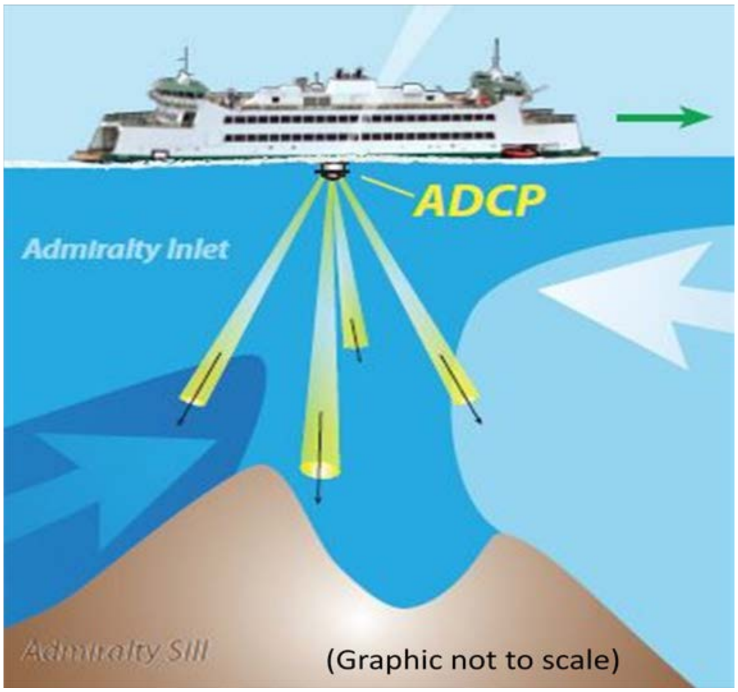
Quality Assurance Project Plan

Ferry-Based Monitoring of Puget Sound Currents

Interagency Agreement C1400045



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This Quality Assurance Project Plan is available on the Department of Ecology's website at https://fortress.wa.gov/ecy/publications/SummaryPages/1403110.html

Copies of this Quality Assurance Project Plan and the final project report will be available, on request, from the Department of Ecology.

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1.0 Title Page/TOC

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May 2014

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2.0 Abstract

To manage water quality in Puget Sound (nutrient enrichment, low dissolved oxygen conditions, the transport of toxic chemicals, harmful algal blooms, and ocean acidification), scientists need a better understanding of the circulation and exchange of water masses. Determining the exchange between Puget Sound and the Strait of Juan de Fuca is particularly important in order to quantify the influence of oceanic water on Puget Sound water quality. This project describes a cooperative program involving the Washington State Department of Ecology (Ecology) and the Applied Physics Laboratory at the University of Washington (APL-UW) that will collect continuous current measurements in key areas of the sound, e.g., constriction points between basins. The plan is to install and maintain Acoustic Doppler Current Profilers (ADCPs) on two public ferries run by the Washington State Department of Transportation (WSDOT), which routinely transit a strategic cross-section near the entrance to Puget Sound, Admiralty Inlet. Two ferries that are particularly well-suited to hull mounted instruments will have ADCP units installed when they are next scheduled for dry-dock. Ecology will purchase the instruments and APL-UW will provide all planning, design, installation, commissioning, and operation of the instruments, including data transmission and processing. When in operation, the ADCPs will provide nearly-continuous surface-to-bottom measurements of current velocities and direction, thus allowing the determination of water-mass movement and transport between basins. These measurements are key to understanding overall water quality, improving our 303(d) listing decisions, and for improving the performance and calibration of numerical models in Puget Sound.

3.0 Background

3.1 Study area and surroundings

Admiralty Inlet is the main link between Puget Sound and the ocean, via the Strait of Juan de Fuca. ADCP instruments will be installed on two ferries that occupy the route across Admiralty Inlet (between Port Townsend and Coupeville), and the collected data will be used to quantify the influx and outflow of water to/from the ocean and greater Puget Sound.

3.1.1 Logistical problems

Dedicated research vessels are prohibitively expensive for continuous monitoring operation, and moorings have insufficient spatial resolution to characterize the complex circulation that occurs in Admiralty Inlet. Repeated ferry crossings are a cost-effective means of collecting transect data over long periods.

3.1.2 History of study area

Admiralty Inlet is largely undeveloped; however, it is heavily used by marine traffic. Admiralty is the intended location for a pilot tidal energy installation by the Snohomish Public Utility District, for which detailed site characterization measurements have been on-going since 2009. Deppe (2013) used this data to show that intrusions of dense water from the ocean can carry hypoxic water into Puget Sound.

3.1.3 Contaminants of concern

None.

3.1.4 Results of previous studies

During 2012, APL-UW conducted proof-of-concept measurements, using a hull-mounted ADCP on the R/V Jack Robertson, traveling along the intended ferry route and at the higher speeds the ferries attain. The results were reported in a data memo to Ecology (Appendix D) as a deliverable under Interagency Agreement C1300039 as part of the NEP Nutrient Synopsis grant. These results are shown in Figure 1 as a transect of depth versus time (color scale is velocity). Much of the project plan that follows is based upon these test results. ADCPs are common instruments in modern oceanography, and thus there is a wide literature and user-base for this technology.

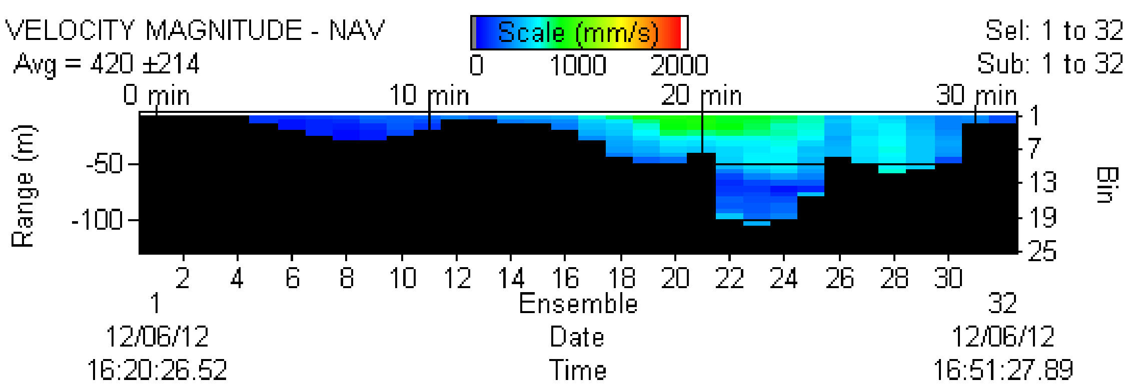

Figure 1. Example transect of ADCP-measured current speeds along the Coupeville – Port Townsend ferry route.

3.1.5 Regulatory criteria or standards

The ADCPs are entirely contained (sealed) within the hull-mount and the acoustic signals are similar to fathometers commonly found on recreational and commercial vessels—thus, there is no environmental or regulatory concern surrounding their use.

These measurements will be useful in understanding overall water quality, improving our 303(d) listing decisions, and improving the performance of numerical models in Puget Sound.

