

# **Kenai River Chinook Salmon Sonar Assessment**

by

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and

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February 2014

Alaska Department of Fish and Game

Divisions of Sport Fish and Commercial Fisheries



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<b>Weights and measures (metric)</b>		<b>General</b>		<b>Mathematics, statistics</b>	
centimeter	cm	Alaska Administrative Code	AAC	<i>all standard mathematical signs, symbols and abbreviations</i>	
deciliter	dL	all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.	alternate hypothesis	$H_A$
gram	g			base of natural logarithm	$e$
hectare	ha	all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.	catch per unit effort	CPUE
kilogram	kg			coefficient of variation	CV
kilometer	km	at	@	common test statistics	(F, t, $\chi^2$ , etc.)
liter	L	compass directions:		confidence interval	CI
meter	m	east	E	correlation coefficient (multiple)	R
milliliter	mL	north	N	correlation coefficient (simple)	r
millimeter	mm	south	S	covariance	cov
		west	W	degree (angular)	$^\circ$
<b>Weights and measures (English)</b>		copyright	©	degrees of freedom	df
cubic feet per second	ft <sup>3</sup> /s	corporate suffixes:		expected value	$E$
foot	ft	Company	Co.	greater than	>
gallon	gal	Corporation	Corp.	greater than or equal to	$\geq$
inch	in	Incorporated	Inc.	harvest per unit effort	HPUE
mile	mi	Limited	Ltd.	less than	<
nautical mile	nmi	District of Columbia	D.C.	less than or equal to	$\leq$
ounce	oz	et alii (and others)	et al.	logarithm (natural)	ln
pound	lb	et cetera (and so forth)	etc.	logarithm (base 10)	log
quart	qt	exempli gratia (for example)	e.g.	logarithm (specify base)	log <sub>2</sub> , etc.
yard	yd	Federal Information Code	FIC	minute (angular)	'
		id est (that is)	i.e.	not significant	NS
<b>Time and temperature</b>		latitude or longitude	lat or long	null hypothesis	$H_0$
day	d	monetary symbols (U.S.)	\$, ¢	percent	%
degrees Celsius	°C	months (tables and figures): first three letters	Jan,....Dec	probability	P
degrees Fahrenheit	°F	registered trademark	®	probability of a type I error (rejection of the null hypothesis when true)	$\alpha$
degrees kelvin	K	trademark	™	probability of a type II error (acceptance of the null hypothesis when false)	$\beta$
hour	h	United States (adjective)	U.S.	second (angular)	"
minute	min	United States of America (noun)	USA	standard deviation	SD
second	s	U.S.C.	United States Code	standard error	SE
		U.S. state	use two-letter abbreviations (e.g., AK, WA)	variance	
<b>Physics and chemistry</b>				population sample	Var var
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				

***REGIONAL OPERATIONAL PLAN SF.SA.2013.23***

**KENAI RIVER CHINOOK SALMON SONAR**

by

Debby Burwen, James Miller, and Steve Fleischman

Alaska Department of Fish and Game, Sport Fish Division, Anchorage

Alaska Department of Fish and Game  
Division  
February 2014

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## PURPOSE

Alaska Department of Fish and Game (ADF&G) has monitored Chinook salmon passage in the Kenai River using side-looking sonar technology from 1987 to present. The original acoustic technology, dual-beam sonar (1987-1994) was replaced by split-beam sonar (1995 – 2011), and most recently by DIDSON (2011- present). Starting in 2013, ADF&G will operate two sonar stations, one at the historical site at Kenai River mile 8.6 and a second experimental site at Kenai River mile 13.7.

## BACKGROUND

Fixed-location, side-looking sonar techniques are commonly used to obtain in-season estimates of run strength for anadromous fish stocks in rivers that are too wide for installing weir structures or too occluded for visual observations (Daum and Osborne 1998; Enzenhofer et al. 1998; Gaudet et al. 1990; Maxwell and Gove 2007). In Alaska, sonar estimates of inriver passage often provide the basis for estimating spawning escapement and for regulating harvests of commercially important salmon stocks (Westerman and Willette 2006; Miller et al. 2010). Acoustic assessment sites currently exist on at least ten rivers in Alaska. One of the barriers to even wider use of sonar assessment has been the need to estimate the number of spawning salmon separately by species. Apportioning sonar counts by species often requires separate intensive sampling programs such as netting programs (Bromaghin 2005; Carroll and McIntosh 2008) or fish wheel programs (Fair et al. 2009) that are costly to implement and subject to biases that can be difficult to resolve.

Since 1987, ADF&G has used dual beam (1987-1994) and split beam (1995-2011) side-looking sonar technology to estimate Chinook *Oncorhynchus tshawytscha* passage in the Kenai River. Since the project's inception, acoustic size (average strength of returning echoes) and range (distance from shore) thresholds have been used to differentiate between sockeye *O. nerka* and Chinook salmon. These criteria are based on the premise that sockeye salmon are smaller and migrate primarily near shore, whereas Chinook salmon are larger and tend to migrate up the middle of the river. However, studies have shown that these criteria can lead to inaccurate estimates (Burwen et al. 1998, Hammarstrom and Hasbrouck 1999). Extensive research has been conducted at the Kenai River Chinook sonar site toward improving our ability to identify species from acoustic data (Burwen and Fleischman 1998; Burwen et al. 2003; Miller et al. 2010). Most recently, ADF&G evaluated the potential for dual-frequency identification sonar (DIDSON) to provide improved discrimination of larger Chinook from smaller species of salmon based on size measurements taken directly from high-resolution images of migrating salmon (Burwen et al. 2007). Based on results of the DIDSON evaluations, and due to the inaccuracy of the split-beam estimates (citations), production of split-beam estimates was discontinued following the 2011 season, and replaced by DIDSON-based estimates in 2012.

DIDSON is a high-definition imaging sonar designed by the University of Washington's Applied Physics Laboratory for military applications such as harbor surveillance and mine identification. DIDSON incorporates a lens that provides high resolution images approaching the quality achieved with conventional optics (Simmonds and MacLennan 2005), with the added advantage that images can be obtained in dark or turbid water and at farther ranges than is possible with camera technologies. Since 2002, ADF&G has worked closely with Sound Metrics Corporation (SMC) to adapt this technology to estimating fish passage in rivers.

Applications of DIDSON systems for monitoring fish populations are becoming more widespread (Galbreath and Barber 2005; Holmes et al. 2006; Burwen et al. 2007; Maxwell and Gove 2007; Mueller et al. 2008), and recently, DIDSON has been used to obtain information about fish size. Cronkite et al. (2006) compared the mean length for 2,874 sockeye salmon measured from DIDSON images at an acoustic monitoring site on the Horsefly River with the mean length from 6,260 salmon measured at a nearby tagging station and found that the DIDSON-based mean was 1.6 cm larger. Baumgartner et al. (2006) found a strong linear relationship between manual DIDSON-based lengths and true lengths for golden perch, silver perch and goldfish that were free-swimming in a tank. Burwen et al. (2007) concluded that at close ranges (approximately < 12m), reasonably good estimates of fish length could be obtained by manually measuring images of fish produced by a standard DIDSON operating in high frequency (1.8 MHz) mode. In these studies, fish were insonified at relative close ranges (less than 15 m) with a standard DIDSON model. However, to adequately cover the ranges at which Chinook salmon travel at ADF&G's established sonar site on the Kenai River, high-resolution images at ranges up to 30m are required.

Studies conducted by ADF&G in 2007 assessed the potential for a long-range DIDSON model (DIDSON-LR) fitted with a high resolution (large) lens (DIDSON-LR+HRL) to provide improved image resolution at required ranges. The large lens provides almost twice the resolution of the standard lens. These studies concluded that sufficiently accurate estimates of fish length were now possible at ranges up to 22m (Burwen et al. 2010). Additional studies conducted in 2008-2009 with the same hardware, but newer firmware and software, extended that maximum range to 33m (Miller et al. 2012).

With the question of obtaining fish length measurements at longer ranges resolved, subsequent studies in 2008-2009 were directed toward developing an efficient process to generate DIDSON-based estimates of Chinook salmon in a timely manner to meet the needs of fishery managers. Each DIDSON-LR system generates approximately 1 GB of video-like data each hour, and efficient ways of transferring, reviewing, and extracting size-related data from such a large volume of data were needed. A DIDSON-LR+HRL was deployed on the left bank of the Kenai River for 7 days in 2008 and 53 days in 2009. During this time, efforts focused on developing and testing software for collecting and processing DIDSON data efficiently. A relatively efficient procedure was developed to manually track and size individual fish. Ways to automate the process of tracking and sizing individual fish were also explored during this time with limited success (Miller et al. 2012).

In 2010, DIDSON was deployed on both banks to sample the same 60 m mid-section of river insonified by the split-beam sonar for most of the season (83 days, 17 May – 7 August). To achieve a sufficiently high image resolution, DIDSON sampled the river in 10 m range increments (i.e. the shorter the range increment the higher the downrange resolution, see [Appendix A](#)) by programming it to sequentially sample three 10-m range strata (3-13 m, 13-23 m, 23-33 m) or 30m per bank. Hardware focus problems related to changing range strata rendered substantial portions of 31 days of data unusable for measuring fish size. During the remaining 45 days (15 days early run, 30 days late), image resolution was sufficiently high to generate daily estimates of Chinook salmon passage. Although image resolution was frequently reduced in the far-range (23-33 m) strata, there was little evidence that this seriously impacted the ability to distinguish large from small fish. Comparison of paired DIDSON and split-beam data revealed that DIDSON provided improved estimates of Chinook salmon not only because it

provides more accurate estimates of fish length but because it could also interpret complex fish behavior more accurately than the split-beam, distinguish seals and other targets that were incorrectly classified as large Chinook salmon by the split beam sonar, and detect salmon potentially masked by eulachon schools (Miller et al. 2012).

In 2011, DIDSON was again deployed on both banks and sampled the same area covered by the split-beam sonar from May 17 through August 10, 2011. Focus issues were resolved and few hardware- or software-related problems were encountered. Quality control procedures for on-site data collection and office-based data processing were developed and refined. Because data from 2010 DIDSON operations indicated that sizeable numbers of Chinook salmon were traveling in the nearshore strata (i.e. 3-13m from each transducer), a third DIDSON was deployed to insonify the region 10m immediately behind the existing left-bank tripod on 20-26 July. Substantial numbers of large fish were detected during this limited deployment.

In 2012, the split-beam sonar was discontinued and DIDSON was used to generate inseason Chinook passage estimates. Escapement goals based on DIDSON-generated estimates of passage were developed (Fleischman and McKinley 2013, McKinley and Fleischman 2013). Additionally, in 2012, crew conducted a two-week evaluation of a new sonar site located above tidal influence and tested the performance of the newest generation of DIDSON technology referred to as Adaptive Resolution Imaging Sonar or ARIS.

The current site at RM 8.6 was selected primarily because of its suitability for operating a dual-beam (and subsequently a split-beam) sonar system, which requires a near-perfect linear bottom profile over the entire insonified zone or, in this case, from the near shore region to the thalweg. However this site has many disadvantages primarily related to its location within tidal influence such as: 1) incomplete coverage of the river due to tidal activity flooding the region behind the transducers, 2) milling fish behavior related to tidal flux, 3) physical risk to gear by large debris carried by extreme tidal fluxes, and lack of legal access to the property on one bank. Relocating the site farther upriver could improve ADF&G's ability to more accurately estimate king salmon passage by minimizing or eliminating these negative factors. In 1999, ADF&G searched for and subsequently evaluated a second sonar site at RM 13.2 for using split-beam sonar to assess fish passage; but the bottom topography was less acoustically favorable and the fish were more difficult to detect due to increased background noise levels from bottom irregularities and boat traffic (Burwen et al. 2000). Because there were no other sites identified, the idea of moving the site was abandoned.

The transition to DIDSON\ARIS multibeam technology has reopened the option of moving the sonar program above tidal influence because the sonar beams are less sensitive to irregularities in the river-bottom profile. During 2012, a prospective site at RM 13.7 was identified (**Figure 1**) and efforts to implement a full sonar site at this site will commence in 2013. In 2013, ADF&G will run both the historical site at RM 8.6 and the second site at RM 13.7. One of the main advantages of the RM 13.7 site is the potential to achieve bank-to-bank coverage of the river with sonar, which is not possible at the RM-8.6 site. Like the sonar project at RM 8.6, the sonar project at RM 13.7 is scheduled to operate from May 16-August 10, 2013. However, because the project is considered experimental, inseason estimates will not be produced in 2013.

# I. OPERATIONS AT RIVER MILE 8.6 (RM 9)

## RM-9 OBJECTIVES

This portion of the study will provide real-time estimates of the number of Chinook salmon passing river mile 8.6 to fishery managers during the 2013 fishing season. Specifically:

Estimate weekly and seasonal (early- and late-run) midriver<sup>1</sup> upstream passage of Chinook salmon at river mile 8.6 of the Kenai River such that the seasonal estimate is within 10% of the true value 95% of the time. This estimate will be based on fitting a mixture model to DIDSON fish length measurements.

Daily estimates of large fish upstream passage will also be produced based on a DIDSON length threshold.

In addition, a daily “net-apportioned” estimate of Chinook salmon abundance will be produced based on paired netting and DIDSON data.

Daily estimates of fish passage will be produced for 16 May to 10 August. If daily estimates comprise less than 1% of cumulative passage for three consecutive days, operations may be suspended before 10 August.

## RM-9 STUDY DESIGN

### STUDY SITE

This portion of the study will be conducted at the existing Kenai River Chinook sonar site, an established acoustic monitoring site for Chinook salmon located 14 km (8.6 mi) from the mouth of the Kenai River and operated by Alaska Department of Fish and Game (ADF&G, [Figure 1](#)). The river is approximately 125 m wide at the site, with water depth at mid-channel varying from 3 to 8 m due to the strong tidal influence. The Kenai River is glacially fed and is generally cool and highly turbid. Water temperatures during the summer range from 10°C to 15°C and Secchi disk readings from 0.3 to 1.1 m. The bottom substrate on the right bank is comprised of fine glacial mud and on the left bank the substrate is fine gravel with larger cobble. The slope from either bank to the thalweg (approximately 3° on right bank and 5.5° on left bank) is gradual and uniform.

### SAMPLING PROCEDURES

At the rm 8.6 site, a single DIDSON transducer will be deployed on each bank of the river, such that it remains submerged at low tide. As discharge and water levels rise during the summer, tripods may periodically be moved up the river bank.

Transducers deployed on each bank will operate simultaneously, switching between spatial (range, i.e., distance from transducer) strata in 10-minute increments using the schedule in Figure 5. The 4 range strata are: 3.3-8.3, 8.3-13.3, 13.3-23.3, and 23.3-33.3 meters from the transducer. The 13-23m and 23-33m strata will be sampled twice hourly, however, in general, only the data

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<sup>1</sup> Between, and greater than 3 m in range from, both transducers.

from the first of the 2 periods will be processed. Data from the redundant samples will be archived and processed only in the event that the first sample is not usable.

Range, direction of travel, and length (cm, as measured with a graphical software utility, see below) will be recorded by fish. Details regarding which fish to measure and whether or not to record direction of travel differ depending upon rate of fish passage, level of staffing, time constraints related to fishery management, and fish behavior. On a given day, depending on the above factors, one of 3 sampling protocols (summarized in Table 1) will guide processing and analysis of rm-8.6 data.

### **Standard (STD) Sampling Protocol**

Under standard sampling protocol at river mile 8.6:

Length will be measured for all salmon-shaped<sup>2</sup> fish greater than 40 cm (DL)

Direction of travel will be recorded for each measured fish.

### **Fast Track (FT) Sampling Protocol**

During the peak of the sockeye salmon run, generally mid-to-late July, it can become too time-consuming to measure each individual fish, given staffing and time constraints associated with generating daily estimates. Additionally, during periods of peak passage, fish often swim in large tightly-compacted groups and measurements cannot be uniquely associated with specific fish (**Figure 10**). Under these circumstances at river mile 8.6, the following “Fast-Track” sampling protocol will be practiced:

Length will be measured for all salmon-shaped fish greater than 75 cm DL.

Length will also be measured for a subset of salmon-shaped fish  $40 \text{ cm} < \text{DL} < 75 \text{ cm}$ . Either the first  $F$  fish, or fish passing during the first  $M$  minutes of the sampled period will be measured.  $F$  (or  $M$ ) will depend on daily staff time constraints.

The remaining fish  $40 < \text{DL} < 75$  will be marked (tallied) but not measured. To mark fish, staff will watch a short section of the DIDSON movie associated with the chart, count the number of fish in a group, and then make the counted number of marks on the chart. Medium-size fish unintentionally chosen for measurement that turn out to be less than 75 cm will be counted and length will *not* be recorded.

Direction of travel will be recorded *only* for salmon-shaped fish greater than 75 cm DL, *not* for fish  $40 \text{ cm} < \text{DL} < 75 \text{ cm}$ .

### **Large Fish Only (LFO) Sampling Protocol**

Occasionally milling or holding behavior can make it difficult to reliably assess the direction of travel for many fish. This is more likely to happen during even-numbered years when pink salmon are most abundant. In 2010 and 2012, staff were able to easily discern larger Chinook salmon swimming directly through the smaller holding or milling salmon (**Figure 11**). Under these conditions, fish larger than 75 cm will be measured and shorter fish will be ignored. The “Large Fish Only” (LFO) sampling protocol is as follows.

Length will be measured for all salmon-shaped<sup>3</sup> fish greater than 75 cm DL.

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<sup>2</sup> Flatfish, seals, and beluga whales will not be recorded, and fish measured less than 40 cm will be omitted from further calculations.

Direction of travel will also be recorded for measured fish.

Remaining fish will not be recorded in any way, due to the difficulty in ascertaining direction of travel. Medium-size fish unintentionally chosen for measurement that turn out to be less than 75 cm will *not* be recorded.

**Table 1.-** Sampling protocols to be applied in 2013.

	Sampling Protocol		
	Standard STD	Fast Track FT	Large Fish Only LFO
Length Measurements (DL)	Measure all salmon-shaped fish DL>40	Measure all salmon-shaped fish DL>75 Measure a <i>sample</i> of fish 40<DL<75 Count remaining fish 40<DL<75 Delete incidental DL<75	Measure all salmon-shaped fish DL>75
Direction of Travel (DoT)	All salmon-shaped fish DL>40	Record DoT for all fish DL>75 Do <i>not</i> record DoT for fish DL<75	Record DoT for all fish DL>75
Salmon Upstream Estimate $y$	$y$ Eqs 1-4 Up DL>40	$y_{FT}$ Up (DL>75) + Up/Dn (40<DL<75) Biased slightly high	Not possible
Chinook Upstream Estimate $z$	$z = y \pi_C$ Mixture model on Up DL>40	$z = y_{FT} \pi_{FT}$ Mixture model Up (DL>75) / $Y_{FT}$ Unbiased	By reconstruction only
Large Fish Upstream Estimate $x$	$x$ Eqs 1-4 Up DL>75	$x$ Eqs 1-4 Up DL>75	$x$ Eqs 1-4 Up DL>75
Net Apportioned Upstream Estimate $w$	$w = y \pi_{NET}$ Eqs 5-6	$w_{FT} = y_{FT} \pi_{NET}$ Biased slightly high	Not possible

<sup>3</sup> Flatfish, seals, and beluga whales will not be recorded.



# RM-9 DATA COLLECTION

## SONAR EQUIPMENT AND CONFIGURATION

Components of the DIDSON system at river mile 8.6 are listed in Table 2.

DIDSON operates at two frequencies: a higher frequency that produces higher resolution images, and a lower frequency that can detect targets at further ranges but at a reduced image resolution. Two DIDSON models are currently available based on different operating frequencies. For this study, because we require high resolution images to at least 30m, we selected the long-range DIDSON model (DIDSON-LR) that can operate at high frequency at further ranges (up to 30m) than the standard model (up to 15m). The DIDSON-LRs are equipped with an ultra-high resolution lens to further improve image resolution. A detailed discussion of available DIDSON configurations and DIDSON image resolution and a brief explanation of multibeam sonar can be found in Appendix A. More detailed theory can be found in Belcher et al. (2002).

Electronics will be housed in a tent located on the right (north) bank of the river (**Figure 2**). The DIDSONs will be mounted on remote pan and tilt systems (a Remote Ocean Systems PT-25 on the right bank, and a Sound Metrics Corporation X2 on the left bank) for precise aiming in the horizontal and vertical axes. The combined sonar and rotators will be deployed in the river on a tripod-style mount (**Figure 3**). In the horizontal plane, the sonar will be aimed perpendicular to the flow of the river current to maximize the probability of insonifying migrating salmon from a lateral aspect. Internal attitude sensors in the DIDSON will provide measurements of compass heading, pitch, and roll. An AIM 2000 attitude sensor attached to the right bank mount will provide depth measurements throughout the season.

Communication cables from the right bank DIDSON feed directly into the right bank Top Side Box and data collection computer. On the left bank, DIDSON data is transmitted via a wireless bridge to a data collection computer on the right bank (**Figure 4**).

## DATA ACQUISITION

The transmit power of the DIDSON sonar is fixed and the maximum receiver gain (-40 dB) will be used during all data collection. The autofocus feature will be enabled so that the sonar automatically sets the lens focus to the mid-range of the selected display window.

## DATA STORAGE AND MANAGEMENT

Procedures for processing the large volume of data generated daily by the DIDSON systems were developed during the 2010-2012 seasons and will continue to be refined and expanded upon in 2013. Stepwise procedures for daily processing of DIDSON data are given in **Appendix B**.

**Table 2.-**Components of the DIDSON sonar system to be used at river mile 8.6 in 2013.

<b>System Component</b>	<b>Description</b>
<b>Sounder</b>	DIDSON-LR operating at 1.2 MHz (right and left banks)
<b>Lens</b>	Large Lens Assembly with ~3°x15° beam pattern (right and left banks)
<b>Data Collection Computer</b>	Dell Latitude E6500 laptop computer (one for each bank)
<b>Wireless Bridge</b>	For wireless transmission of DIDSON data from left to right bank. Model SMC XMC2891-AG
<b>Remote Pan and Tilt Aiming Unit</b>	Right Bank: ROS Model PT25 Pan and Tilt Left Bank: SMC Model X2 Rotator
<b>Remote Pan and Tilt Aiming Controller</b>	Right Bank: ROS Model PTC-1 Remote Pan and Tilt Controller Left Bank: Controlled through SMC DIDSON software
<b>Remote Depth Sensor</b>	Right Bank: JASCO Model AIM-2000 remote attitude sensor

The process of transferring, analyzing, summarizing, and archiving 30 Gigabytes of DIDSON data generated each day is facilitated by a number of batch files. The names and functions of each batch file are listed in [Appendix Table B2-1](#).

Individual files for each 10-minute sample will vary in size due to the different ping rates for each range strata.<sup>4</sup> File sizes will vary from a maximum of approximately 115,000 KB for the near range strata (3-7m and 7-13m; 8 pings/sec) to approximately 101,000 KB for the mid-range stratum (13-23m, 7 pings/sec), and to approximately 78,000 KB for the offshore stratum (23-33m; 6 pings/sec). At these data collections rates and ranges, approximately 1.2 GB/hour (both banks) or 30 GB per day (worst case) will be generated. Since the season is about 87 days long up to 3.4 TB of data may be generated.

Data from each sample will be stored to a uniquely named file. Filenames are automatically generated by the DIDSON software using year, month, day, military time, and frequency (high or low). For example, a file that started data collection using high frequency on June 1, 2013 at 3:40 AM will be automatically named: 2013-06-01\_034000\_HF.ddf.

One laptop will be dedicated to collecting data from each bank. To ensure correct time stamps in the filenames, laptop clocks will be synchronized using GlobalSat BU-353 Waterproof USB GPS receivers. Data will initially be collected by the host computer hard drive and subsequently transferred to two 4 TB external hard drives (two redundant copies) for permanent archiving at the site (**Figure 6**, **Figure 7**). Data collection computers will be networked with a “main computer” where data can be reviewed and processed on site (see Appendix Table B5 for list of fixed IP addresses). Data transfer to the Soldotna office will occur using 32-GB Jump drives.

<sup>4</sup> Files from individual range strata will vary in size if the ping rate is optimized for each range strata. Since the return time for a ping increases with range, off-shore range strata will require a slower ping rate and files will contain fewer frames.

In the Soldotna office data will then be transferred to a Network Attached Storage Device (Synology DiskStation 1512 with 5 2-TB drives, Raid 5, **Figure 8**, **Figure 9**) where it can be shared with up to 7 users through a 1 GB Ethernet network (i.e. through an 8 port 1 GB Ethernet switch and 1 GB Ethernet cards in each computer).

### **FISH LENGTH AND DIRECTION OF TRAVEL**

Estimates of total length will be made from images using the manual fish-measuring feature also included with the SMC DIDSON Control and Display software. Collaborative efforts with SMC have resulted in a reasonably efficient method of manually measuring individual fish. Detailed instructions for taking manual measurements and the software settings and parameters used are given in **Appendix C**. Direction of travel is determined for an individual fish by observation of sufficient frames to classify it as an upstream or downstream migrant.

## **RM-9 DATA ANALYSIS**

Under the standard sampling protocol (page 4; also Table 1) abundance estimates will be produced as follows.

### **RM-9 MIDRIVER SALMON PASSAGE ESTIMATES**

The number of salmon  $y$  of all species, exceeding DL=40 cm, during day  $i$  that migrate upstream at RM-8.6 in mid-river at least 3 m from the face of each transducer will be estimated as:

$$\hat{y}_i = \sum_j^{24} \hat{y}_{ij} \quad (1)$$

where:

$$\hat{y}_{ij} = \sum_s^8 \hat{y}_{sij}, \quad (2)$$

and  $\hat{y}_{sij}$  is the estimate of passage in stratum  $s$  during hour  $j$  of day  $i$ , as follows:

$$\hat{y}_{sij} = \frac{60}{t_{sij}} c_{sij} \quad (3)$$

where

$c_{sij}$  = number of upstream-bound fish greater than 40 cm in stratum  $s$  for hour  $j$  of day  $i$ ,

$t_{sij}$  = number of minutes (usually 10) sampled in stratum  $s$  during hour  $j$  of day  $i$ .

The sampling variance of the fish passage estimates for stratum  $s$  on day  $i$ , due to systematic sampling in time, will be approximated (successive difference model, Wolter 1985), with adjustments for missing data, as:

$$\hat{V}[\hat{y}_i] \cong 24^2 (1 - f_i) \frac{\sum_{j=2}^{24} \phi_{ij} \phi_{i(j-1)} (\hat{y}_{ij} - \hat{y}_{i(j-1)})^2}{2 \sum_{j=1}^{24} \phi_{ij} \sum_{j=2}^{24} \phi_{ij} \phi_{i(j-1)}} \quad (4)$$

where  $f_i$  is the sampling fraction (proportion of time sampled daily, often 0.17), and  $\phi_{ij}$  is 1 if  $\hat{y}_{ij}$  exists for hour  $j$  of day  $i$ , or 0 if not.

### RM-9 MIDRIVER CHINOOK SALMON PASSAGE ESTIMATES

The estimate of Chinook salmon abundance on day  $i$  will be calculated by multiplying the fish passage estimate by the estimated proportion of Chinook salmon ( $\hat{\pi}_{Csi}$ ), derived by fitting a DIDSON length mixture model to *upstream* DIDSON and netting data as described in Appendix D.

$$\hat{z}_i = \hat{y}_i \hat{\pi}_{Ci} \quad (5)$$

The variance estimate follows Goodman (1960):

$$\text{vâr}(\hat{z}_i) = \hat{y}_i^2 \text{vâr}(\hat{\pi}_{Ci}) + \hat{\pi}_{Ci}^2 \text{vâr}(\hat{y}_i) - \text{vâr}(\hat{\pi}_{Ci}) \text{vâr}(\hat{y}_i) \quad (6)$$

The cumulative estimate of midriver Chinook salmon abundance, and its variance, is the sum across days:

$$\hat{Z} = \sum_i \hat{z}_i \quad (7)$$

$$\text{vâr}[\hat{Z}] = \sum_i \text{vâr}[\hat{z}_i]. \quad (8)$$

### RM-9 MIDRIVER LARGE FISH PASSAGE ESTIMATES

The daily estimate  $x_i$  of large fish passing RM 8.6 in mid-river will be obtained with equations 1-4 after substituting  $c'_{sij}$  for  $c_{sij}$ , where

$c'_{sij}$  = number of upstream-bound fish greater than 3 m from the right- and left-bank transducers exceeding 75 cm in length as measured by the DIDSON during  $t_{sij}$ .

### NET-APPORTIONED RM-9 MIDRIVER CHINOOK SALMON PASSAGE ESTIMATES

The “net-apportioned” daily estimate of midriver Chinook salmon abundance will be calculated by multiplying the RM-9 midriver salmon passage estimate by a netting-derived estimate of the proportion of Chinook salmon ( $\hat{\pi}_{NETi}$ ; Perschbacher 2012).

$$\hat{w}_i = \hat{y}_i \hat{\pi}_{NETi} \quad (9)$$

The variance estimate follows Goodman (1960):

$$\text{vâr}(\hat{w}_i) = \hat{y}_i^2 \text{vâr}(\hat{\pi}_{NETi}) + \hat{\pi}_{NETi}^2 \text{vâr}(\hat{y}_i) - \text{vâr}(\hat{\pi}_{NETi}) \text{vâr}(\hat{y}_i) \quad (10)$$

## MODIFICATIONS UNDER FT PROTOCOL

Under the Fast-Track protocol, length measurements will be available for all fish greater than 75 cm DL and a subset of fish  $40 < DL < 75$ . Direction of travel will be available only for fish greater than 75 cm DL. These constraints will require the following modifications to the abundance estimators.

Daily passage  $y_{FTi}$  will be defined as the number of salmon-shaped fish  $> 40$  cm DL, *except* downstream fish  $> 75$  cm DL. It will be estimated as specified in equations 1-4, except that

$$c_{sij} = \text{number of salmon-shaped fish } > 40 \text{ cm DL, except for downstream fish } > 75 \text{ cm DL, in stratum } s \text{ for hour } j \text{ and day } i.$$

The DL mixture model, modified to accommodate censored lengths from small fish (Appendix D3), will be fit to the same subset of the data described above.

The daily proportion  $\pi_{FTi}$  of these fish that are upstream Chinook salmon (output from DL mixture model) will be multiplied by the estimate of  $y_{FT}$  above to estimate  $z_i$ , number of Chinook salmon migrating upstream in the midriver corridor (Equations 5 and 6).

Because direction of travel information is not available for fish  $40 < DL < 75$ , it will not be possible to estimate  $y_i$ , daily upstream passage of DL  $> 40$  cm, salmon-shaped fish. Quantity  $y_{FT}$  can be substituted to produce the net apportioned estimate, however it will be biased high by an unknown small amount because it includes some downstream fish  $40 < DL < 75$ .

## MODIFICATIONS UNDER LFO PROTOCOL

Under the Large-Fish-Only protocol, only those fish greater than 75 cm DL will be counted and measured. This constraint will require the following modifications to the abundance estimators.

Because small fish are not counted, it will not be possible to directly estimate  $y_i$ , daily passage of upstream, DL  $> 40$  cm, salmon-shaped fish, nor the net apportioned estimate, of which  $y_i$  is a component.

Daily upstream passage  $x_i$  of salmon-shaped fish  $> 75$  cm DL will be estimated as specified in equations 1-4.

The daily abundance model, described below, may be used postseason to obtain an approximate reconstruction of upstream midriver Chinook salmon passage  $z_i$ , as needed.

## IMPUTATION OF MISSING DATA

In the event that DIDSON is functional for one set of spatial strata but not others, it may be necessary to estimate the passage on the non-functional set  $s'$  from passage on the functional set  $s$  with a ratio estimator:

$$\hat{y}_{s'ij} = \hat{R}_{ist} \hat{y}_{sij}, \tag{11}$$

where the estimated bank-to-bank ratio  $R_{ist}$ , for day  $i$  and tide stage  $t$  is calculated by pooling counts from all hours during the previous 2 or more days (to ensure adequate sample size) with tide stage  $t$ :

$$\hat{R}_{ist} = \frac{\sum_{j \in J_t} \hat{y}_{s'(i-2)j} + \sum_{j \in J_t} \hat{y}_{s'(i-1)j}}{\sum_{j \in J_t} \hat{y}_{s(i-2)j} + \sum_{j \in J_t} \hat{y}_{s(i-1)j}} \quad (12)$$

### DAILY ABUNDANCE MODEL

Postseason, daily upstream midriver Chinook salmon passage  $z_i$  will be reconstructed as needed, using the relationship of existing daily Chinook salmon abundance estimates  $z_i$  to daily large fish abundance estimates  $x_i$ , and of  $z_i$  to daily catch rates of Chinook salmon in the inriver netting project  $r_i$ . Under this model, each index ( $x_i$  and  $r_i$ , generically denoted  $I_{xi}$ ) comprises an independent measure of the relative abundance of Chinook salmon on day  $i$ :

$$I_{xi} = q_x z_i \quad (13)$$

where  $q_x$  is the mean ratio of index  $I_{xi}$  to true mid-river abundance  $z_i$ . To allow for a non-stationary relationship between each index and true abundance, an AR(1) error term will be specified.

$$\ln(I_{xi}) = \ln(q_x z_i) + \phi_x v_{x,i-1} + \varepsilon_{xi} \quad (14)$$

where  $\phi_x$  is the AR(1) coefficient, the  $\{v_{xi}\}$  are model residuals

$$v_{xi} = \ln(I_{xi}) - \ln(q_x z_i), \quad (15)$$

and the  $\{\varepsilon_{xi}\}$  are independently and normally distributed process errors with “white noise” variance  $\sigma_x^2$ . Parameters  $q_x$ ,  $\phi_x$ , and  $\sigma_x^2$  will be estimated from the data. WinBUGS code for the daily abundance model is in Appendix D4.

## II. OPERATIONS AT RIVER MILE 13.7 (RM 14)

### RM-14 OBJECTIVES

This portion of the study involves deploying imaging sonar and estimating fish passage at a site above tidal influence at RM 13.7. Unlike operations at RM 8.6, where Chinook salmon passage estimates are generated solely for the midsection of river, this project seeks to provide estimates for virtually the entire river cross-section. The primary objective is as follows:

Estimate weekly and seasonal (early- and late-run) upstream passage of Chinook salmon at river mile 13.7 of the Kenai River such that the seasonal estimate is within 10% of the true value 95% of the time. This estimate will be based on fitting a mixture model to ARIS fish-length measurements.

Because many operational details remain to be worked out at this site, any inseason estimates will be preliminary, internal quantities only, and they may not be available until many days or weeks after data collection.

### RM-14 STUDY DESIGN

#### STUDY SITE

This study will be conducted at RM 13.7 on the Kenai River Chinook Sonar Site (**Figure 1**, **Figure 14**). This location was identified during surveys conducted in 2012 and was selected for its favorable physical characteristics for deploying ARIS multibeam technology, its accessibility via an adjacent boat launch facility, and legal access to property on either bank of the main channel. Bathymetric surveys conducted by Aquacoustics, Inc. on July 9, 2012 showed that the section of river at RM 13.7 has a nearly ideal bottom profile for sonar deployment (**Figure 12**, **Figure 13**, **Figure 14**).

Unlike the RM 8.6 site where only the mid-section of the river will be insonified, efforts will be made to provide almost complete sonar coverage of the river cross section at the RM 13.7 site. Five sonars are required to provide complete coverage, a nearshore and offshore sonar on each bank of the mainstem and one sonar on a right-bank minor side-channel (**Figure 14**). The side-channel, which has sufficient water for fish passage at higher water levels (from approximately mid-June through August), can be covered by a single sonar combined with a fixed weir on either bank (**Figure 14**).

