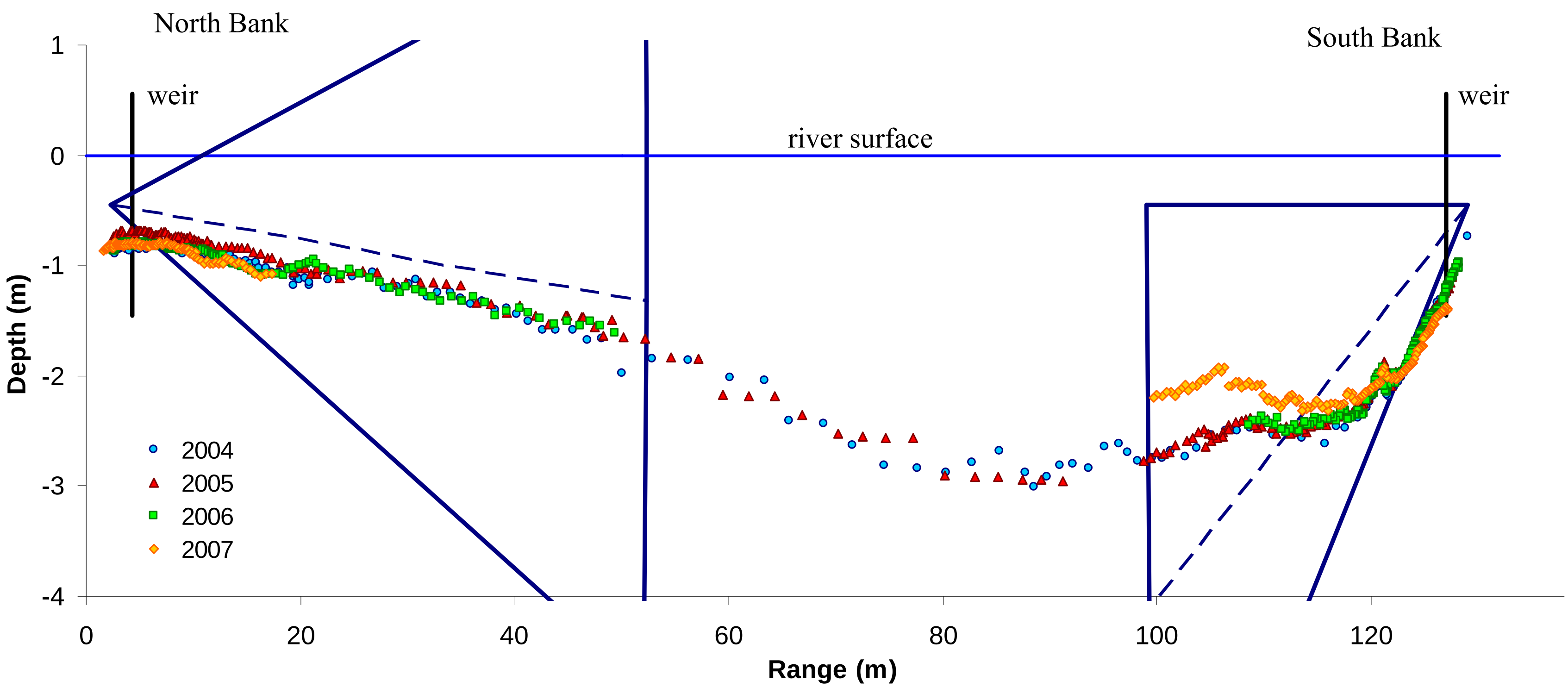

Figure 12.–A cross-river profile of the Kenai River with the DIDSON beams used for fish sampling overlaid. The north bank profile (left) is overlaid with an 8° DIDSON beam angled 1.0° below level. The south bank profile (right) is overlaid with a 14° DIDSON beam angled 7.0° below level.

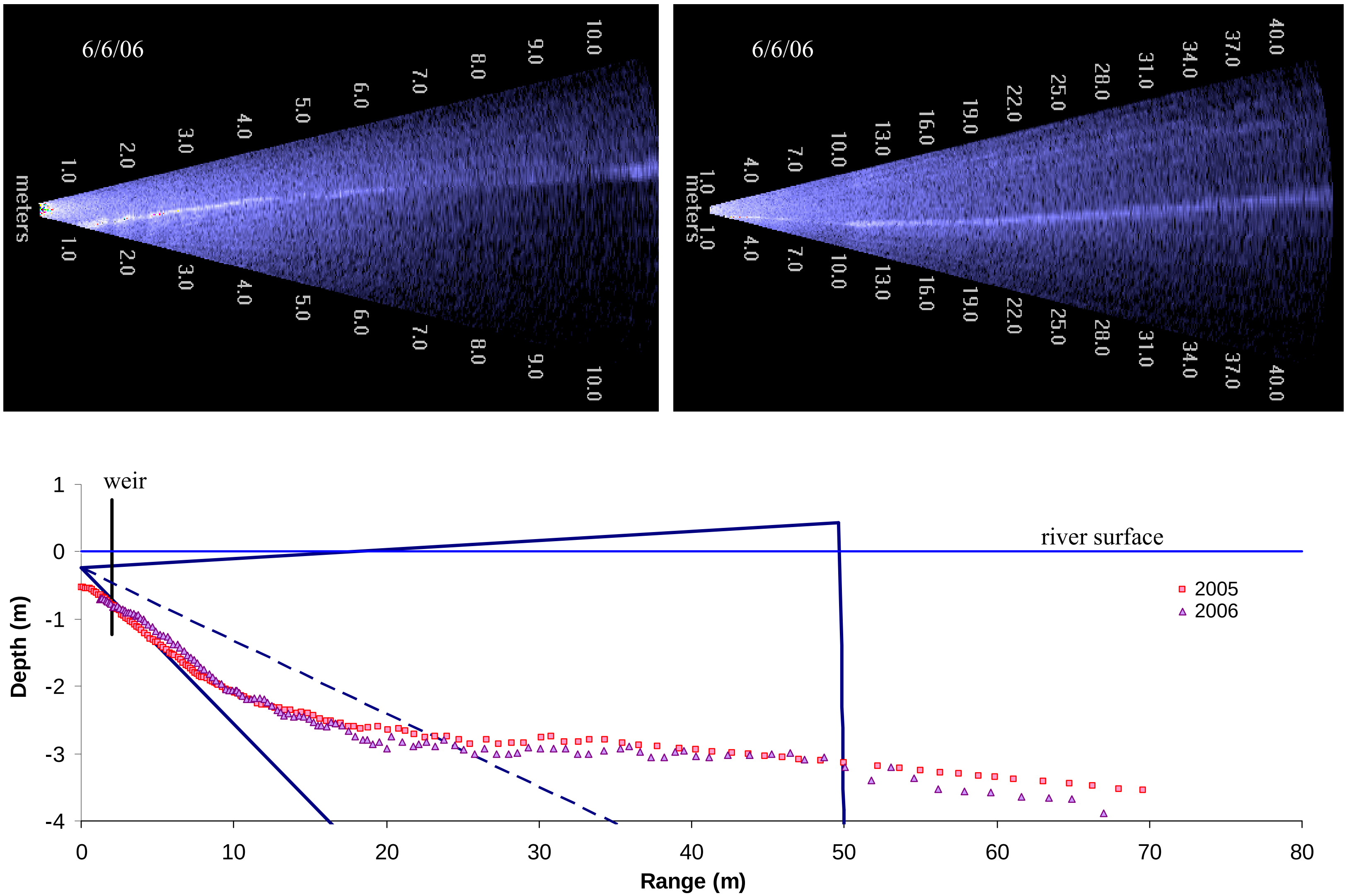

Figure 13.–Nushagak River right bank's river bottom displayed in DIDSON images (top), and the resulting profiles (bottom) overlaid with a 14° DIDSON beam angled 6.2° below level.

