

CECW-EE
CECW-OD

Manual
No. 1110-2-1003

1 April 2004

**Engineering and Design
HYDROGRAPHIC SURVEYING**

Table of Contents

Subject	Paragraph	Page
Chapter 1		
Introduction		
Purpose.....	1-1	1-1
Applicability	1-2	1-1
Distribution	1-3	1-1
References and Bibliography	1-4	1-1
Use of Manual.....	1-5	1-1
Background.....	1-6	1-1
Mandatory Requirements.....	1-7	1-2
Scope of Manual	1-8	1-2
Metrics	1-9	1-3
Brand Names.....	1-10	1-3
Definitions	1-11	1-3
Proponency and Waivers	1-12	1-3
Chapter 2		
Civil Works Applications		
General Scope	2-1	2-1
Civil Works Program Surveying Requirements.....	2-2	2-1
Hydrographic Survey Applications on Civil Works Activities.....	2-3	2-3
Overview of Hydrographic Survey Techniques in Corps--Field-to-Finish	2-4	2-6
Survey Scheduling	2-5	2-7
Pre-Survey Planning	2-6	2-8
Pre-Survey Field Set-up and Calibration	2-7	2-8
Survey Data Acquisition	2-8	2-10
Initial Field Data Review and Editing.....	2-9	2-11
Field Data Submittal to District Office	2-10	2-13
Mandatory Requirements	2-11	2-14

Chapter 3
Corps Accuracy Standards, Quality Control,
and Quality Assurance Requirements

Purpose.....	3-1	3-1
USACE Hydrographic Survey Accuracy Performance Standards (Mandatory)	3-2	3-1
Accuracy, Quality Control, and Quality Assurance.....	3-3	3-2
Project Classifications Relative to Accuracy Standards	3-4	3-2
Navigation and Dredging Support Surveys	3-5	3-3
Other General Surveys and Studies	3-6	3-4
Resultant Elevation/Depth Accuracy Standard.....	3-7	3-4
Horizontal Positioning System Accuracy Standard	3-8	3-5
Object and Shoal Detection Standards.....	3-9	3-5
Reported Feature Horizontal Location Accuracy	3-10	3-5
Supplemental Control Accuracy	3-11	3-5
Tidal or Water Level Surface Modeling Accuracy	3-12	3-6
Survey Density.....	3-13	3-6
Quality Control and Quality Assurance Criteria.....	3-14	3-6
Related Standards.....	3-15	3-7
Mandatory Requirements.....	3-16	3-8

Chapter 4
Survey Accuracy Estimates for Dredging and Navigation Projects

General Scope	4-1	4-1
Hydrographic Survey Accuracy.....	4-2	4-1
Accuracy, Precision, and Root Mean Square Error	4-3	4-2
One-Dimensional Depth Accuracy Estimates--95% Confidence Estimation Level... 4-4	4-4	4-5
Depth Measurement Error Components.....	4-5	4-7
Quantitative Assessment of Depth Measurement Accuracy	4-6	4-8
Approximate Field Assessments of Depth Measurement Accuracy	4-7	4-10
Evaluation of Depth Accuracy on Dredging Projects.....	4-8	4-13
Evaluation of Dredge Quantity Estimates Based on Depth Accuracy and Density. 4-9	4-9	4-14
Horizontal Positioning Accuracy Estimates	4-10	4-18
FGDC Accuracy Reporting Criteria	4-11	4-22
References.....	4-12	4-22
Mandatory Requirements.....	4-13	4-22

Chapter 5
Project Control, Coordinate Systems, and Datums

General Scope	5-1	5-1
Horizontal Control for Navigation and Flood Control Projects.....	5-2	5-1
Positioning of Aids to Navigation in Authorized Projects.....	5-3	5-7
Vertical Control for Navigation and Flood Control Projects.....	5-4	5-7
Tides and Tidal Datums	5-5	5-9
Tide Stations	5-6	5-10
Need for Updated Tidal Datums.....	5-7	5-12
Accurate Tidal Datums	5-8	5-12
NOS Tidal Datums.....	5-9	5-12
Establishing Tidal Datums.....	5-10	5-18
Equipment and Field Work Associated with Operating Tide Stations.....	5-11	5-21