During the early part of the season when the water level is low (approximately mid-May to mid-June), one sonar on each bank will likely be sufficient to insonify most of the main-stem cross section (approximately 60-70m). But later in the season, as water levels rise, a second sonar will be deployed on each bank to insonify the nearshore zone and the first 5-10 m in front of the offshore sonars (**Figure 15**, **Figure 16**). The original (now offshore) sonars cannot be moved closer to shore as water levels rise because they already insonify the maximum range recommended for operation in high-frequency mode (approximately 30-35m, **Appendix A**).

Two different ARIS models will be used to provide optimal coverage of the mainstem cross-section (**Table 4**, **Table 3**, **Figure 16**). ARIS 1200 models with high-resolution lenses will be used as the offshore sonars because they have the higher range capabilities (up to ~35m from tests conducted in 2012) needed to insonify the majority of the mainstem river at lower water

levels and the offshore region of the mainstem during higher water levels. The ARIS 1800 with a standard lens is more advantageous for insonifying close-range targets and nearshore areas because it operates at a higher frequency yielding higher resolution and the standard lens also has better focusing capabilities at closer ranges (Appendix Figure A1-3). Additionally, the wider beam dimensions of the ARIS 1800 without the HRL ( $14^{\circ}\times 28^{\circ}$  versus  $4^{\circ}\times 15^{\circ}$ ) provide better coverage in both vertical and horizontal dimensions at short ranges. Finally, using sonars with different operating frequencies will allow nearshore and offshore strata to be sampled simultaneously without crosstalk interference if desired.

In 2013, an ARIS 1800 system will be deployed as the nearshore sonar on the left bank because the offshore sonar will be positioned only ~ 8m from the bank at ordinary high water (OHW, Appendix Figure F1-5). However, it is not clear whether an ARIS 1800 will have sufficient range capabilities to cover the near shore area on the right bank where the offshore sonar may be positioned ~15m from the OHW (Appendix Figure F1-9). Consequently, an ARIS 1200 with a high-resolution lens will be used in 2013 to insonify the right-bank nearshore area. Once the project is operational, and if it seems feasible to use an ARIS 1800, one will be borrowed from another project for a short trial period.

Sampling for both banks will be controlled by electronics housed in a tent located on the left (west) bank of the river (Figure 14). The ARIS units will be mounted on SMC X2 pan-and-tilt units for remote aiming in the horizontal and vertical axes. Similar to DIDSON deployment at RM 8.6, the sonar and rotator units will be deployed in the river using a tripod-style mount (Figure 3). In the horizontal plane, the sonar will be aimed perpendicular to the flow of the river current to maximize the probability of insonifying migrating salmon from a lateral aspect. Internal sensors in the ARIS will provide measurements of compass heading, pitch, and roll as well as water temperature.

Communication cables from the left bank ARIS units will feed directly into the left bank Top Side Box and data collection computers (Figure 17). On the right bank, data from the three ARIS systems will be transmitted via three wireless bridges to three data collection computers on the right bank (Figure 17,

Figure 18).

## **SAMPLING PROCEDURES**

Similar to the RM 8.6 site, a systematic sample design (Cochran 1977) will be used to sequentially sample discrete range strata (“range windows”) for a total (minimum) of 10 minutes each. Dividing the total range to be insonified into shorter range strata allows the aim of the sonar beam to be optimized for sampling a given river section (i.e. generally the aim must be raised in the vertical dimension as sections further from shore are sampled).



A fixed sampling schedule similar to that shown in Figure

5

for the RM 8.6 site will be developed for the RM 13.7 site at the start of the season after determining how many discrete range strata will need to be sampled. The number and length of range strata required to optimally sample the river cross-section at RM 13.7 have not been determined. ARIS is not limited to fixed range windows like DIDSON (approximately 1.25m, 2.5m, 5m, 10m, 20m...), so there is more flexibility in setting a range stratum length. ARIS also allows the user to set the number of samples per beam to a maximum of 4,000 samples whereas DIDSON is limited to 512 samples; meaning an ARIS 40m range window collected at 4,000 samples provides the same downrange resolution as a DIDSON 5m range window. At close range, a short range window of 5m will likely be used for better focal resolution, but ranges beyond about 10m can be collected at any desired length as long as the aim is appropriate over the entire length of the range. Table 3 lists approximate range strata based on river bottom profiles from bathymetric data collected in July 2012 (**Figure 13, Figure 15**).

Like DIDSON, the ARIS can be programmed to automatically sample each range stratum.

**Table 3.-**Approximate range strata for sampling at RM 13.7 for 2013.

Bank	Sonar	Approx. range
Left	ARIS 1800	2-10m
Left	ARIS 1200+LL	10-20m
Left	ARIS 1200+LL	20-35m
Right	ARIS 1800	2-15m
Right	ARIS 1200+LL	10-20m
Right	ARIS 1200+LL	20-30m

All fish greater than 75 cm will be measured, as well as a subset of fish less than 75 cm. Because we are likely to see far more sockeye salmon at the RM 13.7 site with near bank-to-bank coverage, we will likely have to make greater use of “Fast-Track” or “Large-Fish-Only” sampling protocols described on page 4.

## **RM-14 DATA COLLECTION**

### **SONAR EQUIPMENT AND CONFIGURATION**

At the rm 13.7 site, Adaptive Resolution Imaging Sonar (ARIS), developed by the manufacturers of DIDSON, will be used. ARIS has several advantages over DIDSON technology, including user configurable window lengths, variable transmit pulse lengths, and increased downrange resolution. Additionally, ARIS is a “sealed” system which should negate the need for using a “silt-excluding enclosure” to protect the system from silt buildup inside the lens cavity (**Figure 3**).

Components of the ARIS system are listed in Table 4. The theory behind ARIS multibeam technology is similar to that of the DIDSON and is summarized in Appendix A along with a discussion of the features of the ARIS models used in this study.

**Table 4.-Components of the ARIS systems to be used in 2013.**

<b>System Component</b>	<b>Description</b>
<b>Sounders</b>	(3) ARIS 1200 Left bank mainstem offshore Right bank mainstem offshore Right bank minor channel (2) ARIS 1800 (one for each right and left bank nearshore sonars) Left bank mainstem nearshore Right bank mainstem nearshore
<b>Lens Assembly</b>	(2) Standard lens for ARIS 1800 models with ~12°x30° beam pattern (3) High resolution lens for ARIS 1200 models with ~4°x15° beam pattern
<b>Data Collection Computer</b>	(5) Dell Latitude E6430 laptop computers (one for each sonar)
<b>Wireless Bridge</b>	(3) Wireless Bridge Radio sets - either Cisco Aironet 1310, Radiolabs GS2000 or EZ-Bridge-5G-Lite EZBR-0519
<b>Remote Pan and Tilt</b>	(5) Sound Metrics X2 rotator – controlled via ARISCOPE software

## DATA ACQUISITION

Unlike DIDSON, with ARIS the manufacturers have separated the data collection (ARIScope) and data processing (ARISFish) software. ARIScope has several data collection parameters that are now user selectable rather than being fixed or limited to a few discrete values as with DIDSON Control and Display Software. A consultant from Sound Metrics Corporation will be on site from May 13-17 to assist project personnel with selecting the sampling range intervals and optimizing several parameters for each range interval. The parameters that are now selectable and that will be optimized for each range interval are given in Table 5 along with the corresponding fixed values in the DIDSON system.

**Table 5.- User configurable parameters in SMC ARIScope data collection software and their corresponding values in DIDSON (high frequency/identification mode only).**

<b>Parameter</b>	<b>ARIS 1200</b>	<b>ARIS 1800</b>	<b>DIDSON LR (1200)</b>	<b>DIDSON SV (1800)</b>
Transmit Pulse Length	4µs to 100µs	4µs to 100µs	7µs, 13µs, 27µs, 54µs (relative to window length)	4.5µs, 9µs, 18µs, 36µs (relative to window length)
Downrange Resolution (window length/#samples)	3 mm to 10 cm	3 mm to 100 mm	5mm, 10mm, 20mm, 40mm (relative to window length)	2.5mm, 5mm, 10mm, 20mm (relative to window length)
Source Level	~206-212 dB re 1µPa at 1m	~200-206 dB re 1µPa at 1m		
Window Length	Any	Any	2.5m, 5m, 10m, 20m	1.25m, 2.5m, 5m, 10m
Samples per beam	Up to 4,000	Up to 4,000	512	512

The downrange resolution (i.e., Window Length/#samples) is particularly improved with ARIS. Whereas DIDSON was limited to 512 samples to define the downrange resolution, ARIS can collect up to 4,000 samples per beam.

The autofocus feature will be enabled so that the sonar automatically sets the lens focus to the mid-range of the selected range window (e.g. for a window length of 10m that started at 5m, the focus range would be 15m-5m/2).

**Table 6.-** Approximate data storage needs for data from four mainstem ARIS systems at RM 13.75 site.

<b>Stratum</b>	<b>10-min file size (GB)</b>	<b>Hourly sample size (GB)</b>	<b>Comments</b>
Left Bank Nearshore <sup>1,2</sup> (ARIS 1800 – standard lens)	0.5	3.0	Collect data for 60-min out of each hour. See comment 1 below.
Left Bank Offshore <sup>3</sup> (ARIS 1200+Large Lens) Stratum 1 (~5m – 25m)	0.5	1.5	Collect data for 30 min each hour
Left Bank Offshore <sup>3</sup> (ARIS 1200+Large Lens) Stratum 2 (~25m – 35m)	0.5	1.5	Collect data for 30 min each hour
Right Bank Nearshore <sup>1,2</sup> (ARIS 1800 – standard lens)	0.5	3.0	Collect data for 60-min out of each hour. See comment 1 below.
Right Bank Offshore <sup>3</sup> (ARIS 1200+Large Lens) Stratum 1 (~5m – 25m)	0.5	1.5	Collect data for 30 min each hour
Right Bank Offshore <sup>3</sup> (ARIS 1200+Large Lens) Stratum 2 (~25m – 35m)	0.5	1.5	Collect data for 30 min each hour
<b>Total Hourly</b>	3.0	12.0	
<b>Total Daily (hourly*24)</b>	72.0	288.0	
<b>Season Total (Daily*87days)</b>	6,264	25,056	Or ~25 TB for season <sup>4</sup>

<sup>1</sup> ARIS 1800 files could be twice as large if collected at same resolution as ARIS 1200 because it has twice as many sub-beams (96)

<sup>2</sup> Left- and right-bank near shore sonars will not be deployed until water levels rise (~mid-June), so the 25 TB estimate for the season is generous

<sup>3</sup> Assumes we do not need more than two strata for the offshore sonar

<sup>4</sup> Does not include the "minor channel" ARIS - these files can be left on the external drives

<sup>5</sup> Although ARIS file sizes are bigger than DIDSON files; ARIS strata can be longer in range and will not necessarily generate larger files

## DATA STORAGE AND MANAGEMENT

Individual files for each 10-minute sample will vary in size due to different ping rates for each range stratum<sup>5</sup>. File size also increases with the down-range resolution level. Again, consultant Bill Hanot will assist with determining the optimal resolution value for individual range strata. We estimate that 10-minute file sizes will vary from a maximum of approximately 300,000 KB to approximately 500,000 KB. Table 6 gives a worst case scenario for data storage needs at these sample rates.

Data from each sample will be stored to a uniquely named file. Filenames are automatically generated by the ARIS software using optional identifiers such as sonar serial #, location, bank, year, month, day, military time (hour, min, sec), transmitted pulse length, number of beams sampled, samples/beam, resolution, and range interval. For example, the file:

SN 1064\_Kenai13-75\_LB\_2012-07-17\_004000\_T24\_B48\_S2000\_F12\_R21-35.aris

refers to a file collected by sonar #1064, at RM 13.75 on the left bank of the Kenai River, that started data collection on July 12, 2012 at 0:40 AM using a transmitted pulse length of 24 msec, using all 48 beams, with 2000 samples/beam at resolution 12, over the range interval 21-35m.

Longer file names may be used initially, but pared back if we determine that the long filenames hinder file handling during file transfer/processing/archiving. But initially, the additional information in the filename may help during the early phase of this project when different settings are being evaluated.

One laptop will be dedicated to collecting data from each sonar (for a total of 5, **Figure 20**) and data will be written directly to one of two external hard drives assigned to that computer/sonar (**Figure 17**). The hard drives will be swapped out once per day and transported back to the Soldotna ADF&G office. In the Soldotna office data will be uploaded to a 24 TB Buffalo TeraStation where it can be shared with up to 15 users through a 1 GB Ethernet network (i.e. through a 16 port 1 GB Ethernet switch connected to computers with 1 GB Ethernet cards).

The process of transferring, analyzing, summarizing, and archiving the large volume of ARIS data generated each day will be developed during the 2013 season. Batch files similar to those used to handle DIDSON data from the RM 8.6 site will need to be developed. These batch files are essential for minimizing errors during data transfer and free personnel to perform other tasks during this time consuming process.

### Remote Access to Sonar Site

Because the RM13.7 site will not be manned 24-7 in 2013, a system to remotely access and determine the status of the data collection computers and/or sonars will be implemented if possible. In the sonar tent an AT&T MiFi mobile hotspot will be connected to an 8 port wireless router (**Figure 17**) that will network the five data collection computers. Each computer will have "GoToMyPc" installed for remote access. Bill Hanot of SMC will be onsite May 13-17 to assist with initial setup and installation of the ARIS systems. There are potential issues with the "dual network" setup that is planned in the current ARIS software. Currently, the ARIS software doesn't distinguish between network interfaces, so if the wireless connection is enabled,

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<sup>5</sup> Files from individual range strata will vary in size if the ping rate is optimized for each range strata. Since the return time for a ping increases with range, off-shore range strata will require a slower ping rate and files will contain fewer frames.

the software may not connect to the sonar. The workaround could be to disable the wireless interface while getting the sonars powered up and connected, and then re-enabling the wireless interface.

Note from Bill Hanot at SMC related to remote access: ARIS is not configured with a static IP address. It either gets an IP address from a DHCP server (if present), or gives itself a "link local" IP address. If the PCs are configured as "Automatic IP", they will also give themselves a "link local" IP address. Your diagram shows the wireless bridges configured with a static IP. If they don't have a "link local" option, they can be configured with a static IP on the link local subnet 169.254.xxx.xxx. I'll discuss this with people here. If you have the manual (or at least the make and model) of your wireless bridge equipment that would be a help.

## **FISH LENGTH AND DIRECTION OF TRAVEL**

Estimates of total length will be made from images using the ARISFish V1.5. Detailed instructions for taking manual measurements and the software settings and parameters are given in [Appendix E](#).

## **RM-14 DATA ANALYSIS**

Abundance estimates at RM 13.7 will follow their counterparts at RM 8.6, and will apply to the entire river cross-section.

### **RM-14 SALMON PASSAGE ESTIMATES**

The number of salmon  $y$  of all species, exceeding  $DL=40$  cm, during day  $i$  that migrate upstream at RM-8.6 in mid-river at least 3 m from the face of each transducer will be estimated as:

### **RM-14 CHINOOK SALMON PASSAGE ESTIMATES**

The estimate of Chinook salmon abundance will be calculated by multiplying the RM-13.7 salmon passage estimate by the estimated proportion of Chinook salmon ( $\hat{\pi}_{Csi}$ ), derived by fitting a DIDSON length mixture model to *upstream* DIDSON and netting data as described in equations (5-8).

### **RM-14 LARGE FISH PASSAGE ESTIMATES**

The daily estimate of large fish passing RM 13.7 will be obtained with equations 1-4 after substituting  $c'_{sij}$  for  $c_{sij}$ , where

$c'_{sij}$  = number of upstream-bound fish in the ensonified zone exceeding 75 cm in length as measured by the ARIS during  $t_{sij}$ .

### **NET-APPORTIONED RM-14 CHINOOK SALMON PASSAGE ESTIMATES**

The "net-apportioned" daily estimate of Chinook salmon abundance at RM 13.7 will be obtained following equations 9 and 10.

Modifications required under FT and LFO sampling protocols described on page 11 also apply to RM-13.7 estimates.

Missing data from RM 13.7 may require imputation, following equations 11 and 12, conducted post-season. Likewise, a daily abundance model similar to that described on page 12 may be required post-season to obtain daily estimates of Chinook salmon passage at RM 13.7.

## SCHEDULE AND DELIVERABLES

**Table 7.- 2013 timeline and milestones**

5/1 – 5/15/2013	<p><b>RM 8.6 site</b></p> <ul style="list-style-type: none"> <li>• Normal camp set up with new computer + DIDSONs</li> <li>• Review/update measurement protocol – create a suite of test files that can be used with a tutorial for future training especially at site</li> <li>• Group training on manual DIDSON measures for both “site” and “office” crews</li> <li>• Review/update DIDSON-based camp manual</li> </ul> <p><b>RM 13.7 site</b></p> <ul style="list-style-type: none"> <li>• Check with Mark Hatfield to ensure we have enough tripods and mounts</li> <li>• Construction of new tent platform + new weatherport</li> <li>• Installation of ELP walkways</li> </ul> <p><b>IT needs – mainly Mark’s Duties:</b></p> <ul style="list-style-type: none"> <li>• Update batch files for RM 8.6 DIDSON data (continue with 4 range strata)</li> <li>• Update SAS for RM 8.6 data processing and uploading</li> <li>• Develop new batch files for RM 13.7 ARIS data</li> </ul>
5/10	Delivery date for (1) ARIS 1200 and (1) ARIS 1800 + (2) X2s and (2) LL
5/13-5/17/2013	Bill Hanot on site to assist with sonar testing and configuration
5/15 -6/1/2013	<ul style="list-style-type: none"> <li>• Deploy ARIS on RM 8.6 right bank when dust settles</li> <li>• Conduct tethered fish experiments as early as possible to compare ARIS and DIDSON fish measurements – i.e., when netters start picking up at least several fish/shift</li> <li>• Develop field manual with examples and test files</li> <li>• Training sessions with crew as needed for measuring consistency</li> </ul>
7/22-7/26	Bill Hanot here to assist with any ARIS or DIDSON issues

A report meeting the requirements of ADF&G’s Fishery Data Series will be published. This report will provide an overview of the implemented methodology for generating DIDSON-based Chinook salmon estimates. A draft version will be completed by 4/1/2014. The final report will be completed by 9/1/2014.



## **RESPONSIBILITIES**

List of primary personnel and duties:

- Personnel: Jim Miller, Fishery Biologist II, Alaska Department of Fish and Game  
Duties: General supervision of all aspects of the study. Set up and configure DIDSON\ARIS sonar system. Assist with in-season data collection and post-season data analysis. Primary responsibility for post-season report.
- Personnel: Debby Burwen, Fishery Biologist III, Alaska Department of Fish and Game  
Duties: Assist with conducting and supervising all aspects of the study. Work with Bill Hanot/SMC personnel to develop/update needed data-processing software. Set up and configure DIDSON\ARIS sonar system. Assist with in-season data collection and post-season data analysis. Assist with testing and evaluating evolving DIDSON\ARIS hardware and software. Shared responsibility for post-season report.
- Personnel: Mark Jensen, Fish and Wildlife Tech IV, Alaska Department of Fish and Game  
Duties: Provide expertise for implementing and maintaining wired and wireless networks used to transfer sonar data. Develop batch files and other user-interface programs as needed to transfer, summarize, and archive sonar data. Assist with in-season data processing and analysis. Work dates: May 13 – June 30, 2013.
- Personnel: Steve Fleischman, Fisheries Scientist I, Alaska Department of Fish and Game  
Duties: Provide guidance on sample design and estimation procedures. Assist with in-season and post-season data analysis. Review project operational plan. Shared responsibility for post-season report.
- Personnel: Jiaqi Huang, Biometrician II, Alaska Department of Fish and Game  
Duties: Provide guidance on sample design and estimation procedures. Assist with post-season data analysis. Review project operational plan and report.
- Personnel: Bill Hanot, Senior Engineer, Sound Metrics  
Duties: Provide training in the operation of a new DIDSON prototype (ARIS) and ensure that all hardware and software features are working correctly. Develop software features required to collect or analyze DIDSON\ARIS data. Planned visits are May 13-17, and July 15-19, 2013.
- Personnel: Brandon Key, Fishery Biologist I, Alaska Department of Fish and Game

Duties: Assist Project Leader with all aspects of DIDSON\ARIS deployment, operation, and data analysis. Take lead role in developing protocol for processing DIDSON\ARIS data for the purpose of generating daily estimates of Chinook salmon passage. Primary focus is river mile 13.75 sonar site. Work dates: April 1 – December 31, 2013.

Personnel: Michael Friedrich, Fishery Biologist I, Alaska Department of Fish and Game

Duties: Assist Project Leader with all aspects of DIDSON\ARIS deployment, operation, and data analysis. Take lead role in developing protocol and a comprehensive user manual for processing DIDSON data for the purpose of generating daily estimates of Chinook salmon passage. Primary focus is river mile 8.6 sonar site. Work dates: May 1 – August 15, 2013.

Personnel: Kara Bethune, Fishery Biologist I, Alaska Department of Fish and Game

Duties: Assist Project Leader with all aspects of DIDSON\ARIS deployment, operation, and data analysis. Assist in developing a comprehensive user manual for processing DIDSON\ARIS data for the purpose of generating daily estimates of Chinook salmon passage. Work dates: July 15 – August 10 to assist with processing data during the peak of the late run and at other times as needed to replace other employees requiring leave.

Personnel: Mike Hopp, Fish and Wildlife Technician III, Alaska Department of Fish and Game

Duties: On-site Crew Leader: Supervise, provide training, and oversee work quality of three technicians based at a semi-remote field camp. Assist Project Leader with all aspects of DIDSON\ARIS deployment, operation, and data processing. Develop batch files and other user-interface programs as needed. Work dates: May 1 – August 15, 2013.

Personnel: Nathan Plate, Fish and Wildlife Technician II, Alaska Department of Fish and Game

Duties: Assist Crew Leader with all aspects of DIDSON\ARIS deployment, operation, and data processing. Approximate work dates: May 13 – August 15, 2013.

Personnel: Aaron Gordon, Fish and Wildlife Technician II, Alaska Department of Fish and Game

Duties: Assist Crew Leader with all aspects of DIDSON\ARIS deployment, operation, and data processing. Approximate work dates: May 13 – August 15, 2013.

Personnel: Alex Pettey, Fish and Wildlife Technician II, Alaska Department of Fish and Game

Duties: Assist Crew Leader with all aspects of DIDSON\ARIS deployment, operation, and data processing. Approximate work dates: May 13 – August 15, 2013.

Personnel: Cyndi Jaffa, Fish and Wildlife Technician II, Alaska Department of Fish and Game

Duties: Assist Crew Leader with all aspects of DIDSON\ARIS deployment, operation, and data processing. Approximate work dates: May 13 – August 15, 2013.

Personnel: Lindsay Fagrelius, Fish and Wildlife Technician II, Alaska Department of Fish and Game

Duties: Assist Crew Leader with all aspects of DIDSON\ARIS deployment, operation, and data processing. Approximate work dates: May 24 – August 15, 2013.

## BUDGETS

The total proposed personnel requirements for the Kenai River Chinook Salmon Sonar Project at RM 8.6 (fiscal year, 2014) are summarized in Table 8.

**Table 8.**–Project personnel for RM 8.6 site.

PCN	Name	Title	Funded Man Months
4166	James D. Miller	Fishery Biologist II	12.0
4234	Michael Friedrich	Fishery Biologist I	3.3
1793	Mike Hopp	Fish & Wildlife Technician III	3.3
4146	Alex Pettey	Fish & Wildlife Technician II	3.0
1045	Aaron Gordon	Fish & Wildlife Technician II	3.1
4305	Nathan Plate	Fish & Wildlife Technician II	3.0
			27.7

The total proposed personnel requirements for the new ARIS-based Sonar project at RM13.7 is are summarized in Table 9..

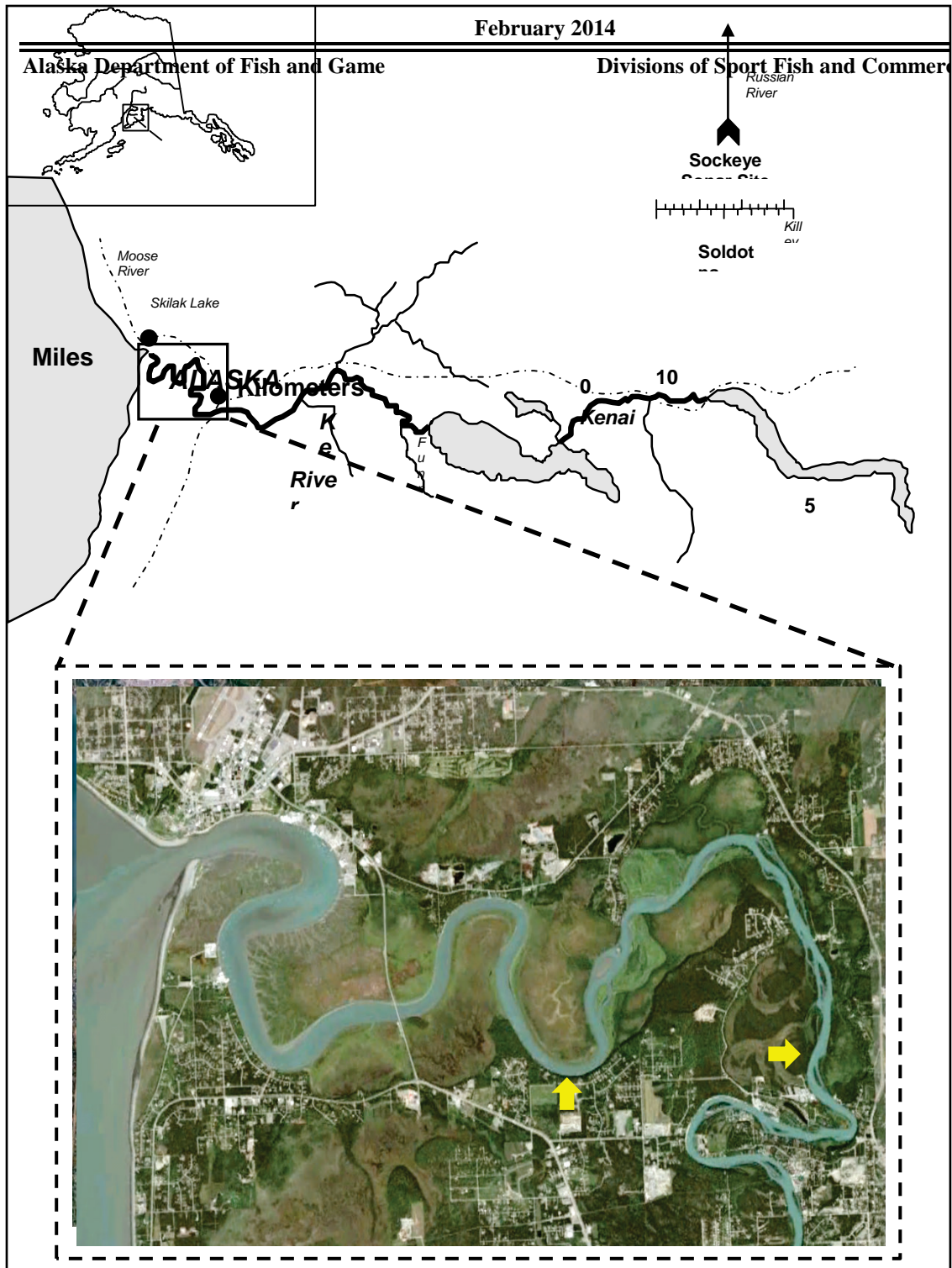
**Table 9.**–Project personnel for RM 13.7 site.

PCN	Name	Title	Funded Man Months
1960	Debby Burwen	Fishery Biologist III	12.0
N13029	Brandon Key	Fishery Biologist I	9.0
<b>B216</b>	Kara Bethune	Fishery Biologist I	2.0
5361	Lindsay Fagrelus	Fish & Wildlife Technician II	3.0
5347	Cyndarienne Jaffa	Fish & Wildlife Technician II	3.0
			29.0

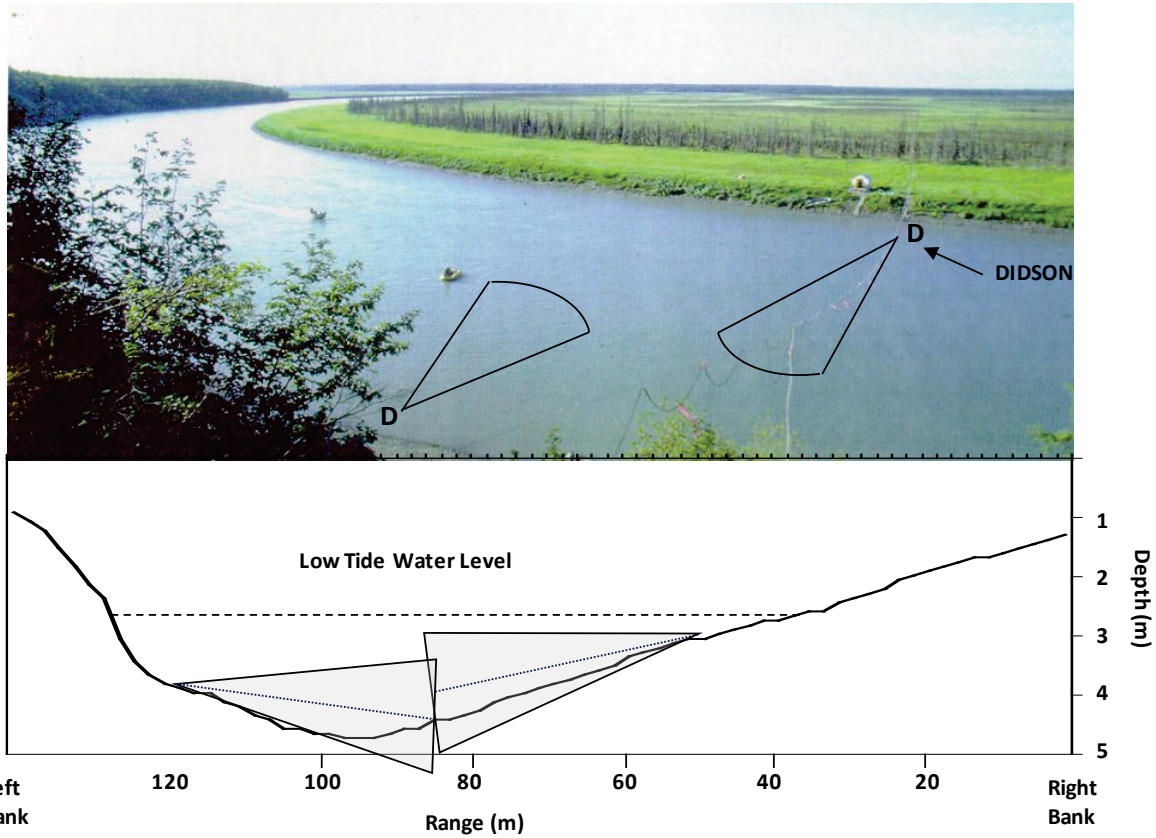
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**Figure 1.**—Map of Kenai River showing location of Chinook salmon sonar sites at river miles 8.6 and 13.7.



**Figure 2.**—Aerial view and bottom profile at the river-mile 8.6 site on the Kenai River with approximate transducer placement and sonar beam coverage.





A

ROS PT-25 pan and tilt rotator

DIDSON with high-resolution lens

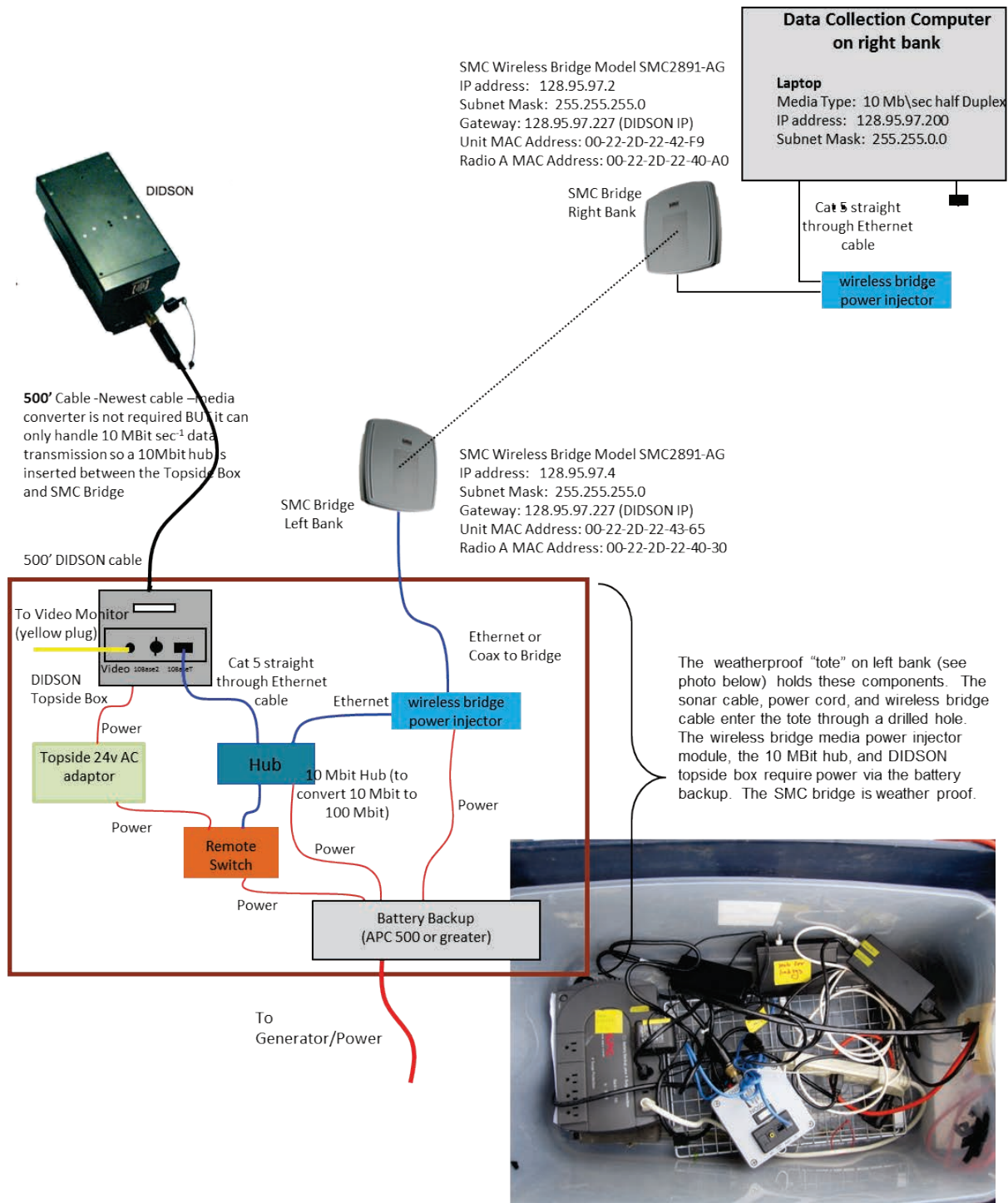


B



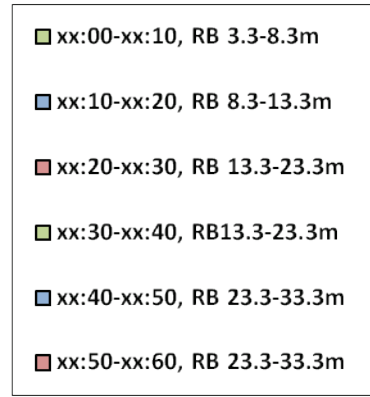
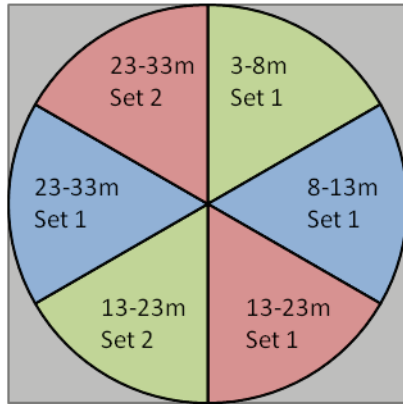
C

**Figure 3.**—A DIDSON-LR with a high-resolution lens (photos A and B). A silt-protection device is used (silt sock, photo B) to protect against silt build up in front of the lens (photo C).