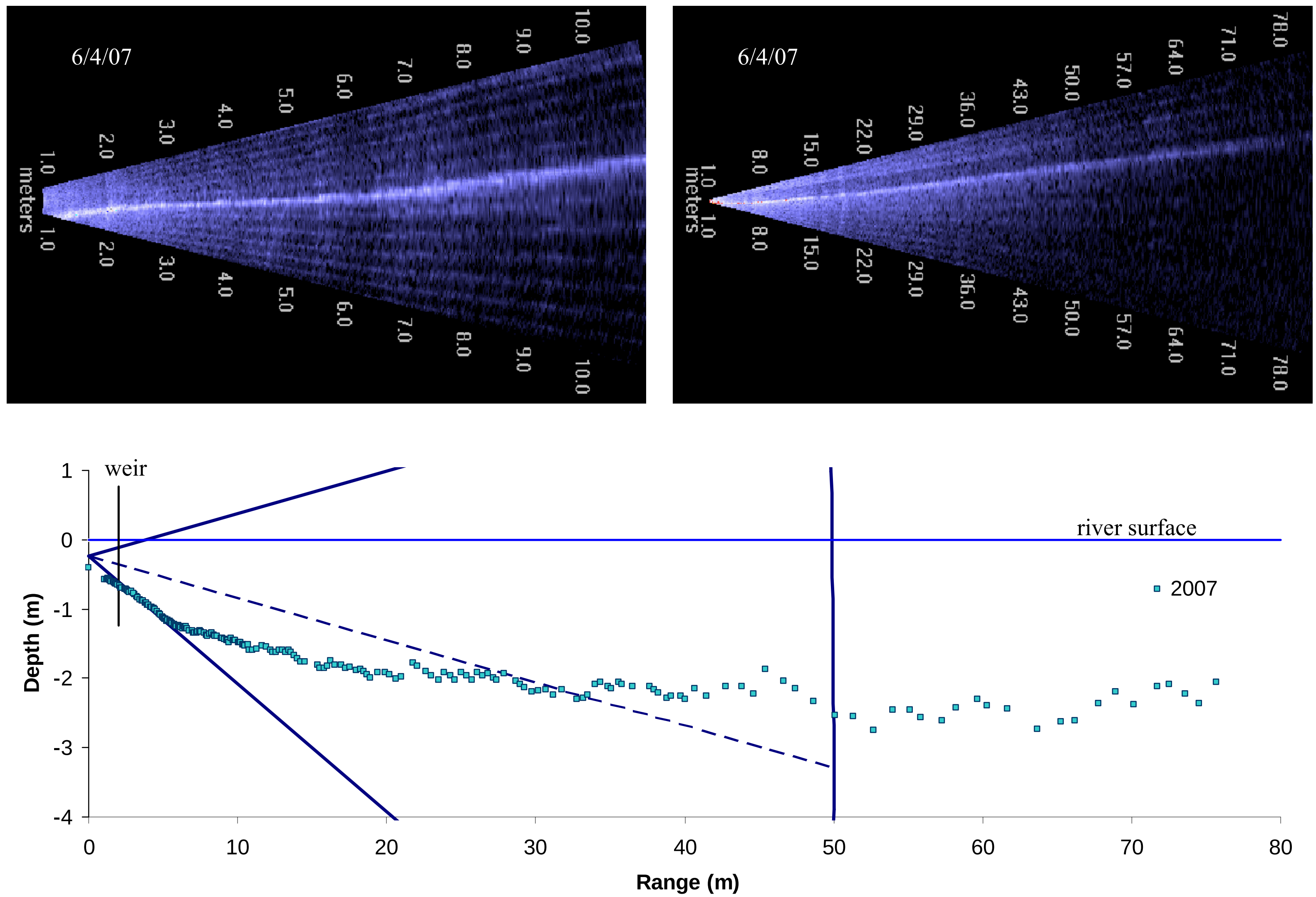

Figure 14.–Nushagak River right bank's bottom displayed in DIDSON images (top), and the resulting profile (bottom) overlaid with a 14° DIDSON beam angled 3.5° below level.

