Appendix C

Mouth of the Columbia River Offshore Disposal Site Study Investigations, Provisional Report prepared by Global Remote Sensing, dated December 12, 2005

Mouth of the Columbia River Offshore Disposal Site Study
Multibeam Investigations
VOLUME 1 of 1

Provisional Report

Report No:

Prepared for:

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12 December 2005

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Issue No.	**Date**	**Description**	**Checked**	**Approved**
0		Preliminary Report		

Table of Contents

Appendices

1. INTRODUCTION

The U.S. Army Corps of Engineers, Portland District is conducting a study to identify bottom characteristics of existing and potential offshore sites and adjacent areas, relating to the disposal of material dredged from the Columbia River mouth (MCR) navigation channel. Multibeam surveys will provide detailed bathymetry of these area. Backscatter information derived from the multibeam survey will be used for bottom classification.

Precision bathymetry was used to obtain complete detailed coverage of the seafloor within the areas of survey as presented in Figure 1-1 and Table 1-1 and outlined in the Statement of Work dated June 13th, 2005 and revised July 27th, 2005, to exclude areas 3B, 3D, and 4A through 4D. The multibeam surveys provide detailed bathymetry of these areas, while the backscatter information derived from the multibeam survey will be used for quantitative bottom classification. Actual survey ranges (line spacing) were based on 125% to 200% coverage's within each of the priority areas. Individual coverage was determined by depth of area, speed, ping rate and line spacings to obtain complete seafloor coverage along with detailed information of the seafloor.

Table 1-1

Area	Descriptor	Distance Offshore	Area km^2	Water Depth ft
1A	DWS	10 to 15	42	180 to 310
1B	SWS	1 to 4	8.1	30 to 80
2A	MCR channel north	0 to 5	7.1	10 to 90
2B	MCR channel offshore	0.5 to 5	4.4	50 to 80
2C	Clatsop Spit	0 to 6	5.2	10 to 70
2D	South Jetty	4 to 5	4.7	30 to 60
2E	MCR channel east	5 to 6	2.7	10 to 130
3A	Offshore SWS	5 to 6	4.4	50 to 70
3C	ODMDS A	0 to 5	12.3	30 to 90

Surveys were conducted 15 August 2005 to 16 September 2005. The multibeam bathymetric surveys were conducted aboard two vessels; the M/V *Oakland Pilot,* a 51' retired pilot vessel from the Harbor of Oakland, CA, with a 16.5' beam, weighing 43 gross tons and drawing just over 6-ft of water and the R/V *Minotaur,* a 29' aluminum vessel with a 8.5' beam, weighing 8 gross tons, with a draft of 2-ft.

1.1 Project Geodesy

Survey was conducted in State Plane, NAD 83, Oregon North. All measurements are in units of Survey Feet. Depths are referenced to MLLW. Following is the geodetic summary of the survey:

Projection: State Plane, NAD 83, Oregon North
Survey Units: US Survey Feet
Vertical Datum: MLLW

2. SCOPE OF WORK

2.1 Offshore Geophysical Surveys

The final scope of work included two elements, namely multibeam bathymetry and MBES backscatter data acquisition/processing within nine designated survey areas as shown by Figure 1-1. The survey would be accomplished by repeated passes over the survey area spaced at intervals determined by the depth. Line spacing was based on 125% to 200% coverage's within the priority areas as a function of water depth. Area information was provided by USACOE.

2.2 Reporting and Charting

Reporting and charting were carried out by Global Remote Sensing (GRS) in their offices in Seattle, WA. This final report includes a description of the methods, surveys, and processing required to deliver a full-coverage description of seabed conditions. Deliverables included with this report are:

- Multibeam bathymetry (see Figure 2-1):
  - Sun-illuminated image of seafloor
  - ASCII XYZ file of gridded elevations
  - Bathymetric contours in agreed intervals
  - Trackline plots
- MBES Backscatter imagery (see Figure 2-2):

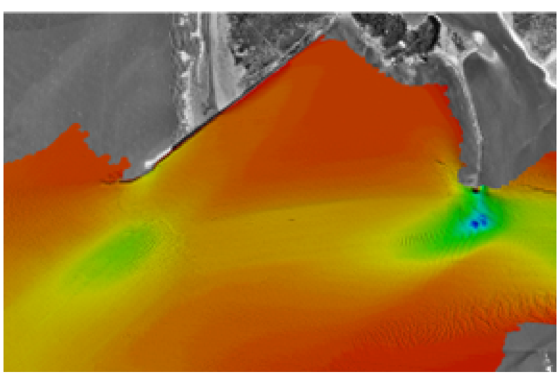


Figure 2-1. Example Sun-illuminated image of Seafloor from MCR survey.