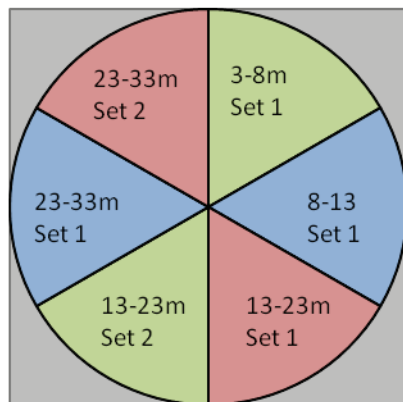


**Figure 4.**—RM-8.6 left bank DIDSON configuration with new (since 2009) 500' cable and SMC wireless bridge that transmits data to right bank for storage and transport to the Soldotna office.

### Right Bank sample scheme



### Left Bank sample scheme



**Figure 5.-** RM-8.6 DIDSON sampling schedules for four range strata on the right (top) and left (bottom) banks for 2012.

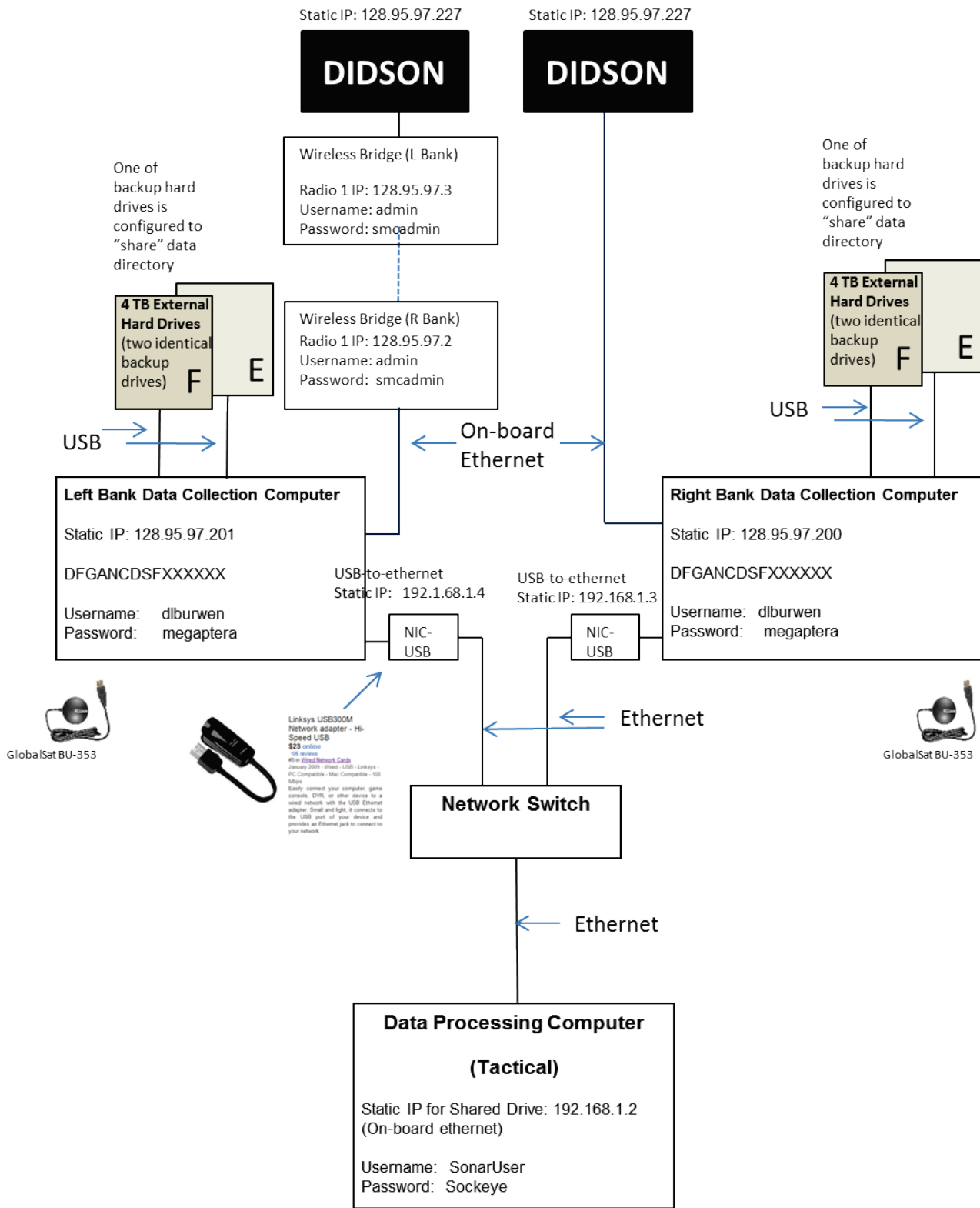
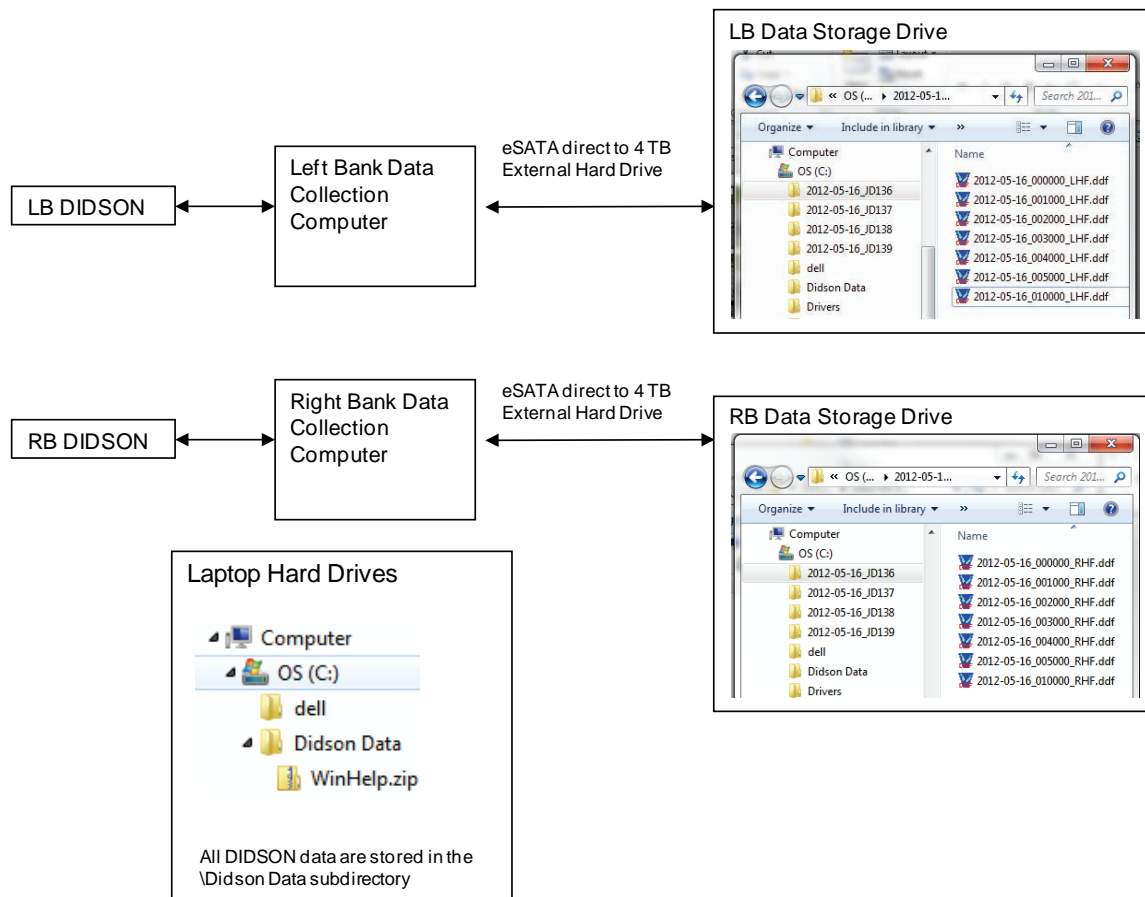
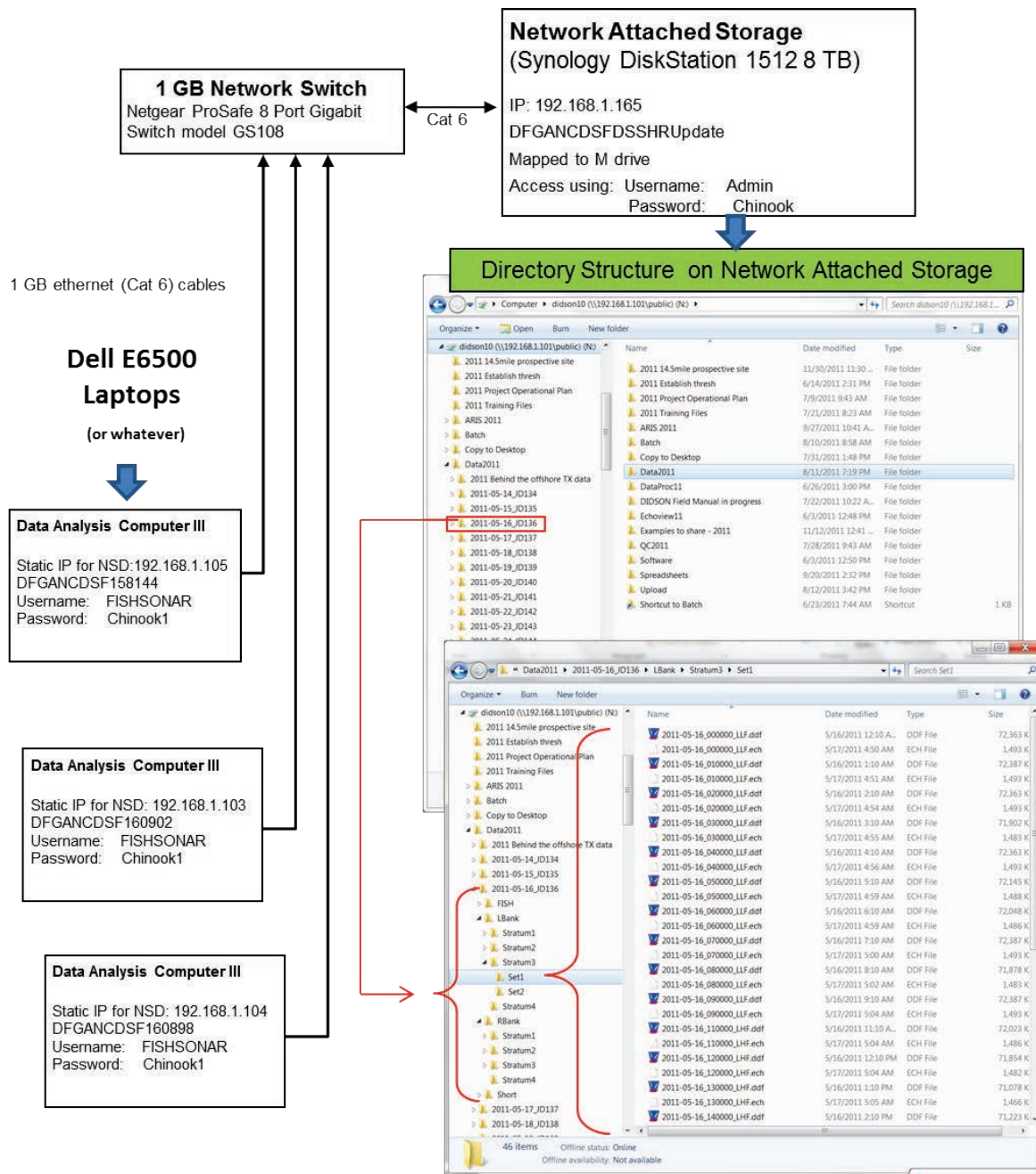


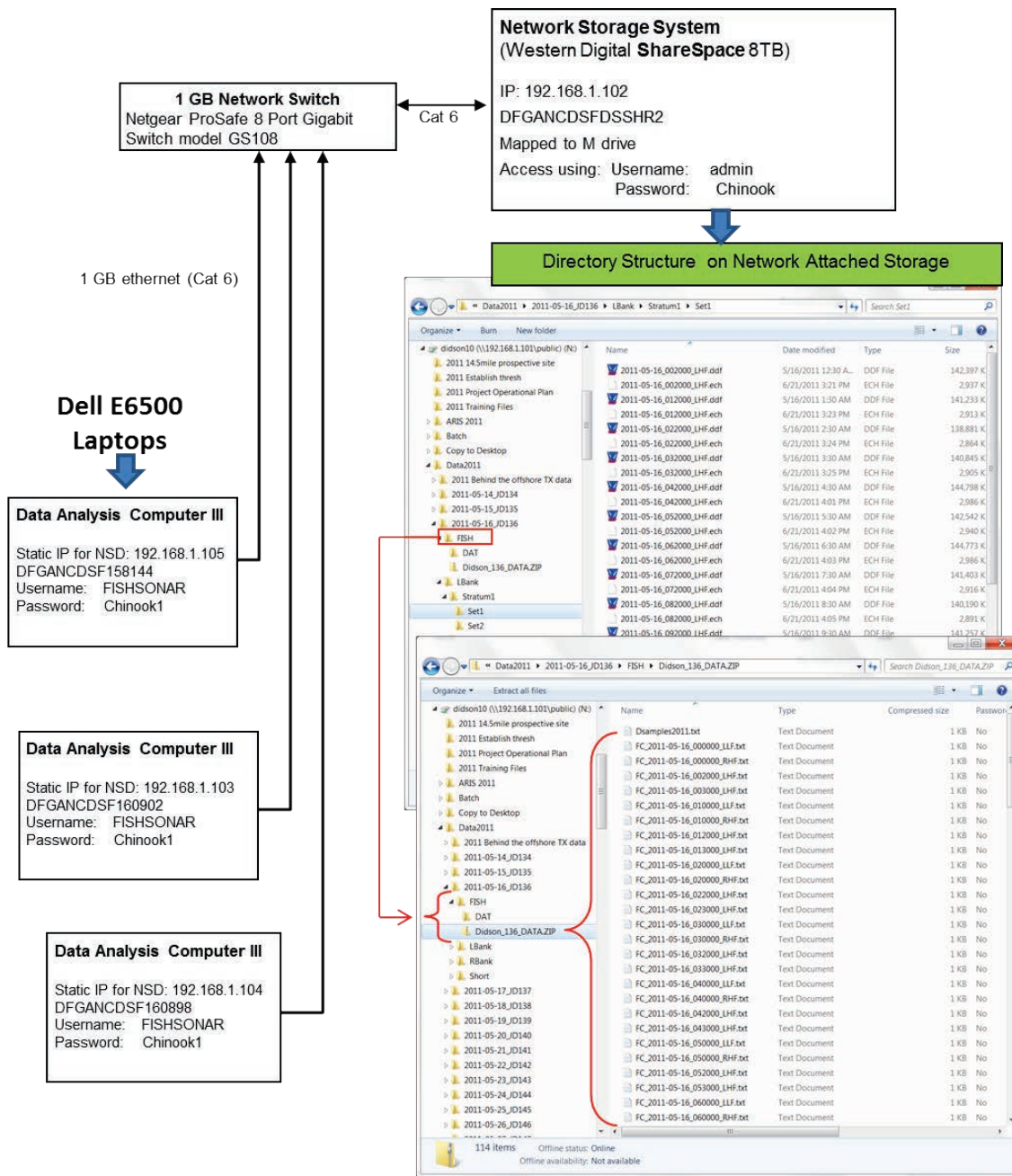
Figure 6.—DIDSON data collection schematic for the RM 8.6 sonar site.



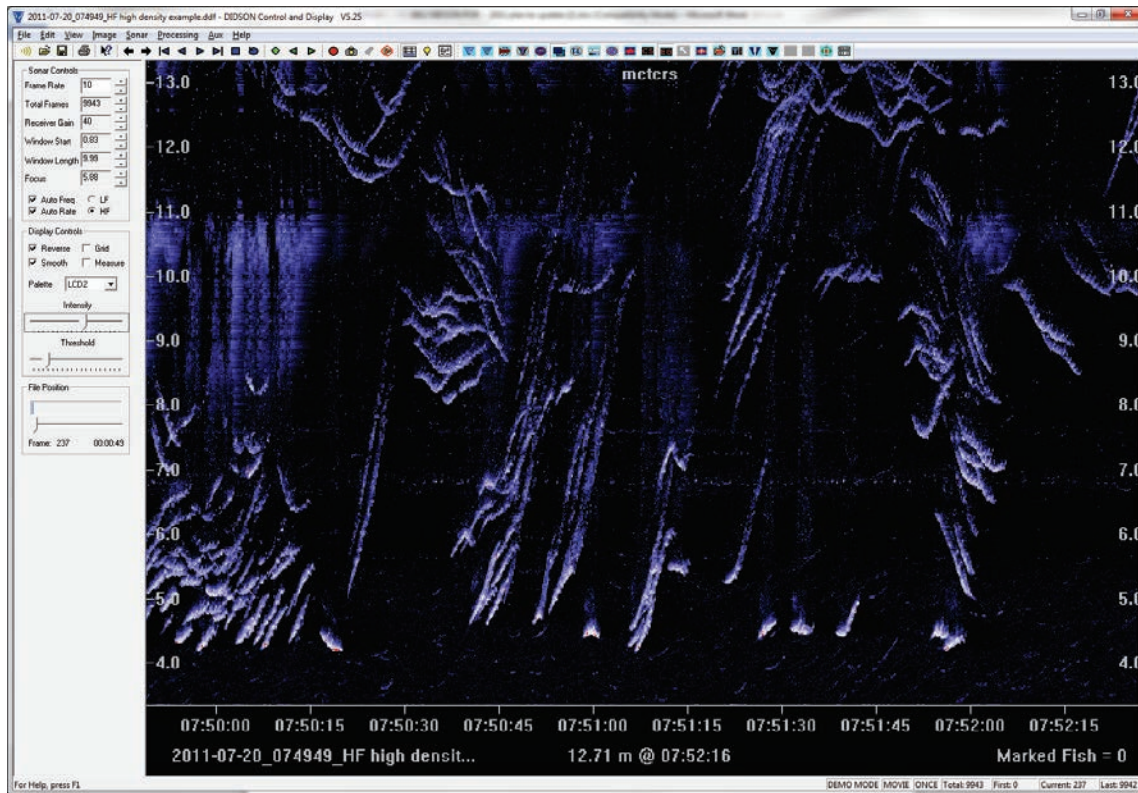
**Figure 7.**—DIDSON data storage configuration and directory structure at RM-8.6 site. DIDSON sample files are initially stored on the data collection computer, then transferred to the external hard drive using a batch file that also appends an “L” or “R” to each filename to indicate which bank the file originated on.



**Figure 8.**– RM-8.6 DIDSON data storage and file management configuration for the Network Storage Device at the Soldotna Office showing the contents of the daily subdirectory for May 16, 2011. For each day, there are Left and Right bank subfolders each of which has subfolders for four range strata. Stratum 1 (3.3-8.3 m) and stratum 2 (8.3-13.3 m) contain a single data set. There are two data sets (and folders) for range strata three (13.3-23.3 m) and four (23.3-33.3 m) because these range strata are sampled twice during two separate 10-min periods (see Figure 5).

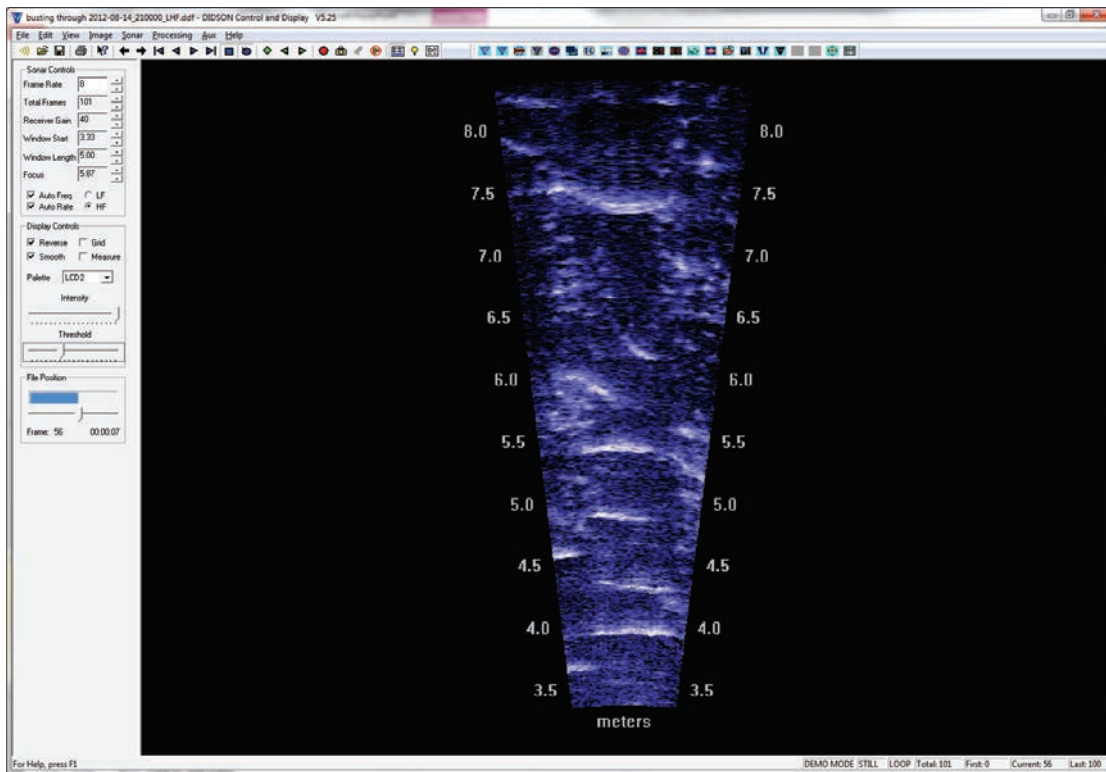


**Figure 9.**– RM-8.6 DIDSON data Storage and file management configuration for Network Storage System in the Soldotna office showing the contents of the fish subdirectory for May 16, 2011. The “Fish” sub-directory for each day contains the .txt files containing manually measured fish lengths. These files are: 1) processed locally using SAS to generate daily estimates of fish passage and 2) uploaded to an Anchorage server for further processing by a Biometrician based in Anchorage or Fairbanks.



**Figure 10.**—Example of high density passage at RM 8.6 on July 20, 2011. There are approximately 150 fish in this 2.5 minute chart recording. A 10-minute sample with such high density can take several hours to process if each individual fish must be measured.

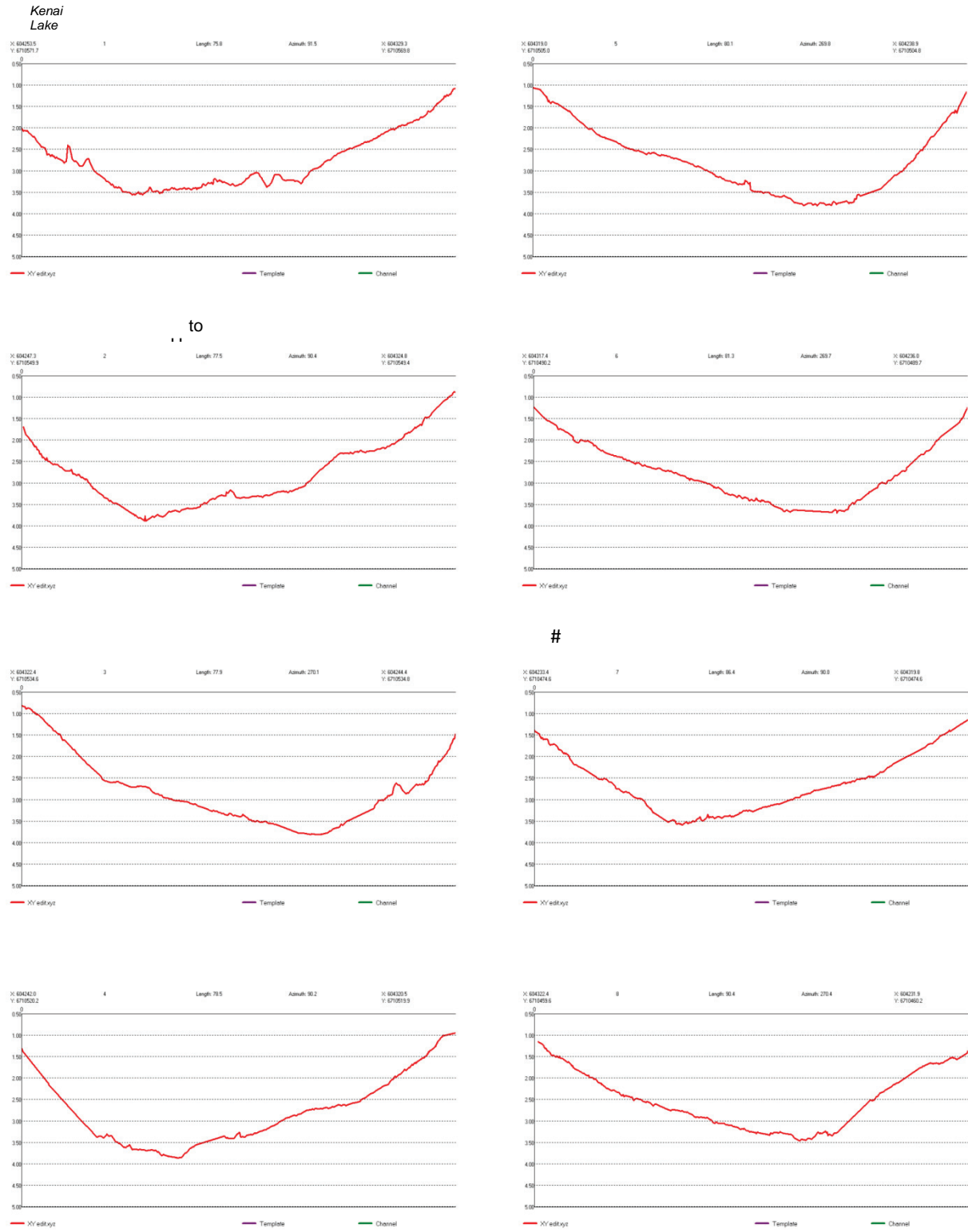




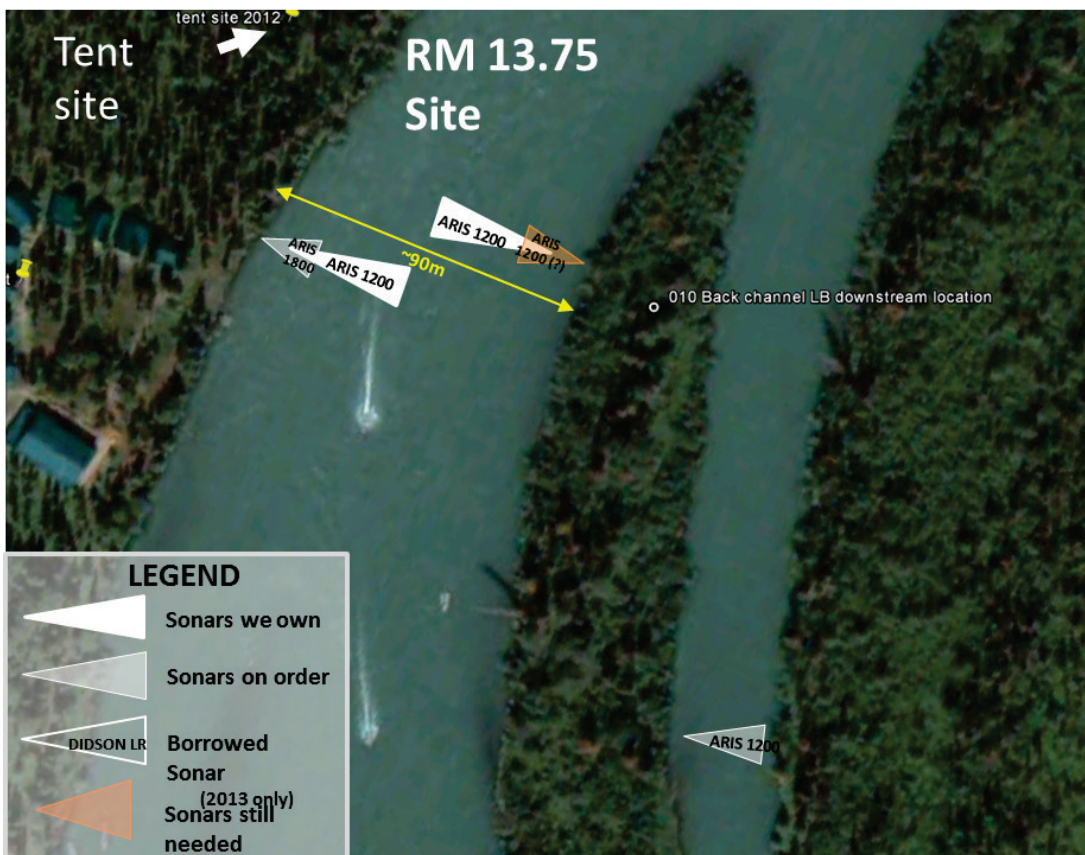
**Figure 11.**—Example of ~ 110 cm Chinook salmon swimming past milling pink salmon at RM-8.6 site on August 14, 2012.



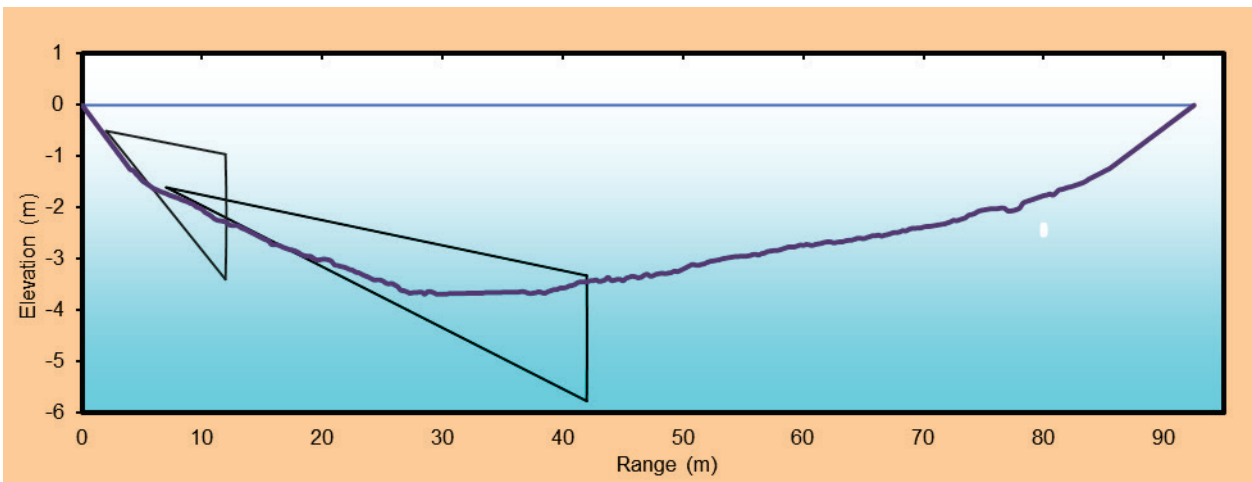
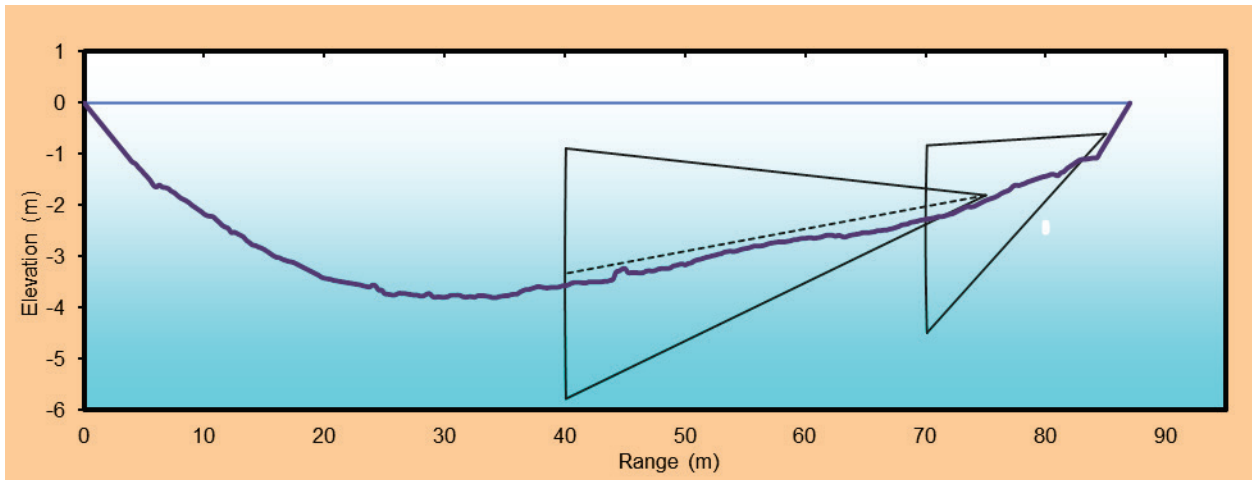
**Figure 12.**– Location of nine transects conducted at the river mile 13.7 site on July, 9, 2012. Yellow arrows indicate preferred locations for sonars on each bank.