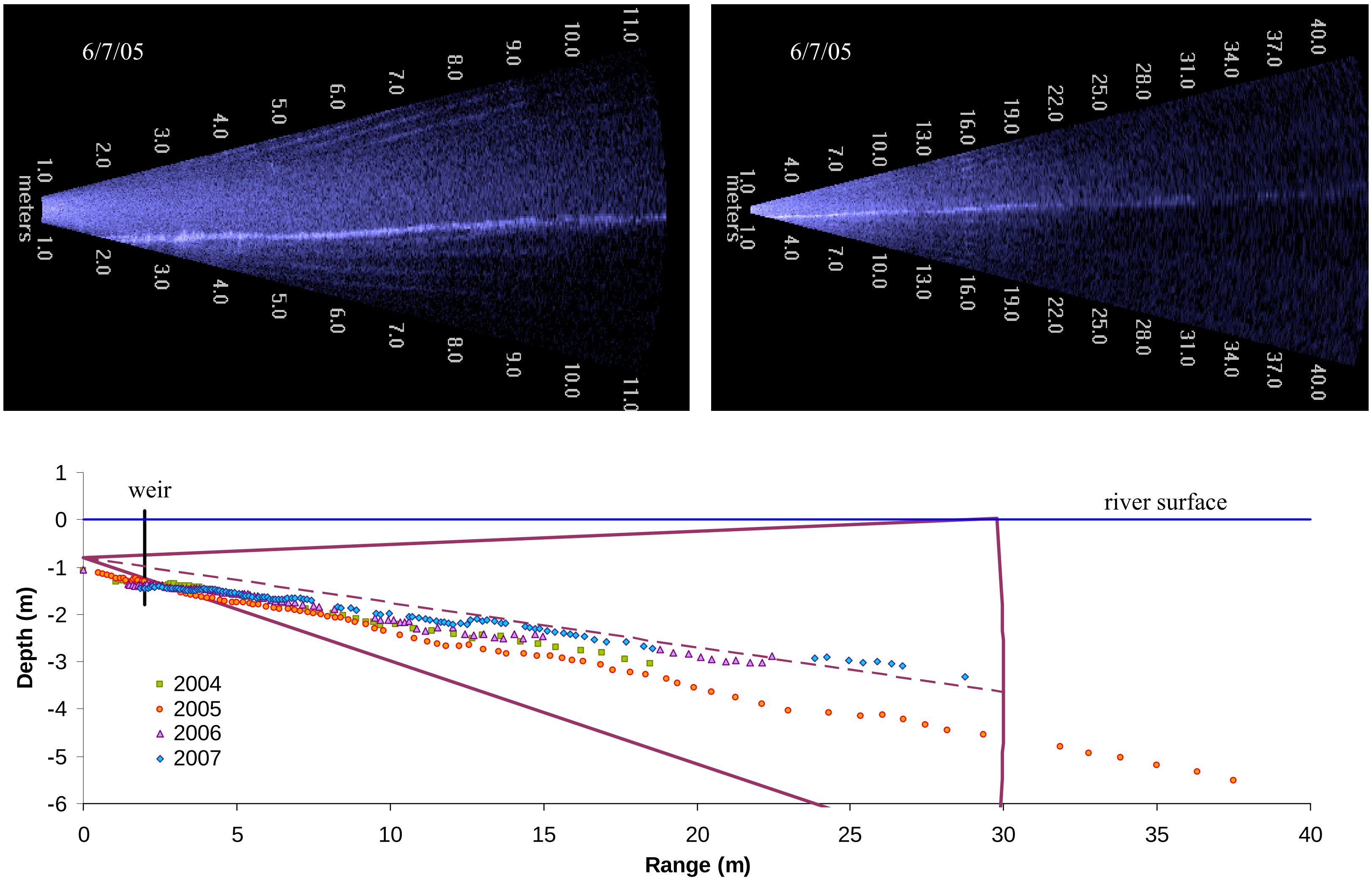

Figure 15.–Nushagak River left bank's river bottom displayed in DIDSON images (top), and the resulting profiles overlaid with a 14° DIDSON beam angled 5.4° below level.

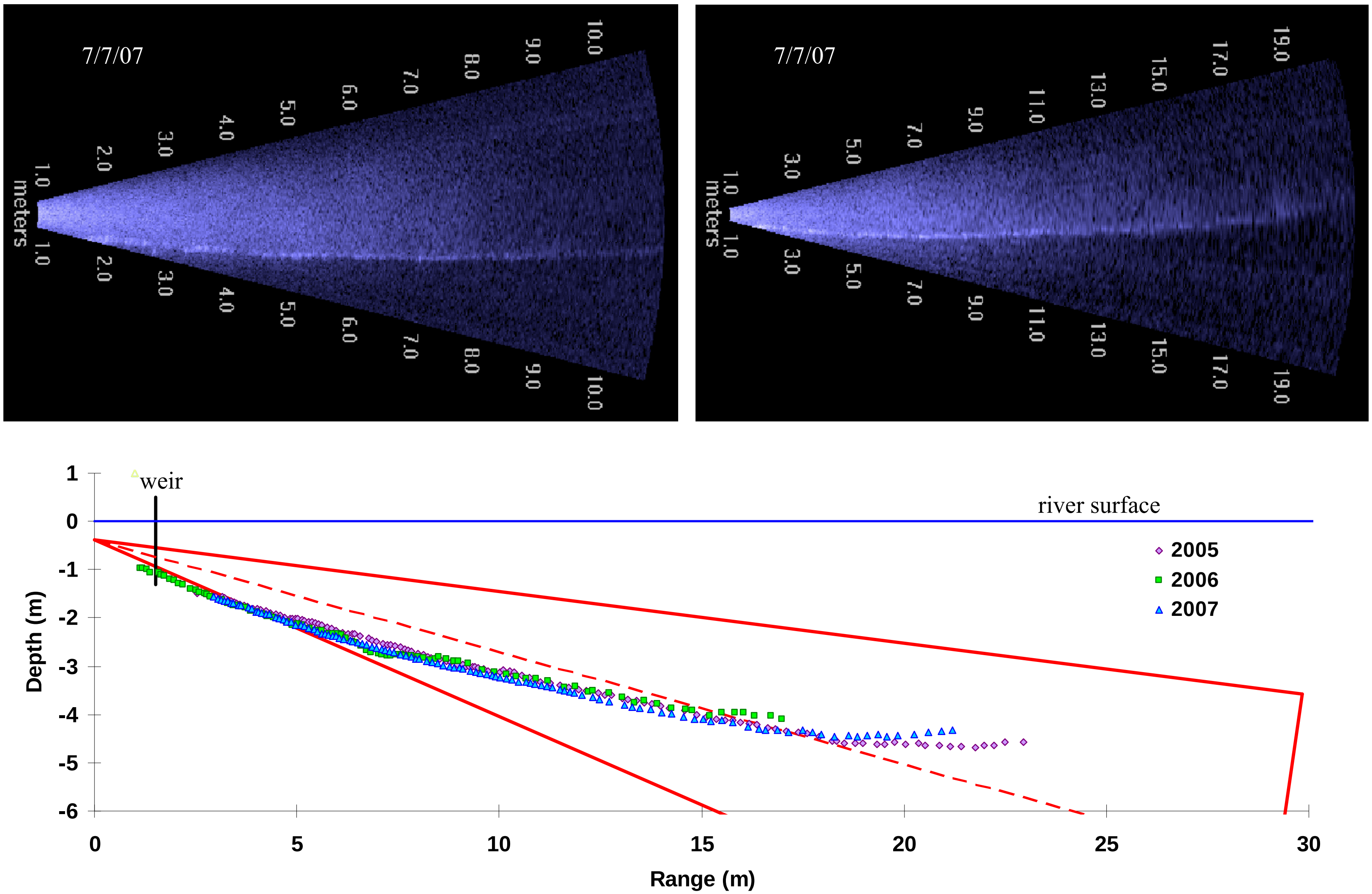

Figure 16.–Yentna River north bank's river bottom displayed in DIDSON images (top), and the resulting profiles (bottom) overlaid with a 14° DIDSON beam angled 13.0° below level.

