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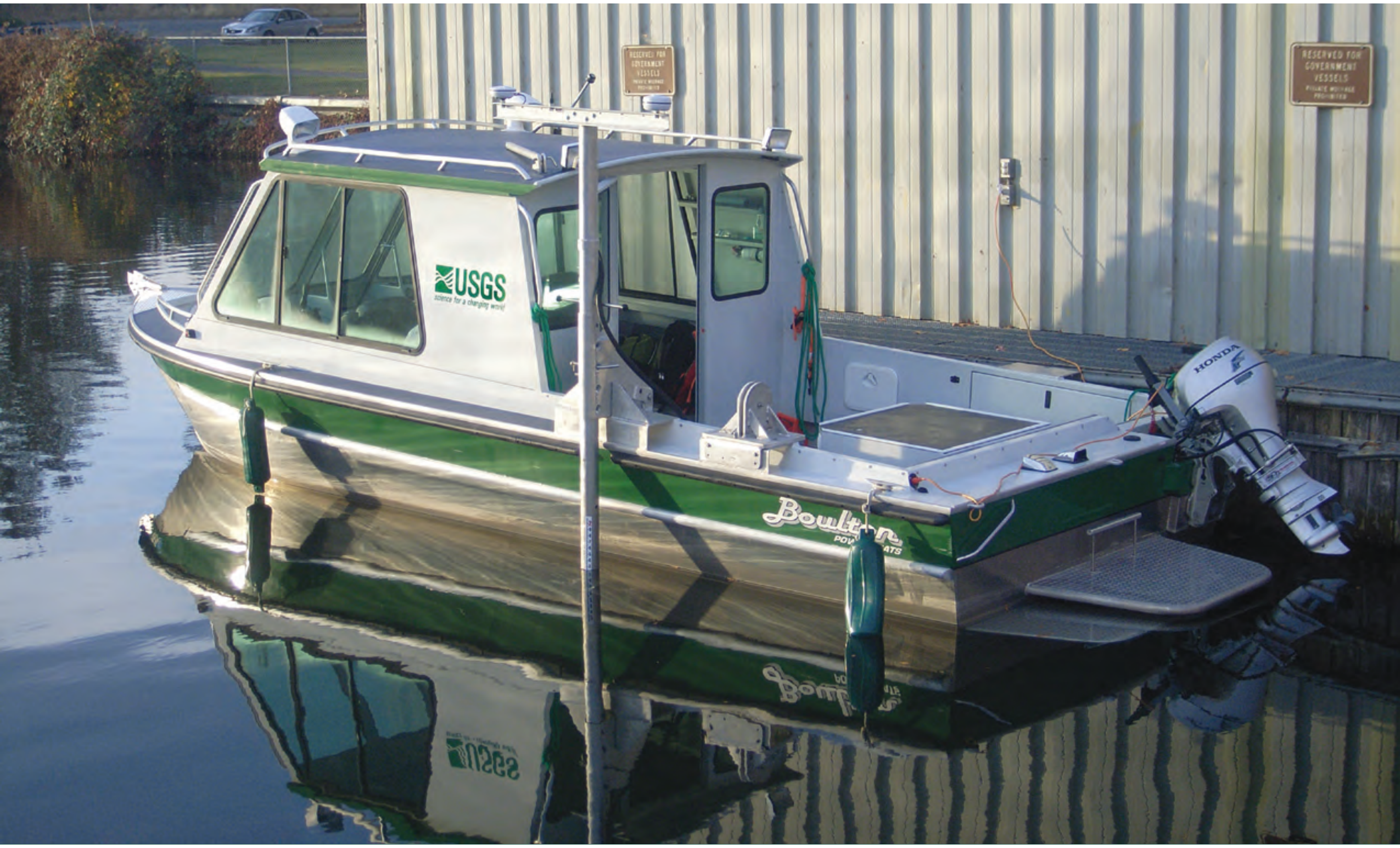
Bathymetric and Underwater Video Survey of Lower Granite Reservoir and Vicinity, Washington and Idaho, 2009–10



Scientific Investigations Report 2012–5089

U.S. Department of the Interior
U.S. Geological Survey

Cover: U.S. Geological Survey hydrographic survey boat (25-foot jet) moored at the U.S. Army Corps of Engineers, Clarkston boat house in preparation for conducting surveys in the Lower Granite Reservoir, Washington.
Photograph taken by Ryan Fosness, U.S. Geological Survey, August 2009.