4.0 Project Description

4.1 Project goals

The goal is to determine the circulation and exchange of water between Puget Sound and the Strait of Juan de Fuca and thereby infer the influence of oceanic source water to Puget Sound water quality.

4.2 Project objective

The first objective is to measure full depth profiles of currents across the entrance to Puget Sound (Admiralty Inlet) using instruments mounted to the hulls of Washington State Ferries (WSF). The second objective is to analyze these currents and estimate the exchange of water between Puget Sound and the Strait of Juan de Fuca, on tidal, seasonal, and inter-annual timescales.

4.3 Information needed and sources

Full depth profiles of the currents (i.e., surface to seabed) are needed once per hour at locations spanning Admiralty Inlet, with at least 500 m resolution across the inlet. The dataset must be nearly continuous and span multiple years, to address all the relevant time scales. This is only possible by utilizing the WSF, since continuous data collection via a dedicated research vessel is cost prohibitive, as is an array of moorings that could provide similar spatial resolution.

4.4 Target population

There is no specific target population. The water circulation we will study has potential effects for all marine species in Puget Sound.

4.5 Study boundaries

The study is focused on Admiralty Inlet, which is the main entrance to Puget Sound from the ocean, via the Strait of Juan de Fuca. The specific transect is an approximate line from Admiralty Head (on Whidbey Island) to Point Wilson (on the Olympic Peninsula).

4.6 Tasks required

The specific tasks are:

A. Oversee logistical and technical aspects of ADCP installation on two WSDOT ferries (vessels currently assigned to the Pt. Townsend-Coupeville route). This will include developing a Standard Operating Procedure (SOP) for Installation of ADCPs on Ferry Vessels.

B. Design, test, troubleshoot, and manage the installation of two Ferry-based Autonomous Sensor and Telemetry (FAST) systems. Systems must ensure adequate power supply/conditioning to ADCPs and ancillary sensors and include robust equipment protection plans. Automated/remote system administration and recovery schemes must be developed to restore system functionality without requiring WSDOT or Ecology personnel to manipulate equipment onboard ferries.

C. Design, test, troubleshoot, and implement software to automate onboard ADCP data collection, pre-processing, QC-screening (Level 0), binning, compression, and transfer.

D. Design, test, troubleshoot, and implement a customizable Remote Data Acquisition and Dissemination System (RDADS) to receive, store/archive, organize, perform QC-screening (Level 1), post-process, and provide remote data access for Ecology and ADCP data users using Commercial Off-the-Shelf (COTS) software and cloud computing technologies. This will include developing an SOP for WSDOT Ferry ADCP Data Processing and QA/QC.

4.7 Practical constraints

All activities for this project rely on the cooperation of WSF and are to be conducted on a not-to-interfere basis with their regular operations. WSF has signed agreement (GCB 1723), which grants permission for the installation and use of ADCPs on WSF vessels. The agreement acknowledges that WSF may reassign routes to vessels at any time, and thus the intended route across Admiralty Inlet is not guaranteed to be measured by an ADCP-equipped ferry. WSF has agreed to act in good faith and attempt to keep ADCP-equipped vessels on that route. In addition, although the original intent was to instrument two ferries, the WSF costs may only cover mounting on one ferry.

Another practical constraint is the ADCP technology itself, which typically requires substantial averaging of raw ‘pings’ to achieve reliable data. Thus, spatial and temporal resolution will be limited to approximately 300 m and 60 s, respectively. Finally, hull-mounted ADCPs can have substantial inference from bubbles along the hull of a vessel (Balfour et al., 2013; Flagg et al., 1998), and this may introduce additional practical constraints on data quality. These potential issues will be addressed in the SOP for Ferry ADCP Data Processing and QA/QC.

4.8 Systematic planning process used

This QAPP is the culmination of the systematic planning for this project. Planning during the life of the project will include regular coordination with WSF, in the form of monthly meetings and regular email updates between APL-UW and Ecology. Planning centers around the shipyard maintenance schedule for WSF.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities (project team, decision-makers, stakeholders, lab, etc.)

- Jim Thomson (APL-UW): Principal Investigator, responsible for data specifications and overall coordination of project.
- Alex deKlerk (APL-UW): Field Engineer, responsible for detailed system design and assembly, including testing and installation.
- Joe Talbert (APL-UW): Field Engineer, assists with system testing and installation, maintenance.
- Carol Maloy (Ecology): Project Manager, initiation of project, oversight and compliance, budget.
- Christopher Krembs (Ecology): Scientist, data specifications and use.
- Brandon Sackmann (Integral Consulting): Data management and delivery.
- Sheila Helgath (WSF): Environmental Program Manager, project liaison.
- Cotty Fay (WSF): Chief Naval Architect, responsible for design of thru-hull "sea chest" mount.
- Bill Hughes (WSF): Captain, determines/approves vessel use.
- Mark Scoville (WSF): Electrical Engineer, determines/approves cable routings.
- M. Burgos (WSF): Network administrator, monitors/approves APL-UW computer for onboard use.

5.2 Organization chart

N/A

5.3 Project schedule

See Table 1.

5.4 Limitations on schedule

The overall schedule (Table 1) depends upon the dry-dock schedule of the selected ferries (Table 2). Once installed, the project is expected to continue indefinitely, subject to funding availability for maintenance and ongoing operations. Operational costs are covered in the original project for two years, after which additional operational funds will become necessary.

Table 1. Deliverable schedule.

Deliverable	Estimated Schedule
Quality Assurance Project Plan (QAPP). Deliverables: • Draft QAPP • Final QAPP	12/31/2013 4/30/2014
Sensor System Prototyping and Installation SOP Development, Ferry #1. Deliverable: Draft WSDOT Ferry ADCP Installation SOP	1/31/14 or 3 months prior to installation of sensors on Ferry #1 (during dry-dock, see Table 1-2)
Sensor System Prototyping and Installation SOP Refinement, Ferry #2. Deliverable: Final WSDOT Ferry ADCP Installation SOP	9/30/14 or 1 mo. prior to installation of sensors on Ferry #2 (during dry-dock, see Table 1-2)
Data Processing/QAQC SOP Development. Deliverables: • Draft WSDOT Ferry ADCP Data Processing/QAQC SOP; • Final WSDOT Ferry ADCP Data Processing/QAQC SOP. • Fully processed/QAQC'd ADCP data products from Ferries 1 and 2	11/30/14 or 6 mo. after installation of sensors on Ferry #1. 4/30/15 - delivered 6 mo. after installation of sensors on Ferry #2. 4/30/15 - delivered 6 mo. after installation of sensors on Ferry #2.

Table 2. Ferry dry-dock schedule, as provided by WSFDOT, that will drive Deliverable schedule in Table 1.

Vessel	Current Route	Next Dry-Dock
#1 MV *Salish*	Pt. Townsend - Coupeville	May 2014
#2 MV *Kennewick*	Pt. Townsend - Coupeville	Oct 2014

5.5 Budget and funding

This project is funded to Ecology by the US Environmental Protection Agency, as part of the National Estuary Program. Ecology has subcontracted APL-UW to implement the project, and APL-UW has subcontracted WSF to retrofit their vessel(s) with ADCP mounts. APL-UW has also selected Integral Consulting to handle the data management and delivery. Table 3 outlines the amounts and responsibilities.