Figure 2-2. Backscatter image of Seafloor.

3. METHODOLOGY

3.1 Offshore Survey Operations

3.1.1 Equipment and Personnel

Surveys were conducted aboard the survey vessels Oakland Pilot and Minotaur. The Oakland Pilot was transited to Astoria from Garibaldi, OR and mobilized out of the Hammond Marina. The R/V Minotaur was transited from Seattle, WA to Astoria and was also mobilized out of the Hammond Marina. The following personnel were involved in carrying out the MCR survey:

Figure 3-1. The Oakland Pilot

Figure 3-2. R/V Minotaur

Jeremiah Brantner	Project Manager and Senior Hydrographer, Global Remote Sensing, LLC
Kevin Tomanka	Hydrographer, Seafloor Systems Inc.
Jed Gray	Hydrographer, Seafloor Systems Inc.
Ryan Poff	Hydrographer, Global Remote Sensing, LLC
Steve Lemke	Hydrographer, Global Remote Sensing, LLC
Jim	Captain, Oakland Pilot
Mark Drage	Captain, R/V Minotaur

Data processing was conducted in the offices of Global Remote Sensing, LLC (GRS).

Jeremiah Brantner	Data Processing Manager, GRS
Kevin Tomanka	MBES Data Processing, SSI
Jed Gray	MBES Data Processing, SSI
Mike Leo	MBES Data Processing, GRS
Richard McGee	Backscatter Processing, GRS
Luciano Fonseca	Backscatter Processing, CCOM UNH
Daryl Pickworth	Charting and Mapping, GRS

3.1.2 Operations Summary and Calibrations

Survey operations consisted of multibeam echosounder (MBES) patch test calibrations, measurement of water column sound velocity distribution, and completion of concurrent multibeam surveys.

Sea conditions during surveys ranged from calm to very rough with the Coast Guard closing the Columbia River Bar on several occasions. Conditions were generally considered sufficient for MBES survey, however conditions were sometimes exceeded in some cases due to restrictions in acquisition timeframe. Actual weather conditions are documented in the daily survey report (Appendix B). All sea trials, calibrations, and surveys were completed by 16 September 2005.

Calibration of the multibeam system involves running a patch test on a newly installed or recently changed sonar mount location or position. The patch test is run to account for roll, pitch, and yaw (degrees) static offsets of the multibeam sensor as well as latency (milliseconds) from the navigation system. Procedures for the acquisition and processing of the patch test data as carried out for MCR can be found in the Caris HIPS & SIPS user's manual[1]. In summary, a series of survey trials were performed over known seafloor configurations run in opposite directions and/or varying survey speeds. Data were then processed to determine actual offsets based on calculated differences in the data sets collected over the same bottom area. The roll test was conducted over fairly flat terrain, running a single survey line in opposite directions. A steeply sloping seafloor was used for the latency, pitch and yaw tests. For pitch, a single line oriented perpendicular to shore was run in opposite directions at normal survey speed. The yaw test required two parallel lines separated by a factor of 1.5 to 2 times the water depth, perpendicular to shore, run in the upslope direction at normal survey speed. The latency test was run over the same area but at different survey speeds. The data were post-processed using Caris HIPS to determine offset values for latency, roll, pitch and yaw. Patch test results are presented in Table 3-1.

Table 3-1. Patch Test Offset Corrections

Oakland Pilot

Patch Test	Offset Correction
Roll (degrees)	2.050
Pitch (degrees)	2.800
Yaw (degrees)	-1.300
Navigation Latency (ms)	700

Minotaur

Patch Test	Offset Correction
Roll (degrees)	0.690
Pitch (degrees)	1.600
Yaw (degrees)	6.000
Navigation Latency (ms)	300

[1] Caris, 2004. Caris HIPS & SIPS User's Guide

3.1.3 DGPS Positioning and Navigation

Oakland Pilot

A CSI Wireless MBX-3 was used to deliver RTCM corrections. Differential positions were obtained by a TSS POS MV attitude and position system, allowing for inertial corrections in the event of a DGPS loss. Position coordinates were transmitted via NMEA0183 GGA strings transmitted across serial communications. All systems received the same GGA string with offset corrections applied independently within each survey system.

Navigation control was accomplished with the Hypack Max hydrographic survey system. Hypack received data from the positioning system, performed the appropriate geodetic transformations, and stored the position information as a backup of navigation data. Primary navigation data was stored directly with the sonar data.