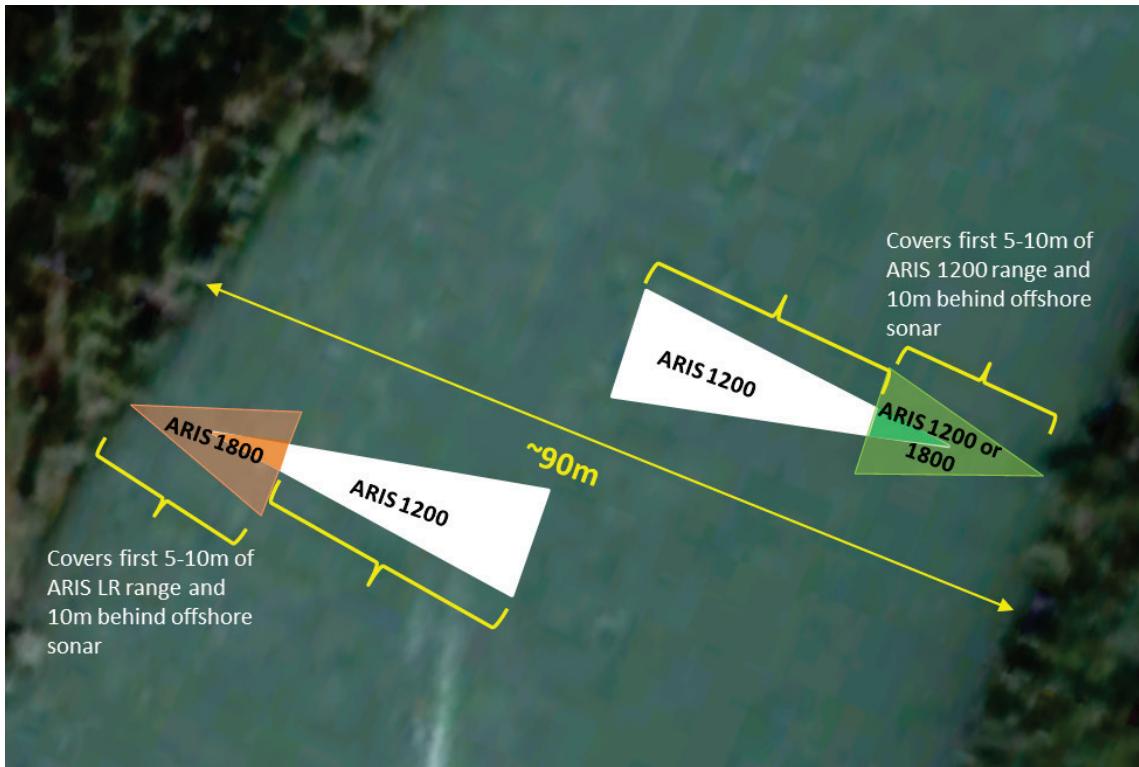
**Figure 13.**— Corresponding profiles for nine transects conducted near river mile 13.7 of the Kenai River.



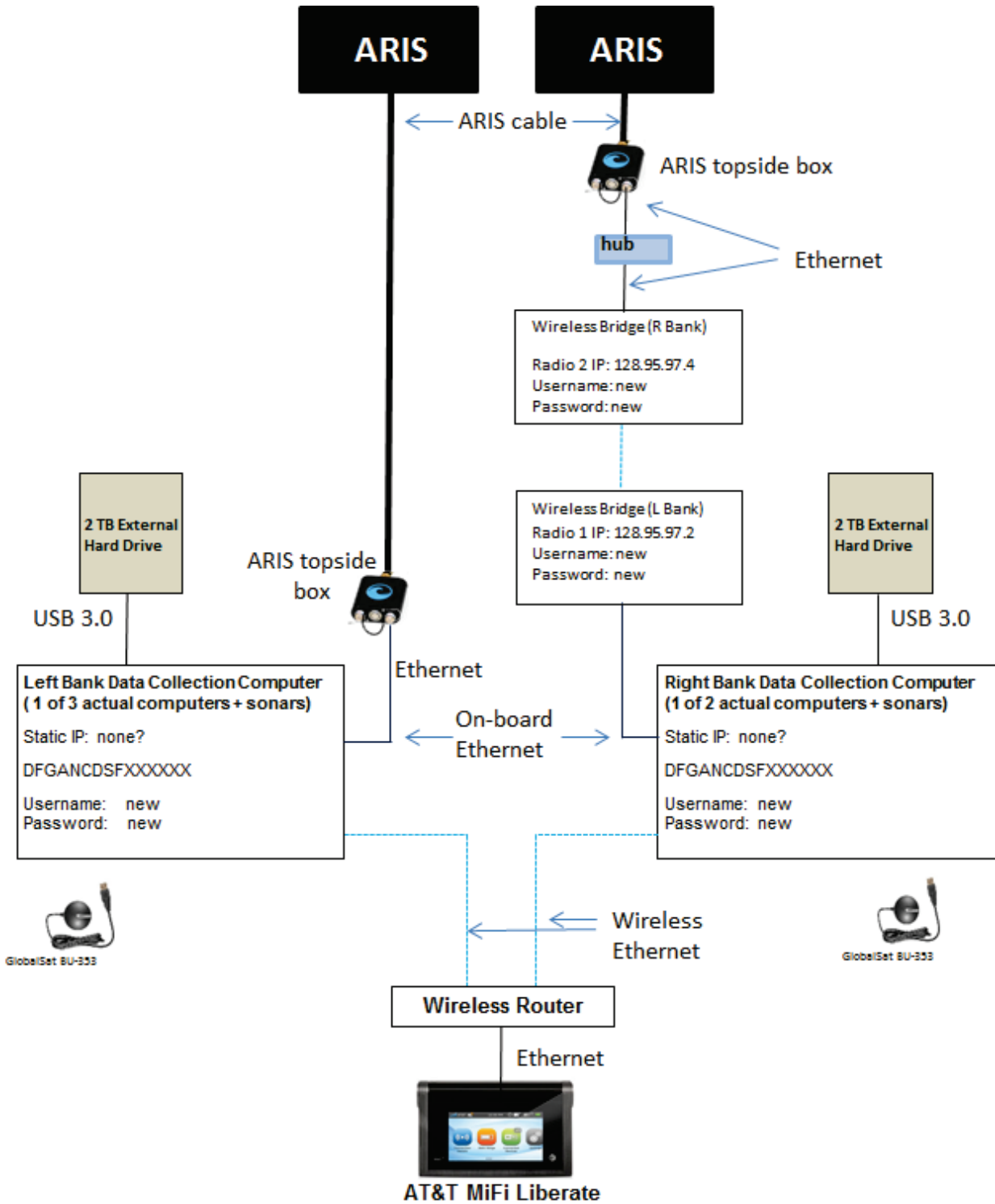
**Figure 14.**– Aerial view of sonar sites at Kenai river mile 8.6 (top) and 13.7 (bottom) with proposed sonar beam coverage. Diagrams are approximate and not drawn to scale.



**Figure 15.**– Proposed coverage for the right bank (top, transect #5 in Figure 16) and left bank (bottom, (transect #6 in Figure 16) at RM 13.7.

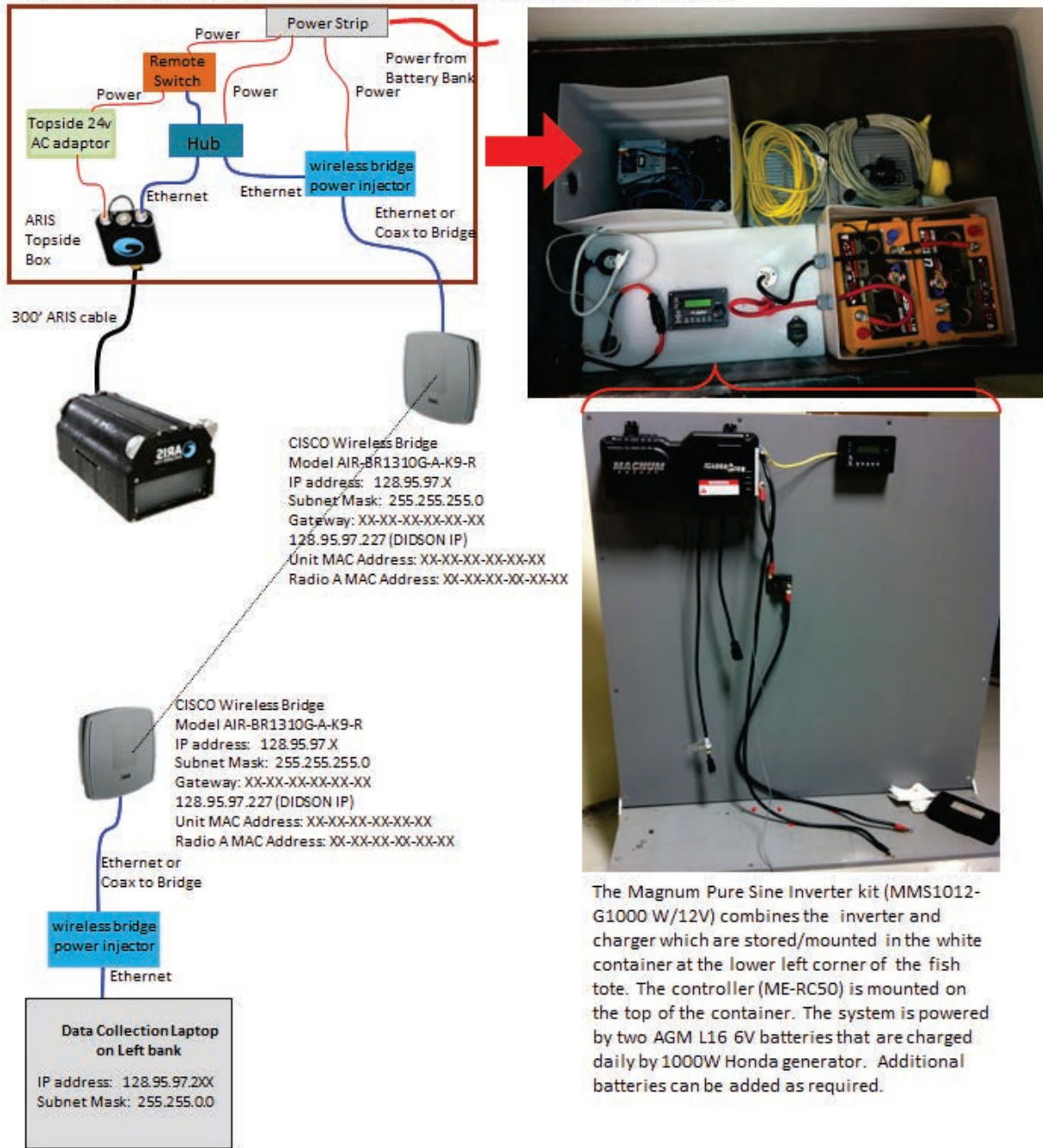


**Figure 16.**— Aerial view of sonar sites at Kenai river mile 8.6 (top) and 13.7 (bottom) with proposed sonar beam coverage. Diagrams are approximate and not drawn to scale.



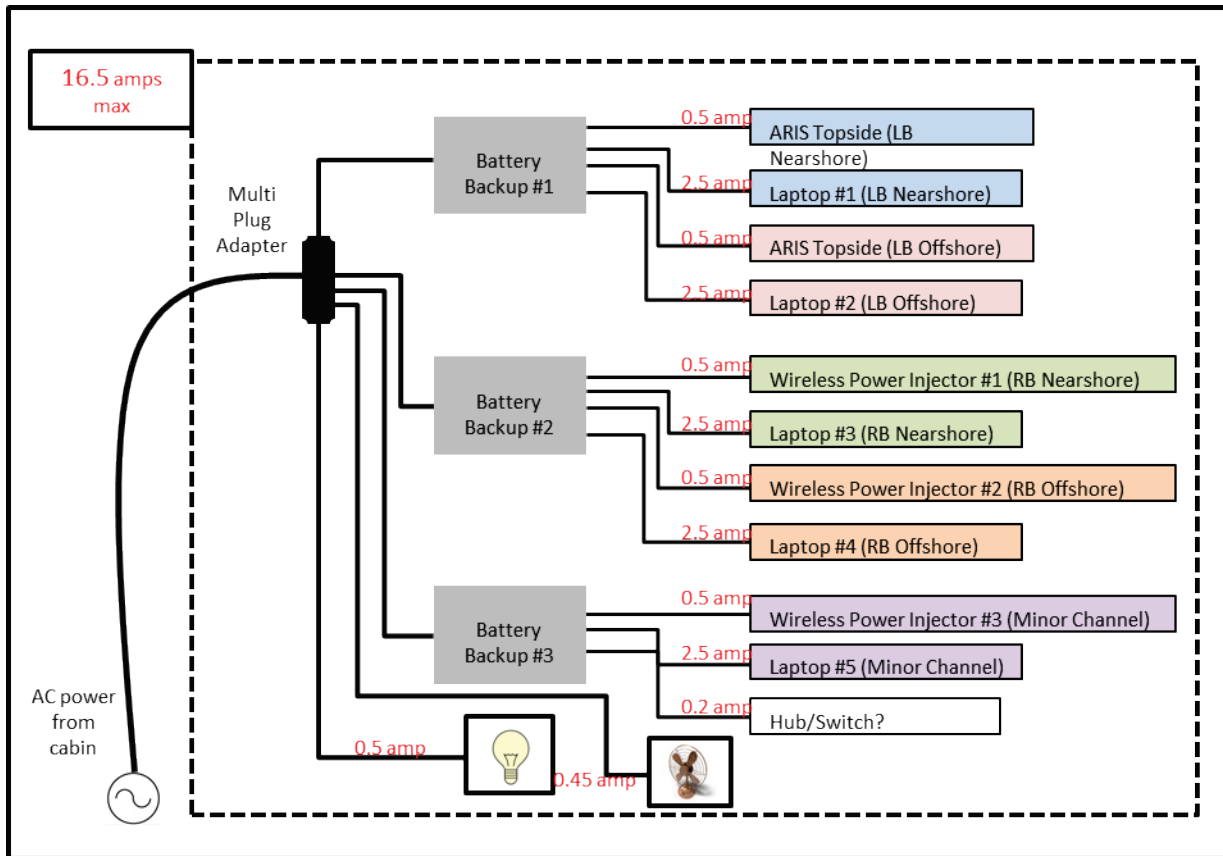
**Figure 17.**— ARIS data collection schematic for the RM 13.7 site. For simplicity, this diagram shows only one-of-three right bank data-collection computer+sonar pairs and one-of-two left bank data collection computer+sonar pairs. The wireless router will accommodate multiple computers.

The components shown in the diagram below are housed in the small white container in the upper left corner of the fish tote (42"x29"x28"). The batteries are stored in a separate container in the lower right corner of the fish tote. The combined charger/inverter are mounted in the third container in the lower left corner.

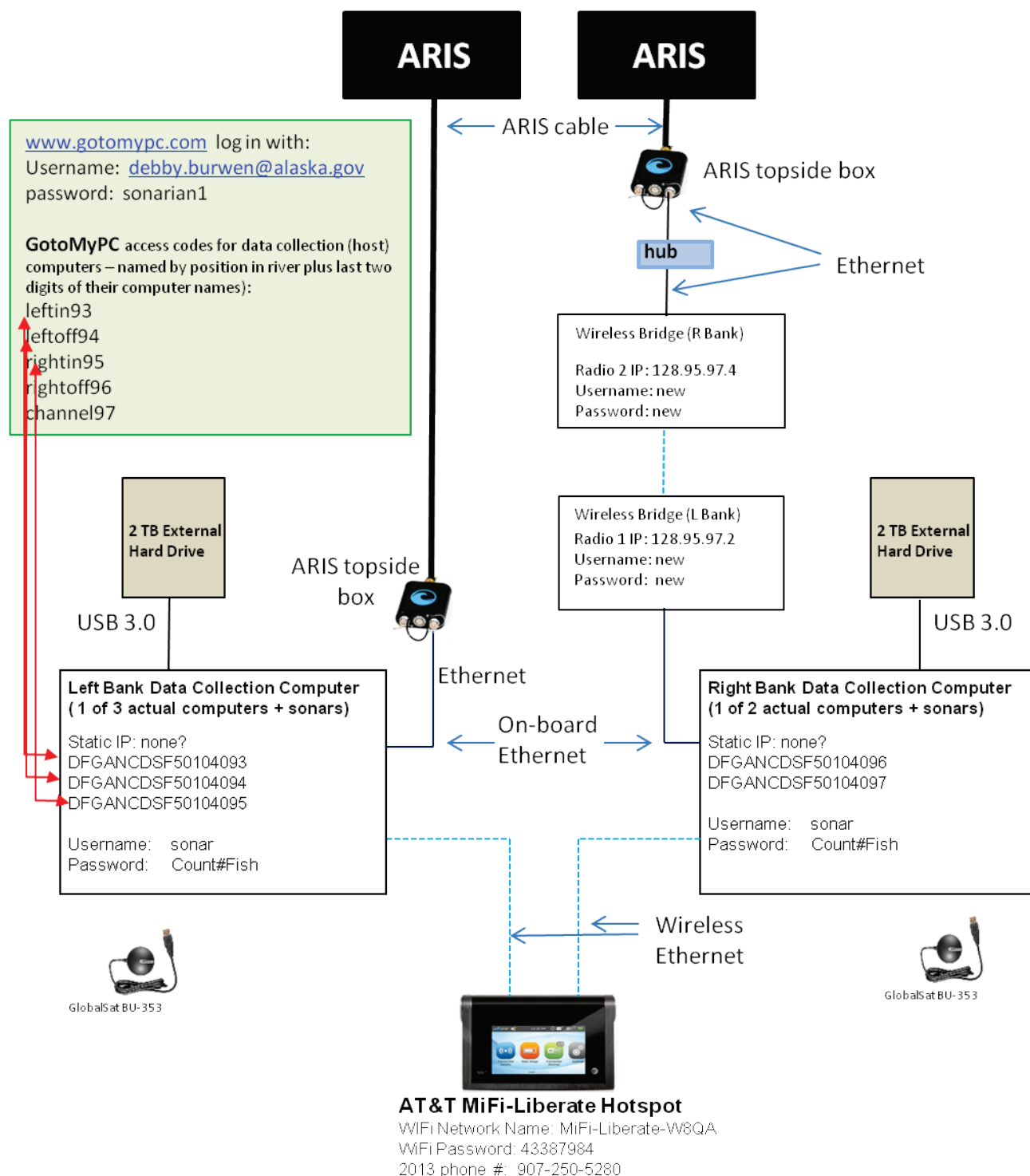


**Figure 18.**– Diagram of components required on RM 13.7 right bank for wireless transmission of ARIS data back to the main camp on left bank. A wireless bridge transmits data to a data collection computer on left bank for storage and subsequent transport to the Soldotna office.





**Figure 19.**– Schematic of power requirements for RM-13.7 left bank main camp electronics.



**Figure 20.**– ARIS data collection schematic for the RM 13.7 site. For simplicity, this diagram shows only one-of-three right bank data-collection computer+sonar pairs and one-of-two left bank data collection computer+sonar pairs. The wireless router will accommodate up to 8 computers.

**APPENDIX A. DIDSON AND ARIS CONFIGURATIONS  
USED ON KENAI RIVER CHINOOK SONAR PROJECTS  
AT RM 8.6 AND RM 13.7, 2013**

**Appendix A 1.**–DIDSON and ARIS configurations used on Kenai River Chinook sonar projects at RM 8.6 and RM 13.7, 2013, including an overview of features that affect resolution and range capabilities

**a. Frequency**

DIDSONs operate at two frequencies, a higher frequency that produces higher resolution images, and a lower frequency that can detect targets at further ranges but at a reduced image resolution. Two DIDSON models are currently available based on different operating frequencies (Table A1-1). The short-range or standard model (DIDSON SV) operates at 1.8 MHz to approximately 15 m in range and at 1.1 MHz to approximately 30 m and produces higher resolution images than the long-range model. The long-range model (DIDSON LR) operates at 1.2 MHz to approximately 30 m in range and at 0.7 MHz to ranges exceeding 100 m, but produces images with approximately half the resolution of the DIDSON-S (see explanation below). The two DIDSON LRs used in this study were operated in frequency mode to achieve maximum image resolution.

Similar to DIDSON, ARIS (for Adaptive Resolution Imaging Sonar) systems operate at two frequencies analogous to the DIDSON frequencies (Appendix A2). The two ARIS models used on this project, ARIS 1800 and ARIS 1200, are essentially updated versions of the DIDSON SV and DIDSON LR models (Table A1-1, Appendix A2). Both ARIS models used in this study were operated in high frequency mode to achieve maximum image resolution.

**b. Beam Dimensions and Lens selection**

The DIDSON-LRs and ARIS 1200s used in this study are fitted with high-resolution lenses to increase the image resolution to the level achieved by the DIDSON-SV and ARIS 1800 (Table A1-1, referred to as DIDSON-LR+HRL, ARIS 12000+HRL). The high-resolution lens has a larger aperture that increases the image resolution over the standard lens by approximately a factor of 2 by reducing the width of the individual beams and spreading them across a narrower field of view (Table A1-1). Overall nominal beam dimensions for a DIDSON-LR or an ARIS 1200 with a standard lens are approximately 29° in the horizontal axis and 14° in the vertical axis. Operating at 1.2 MHz, the 29° horizontal axis is a radial array of 48 beams that are nominally 0.54° wide and spaced across the array at approximately 0.60° intervals. With the addition of the high-resolution lens, the overall nominal beam dimensions of the DIDSON-LR and ARIS 1200 are reduced to approximately 15° in the horizontal axis and 3° in the vertical axis and the 48 individual beams are reduced to approximately 0.3° wide and spaced across the array at approximately 0.3° intervals. The combined concentration of horizontal and vertical beam widths also increases the returned signal from a given target by 10dB, an effect that increases the maximum range of the sonar over the standard lens.

A standard lens will be used with the ARIS 1800s deployed near shore at the RM 13.7 site because the wider beam dimensions are preferred for increasing the beam coverage at close range and reducing biases associated with focal resolution at close range (see below).

**c. Resolution**

The resolution of a DIDSON or ARIS image is defined in terms of down-range and cross-range resolution where cross-range resolution refers to the width and down-range resolution refers to the height of the individual pixels that make up the image (Figure A1-2). Each image pixel in a DIDSON or ARIS frame has (x, y) rectangular coordinates that are mapped back to a beam and sample number defined by polar coordinates. The pixel height defines the down-range resolution and the pixel width defines the cross-range resolution of the image. Figure A1-2 shows that image pixels are sometimes broken down into smaller screen pixels (e.g., pixels immediately to the right of the enlarged pixels), an artifact of conversions between rectangular and polar coordinates.

### Cross-range resolution

The cross-range resolution is primarily determined by the individual beam spacing and beam width, both of which are approximately 0.3° for the DIDSON LR+HRL at 1.2 MHz (Table A1-1). Targets at closer range are better resolved because the individual beam widths and corresponding image pixels increase with range following the formula below:

$$X = 2R \tan(\theta/2) \tag{1}$$

Where

- $X$  = width of the individual beam or “image pixel” in meters,
- $R$  = range of interest in meters, and
- $\theta$  = individual beam angle in degrees (approximately 0.3°).

### Down-range resolution

“Window Length”, i.e., the range interval sampled by the sonar, controls the down-range resolution of the image and is calculated using the formula:

$$Y = W/N$$

Where

$W$  = Window Length (cm)

$N$  = number of range samples (pixels)

With DIDSONs,  $N$  is fixed at 512 samples (pixels) and images with shorter Window Lengths are always better resolved. The DIDSON Window length parameter can only be set at discrete values 2.5, 5.0, 10.0, or 20.0 m for the DIDSON-LR+HRL at 1.2 MHz. Although using shorter window lengths will increase resolution, it will also require more individual stratum to cover the desired range. Dividing the total range covered into too many discrete stratum increases the data-processing time. For this study, a window length of 5m was used for the first two range strata to minimize the bias associated with close range targets (see section d below). A window length of 10 m was used for each of the two subsequent range strata sampled, a compromise which allowed a relatively high resolution while allowing a reasonable distance to be covered by each stratum. The down-range resolution (or pixel height) for a 5m range window is 1 cm (500cm/512) and for a 10 m window length is 2 cm (1,000 cm/512).

ARIS images can attain a finer down range resolution than DIDSON. With ARIS,  $N$  can vary to a maximum of 4,000 samples (pixels) and Window Length is user selectable. This allows the user to collect data over a longer Window Length but increase the number of samples per beam to compensate. Figure A1-2 contrasts images from a DIDSON LR+HRL with an ARIS 1200 +HRL. The ARIS image in Figure A1-2 has twice the down-range resolution of the DIDSON image because it was collected at 2,000 samples (pixels)/beam with a 20m Range Window yielding a down-range resolution of 1 cm (2,000cm/2,000 pixels) compared to a down-range resolution of 2 cm for the DIDSON image that was collected at 512 samples with a 10m Range Window (1,000cm/512).

The pixels comprising the ARIS image appear less well defined because a smoothing algorithm has been applied.

#### **d. Focal resolution in DIDSON and ARIS systems**

When sizing fish from DIDSON images, there can be a bias factor beyond the geometric beam spreading issue, depending on the start range and end range of the image window. The DIDSON depth of field is reduced at closer focusing ranges, with the effect that defocused targets will appear smeared in the azimuthal direction. The degree of bias is dependent on both the set focus range, and the distance of the target from that set focus range. In general, if the focus is set to 5-6m or longer, targets will be in good focus from there out to infinity.

Inside of that range, focus will degrade, significantly so if the start range is < 2-3m (Bill Hanot, Sound Metrics Corporation, Seattle Washington, personal communication).

For DIDSON, focus counts of 0-255 represent the total range of travel of the middle (focus) lens. For the ARIS 1200/1800, which uses the same lens set and has the same focus curves; focus counts of 0-1000 represent the total range of travel (0.1% per unit). Figure A1-3 shows the ARIS lens position (indicated by the numbers in the range 0-1000) versus focus range for the ARIS High Resolution (Large) lens. There is a non-linear relationship of lens position to focus range, with short range focus requiring large movements for small increments in focus range, and long range focus having small changes in lens position for several meters of change in focus range. Also, beyond a certain range, images are generally in focus. Based on the focus curves in Figure A1-3, images are at least 75% in focus starting at 4 m for the standard lens, and starting at 7 m for the large lens.

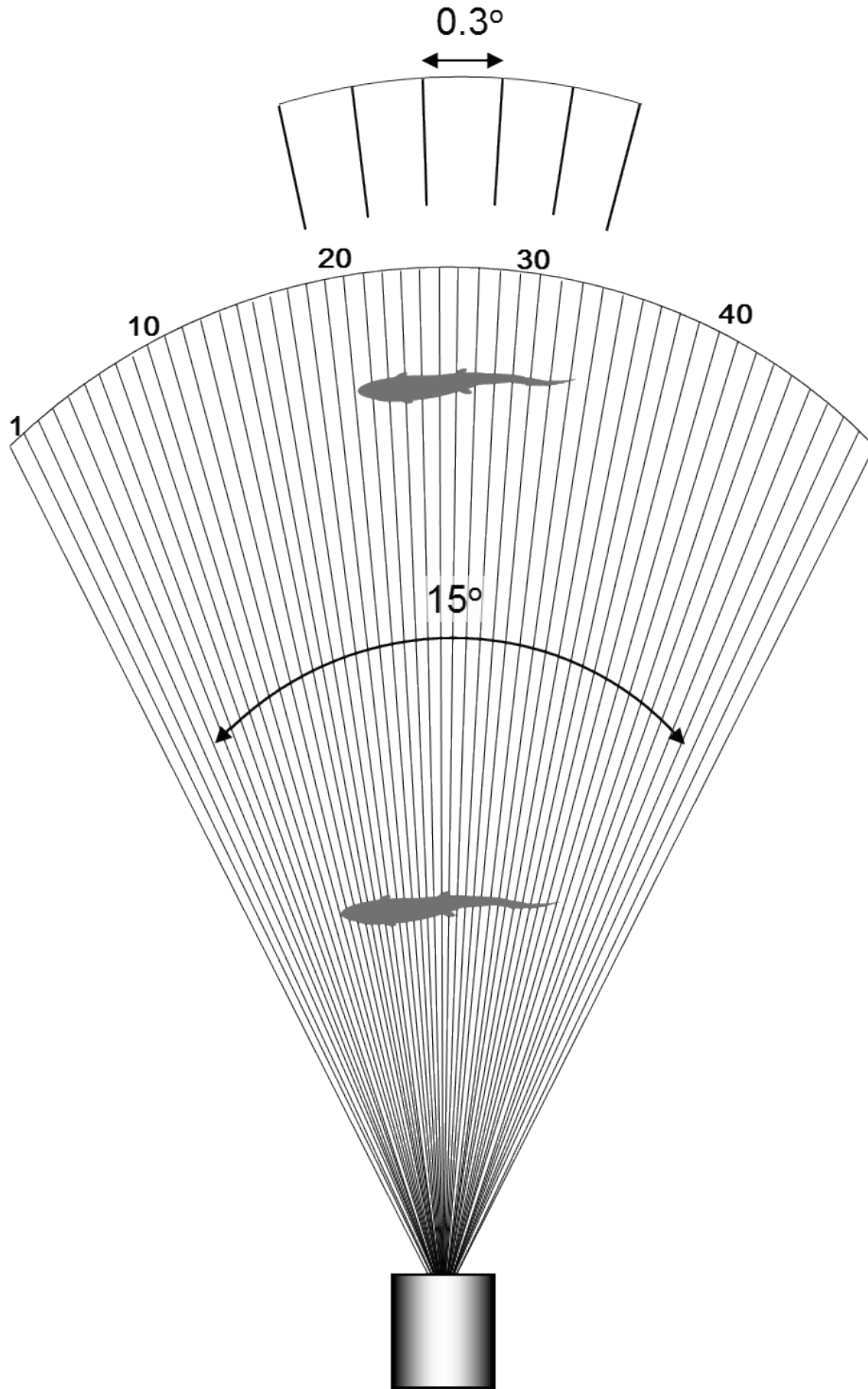
**Table A1-1.**—Summary of manufacturer specifications for maximum range, individual beam dimensions and spacing for DIDSON SV, DIDSON LR, ARIS 1800, and ARIS 1200 systems at two frequencies, with and without the addition of a high resolution lens (specifications from Sound Metrics Corporation). A more complete summary is given in Appendix A2.

System	Maximum range (m) <sup>a</sup>	Horizontal beam width	Vertical beam width	Number of beams	Individual beam width <sup>b,c</sup>	Individual beam spacing <sup>b,c</sup>
DIDSON SV or ARIS 1800 at 1.8 MHz	15	28°	14°	96	0.30°	0.30°
DIDSON SV or ARIS 1800 at 1.1 MHz	30	28°	14°	48	0.40°	0.60°
DIDSON SV or ARIS 1800 at 1.8 MHz + high-resolution lens	20	15°	3°	96	0.17°	0.15°
DIDSON SV or ARIS 1800 at 1.1 MHz + high-resolution lens	40	15°	3°	48	0.22°	0.30°
DIDSON LR or ARIS 1200 at 1.2 MHz	25	28°	14°	48	0.40°	0.60°
DIDSON LR or ARIS 1200 at 0.7 MHz	80	28°	14°	48	0.60°	0.60°
DIDSON LR or ARIS 1200 at 1.2 MHz + high-resolution lens	30	15°	3°	48	0.27°	0.30°
DIDSON LR or ARIS 1200 at 0.7 MHz + high-resolution lens	100	15°	3°	48	0.33°	0.60°

<sup>a</sup>Actual range will vary depending on site and water characteristics.

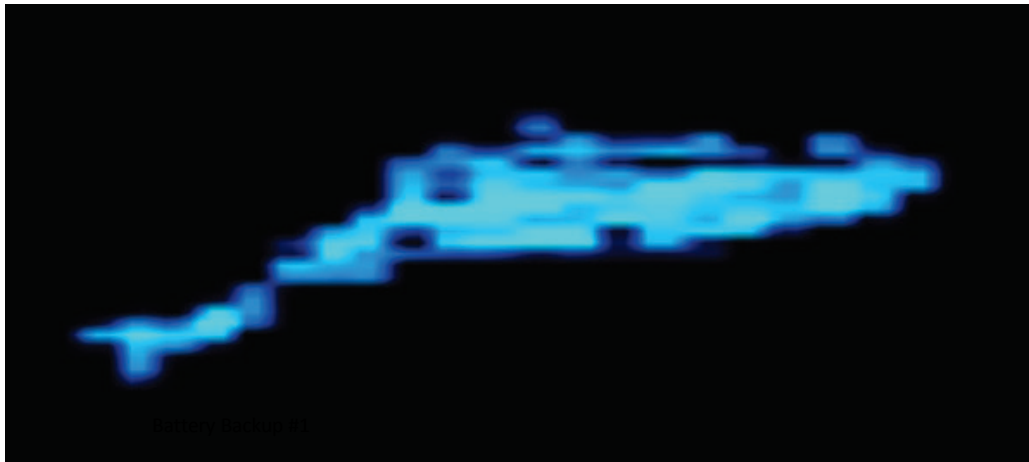
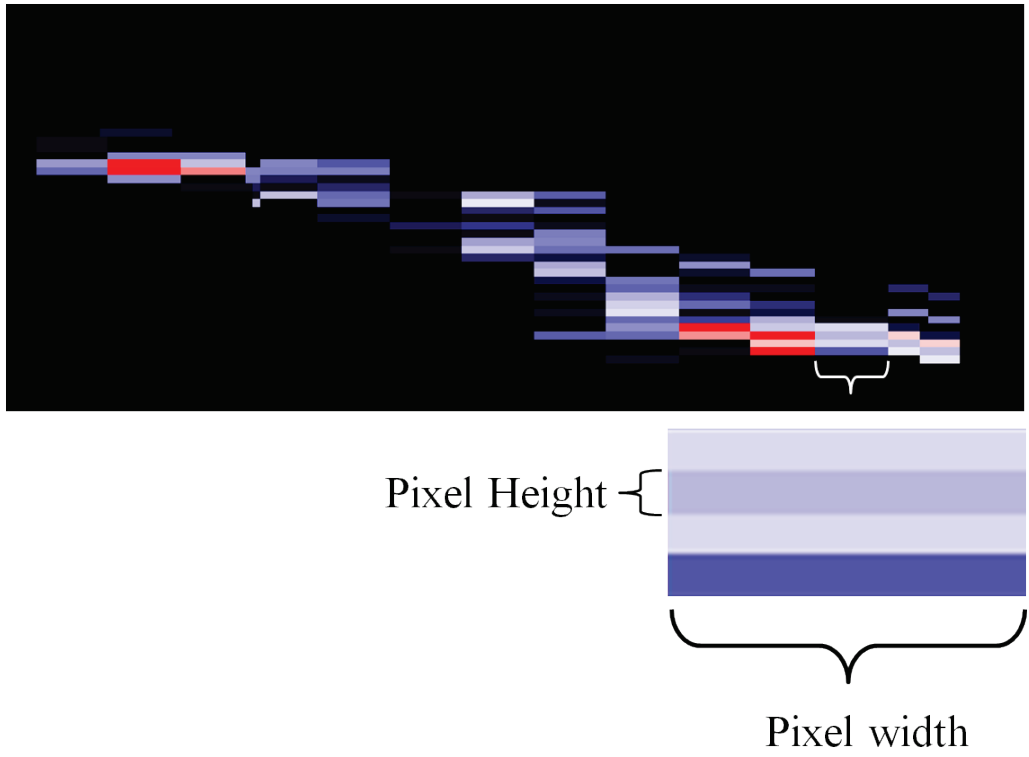
<sup>b</sup> Beam width values are for two-way transmission at the -3 dB points.

<sup>c</sup>Values for beam spacing and beam width are approximate. Beam widths are slightly wider near the edges of the beam and the beam spacing is slightly narrower. Conversely, beams are slightly narrower near the center of the beam, and the beam spacing is slightly wider (e.g. the center beam spacing is closer to .34°, and the beam width is .27 for a DIDSON-S at 1.8 MHz, Bill Hanot, Sound Metrics Corporation, personal communication). Nonlinear corrections are applied by the manufacturer in software to correct for these effects in the DIDSON standard - but not the high-resolution - lens. Nonlinear corrections are applied in software to correct for these effects in both the ARIS standard and high-resolution lens.