Table 3. Project budget.

Organization	Responsibility	Budget
Ecology	Purchase ADCPs, manage project	$58,331
APL-UW	Design, install, and maintain system	$79,507
APL-UW (subcontract with WSF)	Design and fabricate hull mount	$40,000
APL-UW (subcontract with Integral Consulting)	Data management and delivery	$83,269
	(TOTAL)	**$261,107**

6.0 Quality Objectives

6.1 Decision Quality Objectives (DQOs)

None.

6.2 Measurement Quality Objectives

The measurements of currents must be vertical profiles from within a few meters of the seabed to within a few meters of the surface, and these must be collected across transects of Admiralty Inlet.

6.2.1

Table 4. Targets for water velocity (currents).

Metric	Value (ensemble-averaged)
Precision	< 0.1 m/s
Bias	< 0.1 m/s
Sensitivity	< 0.1 m/s
Temporal resolution	60 s
Spatial resolution (horizontal)	500 m
Spatial resolution (vertical)	5 m
Repeat cycle	> 3 times per tide

6.2.1.1 Precision

To determine exchange flows and circulations that are commonly 0.5 m/s, the ensemble averages of water velocities should have a precision of at least 0.1 m/s. This is readily achievable for ensemble-averaged ADCP data, provided vessel motion is correctly removed from the raw data.

6.2.1.2 Bias

Similarly, the bias should be less than 0.1 m/s. ADCP data have an intrinsic zero bias; however, incomplete removal of ship motion data could introduce a bias for hull-mounted data. The rectified data should be consistent, regardless of vessel heading, to within 5 degrees.

6.2.1.3 Sensitivity

The water velocity sensitivity should be at least 0.1 m/s. This readily achievable from ensemble-averaged ADCP data, provided vessel motion is correctly removed from the raw data.

6.2.2 Targets developed for: water velocity (currents)

6.2.2.1 Comparability

A comprehensive ADCP dataset exists from a site characterization study for a tidal energy project at Admiralty Head (Polagye and Thomson, 2012). These measurements have been used to study circulation and exchange flow at a point (see Deppe, 2013), and these can be used to compare with transects that will be collected via ferry ADCP, using very similar instruments. The Admiralty Head site is within 1 km of the typical ferry route, and is characteristic of the Inlet. The Admiralty Head data were collected in accordance with Ecology's SOP for fixed ADCP measurements, and the new ferry ADCP measurements SOP will be adapted from that SOP (in an effort to maintain comparability).

6.2.2.2 Representativeness

Data collection must continue year-round, across all seasons and tidal conditions, to determine the exchange flow patterns at Admiralty Inlet. Deppe (2013) and Deppe et al., (2013) showed that exchange flow depends on tidal phasing, coastal upwelling, and river discharge. A representative dataset for circulation must cover the full range of these parameters and sampled often enough to avoid aliasing the signals (e.g., multiple samples per tide are required). Ferry monitoring is an efficient way to capture such a large dataset and nearly continuous dataset.

6.2.2.3 Completeness

A nominal 95% of the collected ferry ADCP transects should be valid to ensure a successful project. Actual completeness will be determined by comparing exchange flow measurements against the predictions of Deppe (2013).

7.0 Sampling Process Design (Experimental Design)

7.1 Study Design

7.1.1 Sampling location and frequency

ADCP instruments will be installed in the hulls of two separate ferries to minimize the risk of data gaps in case one ferry is temporarily taken out of service or is assigned a different route. ADCP data will be collected continuously (at 2 Hz) during ferry crossings from Coupeville to Port Townsend (i.e., transects of Admiralty Inlet). The number of crossings per day is expected to be around 12, subject to the actual WSF schedule. These crossings will occur every day, from installation onwards.

7.1.2 Parameters to be determined

Vertical profiles of currents will be determined at locations across Admiralty Inlet, from which exchange flow estimates will be calculated (using a 40-hour low pass filter).

7.1.3 Field measurements

Vertical profiles of currents will be measured by hull-mounted Acoustic Doppler Current Profilers. Ancillary data, including acoustic signal strength (backscatter amplitude) and correlation will also be collected and used for quality control. Ship speed and heading will be measured by GPS and used to correct the raw currents to a fixed reference frame.

7.2 Maps or diagram

ADCP measurements will be made onboard WSF ferries crossing from Coupeville to Port Townsend.

7.3 Assumptions underlying design

It is assumed that exchange flows and sub-tidal circulation through Admiralty Inlet are strong enough to be estimated from approximately 12 transect measurements per day. (It is well demonstrated that exchange flows can be estimated from 100 measurements per day at a single mooring location.)

7.4 Relation to objectives and site characteristics

Admiralty Inlet is the most important site for oceanic inflow to Puget Sound, and the Port Townsend to Coupeville ferry route is ideal for monitoring across this site. The only challenge will be in data interpretation during route deviations (when the ferry must alter course to accommodate other traffic and thus not collect data over a uniform grid). These route deviations can be identified by the associated global positioning system (GPS) data. Physical access is difficult and expensive by any other means than the ferries.

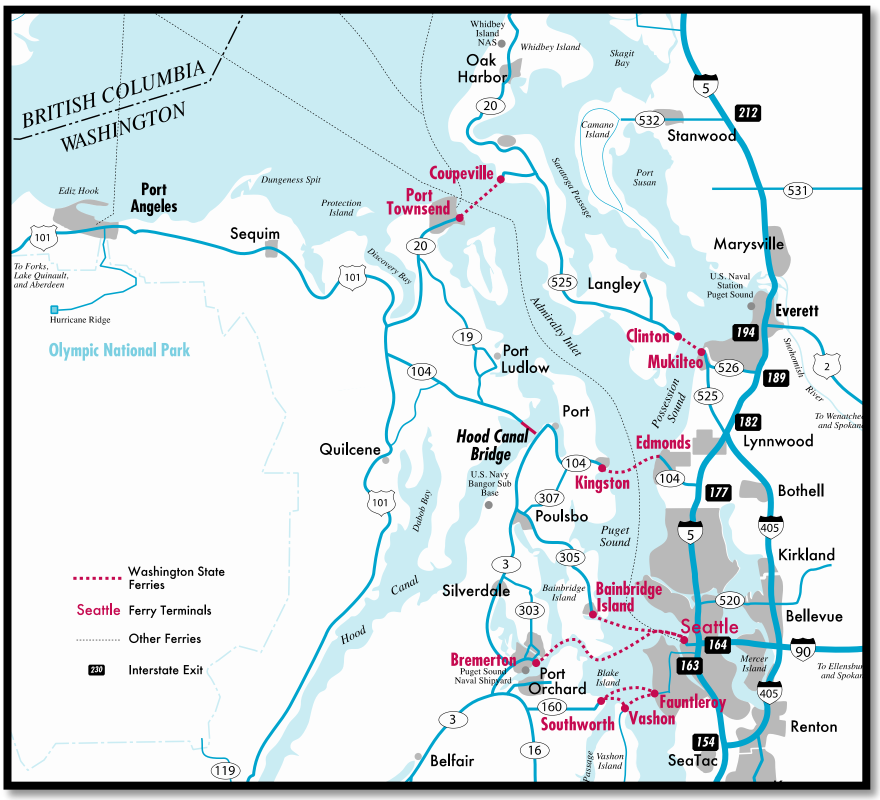

Figure 2. Washington State Ferry routes in Puget Sound.