R/V Minotuar

A CSI Wireless DGPS MAX Differential Global Position Ststem (DGPS) was used to collect RTCM corrections, differential GPS positions were obtained using an Octopus F180, allowing for inertial corrections in the event of a DGPS loss. Position coordinates were transmitted via NMEA0183 GGA strings transmitted across serial communications. All systems received the same GGA string with offset corrections applied independently within each survey system.

Navigation control was accomplished with the Hypack Max hydrographic survey system. Hypack received data from the positioning system, performed the appropriate geodetic transformations, and stored the position information as a backup of navigation data. Primary navigation data was stored directly with the sonar data.

3.1.4 Sound Velocity and Tidal Corrections

- 3.1.4.1 Sound Velocity Corrections

Oakland Pilot

A Reson SV15 Sound Velocity profiler was used to collect sound velocities through the full water column depth. A SVP cast was completed at least every two hours in the water zone associated with each survey section. Results of the SVP cast were applied to the MBES data during real time survey acquisition.

R/V Minotaur

A Seabird Model SBE19 CTD profiler was used to collect sound velocities through the full water column depth. A CTD cast was completed at least every two hours in the water zone associated with each survey section. Results of the CTD cast were applied to the MBES data during real time survey acquisition.

- 3.1.4.2 Tide Measurements

Observed tidal measurements were collected at Hammond Marina using the CCALMR/OHSU tide gauge (Figure 3-1). This gauge is located in close proximity to the USACOE gauge, at 46 12.166N 123 57.107W. All tide measurements were recorded in MSL and converted to MLLW in post processing. See http://www.ccalmr.ogi.edu/CORIE/data/publicarch/methods_meanings_tide.html for formats and quality control procedures. All observed measurements were then adiusted using MCR tidal corrector data to correct for variability in tidal cy Tidal correctors were provided by USACOE and were develope

Figure 3-1, Hammond Marina Tide Station

3.1.5 Bathymetry

The integrated multibeam survey package assembled for this survey included the components shown in Table 3-2.

Table 3-2. Multibeam System Components

Oakland Pilot

Measurement	Model
Multibeam Sonar	Kongsberg-Simrad EM 3002
Attitude (Heave, Pitch, and Roll) and Heading	TSS POS M/V
Positioning	CSI Wireless MBX-3 Differential Receiver / TSS POSM/V
MBES Data Acquisition	Kongsberg Seafloor Information System (SIS)
Navigation	Hypack Max Survey System

Minotaur

Measurement	Model
Multibeam Sonar	Kongsberg-Simrad EM 3002
Attitude (Heave, Pitch, and Roll) and Heading	Octopus F180
Positioning	CSI Wireless Differential GPS / Octopus F180
MBES Data Acquisition	Kongsberg Seafloor Information System (SIS)
Navigation	Hypack Max Survey System

A TSS POSMV 320 position and orientation system, shown in figure 3-2, measured attitude and heading onboard the Oakland Pilot. The POSMV was mounted under one of the ship's galley tables as close to the sonar head as possible, all lever arms were surveyed in and accounted for within the POS M/V. The attitude and heading sensor provides dynamic corrections for vessel motion and actual sonar orientation relative to water level. The attitude sensor provides real-time measurement of heading and transducer heave, pitch, and roll. A detailed system description is provided in Appendix A.

Figure 3-2. Attitude Sensor Installation; Oakland Pilot.

The R/V Minotaur was fitted with an Octopus F180, shown in Figure 3-3, delivering heave, roll, pitch, heading and positioning information in real time, it provides the marine user with highly accurate and reliable motion and position data. The F180 was mounted under a seat in the cabin as close to the transducer as possible, all lever arms were then applied to the F180 which corrected motion output

Figure 3-3, F180

to accommodate the offsets. A detailed system description is provided in Appendix A.

3.1.6 Kongsberg EM 3002

A Kongsberg EM 3002 high-resolution focused multibeam echosounder (Figure 3-4) was utilized to collect the bathymetry on each vessel. The EM 3002 is an advanced multibeam echosounder with extremely high resolution and dynamically focused beams. It is suited for detailed seafloor mapping and inspection with water depths between 0.5 and 150 meters. Due to its electronic pitch compensation system and roll stabilized beams, the system performance is stable even in foul weather conditions. The mounting bracket for the multibeam (see Figure 3-3) was positioned to provide minimal operational offsets of the transducer head relative to vessel attitude. Actual static transducer attitude was determined during calibration of the system. A detailed system description is provided in Appendix A.