Subject	Paragraph	Page
Off-Site Tide Observations	5-12	5-22
Water Level Reference Planes	5-13	5-24
International Great Lakes Datums	5-14	5-25
Low Water Reference Planes (LWRP)--Middle and Lower Mississippi River	5-15	5-28
Other Inland Water Reference Systems	5-16	5-30
Water Level Stage Measurement Systems--Reference Gage Location	5-17	5-33
Tidal Zoning	5-18	5-33
Gage Reading Intervals	5-19	5-36
Leveling Frequency	5-20	5-37
Start/Finish Difference in Gage Elevation	5-21	5-37
Staff Markings/Least Count of Readings	5-22	5-38
Stilling Procedures	5-23	5-38
Mandatory Requirements	5-24	5-38
Chapter 6		
Planning and Processing Surveys for Civil Works Projects		
General Scope	6-1	6-1
General Planning Considerations	6-2	6-1
SECTION I: GENERAL GUIDANCE IN PERFORMING		
HYDROGRAPHIC SURVEYS FOR ENGINEERING AND CONSTRUCTION		6-3
Survey Equipment and Instrumentation Requirements Relative to Project Scope ..	6-3	6-3
Selection of Appropriate Survey Vessel for Project Area	6-4	6-4
General and Specific Survey Planning	6-5	6-8
Data Management	6-6	6-10
SECTION II: PLANNING SURVEY COVERAGE		6-13
Density of Data and Line Spacing	6-7	6-13
Survey Alignment (Cross-Sections and Longitudinal Sections)	6-8	6-20
Positioning Intervals	6-9	6-20
Depth Recording Density	6-10	6-20
SECTION III: DATA PROCESSING, EDITING, AND PLOTTING OPTIONS		6-21
HP/UNIX Field Data Collection System--Norfolk District	6-11	6-21
Depiction on Drawings of Observed Positions and Depths	6-12	6-26
Data Transfer Standards and Formats	6-13	6-28
SECTION IV: USACE STANDARDS FOR SURVEY COVERAGE, PROCESSING, PLOTTING, AND ARCHIVING		6-31
Geospatial Data Standards and Requirements	6-14	6-31
General Hydrographic Survey Acquisition and Processing Criteria	6-15	6-33
Mandatory Requirements	6-16	6-33
Chapter 7		
Positioning Techniques for Offshore Engineering Surveys		
General Scope and Applications	7-1	7-1
Positional Accuracy	7-2	7-1