7.5 Characteristics of existing data

Several years of current profile data exists for a single location in the vicinity of Admiralty Head (near the Coupeville terminal in Figure 2), which is the site of planned tidal energy pilot installation. This data clearly shows that strong (up to 0.5 m/s) inflows of ocean water occur, but the data cannot be used to quantify the total flux of oceanic water, because the data are from a signal location. Transects collected from ADCPs on ferries will provide data on flows across the whole inlet, from which total flux calculations will be possible.

8.0 Sampling Procedures

8.1 Field measurement and field sampling SOPs

A new SOP will be written for hull-mounted ADCP measurements. It will be modified from an existing SOP for moored ADCP measurements (Albertson, 2009).

8.2 Measurement and sample collection

Data collection will use an ADCP (RDI Workhorse Mariner, 300 KHz) mounted to the hull of a ferry, connected via serial cable to a computer in the ship's electronics room. GPS data from the ship's navigation system will be collected simultaneous on the same computer. A block diagram of these elements is shown below in Figure 3.

Data collection will use VMDAS software from the ADCP vendor, Teledyne RDI. The system will be set to start automatically upon power up, via auto-start in the VMDAS settings and the Windows start executable. VMDAS will collect both raw ADCP data and raw GPS data, which will be saved as binary files. VMDAS will process the data in real time to create quality-controlled outputs of current profiles in the fixed earth reference frame (i.e., corrected for vessel motion using both GPS data and the "bottom track" capability of the ADCP). For the correction to work properly, it is important that the 'EA' alignment parameter be set correctly in VMDAS; this describes the difference in alignment of beam #3 on the ADCP relative to the bow of the ship (#1 end on the double-ended ferry). These outputs will be STA (short-term average, 15 s) and LTA (long-term average, 60 s) ensemble values from the raw data (collected twice per second).

Data collection will be continuous during all vessel operations and will be reset daily, via power cycling of the switch PDU (see system diagram). Once a day, the LTA results will be emailed, using an automated python script, to an onshore server administered by Integral Consulting. The raw data and complete files will be off-loaded by hand (hard drive exchange) during maintenance visits to the vessels every 3 months.

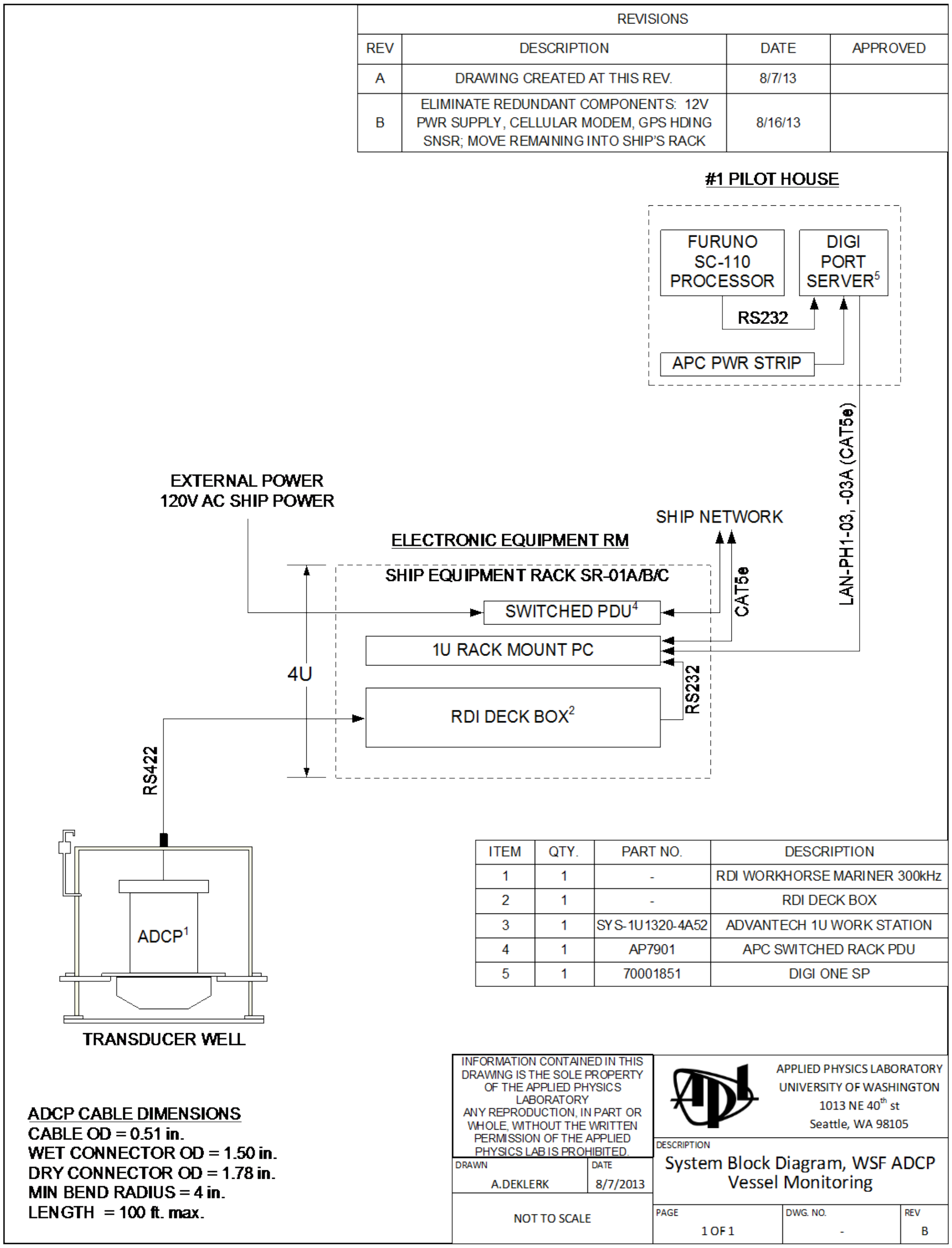

Figure 3. System block diagram.

8.3 Containers, preservation methods, holding times

N/A

8.4 Invasive species evaluation

N/A

8.5 Equipment decontamination

N/A

8.6 Sample ID

ADCP data files ("samples") will be named with unique sequence IDs and time stamps.

8.7 Chain-of-custody, if required

ADCP data files ("samples") will be collected onboard the ferry using an APL-UW computer. The files will be transmitted nightly to Integral Consulting via an automated email script. Once entered into a database, all data will become custody of Ecology.

8.8 Field log requirements

Logging during regular data collection will be automated in the VMDAS software, which records times and locations for each raw ADCP measurement, prior to onboard processing for ensemble results. A hand-written log will be kept for maintenance visits (every 3 months) onboard the vessels, which will document: date, time, location, personnel, system status, equipment status, and actions/recommendations.

8.9 Other sampling-related activities

All staff participating in on-site activities must be registered with WSF and have Transportation Worker Identification Cards (TWIC).