3.1.7 System Installation

Figure 3-4 Kongsberg EM 3002 Sonar Head

<u>Oakland Pilot</u>

The multibeam sonar transducer was mounted approximately amidships off the starboard railing. The POSMV antennas were mounted directly above the motion sensor using pre-existing mounting brackets. This configuration was surveyed to precisely position all instrument offsets relative to the motion sensor. For this survey, the motion sensor is the selected reference point.

<u>R/V Minotaur</u>

The multibeam sonar transducer was mounted approximately amidships off the starboard railing. The F180 antennas were mounted directly above the motion sensor using pre-existing mounting brackets. This configuration was surveyed to precisely position all instrument offsets relative to the motion sensor. For this survey, the motion sensor is the selected reference point.

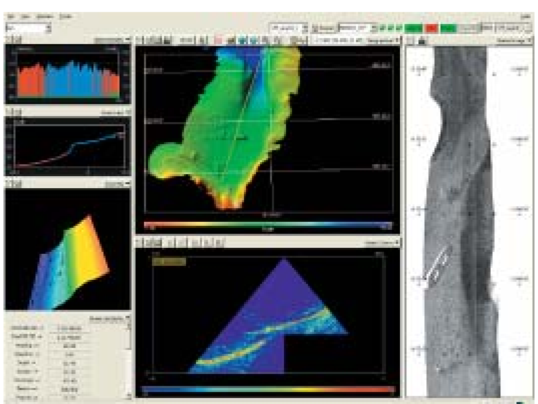


Figure 3-5. Real Time Acquisition Control.

3.1.8 Backscatter Imagery

The Simrad EM multibeam echo sounders all have beam backscattering strengths and optional seabed image reflectivity as part of their data output. These data were acquired for later bottom classification tasks.

3.1.8 Data Acquisition

The Kongsberg Seafloor Information System (SIS) was used to log all data packets during survey (Figure 3-5). SIS is a real time software application designed as the user interface for Kongsberg hydrographic instruments. The main task of SIS is to be a logical and user friendly interface for the surveyor, providing the functionality needed for running a survey efficiently. A detailed system description is provided in Appendix A.

3.2 Data Processing

3.2.1 Bathymetry

Multibeam post-processing was performed using Caris HIPS bathymetric processing system. After completion of patch test calibrations (refer to Section 4.1.2) the data were edited to remove bad or low quality data points. Depths were automatically adjusted within Caris for navigation, attitude, tide, and speed of sound. A mapping grid resolution consistent with the spatial resolution of the survey was then projected onto the survey area. For this survey a 3-meter resolution grid was developed. The final processing step involved geoencoding all corrected data into the survey grid. An output file containing spatial coordinates for all gridded data points (e.g., easting, northing, and depth elevation in MLLW) was created for input into AutoCAD and Terramodel for final chart development and generation of the DTM and contours, respectively. A final contour editing process was conducted to provide contours sufficient for the CADD formats of the engineering drawings.

3.2.2 Backscatter Imagery

Backscatter post-processing was initially performed with Caris SIPS Sidescan Image Processing Software. Navigation data was cleaned to remove any GPS spikes and then the data was combined with adjacent data to create mosaics of each survey area. After completing this process and making comparisons with the bathymetry corresponding areas, questions arose about Caris SIPS ability to handle the data. Several options were explored as alternatives to Caris SIPS, The data was sent to the University of New Hampshire's Center for Coastal and Ocean Mapping (CCOM) for final processing. The following describes the processes performed at CCOM.

During the mosaic preparation, it was necessary to radiometrically correct the backscatter intensities registered by the Simrad system, to geometrically correct and position each acoustic sample in a projection coordinate system and to interpolate properly the intensity values into a final backscatter map. Initially, the original backscatter time series registered in the Simrad image datagrams were corrected for angle varying gains, beam pattern, and filtered for speckle removal. All samples of the time series were preserved during all the operations, ensuring that the full data resolution was used for the final mosaicking. The time series was then slant-range corrected based on beam bathymetry. Subsequently, each backscatter sample of the series was mapped in a Lambert Conformal Conic projected coordinate system (State Plane 83 Oregon North), in accordance to an interpolation scheme that resembles the acquisition geometry. An anti-aliasing algorithm was applied in parallel to the mosaicking procedure. Overlap among parallel lines was resolved by a priority table based on the distance of each sample from the ship track; a blending algorithm was applied to minimize the seams between overlapping lines.