EM 1110-2-1003

Change 1

1 Apr 04

Subject

Paragraph

Page

SECTION I: SEXTANT RESECTION POSITIONING		7-2
General Applications	7-3	7-2
Sextant Resectioning Procedures.....	7-4	7-3
Accuracy and Quality Control of Sextant Resection Positioning.....	7-5	7-4
SECTION II: TRIANGULATION/INTERSECTION POSITIONING		7-5
General Applications	7-6	7-5
Intersection Positioning Procedures	7-7	7-6
Data Recording and Plotting.....	7-8	7-6
Accuracy of Triangulation/Intersection Positioning	7-9	7-6
Quality Control and Quality Assurance	7-10	7-9
SECTION III: VISUAL POSITIONING METHODS		7-10
General Applications	7-11	7-10
Construction/Dredging Control Using Ranges	7-12	7-11
Uncontrolled Project Centerline Surveys	7-13	7-11
Accuracy and Quality Control	7-14	7-11
SECTION IV: TAG LINE POSITIONING METHODS		7-12
General Applications	7-15	7-12
Tag Line Measurement Procedures	7-16	7-13
Tag Line Equipment	7-17	7-16
Accuracy, Calibration, and Quality Control Requirements	7-18	7-17
SECTION V: RANGE-AZIMUTH POSITIONING METHODS		
General Applications	7-19	7-19
Range-Azimuth Survey Procedures	7-20	7-20
Total Station Range-Azimuth Surveys.....	7-21	7-22
Range-Azimuth Accuracy	7-22	7-22
Quality Control Requirements.....	7-23	7-22
SECTION VI: LAND-BASED ELECTRONIC POSITIONING SYSTEMS		7-24
General Scope	7-24	7-24
Types of Electronic Positioning Systems.....	7-25	7-24
EDM Measurement Process.....	7-26	7-25
Microwave Range-Range Positioning Systems	7-27	7-27
Microwave System Calibrations and Quality Control	7-28	7-33
SECTION VII: GLOBAL POSITIONING SYSTEM TECHNIQUES		7-36
General	7-29	7-36
GPS Tracking Modes.....	7-30	7-37
GPS Accuracies	7-31	7-37
GPS Error Sources	7-32	7-39
GPS Positioning Methods	7-33	7-40
Real-Time Code Phase DGPS Concepts.....	7-34	7-42
USCG DGPS Radiobeacon Navigation Service and Commercial DGPS Services	7-35	7-44
Real-Time Carrier Phase DGPS Concepts	7-36	7-47

Subject	Paragraph	Page
SECTION VIII: SUMMARY OF POSITIONING SYSTEM		
QUALITY CONTROL STANDARDS		7-49
Calibration Criteria	7-37	7-49
Quality Control Criteria for Positioning Methods	7-38	7-49
Mandatory Requirements	7-39	7-50
Chapter 8		
Manual Depth Measurement Techniques		
General Scope and Applications	8-1	8-1
Lead Line or Sounding Disk Measurement	8-2	8-1
Sounding Pole	8-3	8-4
Manual Depth Measurement Accuracy and Quality Control Criteria.....	8-4	8-5
Mandatory Requirements	8-5	8-6
Chapter 9		
Single Beam Acoustic Depth Measurement Techniques		
General Scope and Applications	9-1	9-1
Principles of Acoustic Depth Measurement.....	9-2	9-1
Transducer Frequency Specifications	9-3	9-4
Single Beam Echo Sounding Equipment and Procedures.....	9-4	9-7
Depth Collection Density and Bottom Coverage.....	9-5	9-13
Effects of Vessel Heave, Roll, Pitch and Yaw on Single Beam Systems	9-6	9-14
Calibration of Single Beam Echo Sounders.....	9-7	9-19
Bar or Ball Check Calibration Procedures	9-8	9-21
Depth Corrections Based on Bar Check Data	9-9	9-24
Velocity Meter Calibration Method	9-10	9-28
Squat and Settlement Calibration Test.....	9-11	9-33
Miscellaneous Controls and Checks	9-12	9-35
Plotted Depth Options for Single Beam Surveys.....	9-13	9-36
Latency Tests	9-14	9-38
Depth Quality Assurance Techniques for Single Beam Surveys.....	9-15	9-40
Summary of Quality Control Criteria for Single Beam Echo Sounders	9-16	9-43
Referenced Equipment Manufacturers.....	9-17	9-45
Mandatory Requirements	9-18	9-46
Chapter 10		
Multiple Transducer Channel Sweep Systems for Navigation Projects		
General Scope	10-1	10-1
Background	10-2	10-1
Design of Channel Sweep Systems.....	10-3	10-2
Philadelphia District Channel Sweep System	10-4	10-5
Detroit District 120-Ft Strike Detection System.....	10-5	10-6
St. Paul District Channel Sweep Systems for Shallow-Draft Projects.....	10-6	10-7
Mobile District Tuscaloosa Site Office Sweep Systems.....	10-7	10-8
New York District Multiple Transducer and Multibeam Sweep System.....	10-8	10-11
Multiple Transducer System Quality Control and Quality Assurance.....	10-9	10-11
Mandatory Requirements	10-10	10-15