The ADCP will also measure pressure, and this will be used to monitor the status of the "sea chest" thru-hull mount. The pressure should be nearly atmospheric inside the mount. If a leak were to occur in the mount, the pressure would increase by several decibar, because the instrument will be mounted a few meters below the water surface.

9.0 Measurement Methods

No laboratory measurements will be made for this project.

Raw ADCP data will be rectified to a fixed (earth) coordinate system by removing the vessel speed and heading. This will be done using the VMDAS software, with the NMEA navigation data as the reference.

10.0 Quality Control (QC) Procedures

10.1 Table of field QC required (see Table 4)

ADCPs are inherently noisy and prone to errors. These errors will be reduced by the installation procedure, onboard quality control, and by using screening criteria of acoustic signal characteristics. The errors are further reduced by ensemble averaging the raw data.

Initial data acquired from the ADCP must be checked for "ringing", a phenomenon wherein the acoustic signal within the sea chest degrades the data quality of the water velocity measurements. If ringing is found, the blanking distance must be increased in the ADCP configuration.

Initial data acquired from the ADCP must be checked for heading errors, by comparing rectified currents collected with the vessel transiting a known region at multiple headings. The rectified data should be consistent, regardless of vessel heading, to within 5 degrees.

10.2 Corrective action processes

If quality control criteria listed in Table 4 are not met, data will be discarded, and no ensemble result will be reported for that point.

11.0 Data Management Procedures

11.1 Data recording/reporting requirements

Data will be recorded and processed in the field using the VMDAS software from RDI, then automatically emailed to Integral Consulting. Integral Consulting will develop a custom Remote Data Acquisition and Dissemination System (RADS) to receive the data, parse the daily files into individual crossings (transects), and archive them in a nonproprietary database using a standardized format (CF-compliant NetCDF). The RADS will include a web interface to query the data, including visualization and download capabilities. The RADS will also include post-processing to map the data to a uniform grid and determine the 40-hr low pass filtered currents (i.e., sub-tidal exchange flow) across the inlet. The final process will be thoroughly documented in a technical memo or the final project report. Ecology is guaranteed full access to all raw and processed data, as well as all custom-developed programming and databases.

11.2 Lab data package requirements

N/A

11.3 Electronic transfer requirements

Data from RADS must be available in text and NetCDF formats.

11.4 Acceptance criteria for existing data

None.

11.5 EIM/STORET data upload procedures

Once the RADS is up and running, it can be ported over to Ecology's infrastructure for inclusion in EIM or STORET.

12.0 Audits and Reports

12.1 Number, frequency, type, and schedule of audits

Field audits will be accomplished by means of examination the real-time data stream.

12.2 Responsible personnel

N/A

12.3 Frequency and distribution of report

APL-UW will keep all project partners up-to-date with biweekly emails and monthly meetings. APL-UW will produce an installation SOP and will produce a technical memo once the system is running successfully. Integral Consulting will report on design and implementation of the RADS.

12.4 Responsibility for reports

APL-UW will produce a final report and coordinate peer review and approval of interim reporting.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

Collected ADCP data will be transmitted to Integral Consulting, who will verify the data. Integral Consulting will assure the minimum spatial and temporal resolution has been achieved, and that ADCP signal quality is acceptable.

13.2 Lab data verification

N/A

13.3 Validation requirements, if necessary

N/A

14.0 Data Quality (Usability) Assessment

14.1 Process for determining whether project objectives have been met

ADCP data from ferry crossings will be evaluated after one full year of monitoring. Low-passed filtered data will be used to identify exchange flows, which are expected to occur during neap tides with maximum diurnal inequalities (Geyer and Canon, 1982), especially in the late summer and early fall when coastal upwelling is strong (Deppe et al., 2013). Objectives will have been met when sub-tidal exchange flows of order 0.3 m/s are mapped across the entrance to Puget Sound (Admiralty Reach). Additional detail will be included in the SOP for WSDOT Ferry ADCP Data Processing and QA/QC.

14.2 Data analysis and presentation methods

Individual transects of data will be presented as contoured cross-sections, color--scaled by velocity (see Figure 1). Intrusion (the volume of ocean water entering Puget Sound) and discharge (the volume of less saline water leaving Puget Sound) will be estimated as the sum of current velocity measurements (m/s), for each ferry transect, times the area (m^2) of each cross-section represented by each measurement. Exchange flow will be calculated as the average of the intrusion and discharge magnitude per unit time and filtered with a 40-hr window running average that will expose the sub-tidal flows. The result will be tested for statistical significance and compared with the predictions of (Deppe et al., 2013). The data will also be used to validate numerical circulation models (e.g. PNNL's efforts using the FVCOM model).

14.3 Treatment of non-detects

N/A

14.4 Sampling design evaluation

N/A

14.5 Documentation of assessment

Project objectives will be complete when Ecology has two integrated, fault-tolerant FAST systems that provide near-realtime (<1-day) ADCP data products from WSDOT ferries running between Pt. Townsend-Coupeville, and end users with an interface to download and visualize data products in a variety of formats.