Bathymetric and Underwater Video Survey of Lower Granite Reservoir and Vicinity, Washington and Idaho, 2009–10

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U.S. Department of the Interior
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KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

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Contents

Figures

Conversion Factors, Datums, and Abbreviations and Acronyms

Conversion Factors

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Flow		
million cubic yards per year (Myd^3/yr)	0.7646	million cubic meters per year (Mm^3/yr)

Datums

Vertical coordinate information is referenced to the Washington State Plane South, North American Datum 1983 (NAD 83).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

Abbreviations and Acronyms

ASCII	American Standard Code for Information Interchange
EM	engineering manual
GIS	Geospatial Information Systems
MBES	multibeam echosounder
QA	quality assurance
QC	quality control
RM	river mile
RTK-GPS	real-time kinematic-global positioning system
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
UVM	underwater video mapping

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Abstract

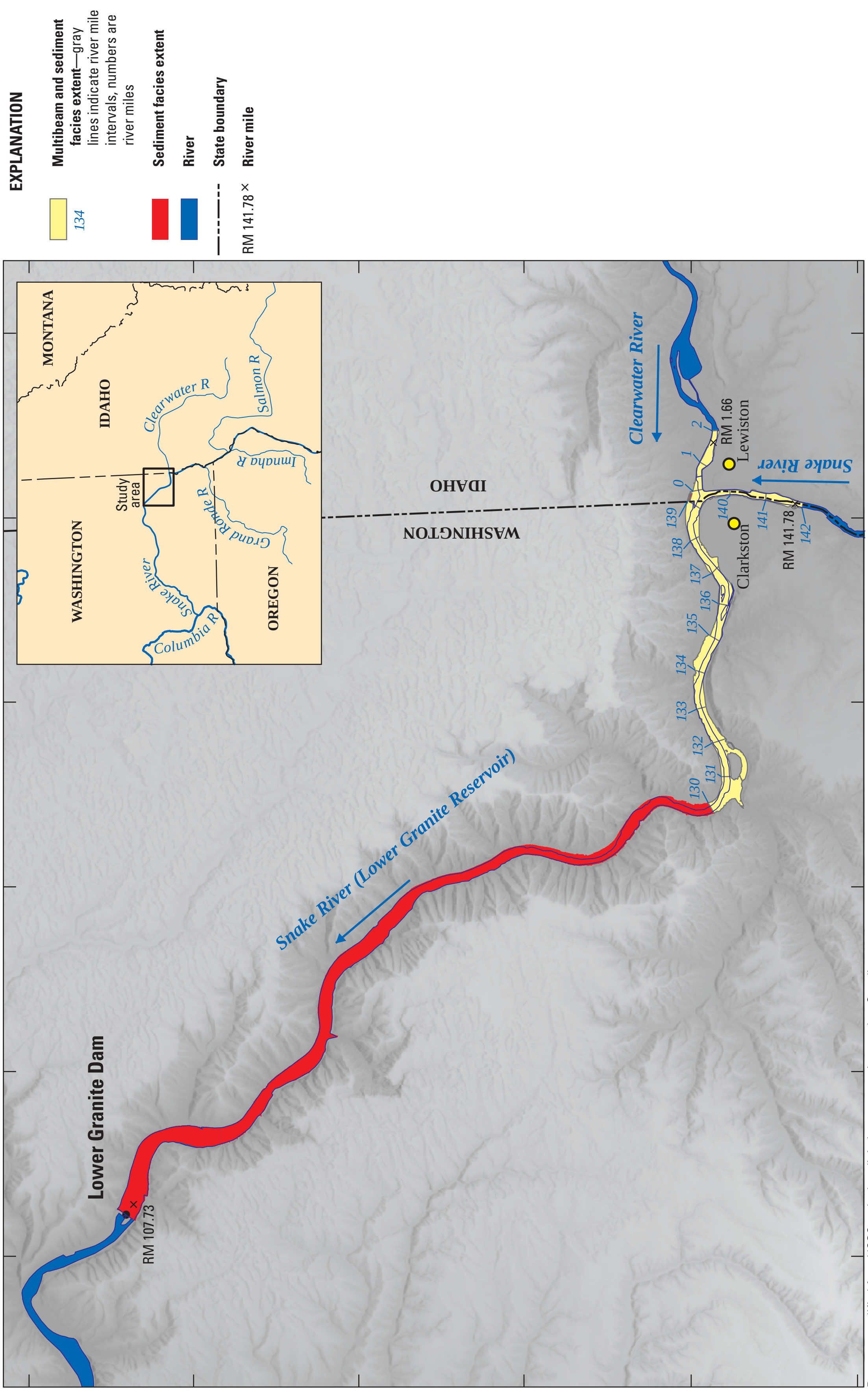
The U.S. Geological Survey conducted a bathymetric survey of the Lower Granite Reservoir, Washington, using a multibeam echosounder, and an underwater video mapping survey during autumn 2009 and winter 2010. The surveys were conducted as part of the U.S. Army Corps of Engineer's study on sediment deposition and control in the reservoir. The multibeam echosounder survey was performed in 1-mile increments between river mile (RM) 130 and 142 on the Snake River, and between RM 0 and 2 on the Clearwater River. The result of the survey is a digital elevation dataset in ASCII coordinate positioning data (easting, northing, and elevation) useful in rendering a 3×3-foot point grid showing bed elevation and reservoir geomorphology. The underwater video mapping survey was conducted from RM 107.73 to 141.78 on the Snake River and RM 0 to 1.66 on the Clearwater River, along 61 U.S. Army Corps of Engineers established cross sections, and dredge material deposit transects. More than 900 videos and 90 bank photographs were used to characterize the sediment facies and ground-truth the multibeam echosounder data. Combined, the surveys were used to create a surficial sediment facies map that displays type of substrate, level of embeddedness, and presence of silt.