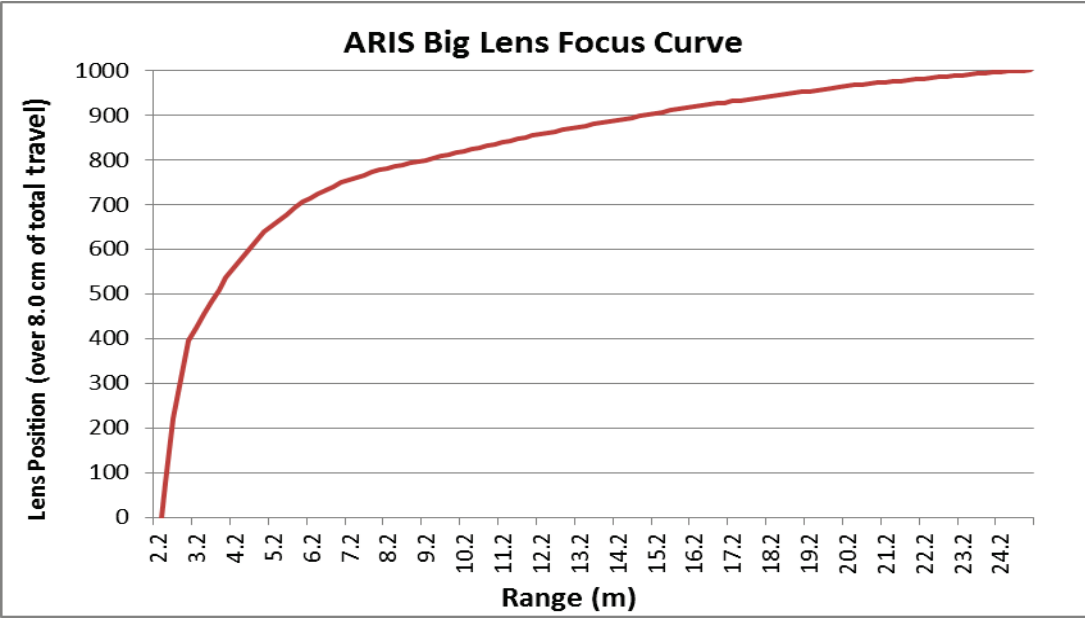
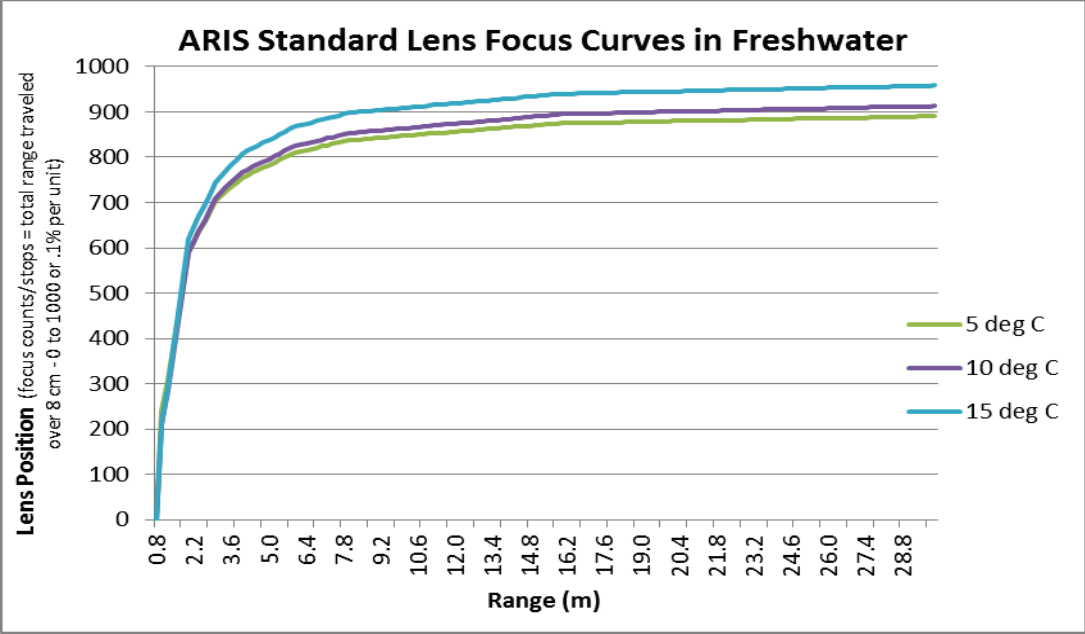


**Figure A1-1.**—Diagram showing the horizontal plane of a DIDSON-LR or ARIS 1200 with a high resolution lens. The overall horizontal beam width of 15° is comprised of 48 sub-beams with approximately 0.3° beam widths. Note that because sub-beams grow wider with range, fish at close range are better resolved than fish at far range (Adapted from Burwen et al. [2007]).





**Figure A1-2.**—An enlargement of a tethered Chinook salmon showing the individual pixels that comprise a DIDSON image (top) contrasted with an ARIS image of a free-swimming Chinook salmon (bottom).



**Figure A1-3.**– Relationships between focal length and lens position for ARIS.

Appendix A 2.–Manufacturer specifications for sonar models ARIS 1200, ARIS 1800, DIDSON SV, and DIDSON LR.

1. **ARIS 1800 Specifications:**

**Detection Mode**

Operating Frequency 1.1 MHz  
Beamwidth (two-way) 0.5° H by 14° V  
Source Level (average) ~200-206 dB re 1  $\mu$ Pa at 1 m (*TBD*)  
Nominal Effective Range 35m

**Identification Mode**

Operating Frequency 1.8 MHz  
Beamwidth (two-way) 0.3° H by 14° V  
Source Level (average) ~200-206 dB re 1  $\mu$ Pa at 1 m (*TBD*)  
Nominal Effective Range 15m

**Both Modes**

Number of beams 96 or 48  
Beam Spacing 0.3° nominal  
Horizontal Field-of-View 28°  
Max frame rate (96 beams) 3-15 frames/s (6-15 frames/sec w/48 beams)  
Minimum Range Start 0.7m  
Downrange Resolution 3mm to 10cm  
Transmit Pulse Length 4 $\mu$ s to 100 $\mu$ s  
Remote Focus 0.7m to max range  
Power Consumption 15 Watts typical  
Weight in Air 5.5 kg (12.1 lb)  
Weight in Water *TBD*, ~1.4kg (3 lb)  
Dimensions 31cm x 17cm x 14cm  
Depth rating 300m  
Data Comm Link 100BaseT Ethernet  
Maximum cable length (Ethernet) 90m (300 feet)

2. **ARIS 1200 Specifications:**

**Detection Mode**

Operating Frequency 0.7 MHz  
Beamwidth (two-way) 0.8° H by 14° V  
Source Level (average) ~206-212 dB re 1  $\mu$ Pa at 1 m (*TBD*)  
Nominal Effective Range 80m

**Identification Mode**

Operating Frequency 1.2 MHz  
Beamwidth (two-way) 0.5° H by 14° V  
Source Level (average) ~206-212 dB re 1  $\mu$ Pa at 1 m (*TBD*)  
Nominal Effective Range 25m

**Both Modes**

Number of beams 48  
Beam Spacing 0.3° nominal  
Horizontal Field-of-View 28°  
Max frame rate (range dependent) 2.5-15 frames/s  
Minimum Range Start 0.7m  
Downrange Resolution 3mm to 10cm  
Transmit Pulse Length 4 $\mu$ s to 100 $\mu$ s  
Remote Focus 0.7m to max range  
Power Consumption 15 Watts typical  
Weight in Air 5.5 kg (12.1 lb)  
Weight in Water *TBD*, ~1.4kg (3 lb)  
Dimensions 31cm x 17cm x 14cm  
Depth rating 300m

Data Comm Link 100BaseT Ethernet  
Maximum cable length (Ethernet) 90m (300 feet)

### 3. DIDSON SV Specifications

#### **Detection Mode**

Operating Frequency 1.1 MHz  
Beamwidth (two-way) 0.4° H by 14° V  
Number of Beams 48  
Beam Spacing 0.6°  
(Extended) Window Start 0.83m to 52.3m in 0.83m steps  
(Extended) Window Length 5m, 10m, 20m, 40m  
Range Bin Size (relative to window length) 10mm, 20mm, 40mm, 80mm  
Pulse Length (relative to window length) 18µs, 36µs, 72µs, 144µs

#### **Identification Mode**

Operating Frequency 1.8 MHz  
Beamwidth (two-way) 0.3° H by 14° V  
Number of Beams 96  
Beam Spacing 0.3°  
(Extended) Window Start 0.42m to 26.1m in 0.42m steps  
(Extended) Window Length 1.25m, 2.5m, 5m, 10m  
Range Bin Size (relative to window length) 2.5mm, 5mm, 10mm, 20mm  
Pulse Length (relative to window length) 4.5µs, 9µs, 18µs, 36µs

#### **Both Modes**

Max Frame Rate (range dependent) 4-21 frames/s  
Field-of-view 29°  
Remote Focus 1m to Infinity  
Control & Data Interface UDP Ethernet  
Aux Display NTSC Video  
Max cable length (100/10BaseT) 61m/152m (200ft/500ft)  
Max cable length (twisted pair, Patton Extender) 1220m (4000ft)  
Max cable length (fiber optics) kilometers  
Power Consumption 25 Watts typical  
Weight in Air 7.9 kg (17.4 lb)  
Weight in Sea Water 1.0 kg (2.2 lb)  
Dimensions 31.0cm x 20.6cm x 17.1cm  
Topside PC Requirements Windows (XP, Vista, 7), Ethernet  
Optional NTSC video monitor

### 4. DIDSON LR Specifications

#### **Detection Mode**

Operating Frequency 0.7 MHz  
Beamwidth (two-way) 0.8° H by 14° V  
Number of Beams 48  
Beam Spacing 0.6°  
Extended Range Settings  
(Extended) Window Start 0.83m to 52.3m in 0.83m steps  
(Extended) Window Length 10m, 20m, 40m, 80m  
Range Bin Size (relative to window length) 20mm, 40mm, 80mm, 160mm  
Pulse Length (relative to window length) 23µs, 46µs, 92µs, 184µs

#### **Identification Mode**

Operating Frequency 1.2 MHz  
Beamwidth (two-way) 0.5° H by 14° V  
Number of Beams 48  
Beam Spacing 0.3° nominal  
Extended Range Settings  
(Extended) Window Start 0.42m to 26.1m in 0.42m steps  
(Extended) Window Length 2.5m, 5m, 10m, 20m  
Range Bin Size (relative to window length) 5mm, 10mm, 20mm, 40mm

Pulse Length (relative to window length) 7 $\mu$ s, 13 $\mu$ s, 27 $\mu$ s, 54 $\mu$ s  
*Both Modes*  
Max Frame Rate (range dependent) 2-21 frames/s  
Field-of-view 29°  
Remote Focus 1m to Infinity  
Control & Data Interface UDP Ethernet  
Aux Display NTSC Video  
Max cable length (100/10BaseT) 61m/152m (200ft/500ft)  
Max cable length (twisted pair, Patton Extender) 1220m (4000ft)  
Max cable length (fiber optics) kilometers  
Power Consumption 25 Watts typical  
Weight in Air 7.9 kg (17.4 lb)  
Weight in Sea Water 1.0 kg (2.2 lb)  
Dimensions 31.0cm x 20.6cm x 17.1cm  
Topside PC Requirements Windows (XP, Vista, 7), Ethernet  
Optional NTSC video monitor

**APPENDIX B. PROCEDURES FOR DAILY DIDSON  
PROCESSING**

**Appendix B1.-** Steps for daily DIDSON processing using batch files.

## **DAILY DIDSON PROCESSING STEPS – Kenai River Chinook Sonar RM-9**

Last updated by Debby Burwen 4-20-2012

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- **Raw Data Transfer and Storage**

Edit then run **didsondownload.bat** (located in **O:\didson12\Batch**) to move/sort data from thumb drives to processing directory on the Network Storage Device.

1. Change Julian date
2. Change the Calendar date
3. Change the drive label(s) for the jump drives if needed (you will see the drive label when you plug the drive in)

- **Manual Target Measurement**

1. Using DIDSON Application (remember: it's free software!), process .ddf files for manual measurement of targets. Basic sequence of events:
2. Open file, create echogram, measure targets, save file <e>, deselect echogram, advance to next file (black right arrow)

*\*See appendices B3 and D1 for more tracking details and appropriate software settings/parameters.*

3. At the end of a strata's worth of data, verify that you have not skipped any files, and log targets of interest (if you haven't already done so). Verify that file sizes are ~ the same (a check on sample length).
4. Edit the **dsamples.txt** file (located in **R:\upload**). This file is used by SAS to identify any missing samples and is uploaded each day for SAS database analysis. This file is best modified in the file **2012 DIDSON daily summary of data quality.xls** (R:\spreadsheets), then copied into the **dsamples.txt** file in notepad using a copy/paste command (needs to be a "tab" delimited file). Copy dsamples.txt to the data directory for that day (e.g. to **R:\Data2012\2012-08-02\_JD214**)

*\*See appendix B4 for more detail on editing the dsamples file and uploading data.*

Once all data for the day is completed:

5. Edit then run **package didson.bat** (**N:\didson12\Batch**), this program moves the completed target data txt files AND dsamples.txt to (**N:\didson12\Upload**) folder to facilitate post processing using database analysis (SAS, Access, Excel)

## Appendix B2.-Primer on Batch (.bat) files.

Batch files are text files containing a series of commands intended to be executed by a command interpreter. When a batch file is run, the shell program (usually COMMAND.COM or cmd.exe) reads the file and executes its commands, normally line-by-line. Batch files are useful for running a sequence of executables automatically and are often used to automate tedious processes.

Before executing a batch file, first edit (right mouse click, <Edit>, and <Run>) the file for the correct assignment of Julian (ordinal) date, Date, Data Set, and drive path. Then save the file with the updated settings before running batch.

**Table B2-1.**List of Batch files and functions currently used in DIDSON data processing:

Batch File Name	Function
DIDSON.bat	Transfers DIDSON data from jump drives delivered from camp to the Network Area Storage (SAN – also referred to as SAN in batch files): <ul style="list-style-type: none"> <li>• Creates directory structure for storing each days data by Julian Date\bank\stratum\set</li> <li>• <b>Renames</b> each file by inserting an R for right bank files and L for left bank (determines bank by sample time in filename)</li> <li>• <b>Moves</b> data from jump drives to appropriate directory</li> </ul>
Package didson.bat	Moves .txt files (for a given Julian Date) AND dsamples.txt to a directory (N:\didson12\Upload) to facilitate processing and summarizing with SAS, Access, Excel
Resort didson.bat	Resorts data files into original directories on the SAN if there is an error during uploading
Move txt files.bat	Moves .txt files (files with measured lengths) created by SMC software back into the SAN directories (R:\julian date\bank\stratum\set) if necessary (e.g. failure of Package DIDSON batch file below, or ?)
<b>Echoview-related batch files</b> – <i>currently not used but available when/if Echoview processing is resumed</i>	
Build directory.bat	Builds directory structure for Echoview-related files
Fetch CSOT files.bat	Copies CSOT files generated by SMC software to the Echoview directory for processing
Package csv.bat	Moves .csv files (contain auto-sizing estimates)n created during Echoview processing



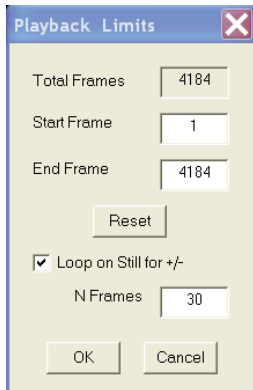
Appendix B3.-DIDSON Control and Display Software Settings and Tools for Tracking using Manual Measurements at river mile 8.6.

Open .ddf file

Check Processing>Background>**Background Subtraction** is **ENABLED**

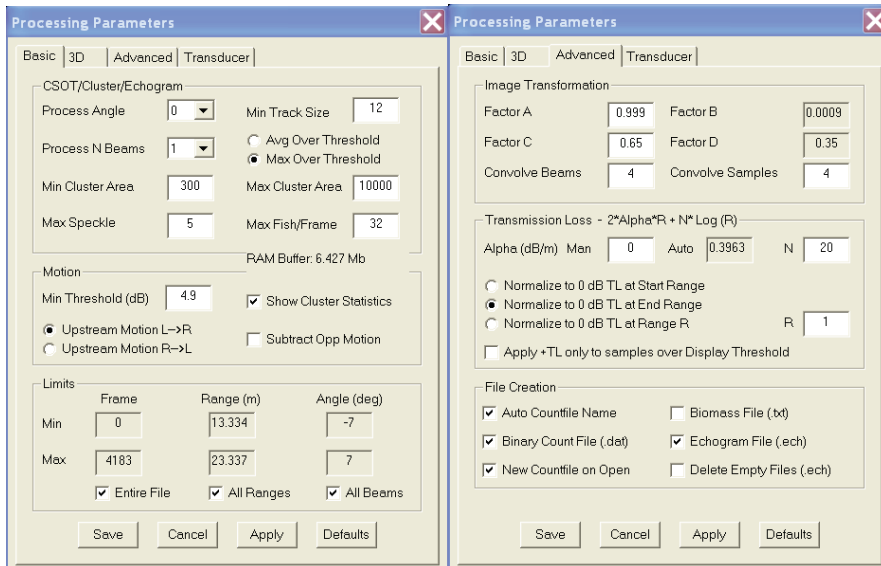
Check Image>Configure>**Auto Threshold/Intensity** is **DISABLED**

Check Image>Playback>Set Endpoints to **ENABLE Loop on Still for +/-** for **N frames 30** (discretional 20-30)



Check Processing>Echogram>**Use Cluster Data** is **ENABLED**

Check Processing>Show Parameters for correct direction of travel (**Motion**) for bank you are tracking (Basic Tab), and **File Creation** and **Transmission Loss** (Advanced Tab).



Ensure display controls are properly adjusted (unique to each strata):

Strata 1: Intensity 50, Threshold 11

Strata 2: Intensity 50, Threshold 11

Strata 3: Intensity 45, Threshold 10

## Helpful Tips

Ensure you can view the entire echogram- if you can't see the range hash marks, you need to expand the screen further with Toggle Header control and/or manually dragging EG window.

Toggling between movie mode and echogram mode- Right mouse click on echogram to see looped movie at same echogram time stamp. Spacebar will pause loop.

Mark targets in EG mode with mouse left click, and try to do so somewhere on target track, because this also logs target range. Right mouse click inside target marker to toggle to movie mode for manual measurement. Zoom into target by mouse right click and diagonally dragging a focal window. Use forward/reverse arrow keys to advance through frames for optimum image measurement. Note that direction of travel is logged based on how you measure the target (head to tail). Press <F> to log target. Note that echogram will now indicate target length and direction of travel (Blue marker=downstream, Yellow=Upstream).

\*Some targets may hold/linger in the beam and should not be tracked unless you deem them to have made sufficient progress up or down stream. Significant over estimation of fish could occur if everything in the beam were tracked/measured without regard for upstream progress.

\*Some targets may glance the corners of the beam, if you feel these targets do not provide sufficient direction of travel information, or that they may be dipping in and out of the beam throughout the sequence, use your discretion at tracking. When Chinook fall into this marginal category, give them closer attention than smaller targets, as missing a small target is less important than missing a KING.

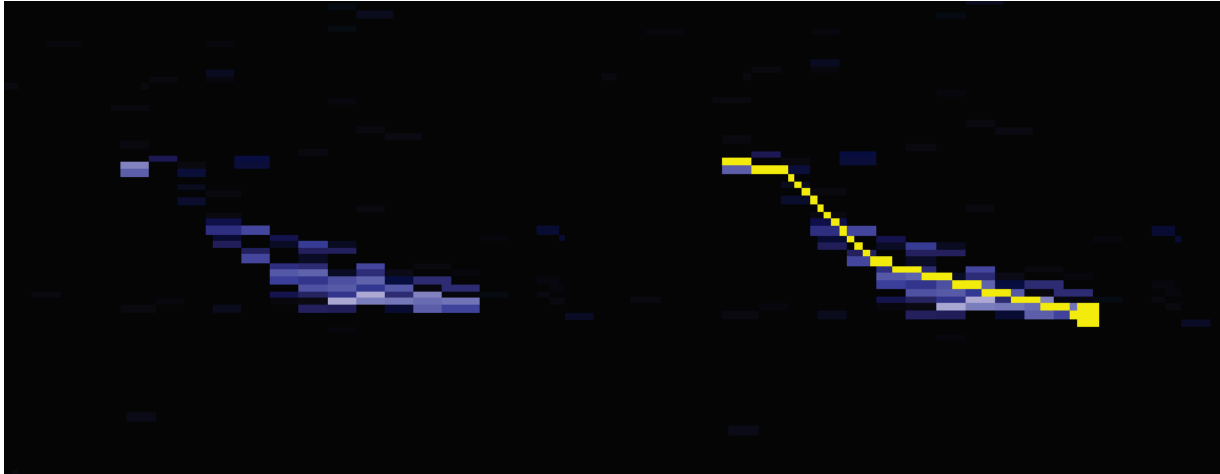
\*Use all the tools at your disposal- the echogram provides a roadmap to not only where targets occur in the sequence, but often gives strong clues to what the target species is. Trace intensity, length, and tail beat amplitude/frequency give you information that comes in handy before you toggle to video mode. Video mode and the video loop allow you to better sort out number, behavior, and location of targets in especially complex sequences.

Press <E> to save your work on each sequence when complete (or before you divert to another task).

## Hot Keys

D	Delete all line segments
U	Delete last line segment
Space Bar	Pause movie loop
R/L Arrow	Advance/Retreat movie frame
L Click Drag	Display movie loop of selected echogram time stamp
R Click Drag	Zoom into selected movie target area
F	“Fish” Target
E	Save tracked sequence

Example of Appropriate Target Picture (and same with three segment manual measurement):



### **Known issues/bugs**

Use of Fixed Background function (Processing>Background>Fixed Background) sometimes causes the Background Subtraction function to become inoperable when advancing to subsequent files. This usually necessitates restarting the DIDSON software. Additionally, use of this function during tracking is necessary if you have reason to scrutinize target(s) by repeated advancing and retreating frames. Under this circumstance, background subtraction will make target more and more diffuse unless fixed background function is enabled.

During length measurements, sometimes the initial mouse click on the target does not work. This missed mark just means that you have to first delete your second mark and retry first.

Some settings are saved, while others may default to undesired values. It is wise to periodically check your settings to confirm. Oftentimes a change in settings will be apparent during normal tracking and quickly corrected.

Appendix B4.-Creating and Editing the dsamples.txt file for SAS processing.

Edit the **dsamples.txt** file (**R:\upload**). This file is used by SAS to identify any missing samples and is uploaded each day for SAS database analysis. This file is best modified in the file **2012 DIDSON daily summary of data quality.xls** (R:\spreadsheets), then copied into the **dsamples.txt** file in notepad using a copy/paste command (needs to be a “tab” delimited file). **Copy dsamples.txt to the data directory for that day (e.g. to R:\Data2012\2012-08-02\_JD214)**

	A	B	C	D	E	F	G	H	I
1									
2	jd	h	R1	R2	R3	L1	L2	L3	
3	137	0	1	1	1	0	0	0	
4	137	1	1	1	1	0	0	0	
5	137	2	1	1	1	0	0	0	
6	137	3	1	1	1	0	0	0	
7	137	4	1	1	1	0	0	0	
8	137	5	1	1	1	0	0	0	
9	137	6	1	1	1	0	0	0	
10	137	7	1	1	1	0	0	0	
11	137	8	1	1	1	0	0	0	
12	137	9	1	1	1	0	0	0	
13	137	10	1	1	1	0	0	0	
14	137	11	1	1	1	0	0	0	
15	137	12	1	1	1	0	0	0	
16	137	13	1	1	1	0	0	0	
17	137	14	1	1	1	0	0	0	
18	137	15	1	1	1	0	0	0	
19	137	16	1	1	1	0	0	0	
20	137	17	1	1	1	0	0	0	

**APPENDIX C. INSTRUCTIONS FOR MANUAL FISH  
MEASUREMENTS AT RM 8.6 USING SMC CONTROL AND DISPLAY  
SOFTWARE VERSION 5.25**

**Appendix C1.- Instructions and settings used for manual length measurements from DIDSON images in 2013 at RM 8.6 using SMC Control and Display Software Version 5.25.28.**

**a. Parameter setup prior to beginning measurements:**

- Step 1. set the number of frames displayed (i.e., when right-clicking on a fish in echogram mode to display in movie mode) from the default of plus minus one second to +/- any number of frames:
1. Select **<image><playback><set endpoints>**
  2. [] Loop on still for +/- N frames
  3. Enter the number of frames (I suggest 20-30) but you be the judge
- Step 2. Select **<Processing><Echogram><Use Cluster Data>** if you want to use ALL the beams when creating your Echogram (we generally do). You can use fewer beams by unchecking this option and selecting the number of beams.
- Step 3. Set up your **processing parameters** (last Icon on right) for **File Creation** as follows:
- ✓ Auto Countfile Name
  - ✓ Binary Count File (.dat)
  - ✓ New Countfile on Open
  - ✓ Echogram File (.ech)
- Step 4. Echogram counts can be reloaded to finish or review at a later time if you have checked the Echogram file as follows:
1. Select **<File><Open> then Files of type .ech** from drop-down menu
  2. Open desired file
  3. The Echogram should reload showing you your previous measurements
- Or this option will work as long as you saved the .dat file (as shown above)
1. Open the file and bring up your echogram as usual (follow instructions below)
  2. Select **<Processing><Echogram><Import Echogram Counts>**
  3. Select the **.dat** file with your saved counts – file should reload showing you your previous measurements (the filename for the .dat file will begin with **FC\_**)
- Step 5. Make sure **<Image><Configure><Auto Threshold/Intensity>** is **UNCHECKED**. This will keep your threshold and intensity settings from changing when you switch between echogram and movie mode
- Step 6. Uncheck the 'Display Raw Data' toolbar icon (first button on left in Combined toolbar). (If you are in the movie mode and it is displaying the raw image data, it is because 'Display Raw Data' is enabled by default).

**b. Instructions for manual echogram-based length measurements**

**\*note that these settings may already be active as some of them have “memory” and are saved until changed**

1. Select **<BS>** (for background subtraction) from toolbar - or under **<Processing><Background><Background Subtraction>**
2. Select **<Processing><Background><Fixed Background>**
3. Select threshold and range settings given in **Table C1-1** (To adjust these settings, use the slider bars under Display Controls to the left of the echogram).
4. Select the threshold and intensity settings for each range strata as indicated below. To adjust these settings, use slider bars under the Display Controls to the left side of the Echogram or Movie window.
5. Select **<EG>** (for view Echogram) from toolbar or under **<Processing><Echogram><View echogram>**
6. **<left click>** on the echogram near/on the fish trace of interest to “mark it” - you should see a white circle
7. **<right click>** **INSIDE** the white circle to switch to movie mode (movie mode will play the 16 frames encompassing this circle continuously)
8. Press **<space bar>** to pause movie
9. Step through the movie frames using the right or left arrows until you find a frame that you think displays the entire length of the fish well (see section C below for selecting optimal images).

10. <right mouse click drag> will magnify the area in the rectangle
11. <left click> on the FISH SNOUT and continue to <left click> along the body to create a “segmented measurement.”  
*The segments should follow the midline of the body of the fish – ending with the tail. Try not to use more than three or four segments to define the fish (see section C below)*
12. <double left click> or select <f> key to add measurement to file (fish it!)
13. <right click> to unzoom
14. <right click> to return to Echogram

### Hot keys:

1. <e> to “save” all echogram measurements to file
2. <f> to “fish it” (to accept the measurement and display it on the echogram)
3. <u> to “undo” the last segment
4. <d> to “delete” the all segments
5. <space bar> to pause in movie mode (if this doesn’t work – click in the black area of the display)
6. <right arrow> forward direction when you select play or advances frame one at a time if the pause button is on (pause button = blue square on the toolbar)
7. <left arrow> opposite of above
8. **Left Click Drag** – to show movie over the selected time
9. **Right Click Drag** – zooms the selected area

**Table C1-1.-**Threshold and intensity settings for range strata. To adjust these settings, use slider bars under the Display Controls to the left side of the Echogram or Movie window.

	3.3-8.3m	8.3-13.3m	13.3-23.3m	23.3-33.3m
<b>Threshold</b>	11	11	10	9
<b>Intensity</b>	50	50	45	40

### c. Selecting optimal images to measure

Measurements should be taken from frames where contrast between the fish image and background are high and where the fish displays its full length (e.g. Panels a, d, and f in [Figure C1-1](#)). In general, the best images are obtained when the fish is sinusoidal in shape (rather than straight and perfectly perpendicular) because the head and tail appear most visible when there is curvature to the fish body (e.g. [Figure C1-2](#)). [Figure C1-2](#) demonstrates the process of measuring a fish using the manual measuring tool. The user pauses the DIDSON movie (top), zooms in on the fish of interest (middle), and measures the fish length with a segmented line created by mouse clicks along the center axis of the fish (bottom). The first mouse click is made at the leading edge of the pixel associated with the snout and the final click on the trailing edge of the pixel associated with the tail. The software adds the individual segment lengths that are calculated from the pixel coordinates of the DIDSON image.

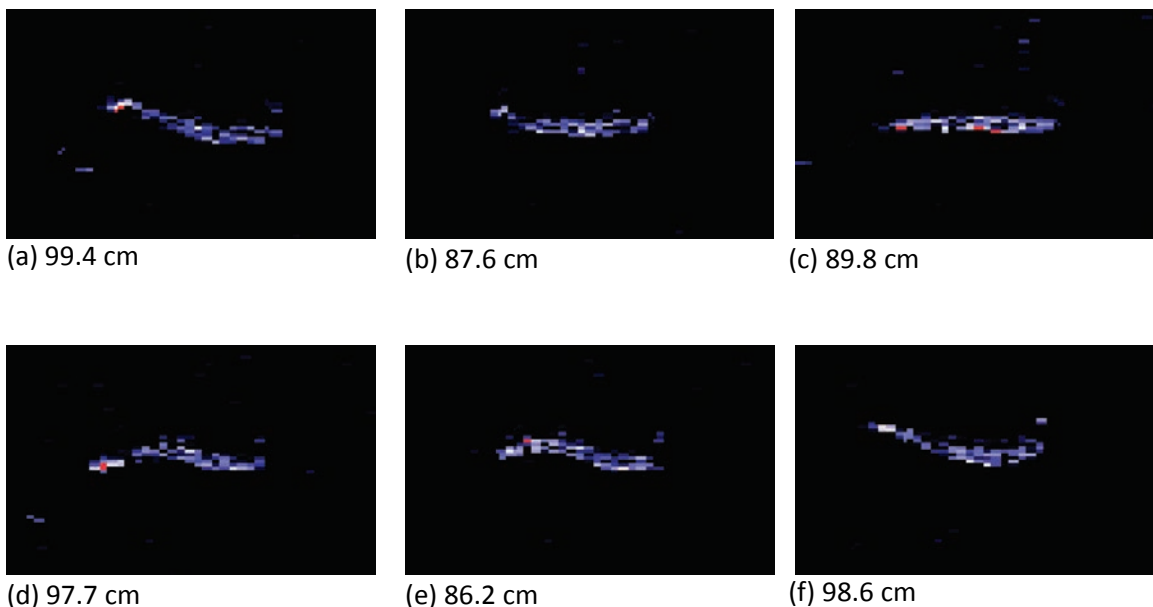
### Helpful Tips

- Ensure you can view the entire echogram- if you can’t see the range hash marks, you need to expand the screen further with Toggle Header control and/or manually dragging EG window.
- Toggling between movie mode and echogram mode- Right mouse click on echogram to see looped movie at same echogram time stamp. Spacebar will pause loop.
- Mark targets in EG mode with mouse left click, and try to do so somewhere on target track, because this also logs target range. Right mouse click inside target marker to toggle to movie mode for manual measurement. Zoom into target by mouse right click and diagonally dragging a focal window. Use forward/reverse arrow keys to advance through frames for optimum image measurement. Note that direction of travel is logged based on how you measure the target (head to tail). Press <F> to log target. Note that echogram will now indicate target length and direction of travel (Blue marker=downstream, Yellow=Upstream).

- Some targets may hold/linger in the beam and should not be tracked unless you deem them to have made sufficient progress up or down stream. Significant over estimation of fish could occur if everything in the beam were tracked/measured without regard for upstream progress.
- Some targets may glance the corners of the beam, if you feel these targets do not provide sufficient direction of travel information, or that they may be dipping in and out of the beam throughout the sequence, use your discretion at tracking. When Chinook fall into this marginal category, give them closer attention than smaller targets, as missing a small target is less important than missing a KING.
- Use all the tools at your disposal- the echogram provides a roadmap to not only where targets occur in the sequence, but often gives strong clues to what the target species is. Trace intensity, length, and tail beat amplitude/frequency give you information that comes in handy before you toggle to video mode. Video mode and the video loop allow you to better sort out number, behavior, and location of targets in especially complex sequences.
- Press <E> to save your work on each sequence when complete (or before you divert to another task).

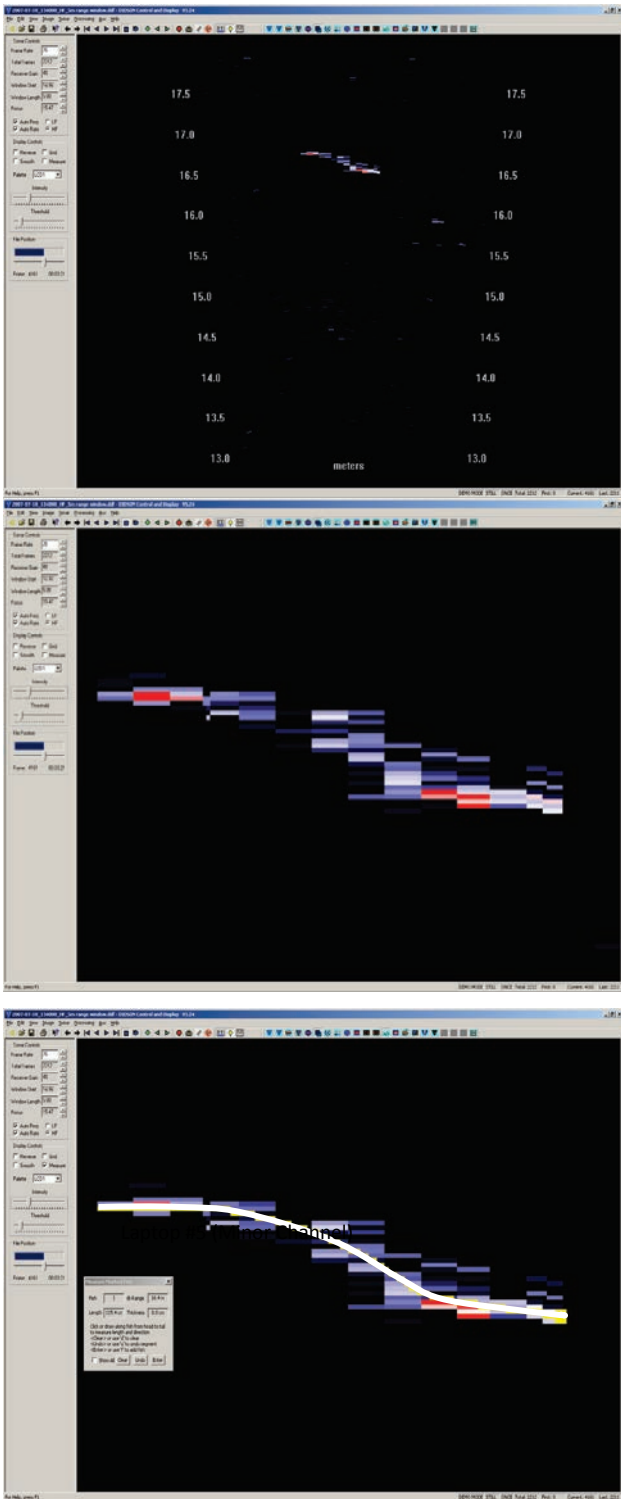
### Known issues/bugs

- Use of Fixed Background function (Processing>Background>Fixed Background) sometimes causes the Background Subtraction function to become inoperable when advancing to subsequent files. This usually necessitates restarting the DIDSON software. Additionally, use of this function during tracking is necessary if you have reason to scrutinize target(s) by repeated advancing and retreating frames. Under this circumstance, background subtraction will make target more and more diffuse unless fixed background function is enabled.
- During length measurements, sometimes the initial mouse click on the target does not work. This missed mark just means that you have to first delete your second mark and retry first.
- Some settings are saved, while others may default to undesired values. It is wise to periodically check your settings to confirm. Oftentimes a change in settings will be apparent during normal tracking and quickly corrected.