Chapter 11**Acoustic Multibeam Survey Systems for Deep-Draft Navigation Projects**

General Scope and Applications	11-1	11-1
Background	11-2	11-1
Principles of Operation	11-3	11-2
USACE Multibeam Policies, Procedures, and Applications	11-4	11-9
Quality Control and Quality Assurance Procedures for Multibeam Systems	11-5	11-15
Initial Installation Alignment and Static Offset Measurements	11-6	11-16
Vessel Squat/Settlement and Draft Variations	11-7	11-17
Patch Test (Residual Bias Calibration)	11-8	11-18
Velocity Measurements	11-9	11-23
Vessel Draft and Index Measurements (Bar Checks)	11-10	11-23
Beam Width Restrictions on Multibeam Systems	11-11	11-25
Quality Assurance Performance Test (Overlapping Models)	11-12	11-25
Multibeam Data Processing--Editing, Filtering, Thinning, and Binning	11-13	11-30
Depth Selection Options	11-14	11-31
Plotting Representative Depths in Plan	11-15	11-32
Recommended Bin Sizes and Depth Selection for USACE Navigation Surveys	11-16	11-33
Contract Specifications for Multibeam Measurement and Payment	11-17	11-35
Multibeam Technical References	11-18	11-36
Mandatory Requirements	11-19	11-36
Summary of Multibeam QC and QA Criteria	11-20	11-37

Chapter 12**Navigation Project Clearance and Object Detection--Mechanical Bar Sweeps and Side Scan Sonar**

General Scope	12-1	12-1
Channel Clearance Bar Sweeps	12-2	12-1
Side Scan Sonar	12-3	12-4
Side Scan Sonar Survey Specifications (NOAA)	12-4	12-10
Channel Obstructions	12-5	12-18
Magnetometer Surveys	12-6	12-20
Quality Control and Quality Assurance Criteria	12-7	12-20
Mandatory Requirements	12-8	12-20

Chapter 13**Airborne LIDAR Hydrographic Surveying**

Introduction: Summary of Technology	13-1	13-1
Operating Principle	13-2	13-2
Typical Survey Products	13-3	13-2
System Characteristics, Performance Specifications, and Accuracy	13-4	13-3
System Constraint	13-5	13-4
SHOALS System	13-6	13-4
Platforms	13-7	13-4
Airborne System	13-8	13-4
Data Processing Sub-system	13-9	13-6
Product Generation	13-10	13-8
Data Preparation	13-11	13-9

Subject	Paragraph	Page
Mapping	13-12	13-9
Applications: Navigation and Structures	13-13	13-10
Applications: Nautical Charting.....	13-14	13-11
Applications: Beach and Shoreline Surveying.....	13-15	13-12
Applications: Emergency Response.....	13-16	13-13
Applications: Shallow Water	13-17	13-14
Applications: Confined Disposal Facilities.....	13-18	13-15
Applications: Hazard Detection	13-19	13-16
Applications: Obtaining SHOALS Surveys.....	13-20	13-16
References.....	13-21	13-17
Mandatory Requirements.....	13-22	13-18

Chapter 14
Dredging Support Surveys

General Scope	14-1	14-1
Background.....	14-2	14-1
Types of Dredging Support Surveys.....	14-3	14-1
Variation in Estimated Quantities	14-4	14-3
Dredge Contracting and Production Measurement Methods	14-5	14-4
Dredged Material Payment Prisms	14-6	14-6
Other Factors Impacting Measurement and Payment Surveys	14-7	14-8
Measurement, Payment, Performance, and Acceptance Surveys	14-8	14-8
Measurement and Payment Surveys Performed by Other than Corps Hired-Labor	14-9	14-13
Unconsolidated Sediments (Fluff) on Dredging Projects	14-10	14-14
Ocean Disposal Positional Monitoring	14-11	14-14
Mandatory Requirements.....	14-12	14-16