4. SURVEY RESULTS

The survey was broken up into nine separate areas that were each surveyed individually. A summary of the nine survey areas and general descriptions of observed geomorphic conditions are presented in Table 4-1. Bathymetric imagery with contours, backscatter imagery and survey trackline charts are included with this report as 11x17 format (half-size) plots. The original D-Size charts are provided in digital AutoCad format with corresponding .pdf format digital files for client reproduction. A cdrom is included with this report that includes all digital charts.

Table 4-1. Survey Area Summary

Area	Descriptor	Distance Offshore	Area km^2	Water Depth ft
1A	DWS	10 to 15	42	180 to 310
1B	SWS	1 to 4	8.1	30 to 80
2A	MCR channel north	0 to 5	7.1	10 to 90
2B	MCR channel offshore	0.5 to 5	4.4	50 to 80
2C	Clatsop Spit	0 to 6	5.2	10 to 70
2D	South Jetty	4 to 5	4.7	30 to 60
2E	MCR channel east	5 to 6	2.7	10 to 130
3A	Offshore SWS	5 to 6	4.4	50 to 70
3C	ODMDS A	0 to 5	12.3	30 to 90

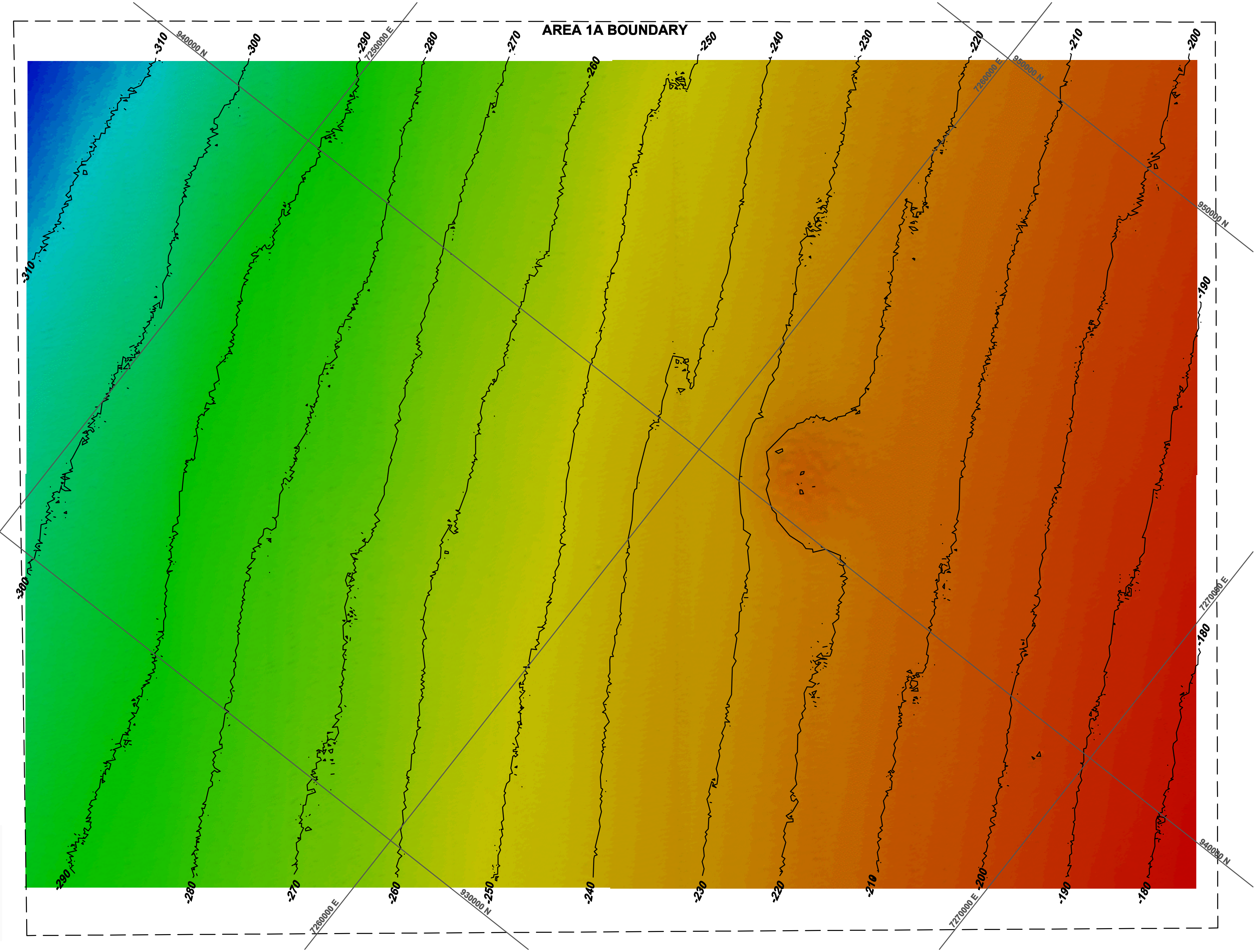
Area	Overview of Geomorphic Condition
1A	Uniform offshore slope, 2 dump sites visible in backscatter
1B	Flat topography with ship channel in south; large sand wave field dominates area
2A	Flat topography with ship channel in south; sand waves track around north boundary of area
2B	Channel with scour area near end of North Jetty; large sand waves surround scour
2C	Flat topography in south with channel to the north; large sand waves dominate channel edge in northern area
2D	Very flat topography; Backscatter shows 6 E-W disposal tracks, no measurable bathymetric relief
2E	Channel with vertical escarpment to the north; deep scour with large sand waves in SW of area, area has two hard targets mid channel
3A	Flat topography, nondescript area
3C	Scour at end of South Jetty with several hard targets; shoal area west of jetty