Introduction

As the farthest upstream of four impoundments on the lower Snake River, Lower Granite Reservoir (fig. 1) entraps the greatest volume of sediment flowing out of the upstream drainages—namely the Salmon, Grande Ronde, Imnaha, Clearwater, and the Snake Rivers. According to U.S. Army Corps of Engineers (USACE) (2003) calculations, the yearly sediment deposition into Lower Granite Reservoir has been 2.6 Myd^3/yr since completion of the impoundment in 1975. The USACE goes on to state that sedimentation is affecting the safety of commercial navigation in the Ports of Clarkston and Lewiston and reducing the storage capacity of the reservoir. Any increase in reservoir stage to overcome the effects of sedimentation will reduce the effectiveness of the levees necessary to prevent flooding. Historically, the USACE has dredged the sediment to keep navigation channels clear and to maintain adequate storage capacity. However, in recent years, other Federal agencies, affected Tribes, and special interest groups have questioned whether dredging negatively affects threatened or endangered species. To address these concerns, the USACE initiated a multi-year project to assess the status of sediment deposition in the reservoir, and to explore alternative sediment control measures. The bathymetric and underwater video surveys are a part of that effort.

During autumn 2009 and winter 2010, the U.S. Geological Survey (USGS), in cooperation with the USACE, conducted a hydrographic survey using a multibeam echosounder system (MBES) to develop a digital elevation dataset on 12 river miles of the Snake River, and 2 river miles of the Clearwater River upstream of the confluence with the Snake River (fig. 2). The confluence of the Snake and Clearwater Rivers is a transitional area where the rivers change from a free-flowing environment to one characterized by increased backwater effects created by the Lower Granite Dam. Data from the survey will be used by the USACE to develop a model that can help better understand and estimate sediment transport and deposition in the reservoir as part of its Programmatic Sediment Management Plan (U.S. Army Corps of Engineers, 2003). The digital elevation dataset also can be used to display riverbed elevation, geomorphology (scour holes, rock outcroppings), and bedforms (ripples and dunes) when viewed using a geographic data software. The survey acts as a snapshot of benthic geomorphology that can rapidly change due to reservoir stage, river discharge, and boat traffic.