**Figure C1-1.** – Panels a-f show the variability in length measurements from DIDSON images of a tethered Chinook salmon during one full tail-beat cycle (adapted from Burwen et al. 2010).





**Figure C1-2.** – DIDSON images from a tethered Chinook salmon showing the original DIDSON image (top), the zoomed image (middle), and the segmented lines that result when the observer clicks along the length of the fish to mark its length (bottom). Adapted from Burwen et al. 2010.

**APPENDIX D. DIDSON LENGTH MIXTURE MODEL AND  
ASSOCIATED BUGS PROGRAM CODE**

## Appendix D1.– Mixture model for estimating species composition of migrating fish.

Mixture models are useful for extracting information from the observed frequency distribution of a carefully-selected measurement. If one were able to observe the exact length, but not the species, of every fish passing the sonar in the Kenai River, the distribution of such measurements might look something like Figure D1-1. Given additional knowledge about the size of sockeye and Chinook salmon, the shape of the overall distribution can reveal much about the relative abundance of sockeye and Chinook. For instance, if it is known that sockeye salmon do not exceed 70 cm in length, and that small Chinook are very rare, one can conclude that the left hand mode of the distribution is composed almost entirely of sockeye salmon and that the species composition is perhaps 50/50 sockeye/Chinook. Mixture model analysis is merely a quantitative version of this assessment, in which the shape of the overall frequency distribution is modeled and “fitted” until it best approximates the data. Uncertainty is assessed by providing a range of plausible species compositions that could have resulted in the observed frequency distribution.

As another example, imagine that there are substantial numbers of small Chinook, and that there is error in the length measurements. The effect of the measurement error is to cause the modes to begin to overlap, reducing the ability to detect detail in the length distribution and reducing the precision of the estimates. Under this scenario it is still possible to make subjective assessments about the true species composition, but to quantify the uncertainty is more difficult. Mixture models provide an objective way to accomplish this.

Such a model can be conducted on any quantity related to length, including length as measured from DIDSON images (“Dlength”). Given knowledge of the relationship between length and the observed quantity (e.g., Burwen et al. 2010), it is straightforward to convert from length units to the new units by including the slope, intercept, and mean squared error of the relationship in the mixture model (Equation 10 below). The more closely related the surrogate measurement is to the one of interest, the more the two distributions will resemble each other and the better the resulting estimate will be. Since Dlength is a reasonably good predictor of fish length (Figure D1-2; Burwen et al. 2010) the observed frequency distribution of Dlength supplies valuable information about species composition, even though there is some overlap of Dlength measurements between species.

The Dlength mixture model is described below. See also Fleischman and Burwen (2003) and Miller et al. (2012) for a similar model using split-beam echo length as the hydroacoustic variable.

The probability density function (pdf) of hydroacoustic variable  $y$  (= Dlength) is modeled as a weighted mixture of two component distributions arising from sockeye and Chinook salmon (Figure D1-3),

$$f(y) = \pi_s f_s(y) + \pi_c f_c(y) \quad (D1.1)$$

where  $f_s(y)$  and  $f_c(y)$  are the pdf’s of the sockeye and Chinook component distributions, and the weights  $\pi_s$  and  $\pi_c$  are the proportions of sockeye and Chinook salmon in the population.

Individual observations of  $y$  are modeled as normal random variates whose mean is a linear function of fish length  $x$ :

$$y_i = \beta_0 + \beta_1 x_i + \varepsilon_i \quad (D1.2)$$

where  $\beta_0$  is the intercept;  $\beta_1$  the slope; and  $\varepsilon_i$  is normally distributed with mean 0 and variance  $\sigma^2$ . Thus the component distributions  $f_s(y)$  and  $f_c(y)$  are functions of the length distributions  $f_s(x)$  and  $f_c(x)$  and the linear model parameters  $\beta_0$ ,  $\beta_1$ , and  $\sigma^2$  (Figure D1-3). The species proportions  $\pi_s$  and  $\pi_c$  are the parameters of interest.

Length measurements are obtained from fish captured by gillnets (e.g., Eskelin 2010) immediately downstream of the sonar site. Length data are paired with hydroacoustic data from the same time periods. In this version of the analysis, we assume no gillnet size selectivity.

Sockeye and Chinook salmon return from the sea to spawn at several discrete ages. We modeled sockeye and Chinook length distributions as three-component normal age mixtures.

$$f_S(x) = \theta_{S1} f_{S1}(x) + \theta_{S2} f_{S2}(x) + \theta_{S3} f_{S3}(x) \quad (D1.3)$$

$$f_C(x) = \theta_{C1} f_{C1}(x) + \theta_{C2} f_{C2}(x) + \theta_{C3} f_{C3}(x) \quad (D1.4)$$

where  $\theta_{Ca}$  and  $\theta_{Sa}$  are the proportions of Chinook and sockeye salmon belonging to age component a,

$$f_{Sa}(x) \sim N(\mu_{Sa}, \tau_{Sa}^2), \text{ and} \quad (D1.5)$$

$$f_{Ca}(x) \sim N(\mu_{Ca}, \tau_{Ca}^2). \quad (D1.6)$$

The overall design is therefore a mixture of (transformed) mixtures. That is, the observed hydroacoustic data are modeled as a two-component mixture of y, each component of which is transformed from a three-component normal mixture of x.

Bayesian statistical methods will be employed because they provide realistic estimates of uncertainty and the ability to incorporate auxiliary information. We will implement the Bayesian mixture model in WinBUGS (Bayes Using Gibbs Sampler; Gilks et al. 1994). Bayesian methods require that prior probability distributions be formulated for all unknowns in the model. Species proportions  $\pi_S$  and  $\pi_C$  are assigned an uninformative Dirichlet(1,1) prior. Age proportions  $\{\theta_{Sa}\}$  and  $\{\theta_{Ca}\}$  are assigned informative Dirichlet priors based on a hierarchical analysis of historical data (Appendix D5). Likewise, informative normal priors based on historical data are used for the length-at-age means  $\mu$  and standard deviations  $\tau$ . Prior information about regression parameters  $\beta_0$ ,  $\beta_1$ , and  $\sigma^2$  is supplied by embedding an analysis of a subset<sup>6</sup> of tethered fish data in the mixture model (Figure D1-2).

WinBUGS uses Markov chain Monte Carlo methods to sample from the joint posterior distribution of all unknown quantities in the model. We will start at least two Markov chains for each run and monitor Gelman-Rubin statistics to assess convergence. Burn-in periods of 10,000 or more samples will be used. Samples will be thinned 10 to 1, and at least 10,000 samples per chain will be retained.

The end product of a Bayesian analysis is the joint posterior probability distribution of all unknowns in the model. For point estimates, the posterior mean will be used. The posterior standard deviation will be presented as an analogue to the standard error of an estimate from a frequentist (non-Bayesian) statistical analysis.

The mixture model will be fit to daily DIDSON length data but will utilize 7 days of netting data ending on the date of the current DIDSON lengths.

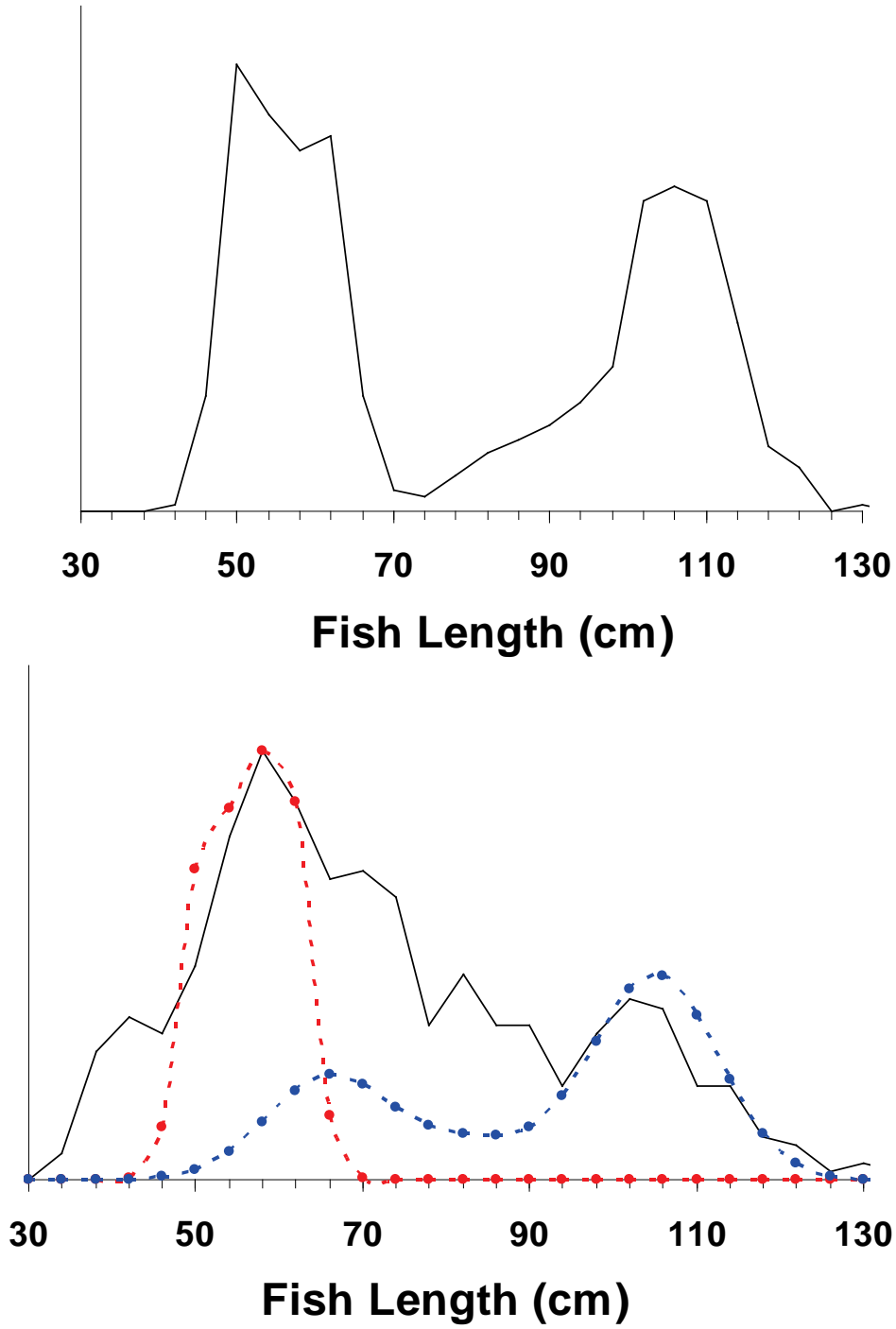
During times when it is impractical to measure every fish recorded by the DIDSON, a “Fast-Track” sampling protocol will be adopted (Table 1), and fish measuring less than 75 cm (DL) will be counted but not measured. These fish will be modeled accordingly, as having come from a left-censored sample. The model for censored observations is specified in the last paragraph of WinBUGS code in Appendix D3.

By default, data will be stratified by day, i.e., daily data from different spatial/temporal strata will be pooled and the above model fit to the pooled data (Equation 5). Sample size limitations may occasionally necessitate

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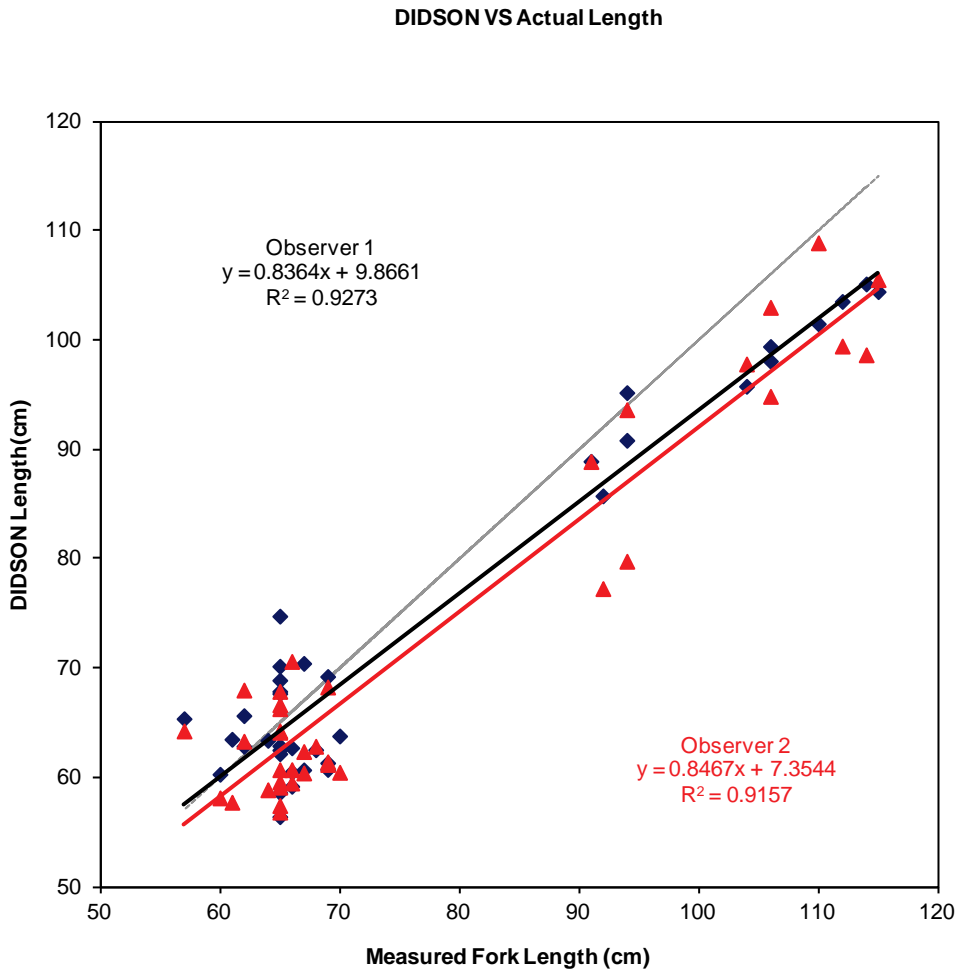
<sup>6</sup> Preliminary work has shown that DIDSON length measurements of tethered fish data are not necessarily representative of measurements from free-swimming fish. Therefore, inclusion of the entire tethered fish data set can bias mixture model results. Fortunately, only weak prior information about the regression parameters is required in order to estimate species composition with the DIDSON length mixture model, and this can be supplied by using only a small subset (n=5) of tethered fish data, which does not cause substantial bias in the species composition estimates.

pooling the data across more than one day. Changes will not be made to stratification structure during the season. Situations that would warrant a (post-season) revision to the estimates include (1) sampling fraction differing greatly among spatial/temporal strata, or (2) evidence that the slope and intercept parameters differ by stratum. In such cases, the data will be divided into appropriate groups before analysis, and spatial and temporal expansions will be specific to each group.

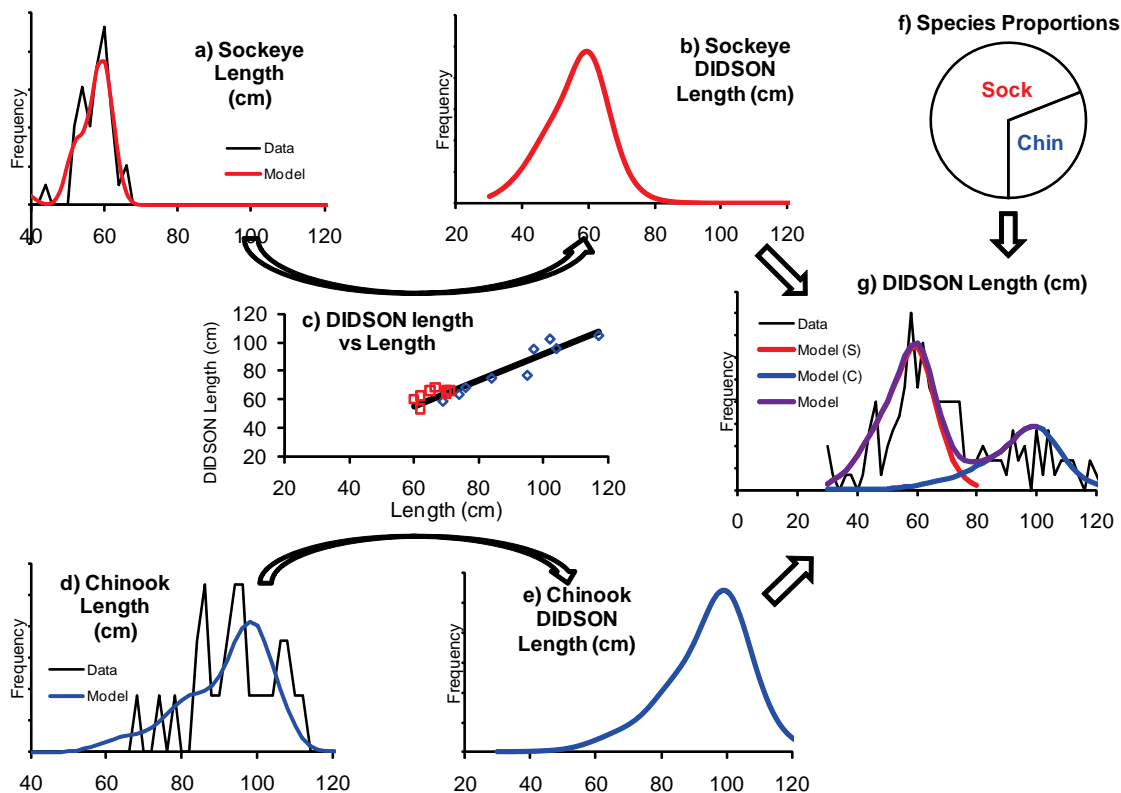


**Figure D1-1.-** Hypothetical distributions of fish length measurements (black solid lines) from the Kenai River. (a, top) Few small Chinook salmon, no measurement error. (b, bottom) 40% of Chinook salmon are small,

measurement error standard deviation = 10 cm. Distributions of sockeye (red dashed line) and Chinook (blue dashed line) true length are shown in case b. In both cases the true species composition is 50% sockeye 50% Chinook.



**Figure D1-2.-**Relationship between DIDSON-based length measures and fork length for two independent observers in 2007. Results are from 37 tethered salmon insonified by a DIDSON-LR sonar with a high-resolution lens at RM-8.6 site.



**Figure D1-3.-**Flow chart of the DIDSON length mixture model described in the text. The frequency distribution of DIDSON length measurements (panel g) is modeled as a weighted mixture of species-specific distributions (b and e), which in turn are the products of species-specific size distributions (a and d) and the relationship between DIDSON-measured length and true length (c). The weights (species proportions, panel f) are the parameters of interest.

**Appendix D2.**– WinBUGS code for mixture model, under standard data processing protocol. Prior distributions in green font, likelihoods in blue.

```

model{
  beta0 ~ dnorm(75,0.0025) #subjective prior sd=20cm
  beta1 ~ dnorm(1,25)      #subjective prior sd=0.2
  sigma.DL ~ dunif(0,20)
  tau.DL <- 1 / sigma.DL / sigma.DL
  ps[1:2] ~ ddirch(D.species[])
  pa[1,1] ~ dbeta(B1,B2)
  theta1 ~ dbeta(B3,B4)
  pa[1,2] <- theta1 * (1 - pa[1,1])
  pa[1,3] <- 1 - pa[1,1] - pa[1,2]
  pa[2,1] ~ dbeta(0.5,0.5)
  theta2 ~ dbeta(0.5,0.5)
  pa[2,2] <- theta2 * (1 - pa[2,1])
  pa[2,3] <- 1 - pa[2,1] - pa[2,2]

  n.chin <- ps[1] * ntgts
  p.large <- ps[1] * (1 - pa[1,1])
  n.large <- p.large * ntgts

  Lsig[1,1] <- 78
  Lsig[1,2] <- 70
  Lsig[1,3] <- 74
  Lsig[2,1] <- 25
  Lsig[2,2] <- 25
  Lsig[2,3] <- 25
  for (s in 1:2) {for (a in 1:3) {Ltau[s,a] <- 1 / Lsig[s,a] / Lsig[s,a] } }
  mu[1,1] ~ dnorm(621,0.0076)
  mu[1,2] ~ dnorm(825,0.0021)
  mu[1,3] ~ dnorm(1020,0.0047)
  mu[2,1] ~ dnorm(380,0.0004)
  mu[2,2] ~ dnorm(500,0.0004)
  mu[2,3] ~ dnorm(580,0.0004)
  for (a in 1:3) {
    pa.effective[1,a] <- pa[1,a] * q1.a[a] / inprod(pa[1,],q1.a[])
    pa.effective[2,a] <- pa[2,a]
  }
  for (k in 1:5) {
    TL.cm.75[k] <- TL.cm[k] - 75
    mu.DL1[k] <- beta0 + beta1 * TL.cm.75[k]
    DL1[k] ~ dnorm(mu.DL1[k],tau.DL)
  }
  for (i in 1:nfish) {
    age[i] ~ dcat(pa.effective[species[i],1:3])
    mefl.mm[i] ~ dnorm(mu[species[i],age[i]],Ltau[species[i],age[i]])
  }
}

```

-continued-



**Appendix D2.**–Page 2 of 2.

```
for (j in 1:ntgts) {  
  species2[j] ~ dcat(ps[])  
  age2[j] ~ dcat(pa[species2[j],1:3])  
  mefl.mm.2[j] ~ dnorm(mu[species2[j],age2[j]],Ltau[species2[j],age2[j]])  
  TL2.cm.75[j] <- (1.1*mefl.mm.2[j] + 2) / 10 - 75 # CONVERSION TO TL  
  mu.DL2[j] <- beta0 + beta1 * TL2.cm.75[j]  
  DL2[j] ~ dnorm(mu.DL2[j],tau.DL)  
}  
}
```

**Appendix D3.**– WinBUGS code for mixture model, under fast-track data processing protocol. Prior distributions in green font, likelihoods in blue.

```

model{
  beta0 ~ dnorm(75,0.0025) #subjective prior sd=20cm
  beta1 ~ dnorm(1,25)      #subjective prior sd=0.2
  sigma.DL ~ dunif(0,20)
  tau.DL <- 1 / sigma.DL / sigma.DL
  ps[1:2] ~ ddirch(D.species[])
  pa[1,1] ~ dbeta(B1,B2)
  theta1 ~ dbeta(B3,B4)
  pa[1,2] <- theta1 * (1 - pa[1,1])
  pa[1,3] <- 1 - pa[1,1] - pa[1,2]
  pa[2,1] ~ dbeta(0.5,0.5)
  theta2 ~ dbeta(0.5,0.5)
  pa[2,2] <- theta2 * (1 - pa[2,1])
  pa[2,3] <- 1 - pa[2,1] - pa[2,2]

  n.upstr <- n_meas + n_small
  n.chin <- ps[1] * n.upstr
  p.large <- ps[1] * (1 - pa[1,1])
  n.large <- p.large * n.upstr

  Lsig[1,1] <- 78
  Lsig[1,2] <- 70
  Lsig[1,3] <- 74
  Lsig[2,1] <- 25
  Lsig[2,2] <- 25
  Lsig[2,3] <- 25
  for (s in 1:2) {for (a in 1:3) {Ltau[s,a] <- 1 / Lsig[s,a] / Lsig[s,a] } }
  mu[1,1] ~ dnorm(621,0.0076)
  mu[1,2] ~ dnorm(825,0.0021)
  mu[1,3] ~ dnorm(1020,0.0047)
  mu[2,1] ~ dnorm(380,0.0004)
  mu[2,2] ~ dnorm(500,0.0004)
  mu[2,3] ~ dnorm(580,0.0004)
  for (a in 1:3) {
    pa.effective[1,a] <- pa[1,a] * q1.a[a] / inprod(pa[1,],q1.a[])
    pa.effective[2,a] <- pa[2,a]
  }
  for (k in 1:5) {
    TL.cm.75[k] <- TL.cm[k] - 75
    mu.DL1[k] <- beta0 + beta1 * TL.cm.75[k]
    DL1[k] ~ dnorm(mu.DL1[k],tau.DL)
  }
  for (i in 1:n_fish) {
    age[i] ~ dcat(pa.effective[species[i],1:3])
    mefl.mm[i] ~ dnorm(mu[species[i],age[i]],Ltau[species[i],age[i]])
  }
}

```

-continued-

**Appendix D3.**–Page 2 of 2.

```
for (j in 1:n_meas) {
  species2[j] ~ dcat(ps[])
  age2[j] ~ dcat(pa[species2[j],1:3])
  mefl.mm.2[j] ~ dnorm(mu[species2[j],age2[j]],Ltau[species2[j],age2[j]])
  TL2.cm.75[j] <- (1.1*mefl.mm.2[j] + 2) / 10 - 75 # CONVERSION TO TL BASED ON NUSHAGAK 2001 DATA
  mu.DL2[j] <- beta0 + beta1 * TL2.cm.75[j]
  DL2[j] ~ dnorm(mu.DL2[j],tau.DL)
}
for (k in 1:n_small) {
  species3[k] ~ dcat(ps[])
  age3[k] ~ dcat(pa[species3[k],1:3])
  mefl.mm.3[k] ~ dnorm(mu[species3[k],age3[k]],Ltau[species3[k],age3[k]])
  TL3.cm.75[k] <- (1.1*mefl.mm.3[k] + 2) / 10 - 75
  mu.DL3[k] <- beta0 + beta1 * TL3.cm.75[k]
  DL3[k] ~ dnorm(mu.DL3[k],tau.DL)|(.70)
}
}
```

**Appendix D4.**– OpenBUGS code for daily abundance model, to be used when it is not possible to generate Chinook salmon passage estimates with DL mixture model. Prior distributions in green font, likelihoods in blue.

```

model{
q.gt80 ~ dnorm(0,1.0E-6)I(0,10)
tau.log.gt80 ~ dgamma(0.001,0.001)
phi.gt80 ~ dnorm(0,1.0E-4)I(-.8,.8)
log.resid.gt80.0 ~ dnorm(0,4)I(-3,3)
sigma.gt80 <- 1 / sqrt(tau.log.gt80)

q.ncpu ~ dnorm(0,1.0E-6)I(0,1)
tau.log.ncpu ~ dgamma(0.001,0.001)
phi.ncpu ~ dnorm(0,1.0E-4)I(-.8,.8)
log.resid.ncpu.0 ~ dnorm(0,4)I(-3,3)
sigma.ncpu <- 1 / sqrt(tau.log.ncpu)

mean.log.N ~ dnorm(0,1.0E-12)
tau.log.N ~ dgamma(0.01,0.01)
N.early <- sum(N[1:46])
N.late <- sum(N[47:87])

for (d in 1:D) {
  log.N[d] ~ dnorm(0,1.0E-12)I(0,)
  DID[d] ~ dlnorm(log.N[d],tau.log.DID[d])
  gt80[d] ~ dlnorm(log.q1Nmean2[d],tau.log.gt80)
  ncpu[d] ~ dlnorm(log.q2Nmean2[d],tau.log.ncpu)
  N[d] <- exp(log.N[d])
  tau.log.DID[d] <- 1 / log(cv.DID[d]*cv.DID[d] + 1)
  log.q1Nmean1[d] <- log(q.gt80 * N[d])
  log.resid.gt80[d] <- log(gt80[d]) - log.q1Nmean1[d]
  log.q2Nmean1[d] <- log(q.ncpu * N[d])
  log.resid.ncpu[d] <- log(ncpu[d]) - log.q2Nmean1[d]
}
log.q1Nmean2[1] <- log.q1Nmean1[1] + phi.gt80 * log.resid.gt80.0
log.q2Nmean2[1] <- log.q2Nmean1[1] + phi.ncpu * log.resid.ncpu.0
for (d in 2:D) {
  log.q1Nmean2[d] <- log.q1Nmean1[d] + phi.gt80 * log.resid.gt80[d-1]
  log.q2Nmean2[d] <- log.q2Nmean1[d] + phi.ncpu * log.resid.ncpu[d-1]
}
}

```

**Appendix D5.**– WinBUGS code for hierarchical age-composition model. Posteriors distributions from fitting this model provide prior distributions for DL mixture model. Prior distributions in green font, likelihoods in blue.

```
# Age Mixture.odc version 6a:
```

```
model {
  #Overall means and std deviations
  for (a in 1:A) {
    sigma[a] ~ dnorm(0,1.0E-4)|(0,)
    tau[a] <- 1 / sigma[a] / sigma[a]
    mu[a] ~ dnorm(0,1.0E-12)|(0,)
  }
  #Dirichlet distributed age proportions across years within weeks
  D.scale ~ dunif(0,1)
  D.sum <- 1 / (D.scale * D.scale)
  for (w in 1:W) {
    pi[w,1] ~ dbeta(0.2,0.4)
    pi.2p[w] ~ dbeta(0.2,0.2)
    pi[w,2] <- pi.2p[w] * (1 - pi[w,1])
    pi[w,3] <- 1 - pi[w,1] - pi[w,2]
    for (y in 1:Y) {
      for (a in 1:A) {
        D[w,y,a] <- D.sum * pi[w,a]
        g[w,y,a] ~ dgamma(D[w,y,a],1)
        pi.wy[w,y,a] <- g[w,y,a]/sum(g[w,y,])
      }
    }
  }
  for (i in 1:nfish) {
    age[i] ~ dcat(pi.wy[week[i],year[i],1:A])
    length[i] ~ dnorm(mu[age[i]],tau[age[i]])
  }
}
```

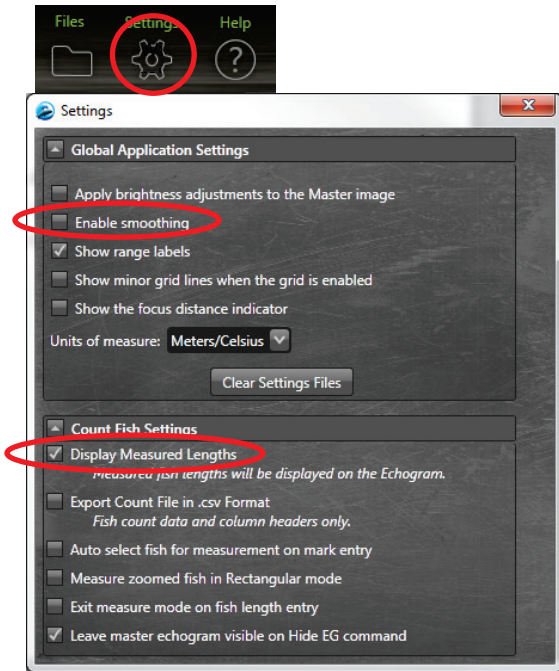


**APPENDIX E. INSTRUCTIONS AND SETTINGS USED FOR  
MANUAL FISH LENGTH MEASUREMENTS FROM ARIS IMAGES  
USING ARISFISH SOFTWARE VERSION 1.5**

**Appendix E1.-** Instructions and settings for manual length measurements form ARIS images in 2013 using SMC ARISFish software Version 1.5.

**a. To set Global Settings after a new installation of ARISFish**

1. Open ARISFish global settings and ensure you have the following settings:



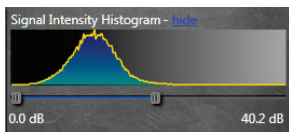
2. Enable smoothing is **off**
3. Display Measured Lengths is **on**

**b. Set processing parameters for a new set of files for a new day or stratum:**

1. Select <Files> <Open Recently Viewed>

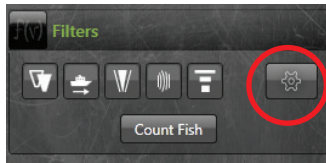


2. Navigate to the appropriate directory and open file
3. Set Signal intensity sliders to 0.0 and 40.2 dB (or other recommended values for a specific stratum)



4. Select <<“settings” cog> from Filters menu

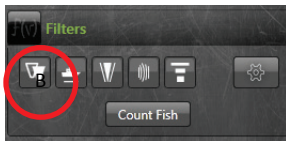




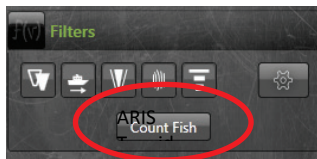
5. Select <SMC adaptive background>



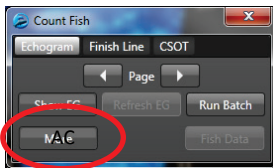
6. Select <Background Subtraction> icon on Filters Menu (Toggle)



7. Select <Count Fish> from the Filters Menu to Display the Count Fish Window



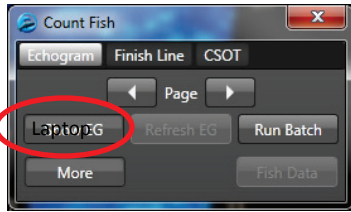
8. Select <More> to get expanded options



9. Increase <Loop> Length to at least 8 s, set <upstream> direction parameter appropriately, then select <Less> to shrink count Fish window



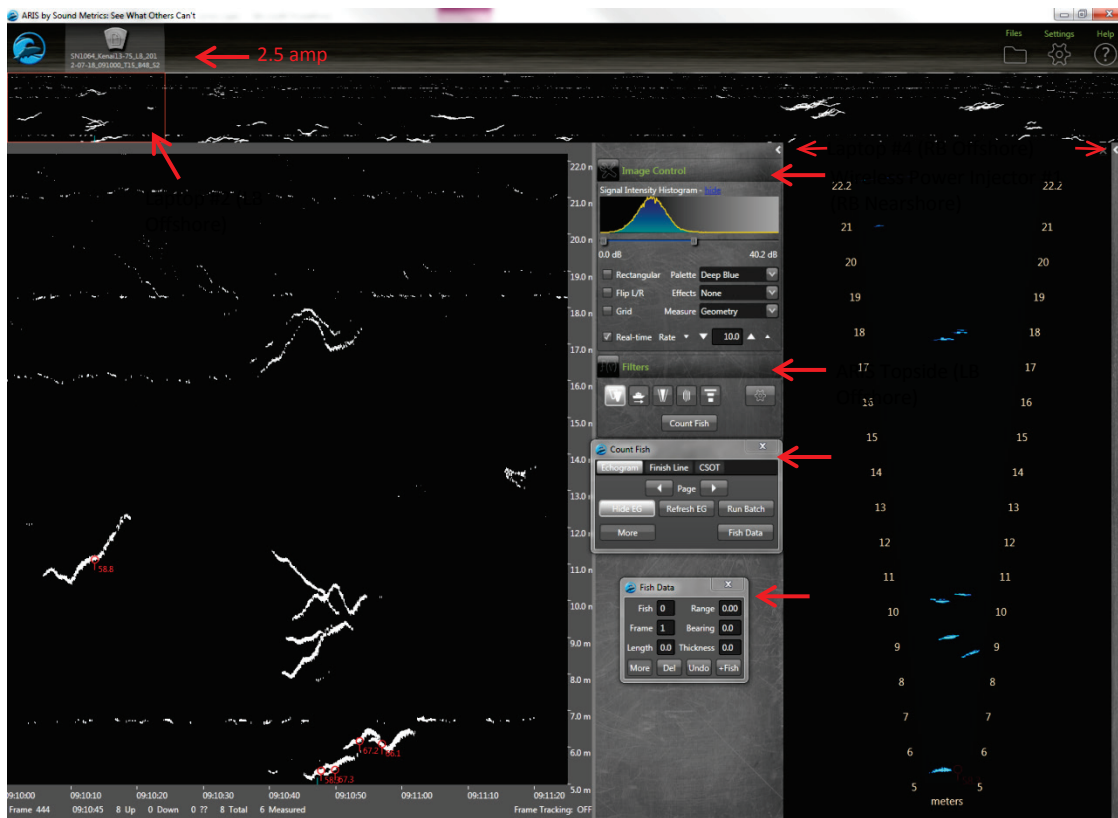
10. Select <Show EG> to display the Echogram



11. Select <Fish Data> to display the Fish Data Window



12. Arrange the <Count Fish> and <Fish Data> windows so your overall display looks similar to:



13. Select <Alt><right arrow> to advance to the next file when needed, all your parameter settings and display configuration should be preserved

14. Now you are ready to start measuring individual fish

c.