4.1 Lessons Learned

The combination of survey location and project acquisition schedule posed significant challenges for delivery of high quality mapping products. The Columbia River Bar can be a difficult and dangerous environment for seagoing operations, especially surveys. Weather and tides often combine to produce sea states considered hazardous to navigation. Adaptive survey management methods were required to complete as much of the survey scope as possible, with operations changing on a daily basis. Due to funding constraints, it was requested that surveys be performed to the limit possible for acquiring acceptable survey data. In some instances, this may have produced degradation in survey quality. For example, Area 2D suffered due to heavy sea conditions during the three days given to survey the area, requiring some filtering to remove unreal motion artifacts on an otherwise flat seafloor surface. Future surveys of this scope and magnitude in the MCR vicinity should be planned to be carried out earlier in the season, closer to June/July rather than August/September and should have a large acquisition window to allow surveyors to be more selective with regards to weather standby situations. This would increase survey production during good survey sea states and enhance overall mapping quality.

The largest issue encountered while processing the data sets was spatial variations in tidal correction. It was decided during negotiations to use observed tide measurements rather than Real-time Kinematic (RTK) GPS tides. Tide measurements were collected at Hammond Marina and converted to reflect tidal differences between Hammond Marina and the river mouth. When applied to the data sets obvious tidal busts became visible, usually showing as much as a 1 to 3 foot bust between data collected on different survey days. This process was done several times using different tide stations, in an attempt to resolve this problem. When all attempts failed a tedious day-to-day tidal manipulation was undergone to improve bathymetric imagery. This process while improving image appearance may take away from overall vertical survey accuracy. It is recommended that future surveys utilize the ability to acquire accurate RTK GPS vertical data; effectively eliminating the tidal issues experienced using the recording tide gage at Hammond. An RTK transmitting base station is maintained at MCR by the Portland District and should be used for all future survey work in this area.

To complete the survey within the agreed time frame, the survey was carried out using multiple survey vessels. The data was cleaned and processed in a central field office and aboard ship during survey operations. This process was very successful except for the application of tidal corrections. Verified tide data were not available until the completion of surveys, at which time the tidal issue was discovered. Again, RTK tidal acquisition would have eliminated this issue.



SUN-ILLUMINATION VALUES

Azimuth	Elevation	Exaggeration
120°	45°	1.0

NOTES:

1. Dates of Survey: August 15-24, 2005.
2. Units: US Survey Feet.
3. Horizontal Datum: North American Datum of 1983 (NAD83), State Plane Coordinate System (SPCS), Oregon North Zone.
4. Vertical Datum: Mean Lower Low Water (MLLW).
5. Contour Interval: 10 Foot.