At the same time that the hydrographic survey was being conducted, the USGS conducted an underwater video mapping (UVM) survey at discrete intervals along historical USACE survey lines and previous dredge-material deposit sites (fig. 3). The UVM survey provided geo-referenced videography that illustrated the type and size of sediment on the surface of the riverbed. The videography also was used to enhance the bathymetric data to create a surficial sediment facies map that the USACE will use to evaluate benthic habitat conditions. This report discusses the methods, equipment, quality assurance, and control information used to conduct the bathymetric and UVM surveys, and presents the results.



Basemap modified from USGS and other digital sources, various scales. Coordinate system: Washington State Plane South, North American Datum of 1983.

Figure 1. Location of Lower Granite Reservoir study area, Washington and Idaho.

Basemap modified from USGS and other digital sources, various scales. Coordinate system: Washington State Plane South, North American Datum of 1983.

Figure 2. Bathymetric survey extents on the Snake and Clearwater River areas of Lower Granite Reservoir, Washington and Idaho.

Figure 3. Map and aerial photograph showing underwater video mapping survey extents on the Snake and Clearwater River areas of Lower Granite Reservoir, Washington and Idaho. Historical cross sections are from U.S. Army Corps of Engineers surveys. Discrete underwater videos points are from U.S. Geological Survey mapping.

Multibeam Echosounder Hydrographic Survey

Methods

The hydrographic survey was from river mile (RM) 130 to 142 on the Snake River, and from RM 0 to 2 on the Clearwater River areas of Lower Granite Reservoir (fig. 2). The survey mapped the part of the river that was accessible to the boat and the echosounder equipment, but very shallow areas along the banks that were inaccessible or too shallow to be measured with echosounder equipment were not mapped. The survey was conducted in 1-mile segments, and the data were combined to provide a continuous digital elevation dataset of the reservoir within the limitations of the project (appendix A). The elevation points in the dataset were referenced to the USACE established benchmarks (table A1) using the real-time kinematic–global positioning system (RTK-GPS); therefore, point elevations were unaffected by reservoir stage changes.

Equipment

The bathymetric survey was conducted using state of the art equipment mounted to a 25-ft jet boat designed for hydrographic surveys of rivers and lakes. The hydrographic survey equipment used included an Odom Hydrographic Systems® ES-3 multibeam echosounder transducer capable of producing 480 beams; an International Industries® DSM-10 TSS dynamic motion sensor used to measure vertical displacement and attitude; and an Odom DIGIBAR-Pro profiling sound velocimeter to provide continuous near-surface velocity data. A Hemisphere® VS110 heading and position receiver using two GPS antennas mounted above the echosounder transducer provided precise heading data. RTK-GPS positioning was accomplished using a Trimble® R8/5800 GPS receiver mounted above the echosounder transducer and radio linked to a 35-watt Trimble® HPB450 transmitter to a Trimble® 5700 receiver using a Zephyr Geodedic GPS antenna over various USACE established survey benchmarks in the study area. Benchmarks used during this survey are listed in table A1. The echosounder data were collected using HYPACK® hydrographic survey software. All the raw data were processed through HYSWEEP® collection and editing software to eliminate backscatter distortion and false sounding data.