### Instructions for manual fish length measurements using SMC ARISFish software version 1.5 in 2013.

1. **<Right Click>** on the fish to be measured (Puts red marker on fish and automatically activates the movie showing the fish bounded by range arcs – see Figure E1-1 below)
2. **<Right Click Drag>** on movie image to zoom in for measurement
3. Press **<space bar>** to pause movie
4. Use **<right arrow>** and **<left arrow>** to step through movie one frame at a time to find a frame that displays the entire fish length well (see section d below for selecting optimal images)
5. **<Left Click Drag>** if necessary to center movie window prior to measuring
6. **<left click>** on the fish snout and continue to **<left click>** along the midline of the fish to create a “segmented measurement.” The segments should follow the midline of the body of the fish – ending with the tail.
7. Select **<f>** key to add measurement to the .txt file (fish it!) – you will see measurement in red (**<Left Click>** on echogram inside mark, if you want to delete measurement and start over)
8. Select **<v>** key to unzoom movie window (not necessary if you have another fish nearby you want to measure)
9. Next fish...repeat steps 1-8, or
10. **<Left Click>** on Master Echogram to advance to new echogram section, or
11. **<Alt><Right Arrow>** to advance to next file

#### Hot keys:

**<e>** to “save” all echogram measurements to file

**<f>** to “fish it” (to accept the measurement and display it on the echogram)

**<u>** to “undo” the last segment

**<d>** to “delete” the all segments

**<space bar>** to pause in movie mode

**<right arrow>** forward direction when you play movie or advances frame one at a time if the movie is pause  
d

**<left arrow>** opposite of above

**Left Click Drag** to show movie over the selected time

**Right Click Drag** zooms the selected area

#### d. Helpful Tips

- Toggling between BS mode and the raw image can sometimes be helpful in determining the actual end of the tail or snout.



- Some targets may hold/linger in the beam and should not be tracked unless they make sufficient progress up or down stream. Significant over estimation of fish could occur if everything in the beam were tracked/measured without regard for upstream progress.
- Some targets may glance the corners of the beam, if you feel these targets do not provide sufficient direction of travel information, or that they may be dipping in and out of the beam throughout the sequence, use your discretion at tracking. When Chinook fall into this marginal category, give them closer attention than smaller targets, as missing a small target is less important than missing a KING.
- Use all the tools at your disposal- the echogram provides a roadmap to not only where targets occur in the sequence, but often gives strong clues to what the target species is. Trace intensity, length, and tail beat amplitude/frequency give you information that comes in handy before you toggle to video mode. Video mode and the video loop allow you to better sort out number, behavior, and location of targets in especially complex sequences.
- Press <E> to save your work on each sequence when complete (or before you divert to another task).

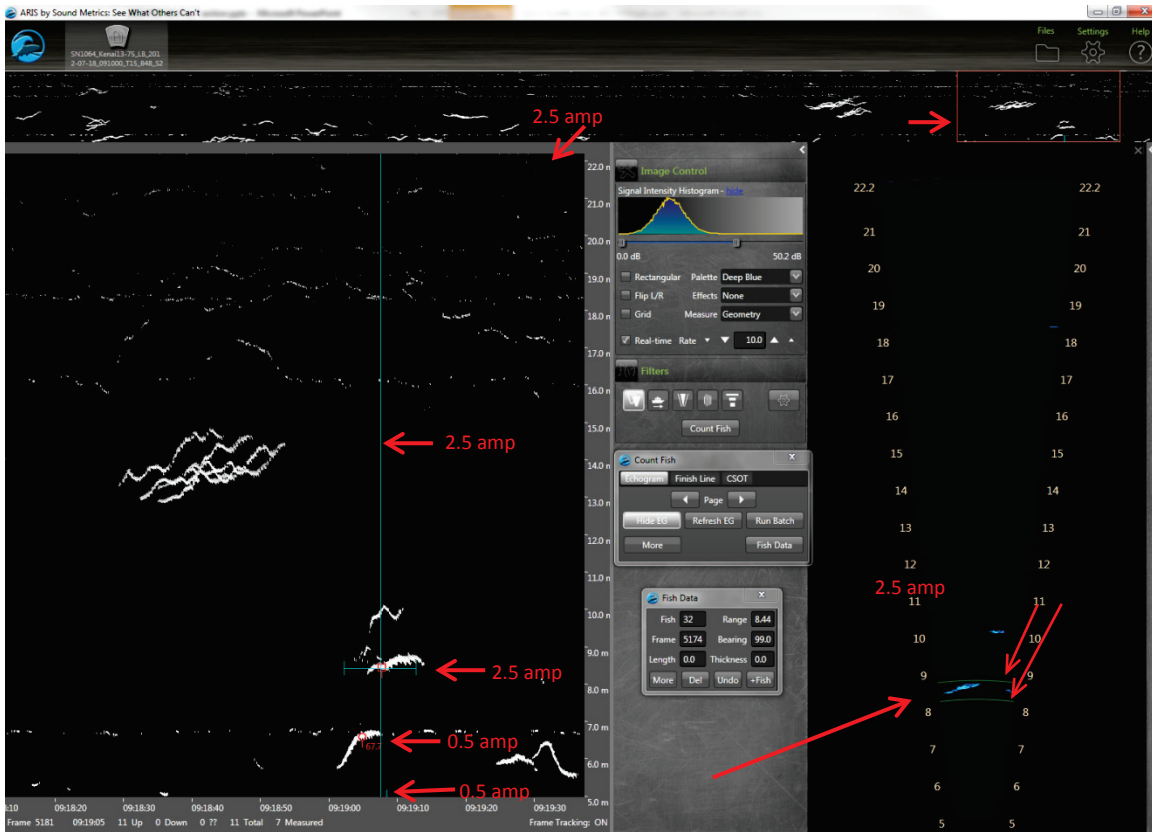
#### e. Known issues/bugs

- Some settings are saved, while others may default to undesired values. It is wise to periodically check your settings to confirm..

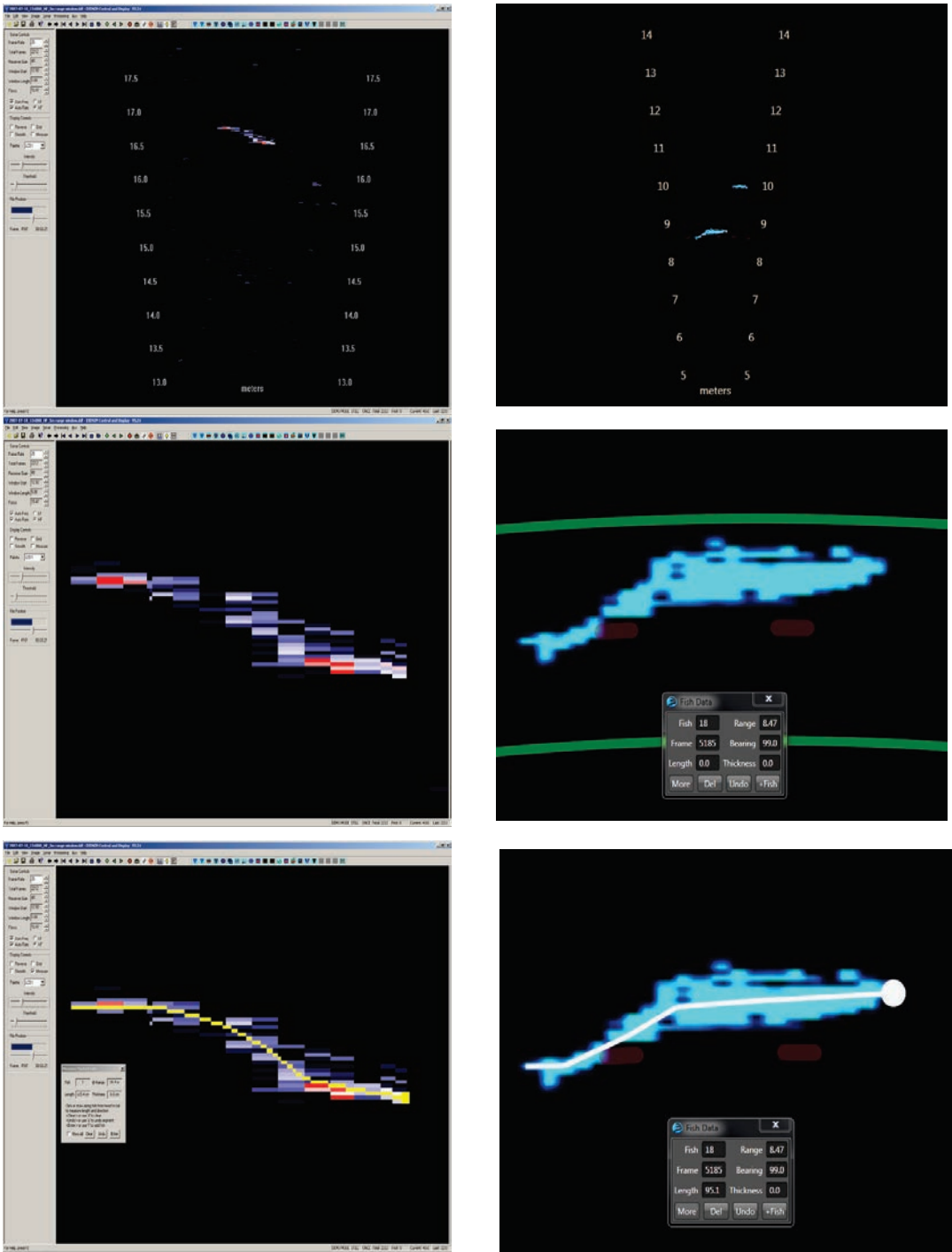
## **f. Instructions for selecting optimal images**

Measurements should be taken from frames where contrast between the fish image and background are high and where the fish displays its full length. This can be difficult to determine at times, especially when the number of frames from a fish is limited (e.g. close-range fish). For example, panels a, b, c, d, g, and l in Figure E1-3 are images where the fish appears to display its full length, and consequently the length estimates are consistently higher than other measurements varying between 95cm -98cm. In general, the best images are obtained when the fish is sinusoidal in shape (rather than straight and/or perfectly perpendicular as in panel j) because the head and tail appear most visible when there is curvature to the fish body. Even when there is curvature to the fish body, it is apparent that in some frames, the fish body compressed.

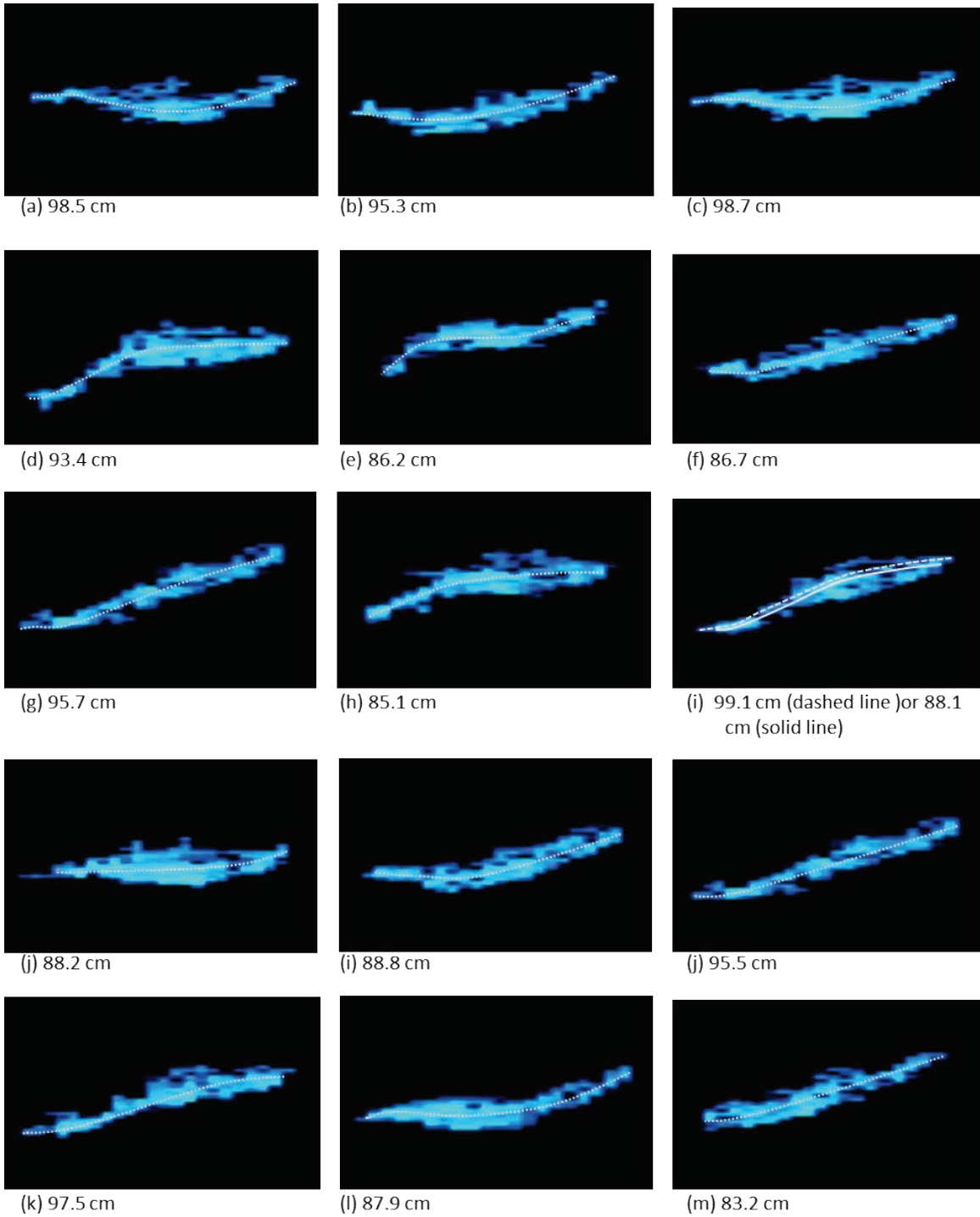
Panel i in Figure E1-3 demonstrates how a fish can measure 99.1 cm (dashed line) or 88.1 cm (solid line) depending on whether the user decides to include "faint" pixels defining the snout and tail. Watching the behavior of the head and especially the tail over several frames, and taking several measurements, is often helpful in distinguishing the best frame.



**Figure E1-1.-** Manual measurements in ARIS echogram mode. A left click on a fish trace places a red marker on the fish trace and automatically activates the movie showing the fish bounded by range arcs. A vertical line defines the selected frame on the echogram, and a horizontal line at the selected range shows the boundaries of the “movie loop.”



**Figure E1-2.-** On right ARIS images from a free-swimming Chinook salmon showing the unzoomed image (top), the zoomed image (middle), and the segmented lines that result when the observer clicks along the length of the fish to mark its length (bottom). On left, comparable DIDSON images from a tethered Chinook salmon. The pixels of the ARIS image are less defined due to a smoothing algorithm applied. Additionally the ARIS image has approximately twice the downrange resolution as the DIDSON image ( $ARIS = 20m/2000pixel = 1cm/pixel$  resolution versus  $DIDSON = 10m/512 = 2cm/pixel$ ).



**Figure E1-3.-** Panels a-m show the potential variability in length measurements taken from images of a free-swimming Chinook salmon at approximately 9 m collected with an ARIS 1200 with a telephoto lens. Frames were taken from file SN1064\_Kenai13-75\_LB\_2012-07-18\_091000\_T15\_B48\_S2000\_F12\_R4-22.aris, approximately frames 5175-5204). The white lines following the fish mid-section show the path taken on the image for the length measurements.



**APPENDIX F. RIVER-MILE 13.7 SITE INVESTIGATION  
DOCUMENTATION**

## Appendix F 1.- Additional details regarding river-mile 13.7 sonar site.

Benefits of the proposed RM 13.7 site include: 1) the State owns land on both sides of the river (DNR land on the left<sup>7</sup> [KPB parcel #055-250-23] and right bank [KPB parcel #057-250-30]); 2) the location is above major tidal influence; and 3) the river channel is a relatively narrow at this location. Upland on both banks is composed of trees and shrubs. The main tent housing sonar electronics will be located on the left bank (Figure F1-1). Data from the right bank will be transmitted to the tent on the left bank using wireless technology.

Providing full (bank-to-bank) coverage will require a total of five sonars; four sonars on the main channel and a fifth sonar to monitor the minor channel on right bank (Figure F1-2). Proposed site diagrams for the left bank can be found in Figures F1-3 to F1-5. Proposed site diagrams for the right bank main river channel can be found in Figures F1-6 to F1-9. Proposed site diagrams for the minor river channel can be found in Figures F1-10 to F1-13.

A 10'x12' tent will be assembled on the left bank at least 50 ft from ordinary high water levels (OHW, Figure F1-3). The tent will be located in a clearing to alleviate the need to remove trees and other vegetation. A small plywood box (~3ft x 3ft) lined with plastic (for spill containment) located near the tent will house a small generator. A power cable will lead from the generator to the tent. Electronic control cables will lead from the tent into the river and attach to each of two ARIS units (nearshore and farshore sonars) mounted to removable steel tripods (Figure F1-4). The sonars will be positioned on the river bottom approximately 6 ft and 24 ft from OHW (Figure F1-5).

On the right bank main-channel site, two waterproof totes (~ 3' x 4') will house a battery bank (Figure F1-6) and the topside sonar electronics (Figures F1-6 to F1-8). A plywood box (~ 3'x 3') lined with plastic (for spill containment) located near the totes will house a small generator (Figures F1-7 and F1-8). A power cable will lead from the batteries to the tote housing the ARIS electronics. Electronic control cables will lead from the topside electronics tote into the river and attach to each of two ARIS units (nearshore and farshore sonars) mounted to removable steel tripods (Figures F1-7 and F1-9). The sonars will be positioned on the river bottom approximately 6 ft and 45 ft from OHW (Figure F1-9).

On the right bank minor-channel site, a single waterproof tote (~3'x4') will house the battery bank (Figure F1-10) and topside sonar electronics (Figures F1-11 and F1-12). Electronic control cables will lead from the topside electronics tote into the river and attach to a single ARIS unit mounted on a steel approximately 40' from OHW. A picket weir will extend approximately 45' from OHW to force fish in front of the sonar (Figures F1-11 and F1-13).

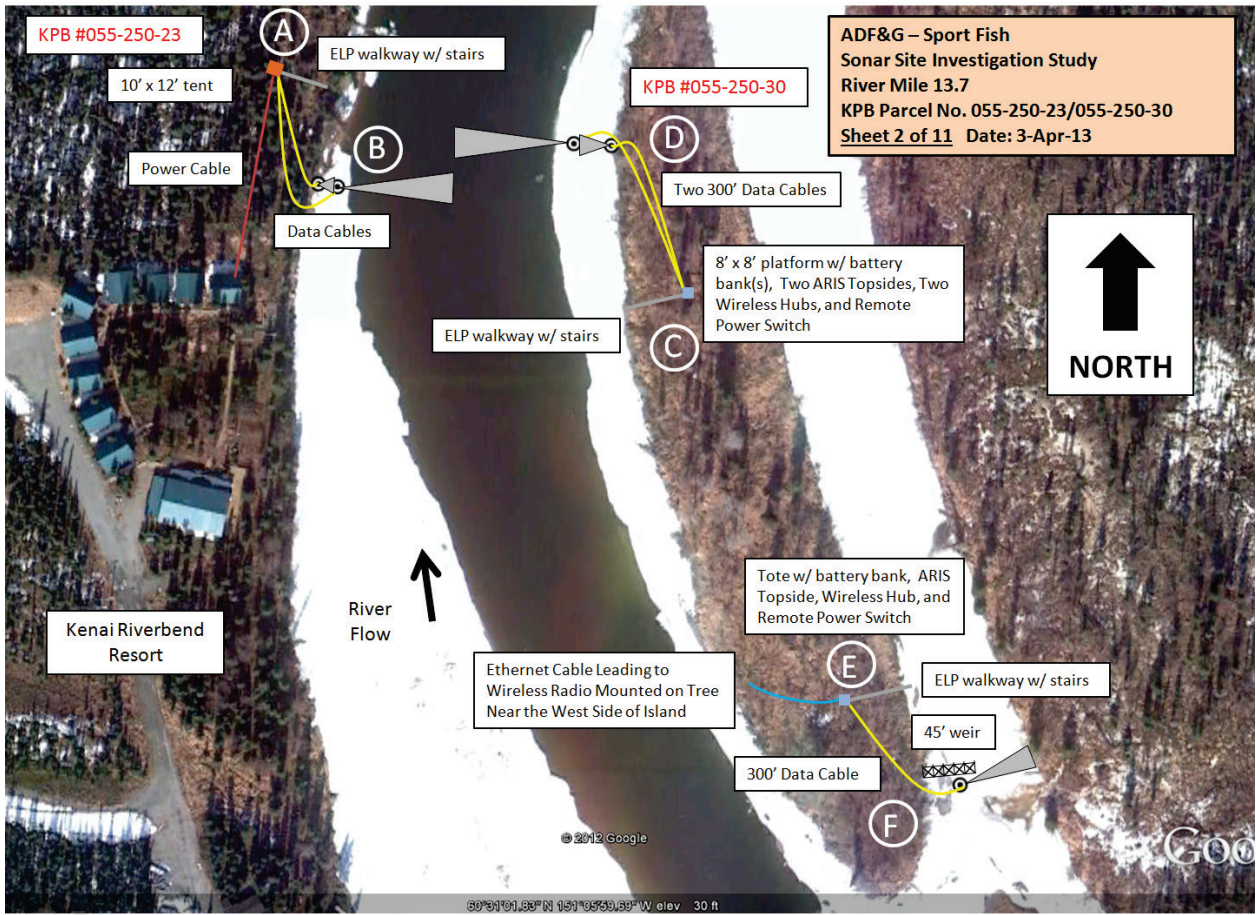
Submerged steel tripods will be marked with a marker float on the water's surface (Figures F1-5 and F1-9). Additional large red "warning" buoys will be placed near the offshore sonar tripods on each bank. Signage warning boaters to stay offshore of the warning buoys will be posted at all boat launches (Figure F1-14) and signage identifying the location of the new sonar project will be placed approximately 300' upriver and downriver of the site.

---

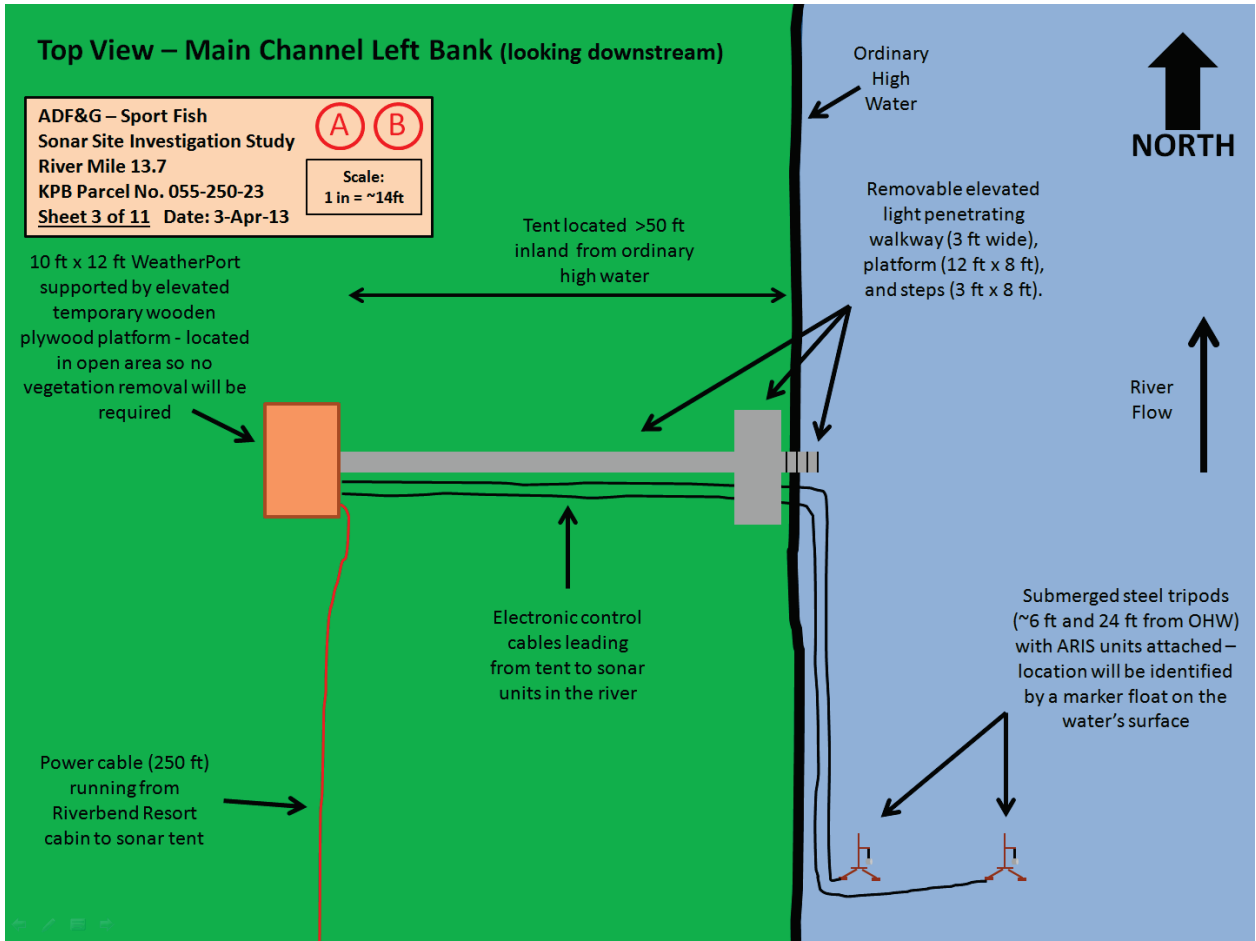
<sup>7</sup> Looking downstream.



Figure F1-1.- Aerial map and parcel numbers for RM-13.7 sonar site.



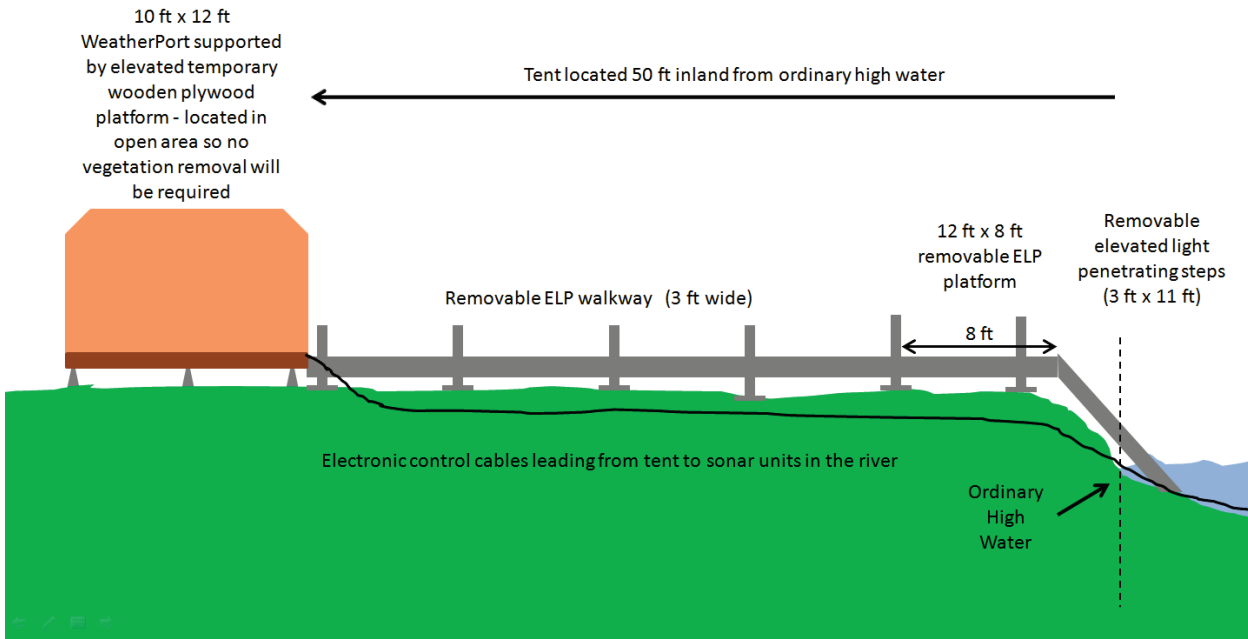
**Figure F1-2.-** Aerial view of sonar deployment at the RM-13.7 sonar site.



**Figure F1-3.-** Aerial view of main channel left-bank camp and sonar deployment at the RM-13.7 sonar site.

Side View – Main Channel Left Bank (looking downstream) – Tent, Walkway, Platform, and Steps

ADF&G – Sport Fish Sonar Site Investigation Study River Mile 13.7 KPB Parcel No. 055-250-23 Sheet 4 of 11 Date: 3-Apr-13	
	Scale: 1 in = ~8 ft



**Figure F1-4.-** Side view of main channel left-bank camp and walkway deployment at the RM-13.7 sonar site.

Side View – Main Channel Left Bank (looking downstream) – Tripod Deployment

ADF&G – Sport Fish  
Sonar Site Investigation Study  
River Mile 13.7  
KPB Parcel No. 055-250-23  
Sheet 5 of 11 Date: 3-Apr-13

(B)

Scale:  
1 in = ~4 ft

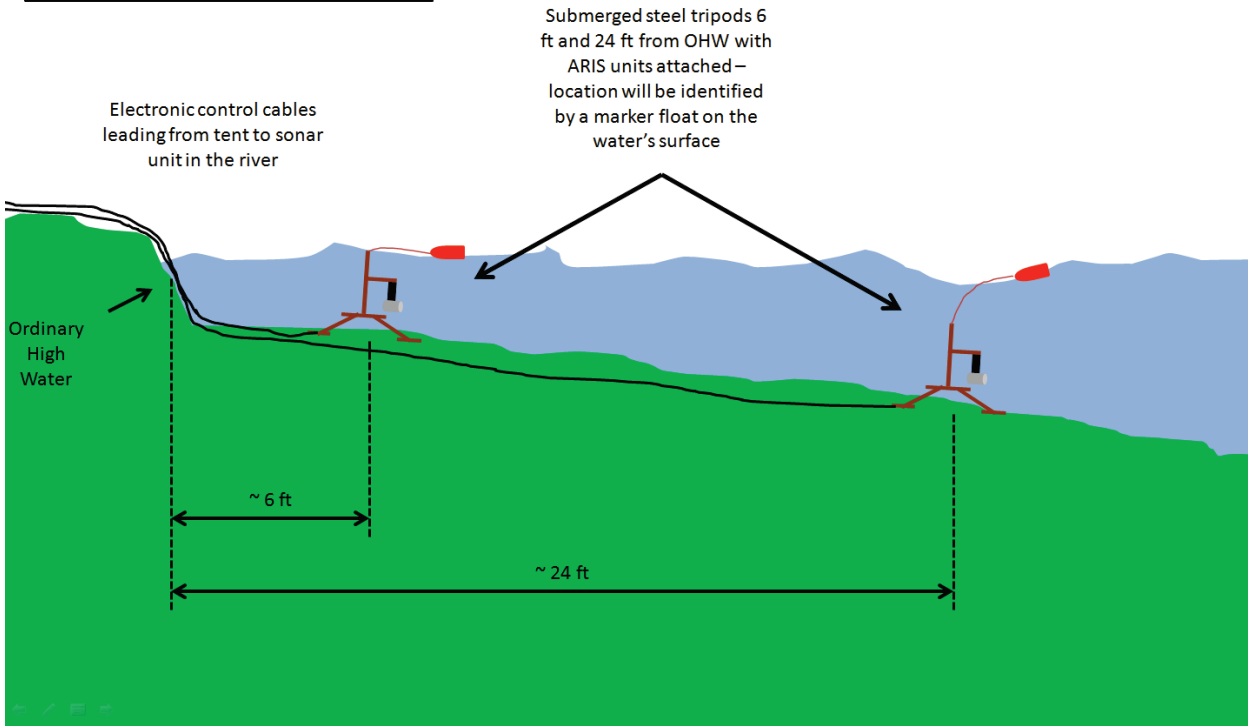
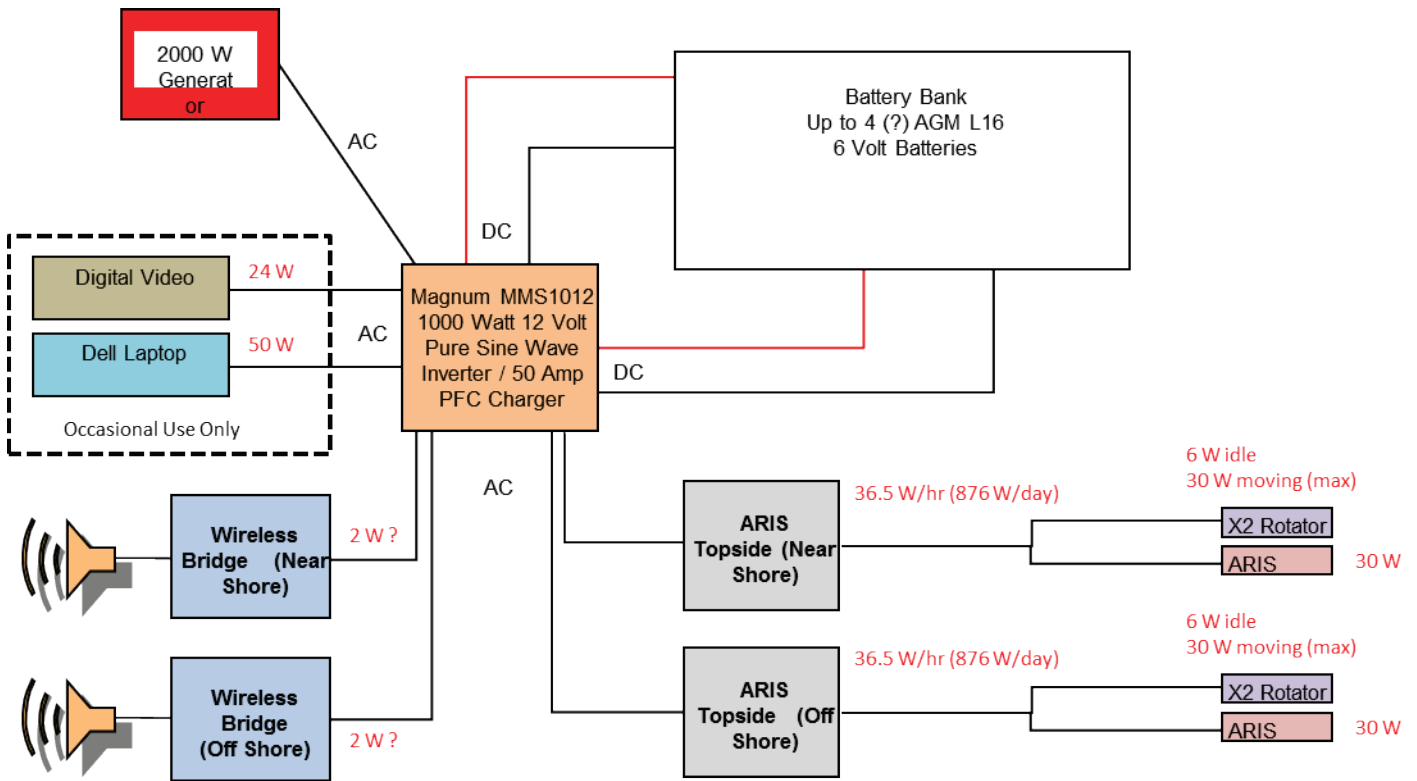


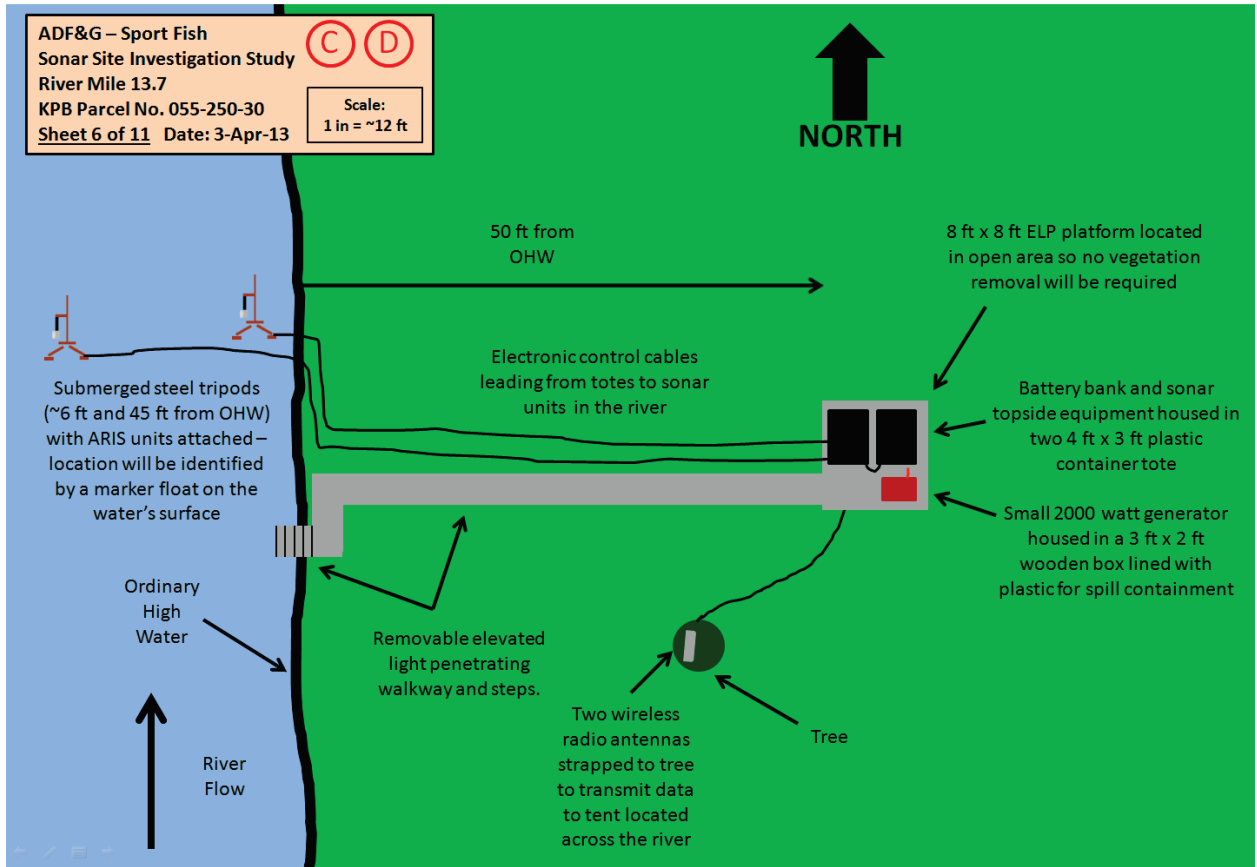
Figure F1-5.- Side view of main channel left-bank sonar tripod deployment at the RM-13.7 sonar site.