APPROVED BY:	R. McGee
CHECKED BY:	J. Brantner
DRAWN BY:	D. Pickworth
DATE:	12/12/05
SCALE:	1" = 2000'
FILE NAME:	1A-05_11x17.dwg

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Mouth of the Columbia River Multibeam Bathymetric Survey
Columbia River, Oregon

AREA 1A MBES BATHYMETRIC CONTOURS AND SUN-ILLUMINATED IMAGERY

U.S. Army Corps of Engineers

2000 0 2000 4000
SCALE: 1" = 2000'
Units in Feet

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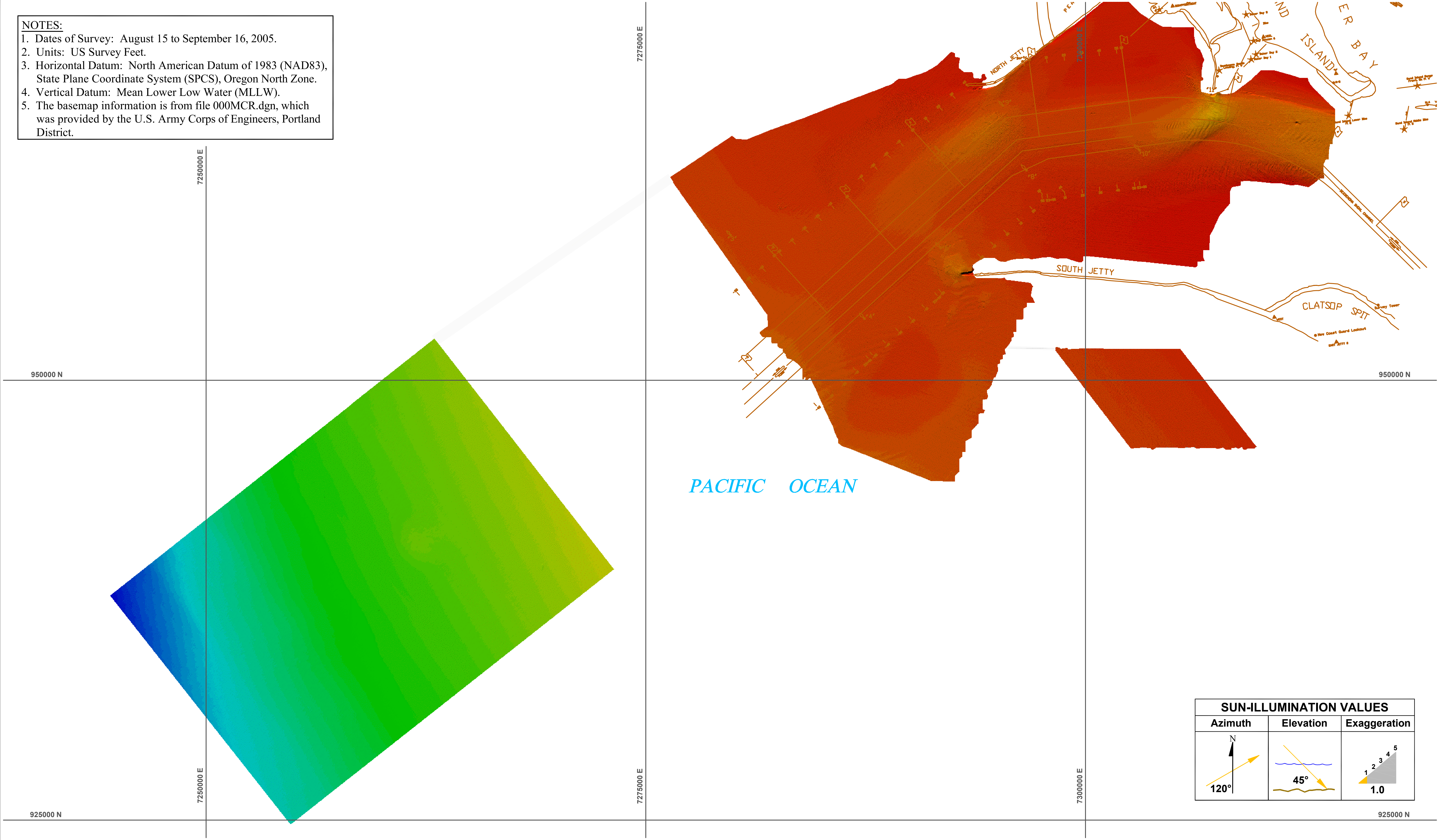
SHEET 5A OF 5A

NOTES:
1. Dates of Survey: August 15 to September 16, 2005.
2. Units: US Survey Feet.
3. Horizontal Datum: North American Datum of 1983 (NAD83), State Plane Coordinate System (SPCS), Oregon North Zone.
4. Vertical Datum: Mean Lower Low Water (MLLW).
5. The basemap information is from file 000MCR.dgn, which was provided by the U.S. Army Corps of Engineers, Portland District.