Quality Control and Quality Assurance

The USACE engineering manual (U.S. Army Corps of Engineers, 2004) provided guidance for quality assurance (QA) and quality control (QC) for this hydrographic survey. The survey team complied with the calibration and control criteria recommended by the manual for general surveys and studies. The sound velocity probes were factory calibrated just prior to the survey. A distilled water calibration assessment of the sound velocity probes also was done monthly, where the performance of the unit at a specific temperature was evaluated against the manufacturer calibration certificate. Sound velocity checks in the water column were conducted twice daily in the survey locations. Bar checks, where a metal plate is suspended by cable to a measured distance below the center or nadir beam of the transducer, were done at the beginning of every survey day to confirm that the system maintained the level of accuracy required by USACE performance standards. Horizontal and vertical accuracy quality assurance checks were done at the beginning and end of each survey day by placing the Trimble® R8/5800 GPS receiver on a 2-meter survey rod at a published benchmark and comparing the measured elevation and horizontal coordinates against published values. Additionally, the RTK-GPS base station antenna was measured at the end of each day and was compared to initial setup values to ensure that the equipment had remained stable throughout the day. The MBES quality assurance performance test was applied during the project to ensure that system performance was within USACE elevation/depth accuracy recommendations. Survey speeds typically were 6–7 knots or less to minimize latency error (the time delay between the measurement and the time when the processed data become available). A detailed description of positional accuracy and the results of the MBES quality assurance performance test are available in the metadata for the hydrographic survey in appendix A.

Results of the Hydrographic Survey

The digital elevation data in appendix A are presented as ASCII coordinate positioning data (easting, northing, and elevation), often referred to as xyz positional data. The survey was conducted using the Washington State Plane South, North American Datum of 1983 (NAD83) horizontal coordinate system in units of U.S. survey feet, and the vertical coordinate system of the North American Vertical Datum of 1988 (NAVD88) in units of U.S. survey feet. The digital elevation dataset consists of more than 1 million points in a 3×3-ft point grid. The primary purpose of these data is to support the USACE's sediment transport modeling effort. However, these data also can provide a visual representation of bed geomorphology useful for other purposes, such as habitat assessment. Figure 4 shows a two-dimensional overhead view of part of the surveyed area and includes areas of dune formation, scour holes, basalt rock formation, and areas where bed material was removed for levee source material.

Basemap modified from USGS and other digital sources, various scales. Coordinate system: Washington State Plane South, North American Datum of 1983.

Figure 4. Example of a bathymetric map and bed morphology from the digital dataset, Snake and Clearwater Rivers, Washington and Idaho. Inset is an overhead image of the Snake River near RM 140.

Underwater Video Map Survey

A surficial sediment facies map should be the first step in any geologic study that simulates sediment processes and defines benthic habitats. Traditional facies maps are created by collecting sediment samples from the bed of the water body and analyzing the samples for grain and rock size and sediment type. The level of effort and cost for such an endeavor limits the number of samples available to create the facies map, and much of traditional map detail is through interpolation. Current underwater video technology, coupled with the high-resolution MBES data, allow for much finer detail in creating sediment facies maps. The video record captures the primary attributes of the substrate such as bottom type, texture, small bedforms, indications of disturbance, unusual features, and embeddedness. The video record also provides ground-truthing of the sediment type that may be interpreted from the MBES data. For bedforms that are greater than the field of view of the camera, especially in limited light conditions, the MBES bed elevation data provide the fidelity to define larger geomorphological features. Coupled, the modern technology provides a great deal of data that are useful in creating sediment facies maps.

Methods and Equipment

The underwater digital point video of sediment facies was recorded from RM 107.73 to 141.78 on the Snake River, and between RM 0 and 1.66 on the Clearwater River (fig. 3). Videos of less than 1 minute were recorded at locations spaced approximately every 165 ft along transects previously established by the USACE (fig. 3). These transects included 61 cross sections that had been used previously to measure sediment accumulation for the evaluation of reservoir capacity, and to ensure depths were adequate for river navigation. Five longitudinal dredge material deposit areas also were surveyed. The geographic coordinates for the center point of the transects and disposal lines are defined in appendix B, table B1 for the Clearwater River, and table B2 for the Snake River.