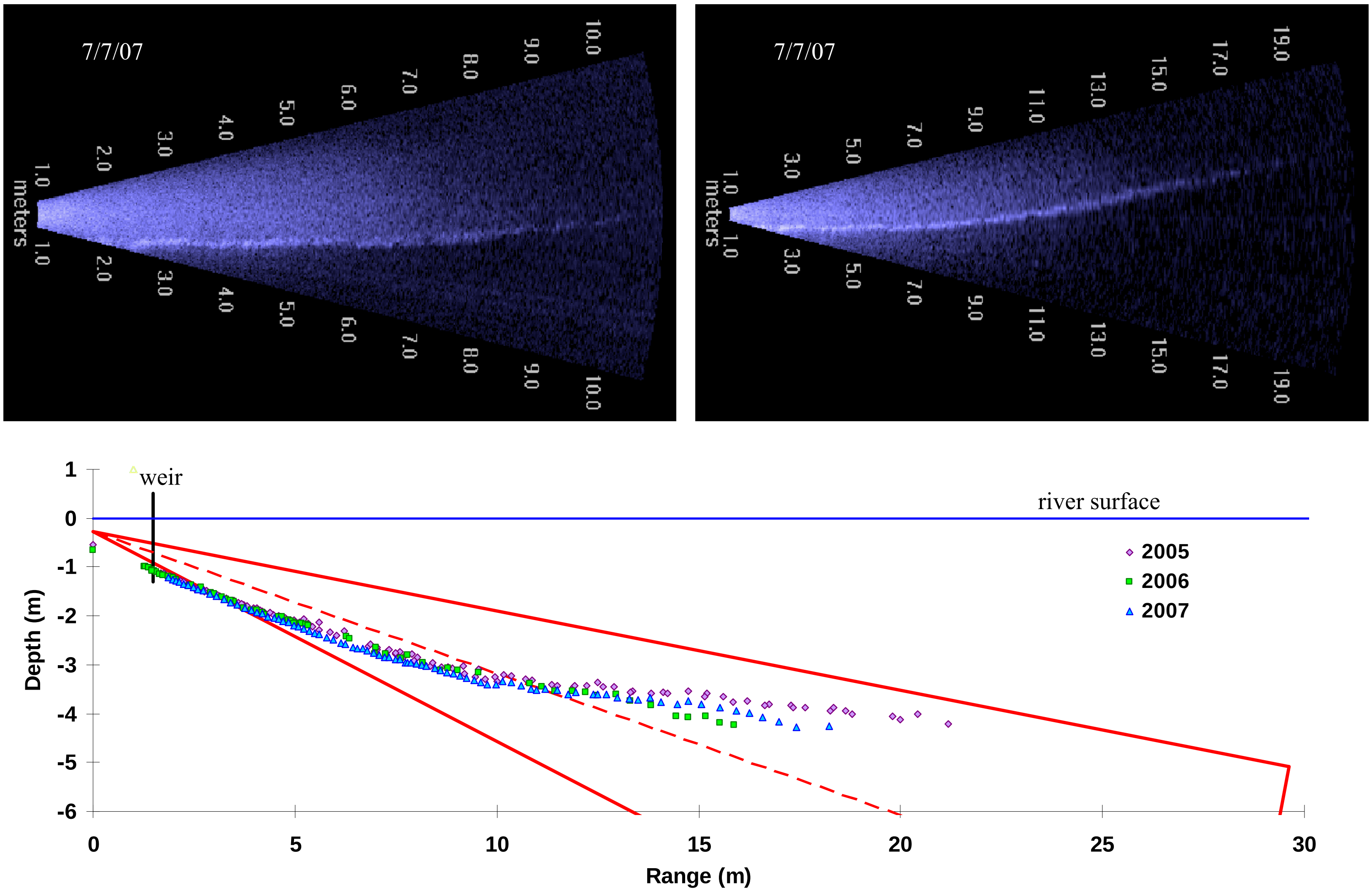

Figure 17.–Yentna River south bank's river bottom displayed in DIDSON images (top), and the resulting profiles (bottom) overlaid with a 14° DIDSON beam angled 16.2° below level.

APPENDIX A

Appendix A1.–DIDSON files and associated measurements used to generate river bottom profiles at ADF&G sonar sites.

Filename (date_time)	DIDSON model	Frequency	Lens depth (cm)	Tilt angle (°)	Depth at transducer (cm)	Water temp. (°C)	Sound speed (m/s)	Window length (m)
Copper River South Bank								
2005-05-11_104815	Long-Range	High	30.9	-18.9	59.7	5.7	1429	1-5
2005-05-11_105130		High	29.6	-11.7	59.7	5.7	1429	1-10
2005-05-11_105644		High	29.6	-11.7	59.7	5.7	1429	1-20
2005-05-11_110035		Low	29.6	-11.7	59.7	5.7	1429	3-40
2005-05-11_182142	Standard	High	23.8	-13.8	50.8	5.7	1429	1-5
2005-05-11_182250		High	23.8	-13.8	50.8	5.7	1429	1-10
2005-05-11_182450		Low	25.1	-11.1	50.8	5.7	1429	1-19
2005-05-11_182533		Low	25.1	-11.1	50.8	5.7	1429	1-40
2005-05-25_114044	Standard	High	23.8	-12.9	63.5	5.7	1429	1-5
2005-05-25_114044		High	23.8	-12.9	63.5	5.7	1429	1-10
2005-05-25_114115		Low	23.8	-12.9	63.5	5.7	1429	1-40
2005-06-13_134003	Standard	High	25.1	-11.3	50.8	9.0	1443	1-5
2005-06-13_13400333		High	25.1	-11.3	50.8	9.0	1443	1-10
2005-06-13_134022		Low	25.1	-11.3	50.8	9.0	1443	1-20
2005-07-10_144228	Standard	Low	34.0	-10.2	63.5	9.0	1443	1-20
Copper River North Bank								
2004-07-27_192928	Long-Range	High	21.0	-7.0	ND	12.0	1455	1-10
2004-07-27_192928		High	21.0	-7.0	ND	12.0	1455	1-20
2004-07-27_193213		Low	21.0	-7.0	ND	12.0	1455	20-60
2005-05-12_154352	Long-Range	High	22.2	-4.7	57.2	7.2	1436	1-10
2005-05-12_154857		High	22.2	-4.7	57.2	7.2	1436	1-20
2005-05-12_155129		Low	21.6	-1.6	57.2	7.2	1436	1-40
2005-06-01_111730	Long-Range	High	29.9	-6.6	33.0	7.2	1436	1-10
2005-06-01_112139		Low	28.9	-5.6	33.0	7.2	1436	1-20
2005-06-01_112139		Low	28.9	-5.6	33.0	7.2	1436	1-40
2005-06-12_153458	Long-Range	High	21.0	-6.6	63.5	7.2	1436	1-10
2005-06-19_113916	Long-Range	High	29.9	-9.7	63.5	7.2	1436	1-10

-continued-

Appendix A1.–Page 2 of 5.

Filename (date_time)	DIDSON model	Frequency	Lens depth (cm)	Tilt angle (°)	Depth at transducer (cm)	Water temp. (°C)	Sound speed (m/s)	Window length (m)
Copper River North Bank								
2005-06-19_114240		Low	28.6	-7.2	63.5	7.2	1436	1-40
2006-05-11_161536	Long-Range	High	17.2	-5.3	59.7	1.1	1408	1-5
2006-05-11_161606		High	17.2	-5.3	59.7	1.1	1408	1-10
2006-05-11_161659		High	17.2	-5.3	59.7	1.1	1408	1-20
2006-06-05_141624	Long-Range	High	14.6	-9.4	58.4	5.5	1428	1-10
2006-06-05_141649		Low	14.6	-9.4	58.4	5.5	1428	1-40
2006-06-16_140947	Long-Range	High	17.2	-8.0	58.4	5.5	1428	1-10
2006-06-16_140957		High	17.2	-8.0	58.4	5.5	1428	1-20
2007-05-19_161629	Long-Range	High	13.3	-3.7	47.3	1.8	1411	1-5
2007-05-19_161716		High	13.3	-3.7	47.3	1.8	1411	1-10
2007-05-19_161737		High	13.3	-3.7	47.3	1.8	1411	1-20
Copper River North Bank								
2007-06-06_153601	Long-Range	High	14.7	-6.6	45.7	6.1	1431	1-5
2007-06-06_153621		High	14.7	-6.6	45.7	6.1	1431	1-10
2007-06-06_153639		High	14.7	-6.6	45.7	6.1	1431	1-20
2007-06-06_153659		Low	14.7	-6.6	45.7	6.1	1431	1-40
2007-06-22_115223	Long-Range	High	11.8	-8.1	42.4	8.3	1440	1-5
2007-06-22_115242		High	11.8	-8.1	42.4	8.3	1440	1-10
2007-06-22_115259		High	11.8	-8.1	42.4	8.3	1440	1-20
2007-06-22_115320		Low	11.8	-8.1	42.4	8.3	1440	1-40
Kasilof River North Bank								
2005-06-27_130229	Standard	High	42.5	-8.3	97.0	14.1	1463	1-10
2005-06-27_130455		Low	41.5	-6.3	97.0	14.1	1463	1-20
2005-06-27_130541		Low	41.5	-6.3	97.0	14.1	1463	10-30
2007-06-19_125650	Standard	High	30.5	-3.8	58.4	11.0	1451	1-5
2007-06-19_125711		High	30.5	-3.8	58.4	11.0	1451	1-10
2007-06-19_125813		Low	30.5	-3.8	58.4	11.0	1451	1-40