Chapter 15
Dredge Measurement and Payment Volume Computations

General Scope	15-1	15-1
Dredge Volume Computation Techniques--Background.....	15-2	15-1
Average-End-Area Volume Computations	15-3	15-2
Triangulation-Based Volume Computations (Triangulated Irregular Networks)....	15-4	15-8
Reference Surfaces and Payment Templates used in Corps	15-5	15-12
Volumes of Irregular Channels or Basins	15-6	15-19
Obtaining Complete Coverage for Quantity Computations.....	15-7	15-21
Accuracy of Excavated Quantity Estimates.....	15-8	15-22
Combined TIN and Average-End-Area Volume Computations.....	15-9	15-25
Example of Using TIN Methods to Compute Dredged Volumes (Baltimore District).....	15-10	15-25
USACE Dredge Volume Computation Standards	15-11	15-27
Mandatory Requirements.....	15-12	15-28

Chapter 16
Real-Time Kinematic Differential GPS Surveys

Real-time Carrier Phase DGPS Technology	16-1	16-1
Reference Station	16-2	16-1
Communication Link	16-3	16-2
User Equipment	16-4	16-2

EM 1110-2-1003

Change 1

1 Apr 04

Subject

Paragraph

Page

Kings Bay Entrance Channel Tidal Modeling for RTK Surveys.....	16-5	16-2
Tidal Datum Diagram	16-6	16-4
GPS Reference Station.....	16-7	16-5
Resultant RTK DGPS Accuracy	16-8	16-6
Survey Vessel.....	16-9	16-7
RTK DGPS Hydrographic Survey Procedures	16-10	16-7
Test Results.....	16-11	16-7
Scope of Work for Modeling Kings Bay Entrance Channel (Jacksonville District)	16-12	16-8
Mandatory Requirements.....	16-13	16-10

Chapter 17

River Engineering Hydraulic and Channel Stabilization Surveys

General Scope and Applications	17-1	17-1
River Hydraulics Studies	17-2	17-1
Obtaining Cross-Sections for Hydraulic Studies	17-3	17-2
Hydraulic Engineering Guidance on Cross-Section Locations.....	17-4	17-7
Cross-Sections Adjacent to Bridges or Culverts.....	17-5	17-8
Required Accuracy of River Cross-Section Data.....	17-6	17-10
Surveys of Navigable Rivers, Locks and Dams, and River Stabilization Structures.....	17-7	17-12
References.....	17-8	17-22
Mandatory Requirements.....	17-9	17-22

Chapter 18

Coastal Engineering Surveys

Introduction.....	18-1	18-1
Background.....	18-2	18-1
Beach Profiling Surveys--General Procedures.....	18-3	18-3
Accuracy Requirements	18-4	18-5
Data Density, Formats, Processing and Archiving	18-5	18-6
Coastal Processes Affecting Surveys.....	18-6	18-6
Overview of Coastal Processes	18-7	18-7
Time Scales.....	18-8	18-8
Waves.....	18-9	18-8
Currents.....	18-10	18-9
Profile Closure	18-11	18-10
Tides and Other Water Level Changes	18-12	18-10
Survey Planning Considerations	18-13	18-11
Additional Considerations in Survey Planning.....	18-14	18-11
Overview of Surveying Methods	18-15	18-13
Technology	18-16	18-14
Rod and Transit.....	18-17	18-14
Survey Sled.....	18-18	18-16
Single Beam Fathometer.....	18-19	18-18
Multibeam System	18-20	18-19
Airborne LIDAR Bathymetry	18-21	18-19
Airborne LIDAR Topography	18-22	18-20
GPS Total Station Backpack.....	18-23	18-22
Jet Ski Beach Surveys.....	18-24	18-22