The videos were collected using a tether-suspended, high-resolution color video camera with a 79-degree field of view and 16 white LED variable-intensity lights. Underwater, high-power laser pointers mounted in parallel on the camera housing emitted two laser points with a 4-in. separation on the substrate surface. The laser points provide a reference distance in order to estimate the size of the substrate on the riverbed. The camera was lowered through the water column until it was near the riverbed and recorded video for as much time as was required to characterize the substrate. For quality control, the lasers were adjusted prior to camera deployment by measuring the distance between the laser points, first with the camera positioned at 4 in., and then at 6 ft from a reflective surface to ensure that they were mounted parallel to each other. In areas that were too shallow for the boat to operate safely, geo-tagged bank photographs were taken to show the type of sediment at the edge of water. This information was incorporated into the geospatial information system (GIS) facies map product.

The geographic position of the camera, time of recording, and depth of the water below the boat transom were continuously superimposed on the video recording. Geographic positioning and time of recording was obtained from a Trimble® mapping grade GPS receiver. The depth displayed on the video recording is provided by an echosounder fixed-mounted on the boat hull to provide the approximate depth below the transom in meters.

Data Processing and Analysis

More than 900 video recordings (appendixes C and D) were analyzed to determine the sediment type and level of embeddedness (which indicates whether sand or silt has filled the interstices of coarse material) for each location. Analysis of the recording was used in combination with bathymetry to create a surficial sediment facies map through ESRI ArcGIS® software. Small bedforms (for example, plane bedform or ripples) are listed as a video point attribute in the GIS tables, but are not visually rendered on the map. Larger bedforms, such as dunes, typically are larger than the camera's field of view and are best observed from the bathymetric dataset, or as a layer in the GIS facies map product.

The surficial sediment facies map uses the following rock diameters and sediment classifications to define facies map areas: bedrock, boulder (>10.1 in.), cobble (>2.5–10.1 in.), gravel (>0.08–2.5 in.), sand (0.002–<0.08 in.), silt (<0.002 in.), and riprap material (Wentworth, 1922). For the purposes of this study, the presentation of coarse substrates on the facies map (for example, boulder, cobble, and gravel) were combined into one category because they can change quickly over a small area. The facies map uses different patterns to distinguish between categories and hatching to indicate the presence of fines. An average percent of embeddedness (the percent to which coarse substrate is surrounded or covered by sand or silt) is depicted by a color ramp on the facies map. For example, one color will be used for a 0–20 percent embeddedness range, where little to no observable silt or sand is filling the interstitial spaces or covering the rocks; a different color will depict the range of 81 to 100 percent where the rocks would be nearly or completely covered by fine sediment. The range for each color is provided in the GIS product.

Underwater Video Mapping Survey Results

The UVM survey analysis was used with the bathymetric survey results to create a surficial sediment facies map as a GIS product (example shown in figure 5). The surface substrate type and embeddedness are variable in the upper reach of the study area, although areas downstream of the confluence affected by backwater from the dam may have only fine grain sediments. Use of the bathymetry in creating the GIS facies map allowed for inclusion of bedform features in what otherwise might be considered a featureless bottom, if determined from analysis of the videos alone. When paired, the UVM and MBES surveys provide information on the benthic geomorphology and habitat conditions of the Lower Granite Reservoir at a level that had not been previously attained.

Future Application and Enhancements

The data provided in this report can be useful in numerous ways. Comparative analysis of ASCII elevation dataset with historical surveys can illustrate areas of sediment deposition, changes in channel morphology, assessment of reservoir capacity, and evaluation of levee effectiveness in the area surveyed. Augmentation of these data with hydrologic streamflow data focused in areas of coarse-grained sediment transition to areas of greater embeddedness of fine grain sediments, and then broadly across the study area using acoustic Doppler current profiler technology can help refine sediment transport modeling efforts for a more accurate model.