-continued-

Filename (date_time)	DIDSON model	Frequency	Lens depth (cm)	Tilt angle (°)	Depth at transducer (cm)	Water temp. (°C)	Sound speed (m/s)	Window length (m)
Kasilof River South Bank								
2007-06-19_143303	Standard	High	12.7	-4.4	43.2	11.0	1451	1-5
2007-06-19_143323		High	12.7	-4.4	43.2	11.0	1451	1-10
2007-06-19_143339		Low	12.7	-4.4	43.2	11.0	1451	1-20
Kenai River North Bank								
2004-08-10_103818	Long-Range	High	42.2	-3.3	81.3	11.1	1452	1-20
2004-08-10_103959		Low	42.2	-3.3	81.3	11.1	1452	8-48
2005-06-30_110707	Long-Range	High	29.7	-0.3	72.5	16.7	1472	1-10
2005-06-30_110753		High	29.7	-0.3	72.5	16.7	1472	1-20
2005-06-30_110818		Low	29.7	-0.3	72.5	16.7	1472	10-50
2005-06-30_110841		Low	29.7	-0.3	72.5	16.7	1472	10-90
2006-06-29_092458	Long-Range	High	42.5	-2.4	71.1	9.1	1444	1-5
2006-06-29_092526		High	45.5	-2.4	71.1	9.1	1444	1-10
2006-06-29_092632		High	42.5	-2.4	71.1	9.1	1444	1-20
2006-06-29_092710		Low	42.5	-2.4	71.1	9.1	1444	10-50
2007-06-29_130209	Long-Range	High	21.6	-3.9	57.8	8.6	1442	1-10
2007-06-29_130209		High	21.6	-3.9	57.8	8.6	1442	1-20
Kenai River South Bank								
2004-08-20_121500	Long-Range	High	23.7	-15.8	73.3	11.1	1452	1-10
2004-08-20_121929		Low	21.8	-4.6	73.3	11.1	1452	1-40
2004-08-20_122244		Low	21.2	-2.4	73.3	11.1	1452	1-80
2005-06-29_115609	Standard	High	42.8	-12.5	78.7	16.7	1472	1-5
2005-06-29_120038		Low	40.0	-2.1	78.7	16.7	1472	5-25
2005-06-29_120112		Low	40.0	-2.1	78.7	16.7	1472	10-30
Kenai River South Bank								
2006-06-27_093819	Standard	High	45.5	-20.0	76.2	9.1	1441	1-5
2006-06-27_094000		High	43.8	-16.6	76.2	9.1	1441	1-10
2006-06-27_094144		Low	42.6	-11.6	76.2	9.1	1441	1-20

-continued-

Appendix A1.–Page 4 of 5.

Filename (date_time)	DIDSON model	Frequency	Lens depth (cm)	Tilt angle (°)	Depth at transducer (cm)	Water temp. (°C)	Sound speed (m/s)	Window length (m)
Kenai River South Bank								
2007-07-09_191500	Standard	High	45.7	-6.0	68.6	10.2	1448	1-10
2007-07-09_190000		Low	45.7	-6.0	68.6	10.2	1448	1-30
Nushagak River Right Bank								
2005-06-08_194203	Long-Range	High	29.3	-10.9	56.5	13.9	1462	1-10
2005-06-09_150431	Long-Range	High	20.4	-6.0	61.6	13.9	1462	1-20
2005-06-09_150646		Low	19.9	-4.7	61.6	13.9	1462	1-40
2005-06-09_151009		Low	19.2	-1.2	61.6	13.9	1462	20-100
2006-06-06_203147	Long-Range	High	17.8	-14.8	43.2	nd	nd	1-10
2006-06-06_203355		High	17.2	-10.1	43.2	nd	nd	1-20
2006-06-06_203541		Low	15.9	-6.0	43.2	nd	nd	1-40
2006-06-06_203651		Low	15.9	-6.0	43.2	nd	nd	10-90
2007-06-04*	Long-Range	High	15.7	-11.1	40.6	10.3	1449	1-10
2007-06-04		High	15.7	-11.1	40.6	10.3	1449	1-20
2007-06-04		Low	14.5	-8.0	40.6	10.3	1449	1-40
2007-06-04		Low	14.5	-8.0	40.6	10.3	1449	1-80
Nushagak River Left Bank								
2004-07-16_122123	Standard	High	89.5	-13.0	106.7	17.0	1473	1-5
2004-07-16_122123		High	89.5	-13.0	106.7	17.0	1473	1-9
2004-07-16_122322		Low	89.5	-13.0	106.7	17.0	1473	1-18
2005-06-07_155941	Standard	High	17.8	-9.0	57.5	13.9	1462	1-10
2005-06-07_160005		Low	17.8	-9.0	57.5	13.9	1462	1-20
2005-06-07_160023		Low	17.8	-9.0	57.5	13.9	1462	1-40
2006-06-07_162211	Standard	High	51.8	-12.1	90.2	nd	nd	1-5
2006-06-07_162527		High	51.8	-10.5	90.2	nd	nd	1-10
2006-06-07_162626		Low	51.8	-10.5	90.2	nd	nd	10-30
2007-06-04_133450	Standard	High	12.7	-6.2	39.4	10.5	1449	1-10