15.0 References

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16.0 Figures

17.0 Tables

18.0 Appendices

Appendix A. RDI Workhorse Mariner Acoustic Doppler Current Profiler
Appendix B. “Sea chest” hull-mount concept.
Appendix C. VMDAS settings.
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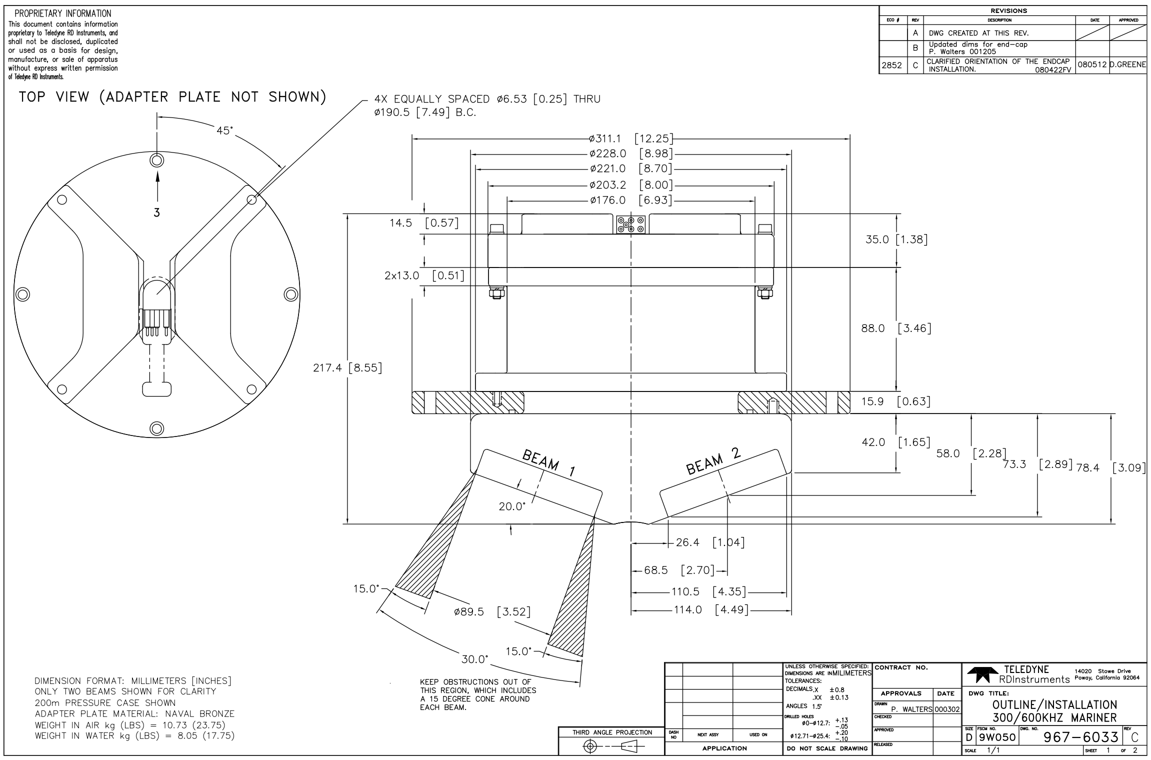
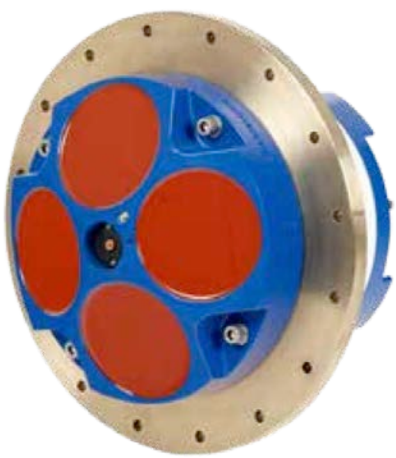
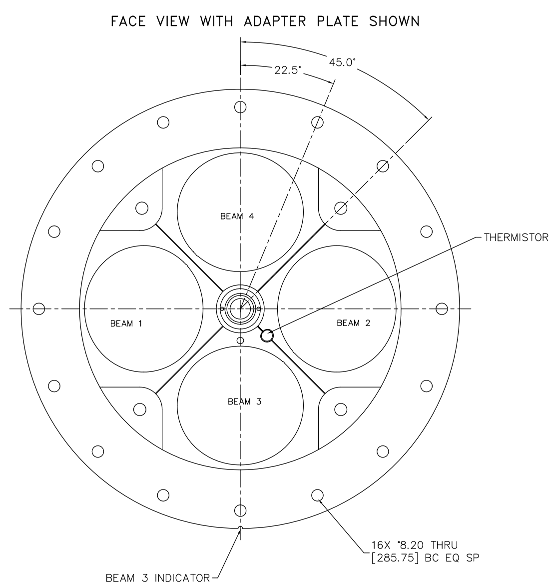
18.0 Appendices

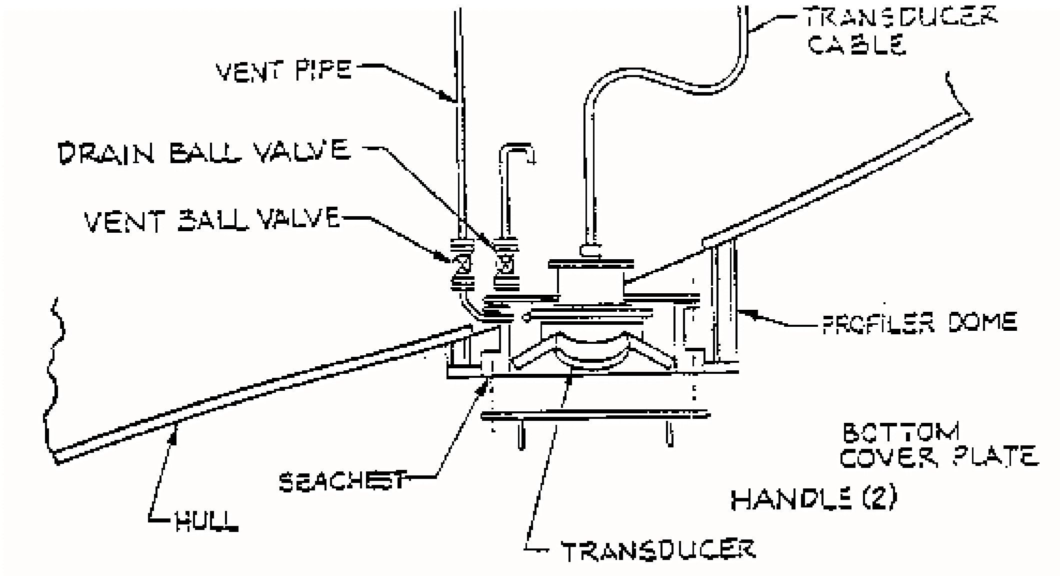
Appendix A. RDI Workhorse Monitor ADCP







Appendix B. Sea chest hull mount concept



Appendix C. VMDAS settings

```
;---------------------------------------------------------------------------\
; ADCP Command File for use with VmDas software.
;
; ADCP type:     300 Khz Workhorse
; Setup name:    default
; Setup type:    Low resolution, long range profile(broadband processing)
;
; NOTE:  Any line beginning with a semicolon in the first
;        column is treated as a comment and is ignored by
;        the VmDas software.
;
; NOTE:  This file is best viewed with a fixed-point font (e.g. courier).
; Modified Last: 12 Jun 2012 (test ferry route settings for WA ECY)
;---------------------------------------------------------------------------/
; Restore factory default settings in the ADCP
cr1

; VmDAS setting for serial output, flow control
CF01110

; set the data collection baud rate to 9600 bps,
; no parity, one stop bit, 8 data bits
; NOTE:  VmDas sends baud rate change command after all other commands in
; this file, so that it is not made permanent by a CK command.
cb411

;  single-ping ensembles
; (WP), 25 (WN) 5 meter bins (WS), 2 meter blanking distance (WF), 800 cm/s
; ambiguity vel (WV)
WB0
WP00001
WN025
WS500
WF200
WV800

; Enable single-ping bottom track (BP),
; Set maximum bottom search depth to 110 meters (BX)
BP001
BX1100

; output velocity, correlation, echo intensity, percent good
WD111100000
```

```
; One half second between bottom and water pings
TP000050

; One second between ensembles
; Since VmDas uses manual pinging, TE is ignored by the ADCP.
; You must set the time between ensemble in the VmDas Communication options
TE00000100

; Set to calculate speed-of-sound, use internal depth sensor (if available), use internal
; compass heading sensor, use internal pitch or roll being used, no salinity sensor, use
; internal transducer temperature sensor
EZ1111101

; Output beam data (rotations are done in VMDAS)
EX00000

; Set magnetic compass offset or compass bias offset (hundredths of degrees)
; Don't use this, set EA (measure during installation) and EV (0 for GPS) in VMDAS
instead
; where EA is alignment of beam 3 relative to the bow of the ship
;EB00000

; Set transducer depth (decimeters)
ED00010

; Set Salinity (ppt)
ES29

; save this setup to non-volatile memory in the ADCP
CK
```

Appendix D. Data Memo on ADCP tests

DATA MEMO

Admiralty Reach ferry-mounted Acoustic Doppler Current Profile (ADCP) tests

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For: Washington State Department of Ecology

13 Dec 2012

BACKGROUND & OBJECTIVES

WA Ecology is planning to install Acoustic Doppler Current Profilers (ADCPs) on passenger ferries transiting key regions in Puget Sound. In Admiralty Reach, the relevant route is the Port Townsend to Coupeville route. To evaluate the potential quality and resolution of such ADCP data, and in particular concerns regarding the 10-12 knt speed of the ferries, the Applied Physics Lab at University of Washington (APL-UW) collected shipboard ADCP along this ferry route using a similar instrument and vessel speed.