APPROVED BY:	R. McGee
CHECKED BY:	J. Brantner
DRAWN BY:	D. Pickworth
DATE:	12/12/05
SCALE:	1" = 5000'
FILE NAME:	Cov_11x17.dwg

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Mouth of the Columbia River Multibeam Bathymetric Survey
Columbia River, Oregon

COVERAGE AREA MBES
SUN-ILLUMINATED IMAGERY

U.S. Army Corps of Engineers

5000 0 5000 10000
SCALE: 1" = 5000'
Units in Feet

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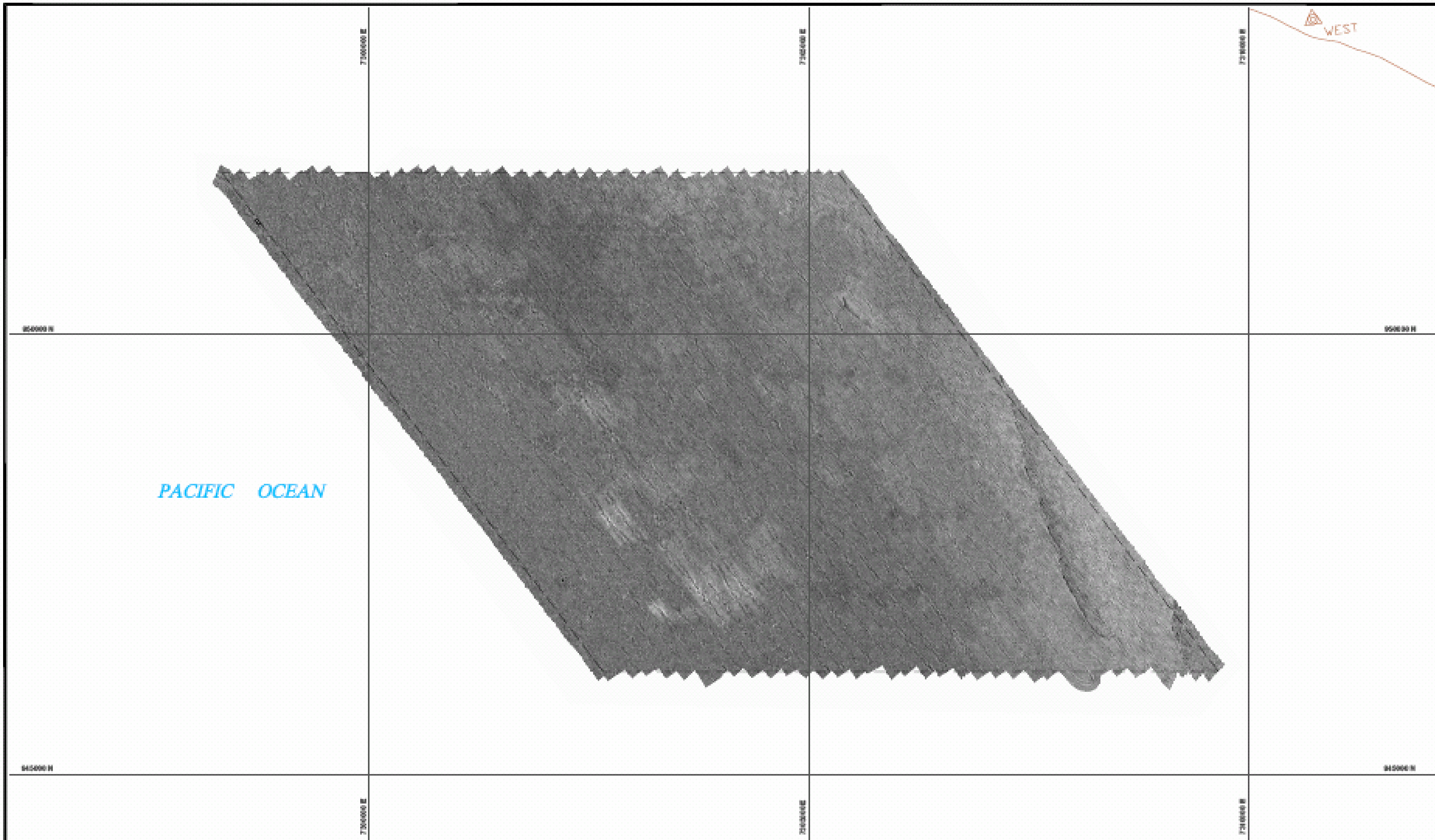
SHEET **1B** OF 1E



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Mouth of the Columbia River Multibeam Bathymetric Survey
Columbia River, Oregon

AREA 2D MBES BACKSCATTER IMAGERY

1000

SCALE: 1" = 1000'
Units in Feet

N

SHEET OF