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Filename (date_time)	DIDSON model	Frequency	Lens depth (cm)	Tilt angle (°)	Depth at transducer (cm)	Water temp. (°C)	Sound speed (m/s)	Window length (m)
Nushagak River Left Bank								
2007-06-04_133524		Low	12.7	-6.2	39.4	10.5	1449	1-20
2007-06-04_133655		Low	12.7	-6.2	39.4	10.5	1449	1-40
Yentna River North Bank								
2005-07-13_153217	Standard	High	21.0	-21.8	58.0	9.5	1445	1-5
2005-07-13_153424		High	22.0	-15.8	58.0	9.5	1445	1-10
2005-07-13_153730		Low	20.0	-9.8	58.0	9.5	1445	10-30
2006-07-10_213947	Standard	High	26.0	-27.5	67.3	12.3	1456	1-10
2006-07-10_214147		Low	27.3	-20.6	67.3	12.3	1456	1-20
2007-07-07_133508	Standard	High	16.5	-11.3	45.7	9.0	1443	1-10
2007-07-07_133519		Low	16.5	-11.3	45.7	9.0	1443	1-20
Yentna River South Bank								
2005-07-12_152009	Standard	High	22.0	-20.7	56.0	9.5	1445	0.5-5
2005-07-12_152141		High	21.0	-16.8	56.0	9.5	1445	1-10
2005-07-12_152411		Low	19.5	-9.7	56.0	9.5	1445	1-40
2006-07-10_183840	Standard	High	21.6	-28.2	64.8	12.3	1456	0.5-5
2006-07-10_184041		High	21.6	-25.4	64.8	12.3	1456	1-10
2006-07-10_184252		Low	19.7	-21.8	64.8	12.3	1456	1-20
2007-07-07_095950	Standard	High	22.9	-18.0	54.6	9.0	1443	1-10
2007-07-07_100004		Low	22.9	-18.0	54.6	9.0	1443	1-20

*The DIDSON software saved the wrong time in the filename so it was not included.

Appendix A2.–A side-looking sonar aiming protocol with instructions for generating river bottom profiles using a dual-frequency identification sonar (DIDSON).

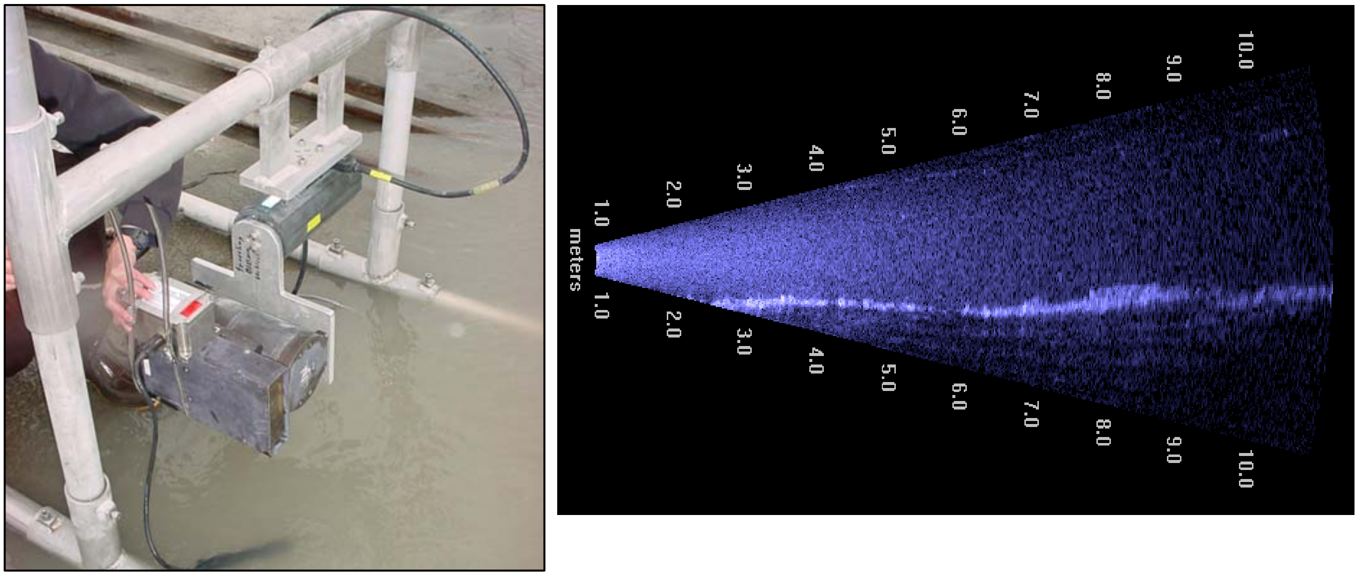

Figure 1.–DIDSON mounted with the multiple beams positioned vertically (left) and a sample river bottom image (right).

Equipment:

- DIDSON and accessory equipment
- Mount and mounting brackets
- Automated rotator or manual method to tilt the DIDSON
- Tilt and roll sensor (internal DIDSON sensor or external sensor)
- Computer
- Power source and appropriate converters
- Bubble level, thermometer, tape measure, tools for mounting equipment and hardware

Required Measurements:

- Water temperature (calculate sound speed in m/s)
- Water depth at the transducer
- Water depth from surface to center of transducer lens
- Transducer tilt angle

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DIDSON
Attach to rotator
=200 ft transducer cable
DIDSON topside box
Ethernet and BNC cables
Power (24 VDC-->120 VAC)

Rotator
Attach to mount
Rotator cable
Rotator control box
Power 120 VAC

Attitude Sensor
Attach to transducer
Sensor cable
Serial or USB Cable
Power (12 V DC-->120 VAC)