DATA COLLECTION

Ferry route ADCP data were collected from the R/V Jack Robertson in both June and September 2012 as part of ongoing research cruises in the area. The ADCP was an RDI 300 kHz Workhorse mounted within a wet-well thru-hull port, approximately 1 m below the waterline. The RDI "VmDas" software was used to collect the data, including a NMEA serial feed of GPS positions and vessel speed over ground (SOG). Two crossings (one eastbound, and one westbound) were conducted on each cruise. The data were processed and viewed in realtime using the RDI "WinADCP" software package. The data and configuration files were delivered to Ecology via email, and are archived by APL-UW at http://faculty.washington.edu/jmt3rd/FerryADCPtests.zip

Raw data were recorded in standard RDI binary formats, then quality control was applied in WinADCP. The ADCP settings were: 25 x 5 m bins, 2 m blanking distance, 8 m/s ambiguity velocity, pinging as fast as possible (nominally 1 s). Bottom tracking, which is usually preferred

for shallow shipboard ADCP data collection, was disabled because of the fast vessel speeds. However, in September, bottom tracking was used successfully.
During data collection, all other sonars (i.e., depth sounders) were turned off, because of previous experience with acoustic interference (despite a difference of 50 kHz between the instruments). The interference is thought to be exaggerated on the Robertson, because the depth sounder is mounted close the ADCP.

RESULTS

The data collection was successful and the resulting transects of velocity suggest that high quality shipboard ADCP data can be expected from ferry routes. The primary trade-off is between resolution and accuracy. By using large vertical bins (5 m), the Doppler noise of individual pings is reduced. However, individual pings are still too noisy for robust estimates of the currents, and thus ensemble time averaging is used to improve the estimates. Figure 1 shows an eastbound transect using a short-term average (STA) of 15 seconds and the same data using a long-term average (LTA) of 1 minutes. Since the data was collected in raw form, the choice of time-average can be easily adjusted in post processing (via WinADCP or third party software). The STA results have some evidence of noise, which is reduce in the LTA results. Figure 2 shows a westbound transect, which is similar, except for spurious data at the beginning of the transect with the Robertson was turning too fast for the heading sensor to adjust. In these examples, the LTA results are sufficient resolution (1 minute ~ 300 m) to resolve the large-scale flow patterns through Admiralty Reach.

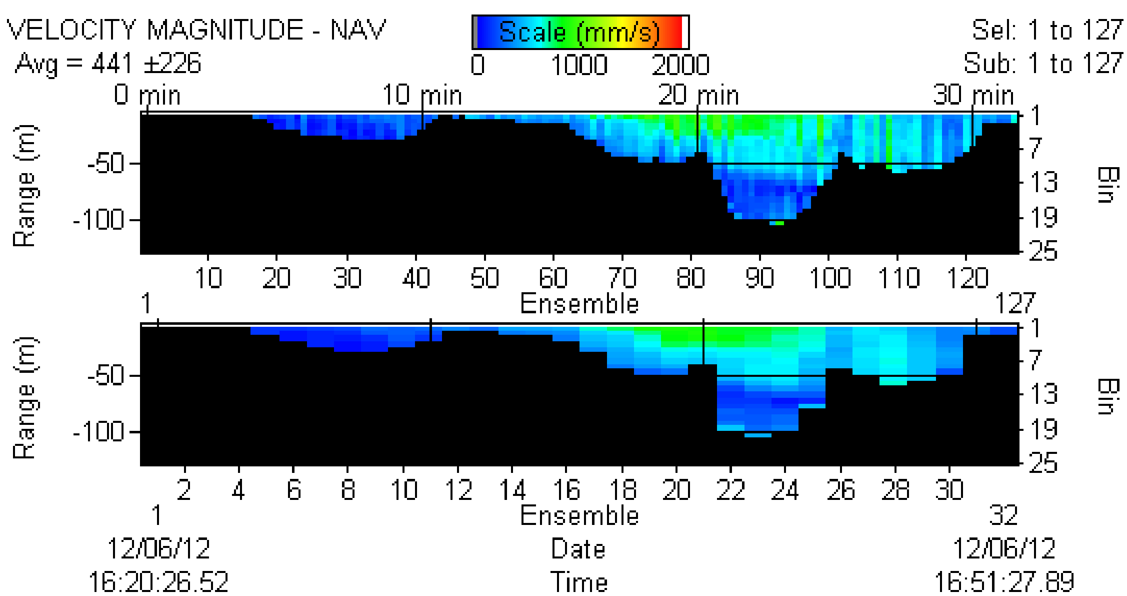

Figure 1. Eastbound ADCP transect at 10 knts SOG, processed with short-term averaging (top) and long-term averaging (bottom).

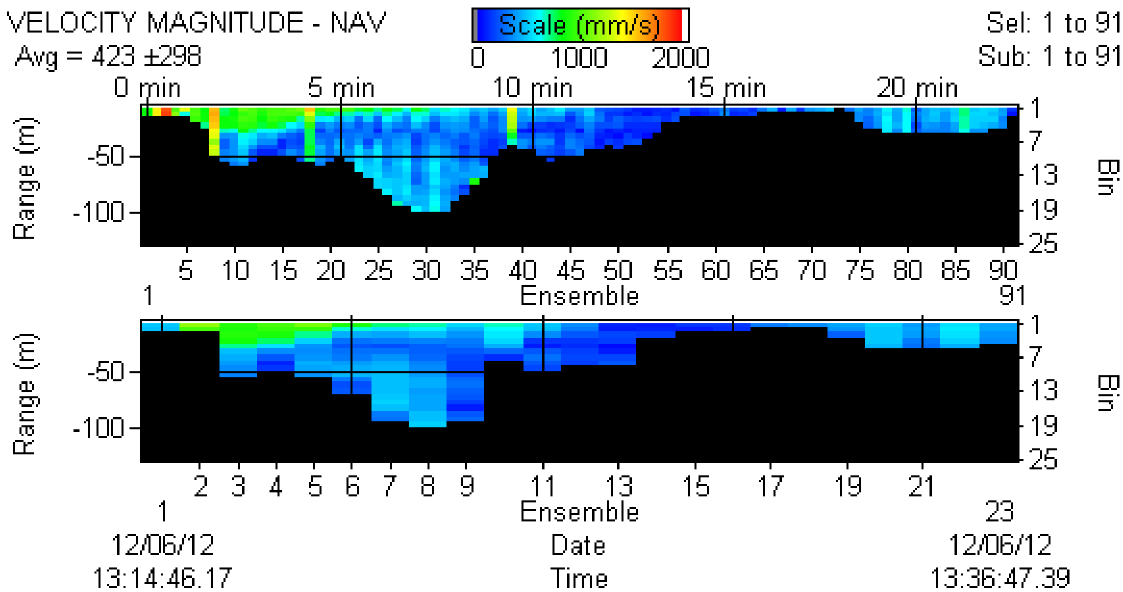

Figure 2. Westbound ADCP transect at 10 knts SOG, processed with short-term averaging (top) and long-term averaging (bottom).