**Figure F1-6.-** Proposed schematic for the supplying DC power to the two right-bank main channel ARIS systems at RM 13.7 via a battery bank charged by a 2000W generator.

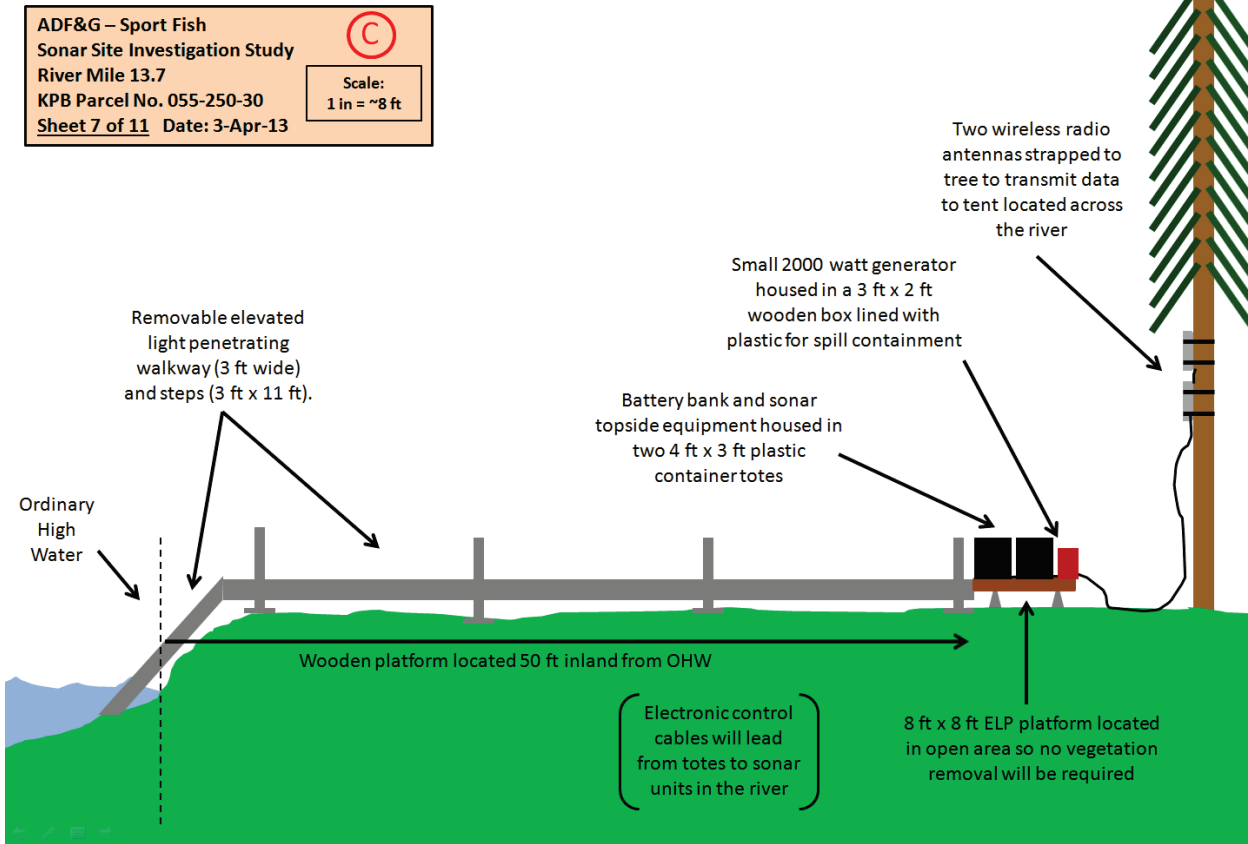


Top View – Main Channel Right Bank (looking downstream) – Walkway, Platform, Tripod Deployment



**Figure F1-7.-** Aerial view of main channel right-bank battery bank and sonar deployment at the RM-13.7 sonar site.

Side View – Main Channel Right Bank (looking downstream) – Walkway and Platform



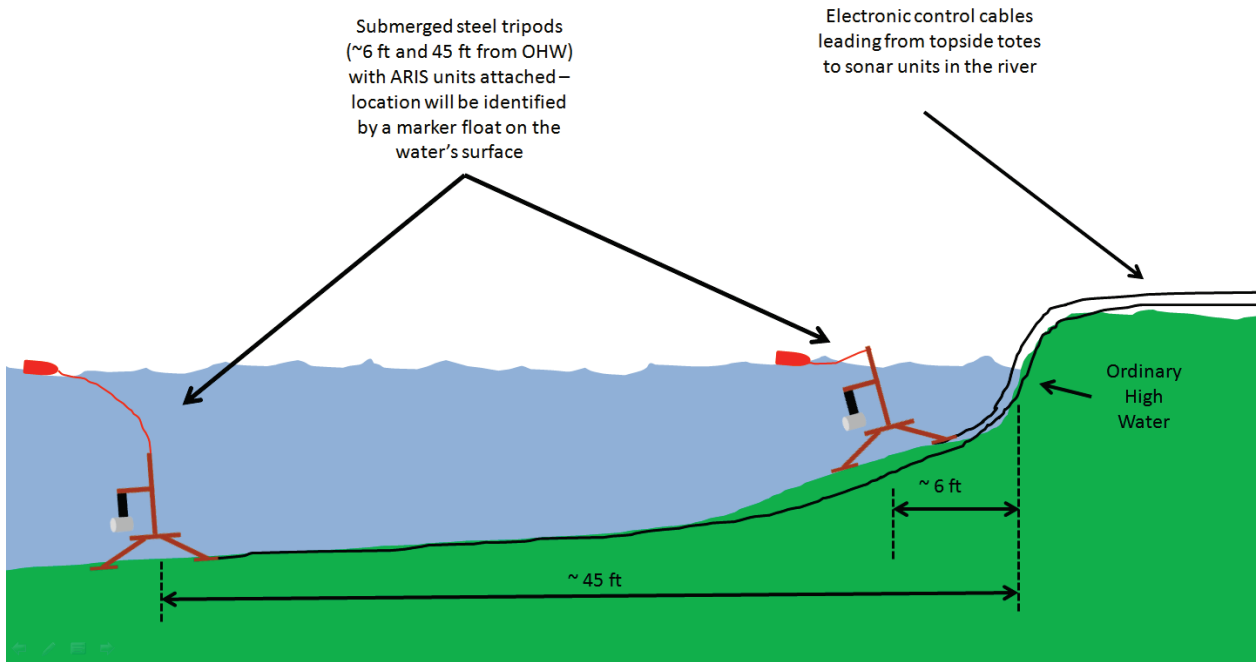
**Figure F1-8.-** Side view of main channel right-bank battery bank and walkway deployment at the RM-13.7 sonar site.

# Side View – Main Channel Right Bank (looking downstream) – Tripod Deployment

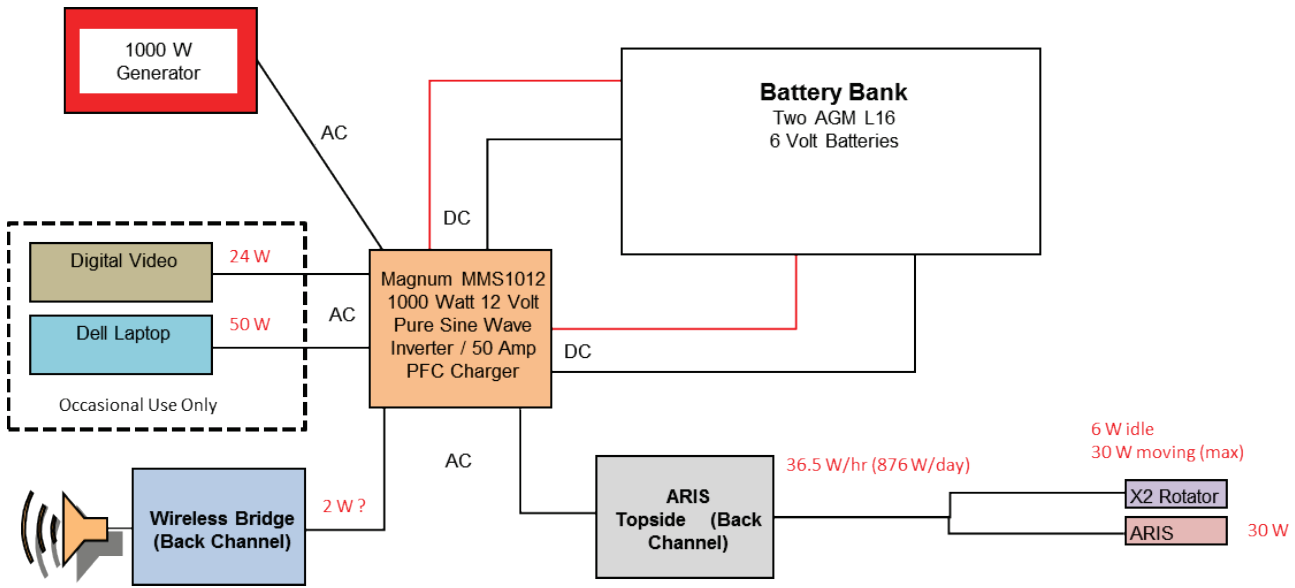
ADF&G – Sport Fish  
Sonar Site Investigation Study  
River Mile 13.7  
KPB Parcel No. 055-250-30  
Sheet 8 of 11 Date: 3-Apr-13

(D)

Scale:  
1 in = ~6 ft

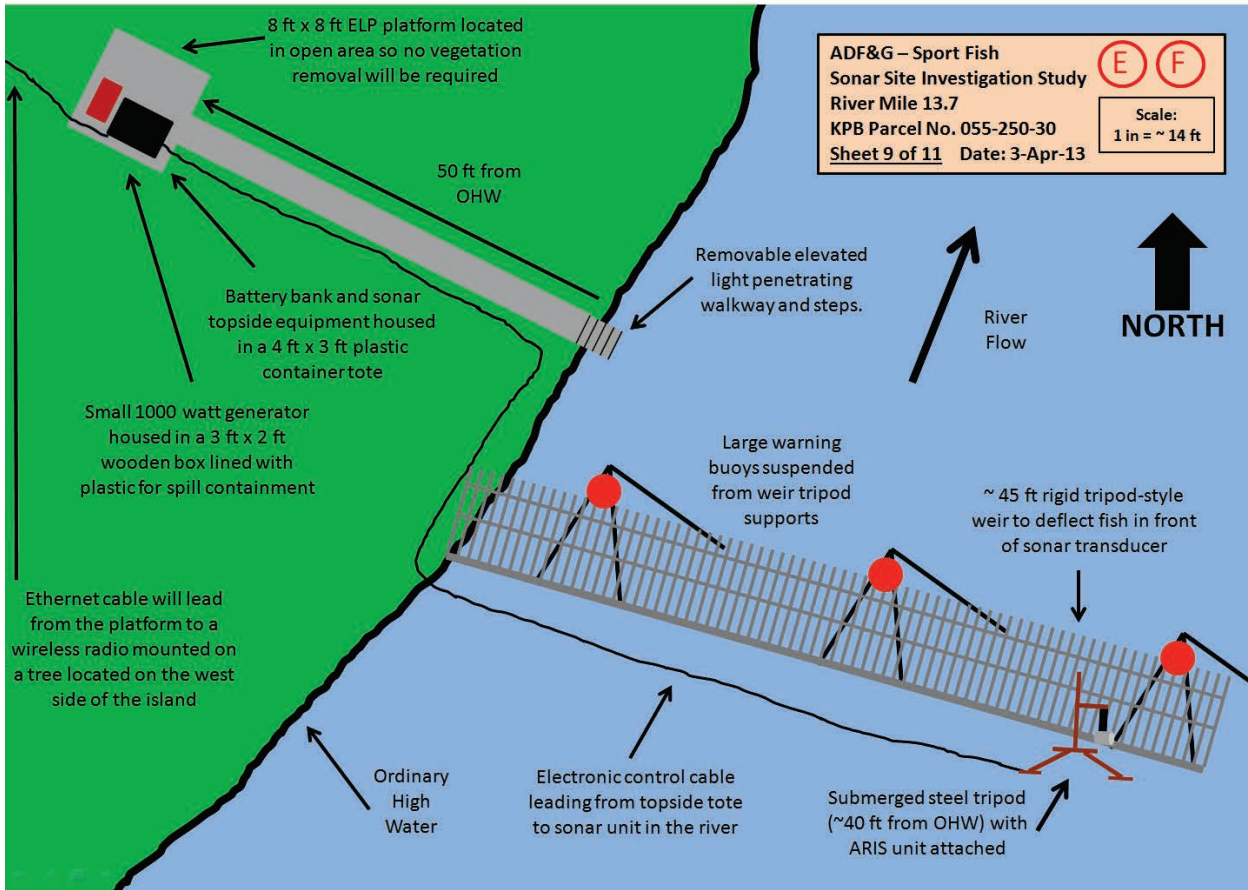


**Figure F1-9.-** Side view of main channel right-bank sonar tripod deployment at the RM-13.7 sonar site.



**Figure F1-10.-** Proposed system schematic for the supplying DC power to the minor-channel ARIS system at RM 13.7 via a battery bank charged by a 2000W generator.

**Top View – Minor Channel Left Bank – Platform, Walkway, Weir, and Tripod Deployment**



**Figure F1-11.-** Aerial view of minor channel battery bank, weir, and sonar deployment at the RM-13.7 sonar site.

Side View – Minor Channel Left Bank (looking downstream) – Walkway and Platform

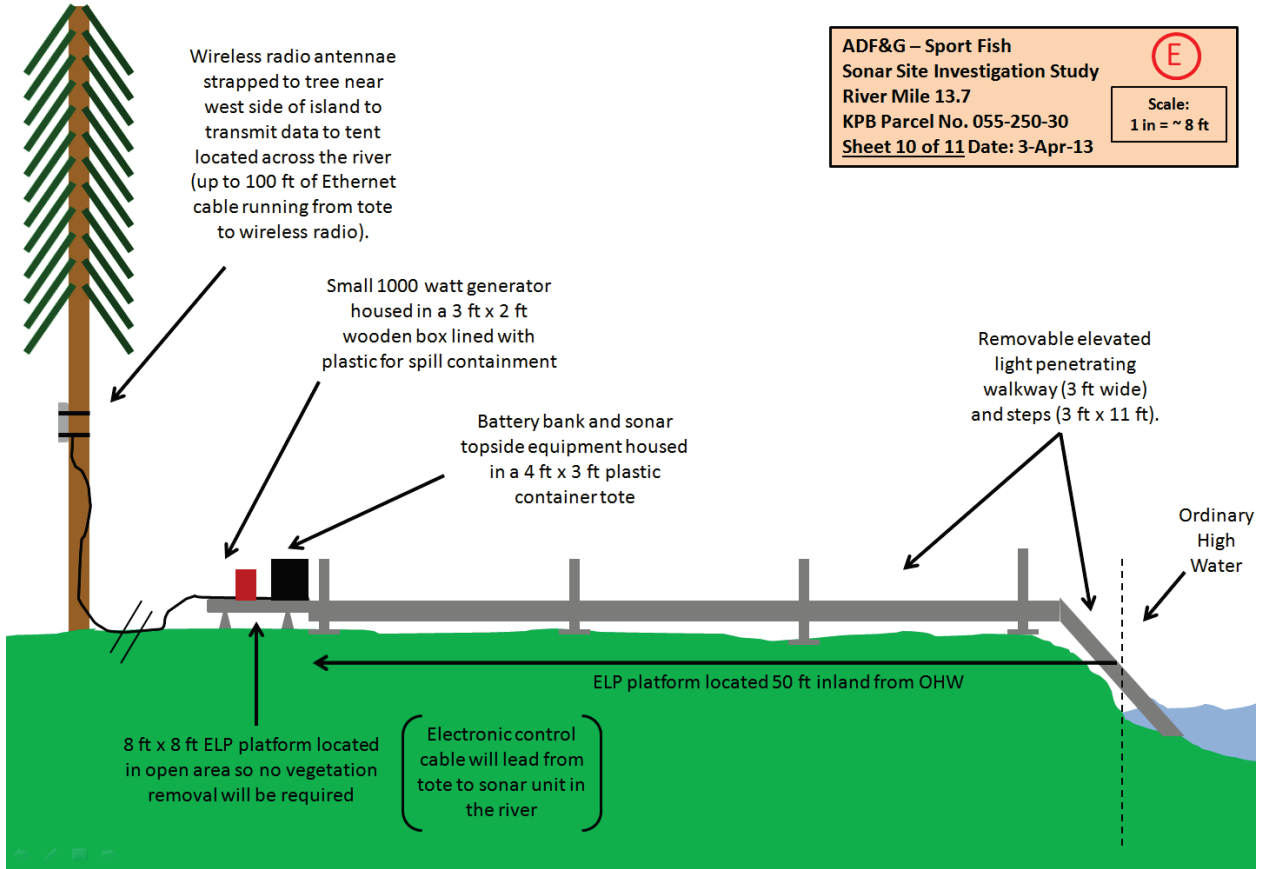

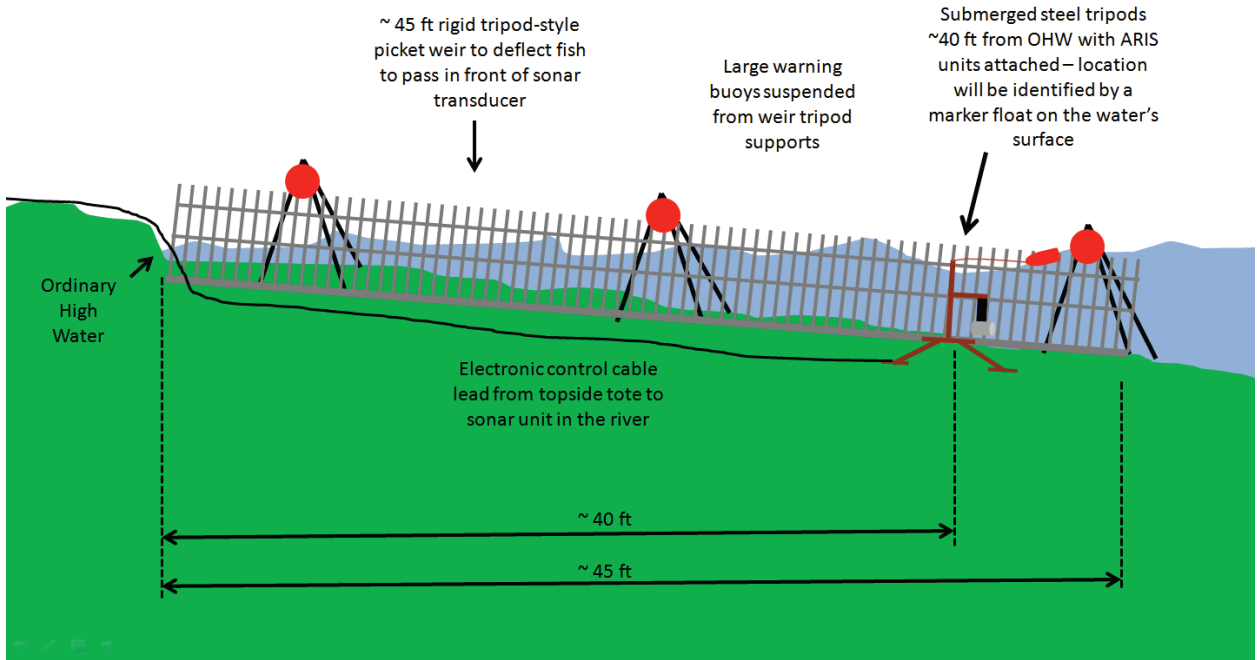


Figure F1-12.- Side view of minor channel battery bank and walkway deployment at the RM-13.7 sonar site.

Side View – Minor Channel Left Bank (looking downstream) – Weir and Tripod Deployment

ADF&G – Sport Fish Sonar Site Investigation Study River Mile 13.7 KPBB Parcel No. 055-250-30 Sheet 11 of 11 Date: 3-Apr-13	
	Scale: 1 in = ~6 ft



**Figure F1-13.-** Side view of minor channel battery weir and sonar tripod deployment at the RM-13.7 sonar site.

# RM 13.7 Tent Electronics Schematics

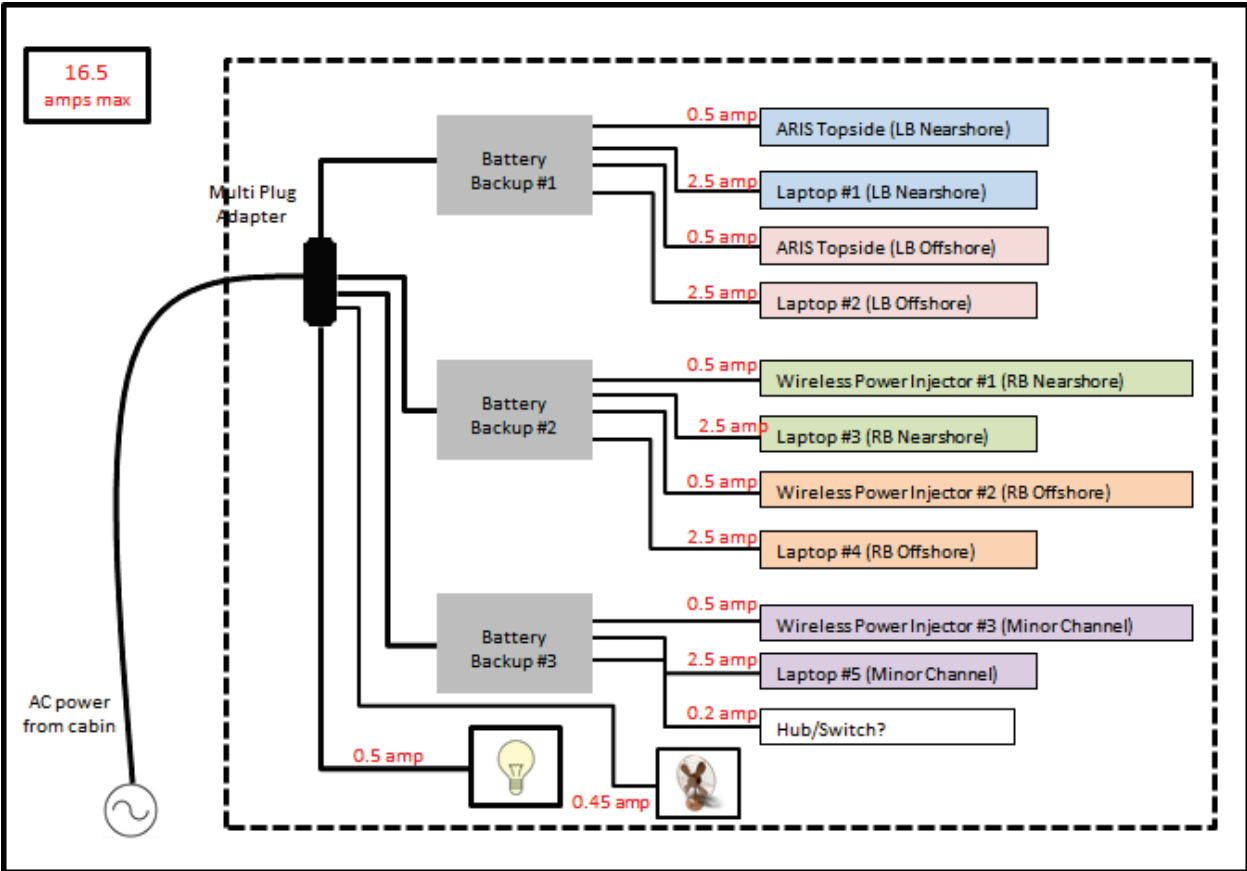


Figure F1-14.-Estimated power requirements for electronics based in the main camp on left bank.



## **APPENDIX G. IP ADDRESSES**

## Appendix G1.- RM-8.6 sonar site IP addresses

Device	IP address	Where located	Serial #	Username	Password	Device name or purpose
<b>SONAR SITE at RM 8.6</b>						
All subnet masks	255.255.255.0	RM 8.6				
Synapsis NetBooter – Left bank on/off switch	128.95.97.150	RM 8.6		Admin: admin User: sonar	Admin: Chinook User: Chinook	Remotely on/off Left bank DIDSON
<b>Local/Tactical SubNet:</b>						
Tactical Computer (one connection)	192.168.1.2	RM 8.6		SonarUser	Sockeye	Main computer for on-site data processing
Right Bank Laptop (NOT onboard but USB-to-Ethernet)	192.168.1.3	RM 8.6		dlburwen	megaptera	Sharing data from E: drive with Tactical
Left Bank Laptop (USB-to-Ethernet)	192.168.1.4	RM 8.6		dlburwen	megaptera	Sharing data from E: drive with Tactical
<b>L-Bank Offshore DIDSON SubNet</b>						
DIDSON SONAR LR	128.95.97.227	RM 8.6	381			
Left Bank DIDSON laptop (onboard Ethernet)	128.95.97.204	RM 8.6		dlburwen	megaptera	
SMC Bridge Radio for offshore DIDSON	128.95.97.2 (on right bank)	RM 8.6		admin	smcadmin	
SMC Bridge Radio for offshore DIDSON	128.95.97.4 (on left bank)	RM 8.6		admin	smcadmin	
<b>L-Bank Nearshore DIDSON SubNet</b>						
Std DIDSON (Anchor Rivers)	128.95.97.227	RM 8.6	20	dlburwen	delphi-17	DFGANCDSF164927
Nearshore DIDSON laptop (2012 temporary computer used on both banks)	192.95.97.175	RM 8.6		dlburwen	delphi-17	
CISCO Left bank Radio for NearShore DIDSON	128.95.97.2 (on right bank)			admin	Chinook	
CISCO Left bank Radio for NearShore DIDSON	128.95.97.4 (on left bank)	RM 8.6		admin	Chinook	
<b>R-Bank Offshore DIDSON SubNet</b>						
DIDSON SONAR LR	128.95.97.227	RM 8.6	340			
Right Bank DIDSON laptop (onboard Ethernet)	128.95.97.203	RM 8.6		dlburwen	megaptera	
Nearshore DIDSON laptop (2012 temporary computer)	192.95.97.175	RM 8.6		dlburwen	Delphi-17	DFGANCDSF164927
<b>R-Bank Nearshore DIDSON SubNet</b>						
Std DIDSON (Anchor Rivers)	128.95.97.227	RM 8.6	20			
Nearshore DIDSON laptop (2012 temporary computer used on both banks)	192.95.97.175	RM 8.6		dlburwen	delphi-17	

## Appendix G2.- Soldotna sonar office IP addresses

SONAR Office	IP address	Where	Serial	Username	Password	Device name or
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		located	#			purpose
<b>Network Attached Storage</b>						
Western Digital Sharespace 4 GB	192.168.1.101	Sonar Office		Admin	Chinook	DFGANCDSDSSH R3 2011 data
Western Digital Sharespace 4 GB	192.168.1.103	Sonar Office		Admin	Chinook	2012 data
Synology DiskStation 1512 10 TB	192.168.1.165	Sonar Office		Admin	Chinook	2012 ARIS data + backup
Buffalo TeraStation Pro 8 24 TB						New 2013
<b>Computers</b>						
Dell Workstation Laptop (LAN 2) Dell Workstation Laptop (LAN 1)	192.168.1.205 146.63.15.200	Sonar Office SOA network		dlburwen	Delphi-18	DFGANCDSF18574 9
Dell Optiplex 980	192.168.1.121 146.63.15.200	Sonar Office SOA network		Jim's state domain login	Jim's state domain password	Main data-processing computer
Dell Optiplex 760	Older XP machine about to retire			Jim's state domain login	Jim's state domain password	Backup data-processing computer (XP)
Dell Optiplex 990	192.168.1.xxx 146.63.15.xxx	Sonar Office netwok SOA network		Jim's state domain login	Jim's state domain password	Backup data-processing computer (Jim's)
Dell Optiplex 990	192.168.1.110 146.63.15.xxx	Sonar Office SOA network		sonargear	smaLLfry2	ARIS/DIDSON data processing (Brandons) DGSXQDCF102790
Dell Optiplex 990	192.168.1.105 146.63.15.xxx	Sonar Office SOA network		sonargear	smaLLfry2	ARIS/DIDSON data processing (Kara's) DGSXQDCF102793
Dell Optiplex 990	192.168.1.104 146.63.15.xxx	Sonar Office SOA network		sonargear	smaLLfry2	ARIS/DIDSON data processing (Trevor's) DGSXQDCF102792
Dell Optiplex 9010 minitower						New
Dell Optiplex 9010 minitower						New
Dell Optiplex 9010 minitower						New
Dell Latitude Laptop				dlburwen	Delphi-21	Deb's personal laptop DFGANCDSF16492 7
<b>Sometimes in the office...but now used as backups for sonar field sites....</b>						
Dell Latitude Laptop E6500				FISHSONAR 2	Pinghappy2	Trevor's former laptop DFGANCDSF16089 8
Dell Latitude Laptop E6500				FISHSONAR	Chinook1	Kara's former laptop
Dell Latitude Laptop E6500				FISHSONAR	Chinook1	Brandon's former laptop

Map drives to local address \\192.168.1.103\...

**Appendix G3.- RM-13.7 sonar site IP addresses (2013 configuration)**

River Mile 13.75 SONAR Site	IP address	Where located	Serial #	Username	Password	Device name or purpose
<b>L-Bank Nearshore ARIS SubNet</b>						
ARIS sonar						New
Dell Latitude Laptop E6430						New
<b>L-Bank Offshore ARIS SubNet</b>						
ARIS sonar	128.95.97.227					
Dell Latitude Laptop E6400						New
<b>R-Bank Nearshore ARIS SubNet</b>						
ARIS sonar						New
Dell Latitude Laptop E6430						New
NetBooter						New
EZBridge Radio for ARIS						
Left bank radio	128.95.97.4					New
Right bank radio	128.95.97.2					New
<b>R-Bank Offshore ARIS SubNet</b>						
Dell Latitude Laptop E6430						New
NetBooter	128.95.97.150	admin	Chinook			
Radiolabs Bridge Radio for ARIS						
Left bank radio	128.95.97.4					
Right bank radio	128.95.97.2					Hmmm instructions say it uses 192.168.1.10 with sub net 255.255.255.0
<b>R-Bank Side-Channel SubNet</b>						
ARIS sonar						New
Dell Latitude Laptop E6430						New
NetBooter						New
EZBridge Radio for ARIS						
Left bank radio	128.95.97.4					New
Right bank radio	128.95.97.2					New
<b>Backup Computers (from 2012)</b>						
Dell Latitude Laptop E6500	128.95.97.151	FISHSON AR	Chinook1			Brandon's former laptop
Dell Latitude Laptop E6500	128.95.97.153	FISHSON AR	Chinook1			Kara's former laptop

Other info related to networks:

- \*The Didson networks for Right and Left Banks are NEVER connected together. Therefore, the separate laptops or the underwater units, respectively\*\*, can have the same IP addresses. (\*\*Of course, no device can have the same IP address on the same network.)
- The Local and Didson networks are not bridged together in any way.