Mount

Computer
Ethernet port
120 VAC power

Power
1000 W generator

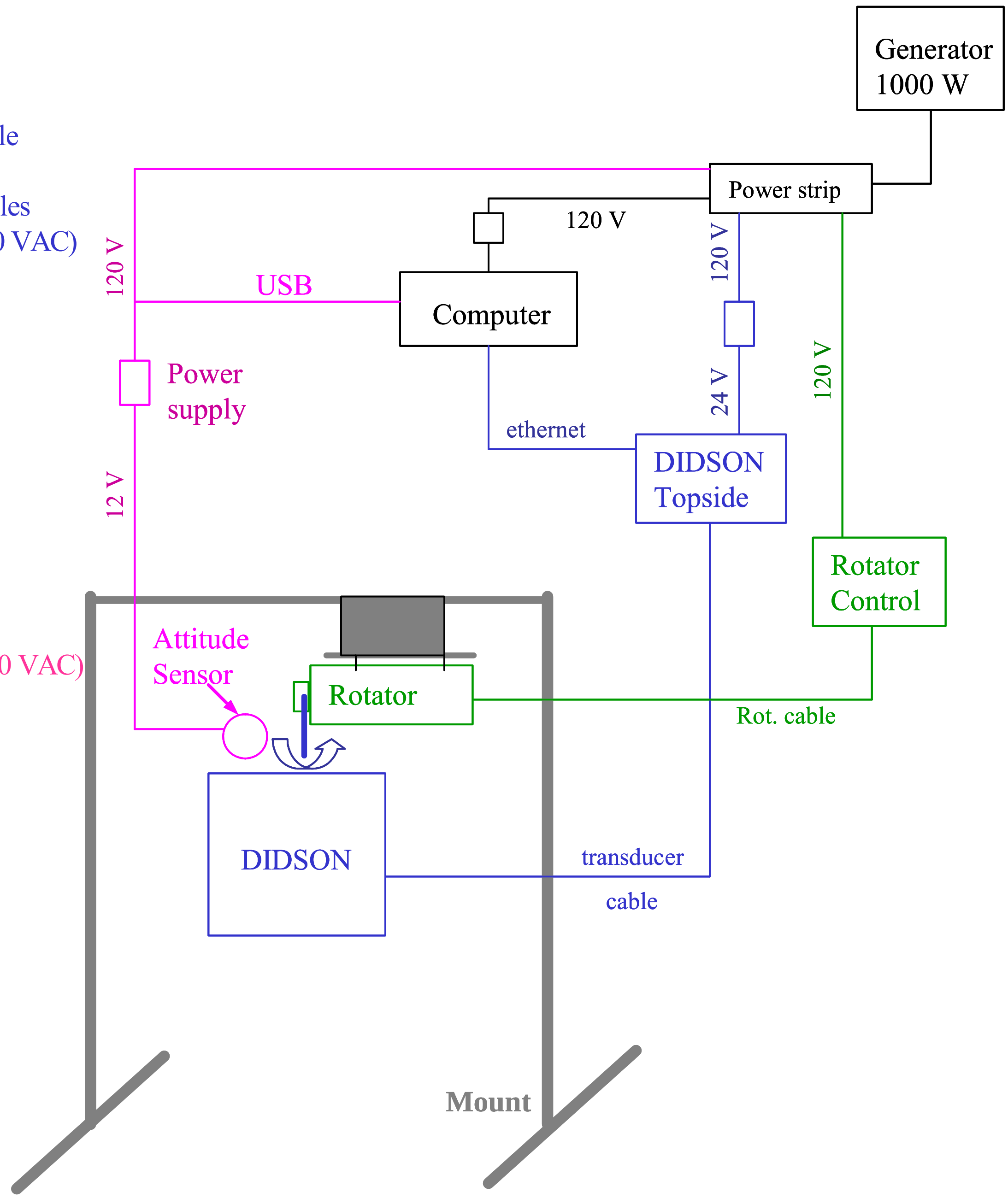

Figure 2.–DIDSON set-up using 120 VAC power.

Equipment set-up

1. **Attach the automated rotator** to the aluminum H-shaped mount in a configuration that ensures tilt movement of the transducer.
2. **Set up the DIDSON** as shown in the picture, on the mounting plate with the lens positioned vertically, and attach to the rotator. The DIDSON should be mounted ~15-30 cm from the river bottom. The DIDSON can be used with a ≤ 200 ft cable connected directly to the topside box. A computer ethernet cable connects the topside box to the computer. If a DIDSON cable longer than 250 ft is needed, connect the 50 ft cable to the DIDSON and to the side of the thinnet converter marked *Sonar*. Connect the long cable to the side of the thinnet converter marked *Topside* and to the topside box. A short computer ethernet cable plugs into the topside box and links to the ethernet extender. Connect a second ethernet cable from the ethernet extender to the computer.
3. **Mount the attitude sensor** on the top flat surface of the lens using hose clamps. Ignore this step if you are using a DIDSON with an internal compass.
4. **Calibrate the sensor** with a bubble level on shore to obtain a zero attitude point. Place a level on top of the sensor or DIDSON and move the rotator until the sensor is level. Zero it in the sensor program. If you are using the DIDSON internal compass zero the compass in the DIDSON program (*Sonar> Configure> Zero Tilt/Roll/Depth Offsets*).
5. **Test and record the limits of the rotator** while the mount is still onshore. Rotate slowly and record pan and tilt limits that stop the DIDSON with enough space to safely prevent encountering the mount. For the ROS rotator with the computer control, these limits can be set in the software. For other rotators, it is necessary to record the limits in the front of the logbook and remind each sonar operator about these limits.
6. **Deploy the sonar** with the lens perpendicular to the river's current. Push the mount offshore until the DIDSON and sensor are submerged.
7. **Open the DIDSON program** and turn on the sonar at the topside box. It may take a minute for it to connect (See the Troubleshooting section if there is a problem).

Collecting profiling data

1. **Adjust window settings** in the *Sonar Controls*. For the best resolution, start with a short window length and use the high frequency mode. Set the Window Start to ~1 m and the Window Length to 5 m.
2. **Adjust the tilt** of the transducer using the rotator until the river bottom profile (line running the length of the image) is in the middle of the viewing window.
3. **Measure** the water depth at the transducer, lens depth (center of lens to river surface), distance from the transducer to a fixed location on shore, and water temperature in Celsius. For the lens depth, the top of the lens to the surface can be measured and added to half of the lens length (total lens length = 6 in). Calculate the sound speed and enter in the Didson.ini File *(Edit> Sonar> Didson.ini File*; Figure 3*)*. Make sure all the other settings in the file are correct and check *Enable Update* if changes are being made.

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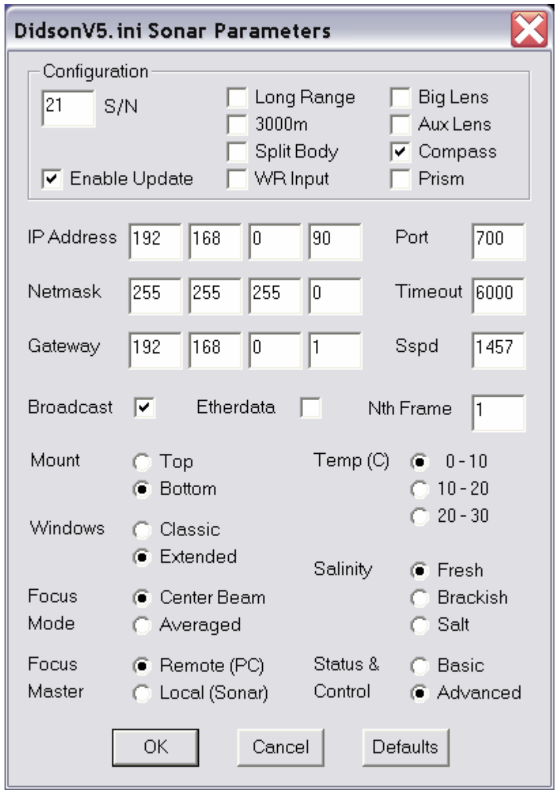

Figure 3.–Example of the DIDSON .ini file located in the DIDSON software where the sonar parameters are entered.

4. **Input information in the Header ID** *(Edit> Header ID)*: river, bank, and measurements. If using an external sensor be sure to add the DIDSON's tilt angle.
5. **Set the file directory.** Go to *File> Set Save Dir/Name* and navigate to folder where you want to export the data files. Leave the default name and click Save. Click NO when the 'Replace HHMMSS etc.' window pops up and YES to the 'Append Frequency' (if desired). The files are named with the date, time, and frequency (i.e. 2006-05-13_130000_LF.ddf).
6. **Record data.** Click on the record button (red circle on toolbar) to start and stop recording. Keep the length of the recording small (5-10 s).
7. **Increase the window length** to 10 m and if necessary, adjust the DIDSON's tilt angle and re-measure the lens depth (this distance changes whenever the tilt angle is changed). Enter this new information in the *Header ID*. Keep extending the window length and recording until the bottom profile is no longer visible. Adjust the tilt angle when necessary. For close ranges, we use the high frequency mode and tilt the DIDSON down at a greater angle. For longer ranges, we use the low frequency mode and raise the DIDSON to extend the viewing range.
8. **Write in the logbook** the DIDSON file names and all measurements.