In addition to time-averaging, the values in Figure 1 & 2 were quality controlled using optional settings with the WinADCP software. The threshold for *percent good pings* was set to 90, and the *RSSI bump detection* was used to remove data at or below the seabed. Again, because the data was collected in raw format, these quality control choices can be adjusted in post-processing. The size of the raw data for a signal transect is approximately 3 MB.

RECOMMENDATIONS & CONCLUSIONS

Collection of ADCP data from WA State ferries is recommended as useful tool in quantifying the large scale flow along ferry routes that transect of Puget Sound. Tests aboard the R/V Jack Robertson suggest that high-quality data can be collected at vessel speeds of 10 knts or more, and averaging the raw ping data as 1 minute ensembles provides a useful description of the flow with low sampling noise. Quality control measures available in the RDI WinADCP software are sufficient. To make full use of the quality control options, it is strongly recommended that ADCP data be collected in raw format using VmDas. Finally, if it is necessary to run an ADCP simultaneously with a depth sounder onboard a ferry, the two instruments should be mounted as far apart as possible, and the ADCP data should be evaluated for interference (which would appear as elevated backscatter amplitude when pings cross).

Appendix E. Glossary, Acronyms, and Abbreviations

Quality Assurance Glossary

Accuracy - The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms precision and bias be used to convey the information associated with the term accuracy. (USGS, 1998)

Calibration - The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured. (Ecology, 2004)

Comparability - The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator. (USEPA, 1997)

Completeness - The amount of valid data obtained from a data collection project compared to the planned amount. Completeness is usually expressed as a percentage. A data quality indicator. (USEPA, 1997)

Data Integrity - A qualitative DQI that evaluates the extent to which a dataset contains data that is misrepresented, falsified, or deliberately misleading. (Kammin, 2010)

Data Quality Indicators (DQI) - Data Quality Indicators (DQIs) are commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity. (USEPA, 2006)

Data Quality Objectives (DQO) - Data Quality Objectives are qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions. (USEPA, 2006)

Dataset - A grouping of samples, usually organized by date, time and/or analyte. (Kammin, 2010)

Data validation - An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment, and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability and integrity, as these criteria relate to the usability of the dataset. Ecology considers four key criteria to determine if data validation has actually occurred. These are:

- Use of raw or instrument data for evaluation
- Use of third-party assessors
- Dataset is complex
- Use of EPA Functional Guidelines or equivalent for review

Examples of data types commonly validated would be:

- Gas Chromatography (GC)
- Gas Chromatography-Mass Spectrometry (GC-MS)
- Inductively Coupled Plasma (ICP)

The end result of a formal validation process is a determination of usability that assigns qualifiers to indicate usability status for every measurement result. These qualifiers include:

- No qualifier, data is usable for intended purposes
- J (or a J variant), data is estimated, may be usable, may be biased high or low
- REJ, data is rejected, cannot be used for intended purposes (Kammin, 2010; Ecology, 2004)

Data verification - Examination of a dataset for errors or omissions, and assessment of the Data Quality Indicators related to that dataset for compliance with acceptance criteria (MQO's). Verification is a detailed quality review of a dataset. (Ecology, 2004)

Measurement Quality Objectives (MQOs) - Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness. (USEPA, 2006)

Measurement result - A value obtained by performing the procedure described in a method. (Ecology, 2004)

Method - A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed. (EPA, 1997)

NMEA data - National Marine Electronics Associated standard format for sending navigational data, as collected by a Global Positioning System (GPS), such as vessel latitude, longitude, and speed over ground (SOG), and true heading (HDT)

Percent Relative Standard Deviation (%RSD) - A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

Percent relative standard deviation, %RSD = (100 * s)/x where s = sample standard deviation, and x = sample mean. (Kammin, 2010)

Parameter - A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene, nitrate+nitrite, and anions are all “parameters”. (Kammin, 2010; Ecology, 2004)

Precision - The extent of random variability among replicate measurements of the same property; a data quality indicator. (USGS, 1998)

Quality Assurance (QA) - A set of activities designed to establish and document the reliability and usability of measurement data. (Kammin, 2010)

Quality Assurance Project Plan (QAPP) - A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives. (Kammin, 2010; Ecology, 2004)

Quality Control (QC) - The routine application of measurement and statistical procedures to assess the accuracy of measurement data. (Ecology, 2004)

Relative Percent Difference (RPD) - RPD is commonly used to evaluate precision. The following formula is used:
Abs(a-b)/((a+b)/2) * 100
Where a and b are 2 sample results, and abs() indicates absolute value
RPD can be used only with 2 values. More values, use %RSD.
(Ecology, 2004)

Representativeness - The degree to which a sample reflects the population from which it is taken; a data quality indicator. (USGS, 1998)

Sample (statistical) - A finite part or subset of a statistical population. (USEPA, 1997)

Sensitivity - In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit. (Ecology, 2004)

Standard Operating Procedure (SOP) - A document which describes in detail a reproducible and repeatable organized activity. (Kammin, 2010)

References for QA Glossary

Ecology, 2004. Guidance for the Preparation of Quality Assurance Project Plans for Environmental Studies. https://fortress.wa.gov/ecy/publications/summarypages/0403030.html

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USEPA, 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process EPA QA/G-4. http://www.epa.gov/quality/qs-docs/g4-final.pdf

Kammin, 2010. Definition developed or extensively edited by William Kammin, 2010. Head

USGS, 1998. Principles and Practices for Quality Assurance and Quality Control. Open-File Report 98-636. http://ma.water.usgs.gov/fhwa/products/ofr98-636.pdf

Glossary – General Terms

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

Parameter: A physical chemical or biological property whose values determine environmental characteristics or behavior.

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality-limited estuaries, lakes, and streams that fall short of state surface water quality standard, and are not expected to improve within the next two years.

Acronyms and Abbreviations

e.g.	For example
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
GIS	Geographic Information System software
GPS	Global Positioning System
i.e.	In other words
MQO	Measurement quality objective
NMEA	National Marine Electronics Association

QA	Quality assurance
RADS	Remote Data Acquisition and Dissemination System
RDI	R D Instruments
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
TMDL	(See Glossary above)
UW	University of Washington
VMDAS	Software from RDI (ADCP manufacturer)
WSF	Washington State Ferries

Units of Measurement

cfs	cubic feet per second
cms	cubic meters per second, a unit of flow.
ft	feet
kcfs	1000 cubic feet per second
km	kilometer, a unit of length equal to 1,000 meters.
l/s	liters per second (0.03531 cubic foot per second)
m	meter
mg	milligram
mL	milliliters
mm	millimeter
psu	practical salinity units
um	micrometer