Subject	Paragraph	Page
Offshore Jetty, Breakwater, and Groin Surveys	18-25	18-23
Probings	18-26	18-25
Sub-Bottom Profiling by Seismic Reflection Methods.....	18-27	18-26
Sub-Bottom Profiling by Ground Penetrating Radar (GPR).....	18-28	18-27
Offshore Disposal or Borrow Area Surveys	18-29	18-27
References.....	18-30	18-28
Mandatory Requirements.....	18-31	18-29

Chapter 19

Electronic Charts of Inland and Coastal Navigation Systems

Purpose.....	19-1	19-1
Scope.....	19-2	19-1
Background.....	19-3	19-1
USACE Electronic Charting Policy.....	19-4	19-3
Navigation Product Standards and Specifications	19-5	19-4
Project and Channel Condition Reports.....	19-6	19-10
Electronic River Charts and Related Navigation/GIS Data	19-7	19-13
Web Posting of Navigation Charts and Surveys.....	19-8	19-16
Mandatory Requirements.....	19-9	19-21

Chapter 20

Reservoir Sedimentation Surveys

Introduction and Background.....	20-1	20-1
Survey Methodology.....	20-2	20-2
Application: Hydrographic Surveys and Area Capacity Curves--Baltimore District.....	20-3	20-3
Area-Capacity Computations.....	20-4	20-10
Area-Capacity Curves.....	20-5	20-12
Mandatory Requirements.....	20-6	20-12

Chapter 21

Depth Measurement over Irregular or Unconsolidated Bottoms

General Scope	21-1	21-1
Causes of Suspended Acoustically Reflective Material.....	21-2	21-2
Acoustic Depth Measurement in Suspended Sediments.....	21-3	21-2
Attenuation of Acoustic Energy in Suspended Sediments.....	21-4	21-6
Effects of Surface Roughness and Incident Angle.....	21-5	21-8
Alternative Depth Measurement Techniques in Suspended Sediments.....	21-6	21-9
Bottom Imaging Using Acoustic Impedance Measurements.....	21-7	21-11
Procedures to Use in Unconsolidated Sediment Areas.....	21-8	21-14
Dual-Frequency Depth Sounding in Areas with Suspended Sediment Conditions	21-9	21-15
Dual Frequency Parametric Subbottom Profiling.....	21-10	21-19
Standards for Depth Measurement in Suspended Sediments.....	21-11	21-22
Mandatory Requirements.....	21-12	21-22

Chapter 22

Contracted Survey Specifications and Cost Estimates

General.....	22-1	22-1
Background.....	22-2	22-1

EM 1110-2-1003

Change 1

1 Apr 04

Subject

Paragraph

Page

Brooks Architect-Engineer Act.....	22-3	22-1
Types of Contracted Hydrographic Survey Projects.....	22-4	22-2
Contracting Processes and Procedures.....	22-5	22-3
Indefinite Delivery Order Contracts	22-6	22-4
Contracted Construction Measurement and Payment Surveys	22-7	22-5
Contract Specifications and Accuracy Standards	22-8	22-6
Contract Statements of Work.....	22-9	22-7
IDC Task Order Requests for Proposals and Specifications.....	22-10	22-12
FFP and IDC Contract Pricing.....	22-11	22-26
Preparing Independent Government Estimates for Hydrographic Survey Services	22-12	22-26
Estimating Daily Unit Cost Rates for Indefinite Delivery Contracts.....	22-13	22-27
Contract Price Schedule.....	22-14	22-30
Task Order Time and Cost Estimates	22-15	22-30
Firm Fixed Price Contract Schedule	22-16	22-34
Cost per Work Unit Schedule	22-17	22-34
Labor Hour Contracts for Surveying Services.....	22-18	22-35
Verification of Contractor Cost or Pricing.....	22-19	22-36
Contract Quality Control and Quality Assurance	22-20	22-37
Contractor Performance and Responsibility	22-21	22-37
Mandatory Requirements.....	22-22	22-39

Appendix A

References

Appendix B

FGDC Hydrographic Accuracy Standard

Appendix C

FGDC Hydrographic Data Content Standard

Glossary