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Processing DIDSON profiles

1. **Open a recorded file** in the DIDSON program. Go to *File*> *Open* and navigate to the first file to process.
2. **Adjust the threshold and intensity settings** of the raw image to view the profile as clearly as possible. Make sure the river surface is on the left side of the image. (You will know if the surface is on the left if when tilting the transducer down, the bottom profile moves from right to left in the display window) Click *Reverse* in the *Display Controls* if it is not.
3. **Check the sound speed** in the Sonar Status window to see if it is the same as when the file was recorded. If not, go to *Edit*> *Sonar*> *Didson.ini File* and enter the correct sound speed and check the *Enable Update* box. Click 'OK'. Close out the DIDSON program and reopen the file. (This will save the sound speed information in the DIDSON's initialization file.)
4. **Go to *Processing*> *Special*> *Mark Depth Profile*.** A pop-up box will ask if the river surface is on the left side of the image, click OK.
5. **Enter lens depth and tilt.** Lens depth is from mid-lens to the river's surface. The tilt is entered as a positive value even though it is tilted down.
6. **Mark the profile** by using the computer mouse to click along the top edge of the river bottom image from the start to end range to create range and depth data points. To erase a mark, click it a second time. When finished, right-click and a graph of the data points will appear.
7. **Export the range and depth points.** Go to *Processing*> *Special*> and uncheck *Mark Depth Profile*. Click Yes you want to save to a text file. Name the new file with the date and hour of the image file and click Save.

Creating a DIDSON Profile

For this step, obtain a copy of the Excel "Beam Workbook" containing macros that allows the user to place a model beam over the river bottom profile and vary the tilt angle (the workbook is available from either author). The directions below are for use with this workbook. If the workbook is not available, the user may create their own by plotting the river bottom profile in a range versus depth plot, converting the beam dimensions and transducer position measures to rectangular coordinates and plotting the edges, end, and center of the resulting beam.

1. **Copy and paste the data** from the text file into the Beam Workbook. The exported text files list the range in the first column and depth in the second column. To separate the data into two columns go to *Data*> *Text to Columns*> *Delimited*> *Next*> check *Comma*> *Next*> *Finish.*

2. **Make the depth values negative.**

3. **Plot the range and depth values**. Select the beamchart tab in the workbook, right-click on the chart, and select *Source Data*> *Series* tab> *Add* to enter the profile data. Name the profile and select the data for the X (range) and Y (depth) values. Click OK.

4. **Deploy** the horizontally-positioned DIDSON in the same location where the profiles were recorded.

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5. **Measure** the distance to shore, the lens depth, and the water depth at the position of the transducer.
6. **Add a model DIDSON beam** to the plot. Turn on the beams in the worksheet using the colored buttons at the top.
   a. **Enter the beam size and desired range.** The DIDSON's vertical beam width is 14°. Enter the desired sampling range in the colored column above the beam you selected.
   b. **Enter the range (x) and depth (y)** of the horizontally-positioned transducer that will be used for sampling at the top right of the worksheet.
   c. **Tilt the beam** using the rotator arrow buttons until a reasonable tilt angle is found. Align the beam center with the region of the river where we suspect most fish pass, just above the river bottom. Use this tilt angle to aim the side-looking sonar for fish counting.
7. **Tilt** the fish-counting sonar to the tilt angle selected from the beam workbook.
8. **Modify the tilt angle** slightly if needed to reduce the occurrence of surface or bottom disturbances.
9. **Enter the final aim** into the beam workbook to observe the effect of the aim.

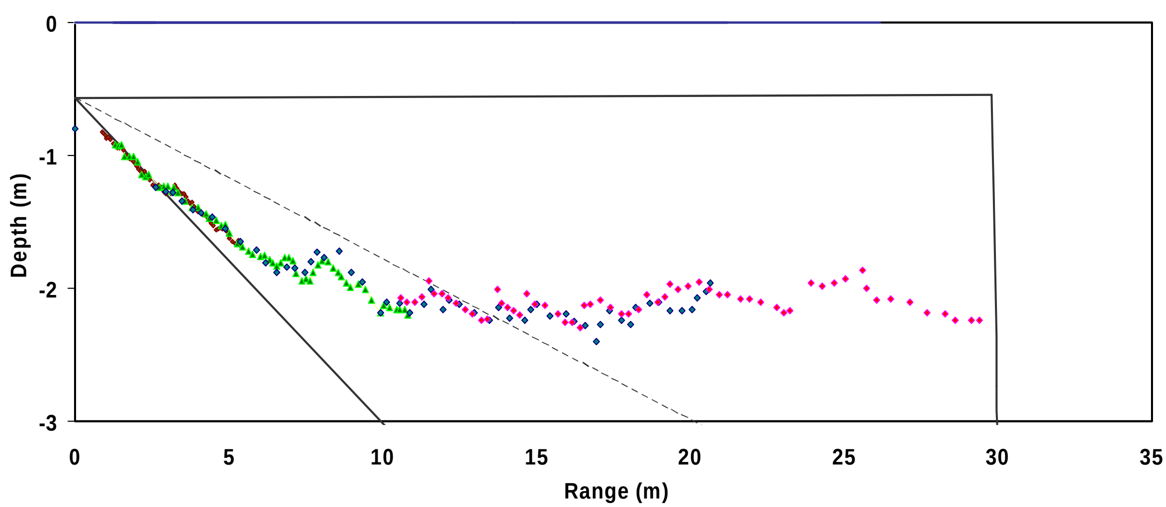

Figure 4.–River bottom profile created from DIDSON images with a 14° DIDSON model beam.

Troubleshooting - If the DIDSON is not connecting:

1. Make sure the program is not in Demo Mode *(Edit>Mode*>uncheck *Demo).*
2. When using the 500 ft transducer cable, the Ethernet transfer mode should be in packets (*Sonar>Configure>Ethernet Transfer Mode*>check *by Packet Request*). When using a ≤ 200 ft cable, the transfer mode should be *by Frame Request*.

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3. Check the parameters and IP address in the .ini file *(Edit> Sonar> Didson.ini File)*.
4. Check the IP address on the computer *(Control Panel>Network Connections>Local Area Connection>Internet Protocol>Properties)*. At start-up the computer should obtain it automatically or type in 128.95.97.100 for IP & 255.255.255.0 for netmask.
5. Close down the program and recycle the topside power. Reopen the program to see if it connects. Sometimes it is good to completely shut down the computer and start over.
6. Check all the connections inside and outside, and reset.
7. Plug the video monitor into the topside box and restart the sonar to see if it is booting up. This will help narrow down the problem to either the sonar or computer connection. The sonar boot up process will be shown on the monitor along with the IP address it is trying to connect to.

Appendix A3.–Sample worksheet for recording the information needed to create river bottom profiles using a dual-frequency identification sonar (DIDSON).

DIDSON River Bottom Profiling

Year:__________________________ Model & S/N:____________________

River:__________________________ Bank:__________________________

Location Description:____

Filename	Depth at transducer (in)	Lens depth (in)	Tilt angle (^{o})	Water temp. (^{o}C)	Sound speed (m/s)	Window length (m)