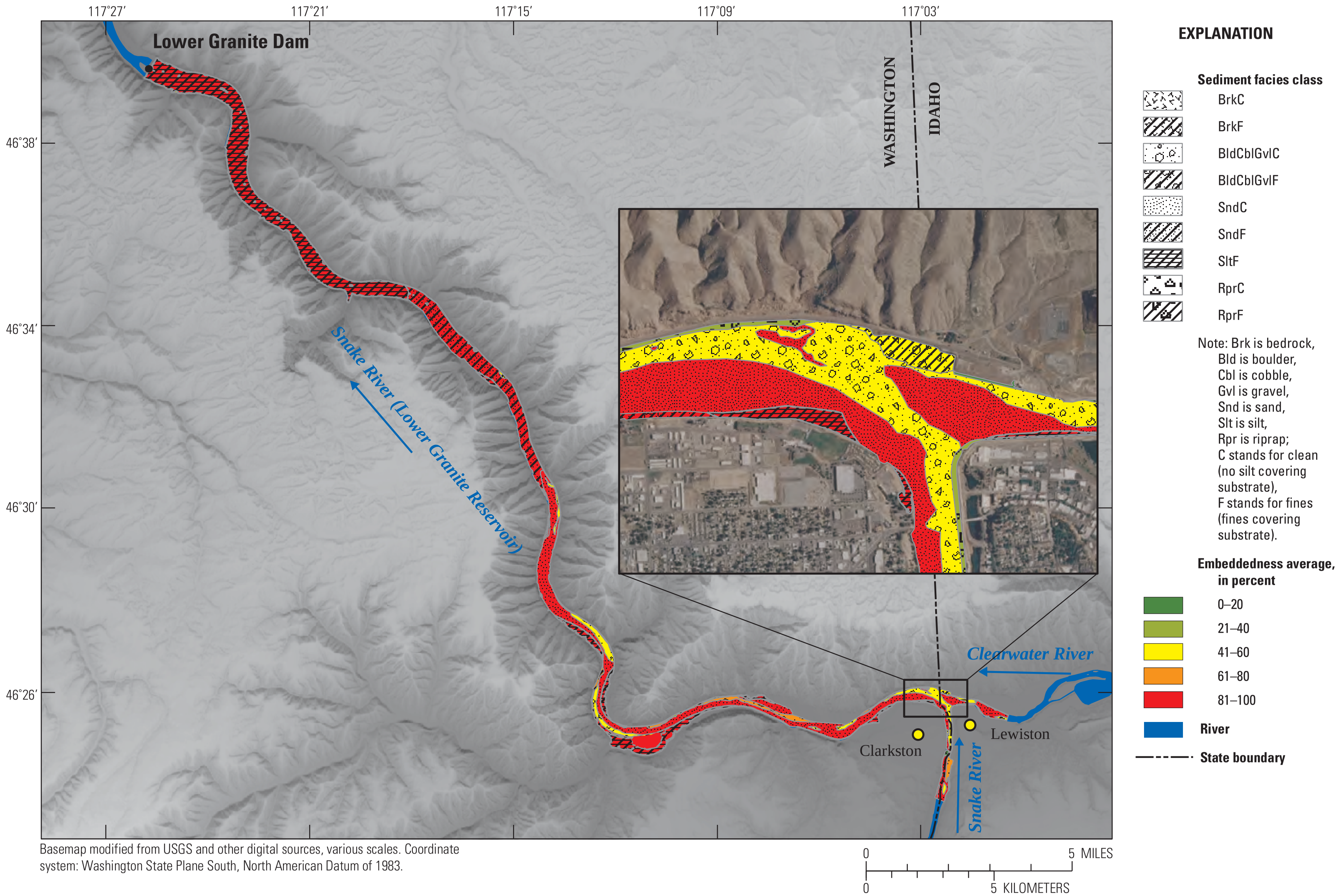


Figure 5. Sample of surficial sediment facies map of the Snake and Clearwater Rivers, Washington and Idaho.

Summary

The U.S. Geological Survey, in cooperation with the U.S. Army Corps of Engineers, conducted a bathymetric survey of the Lower Granite Reservoir, Washington, using a multibeam echosounder, and an underwater video mapping survey during autumn 2009 and winter 2010. The surveys were conducted as part of the U.S. Army Corps of Engineer's study on sediment deposition and control in the reservoir. The multibeam echosounder survey was performed in 1-mile increments between river mile (RM) 130 and 142 on the Snake River, and between RM 0 and 2 on the Clearwater River. The result of the survey is a digital elevation dataset in ASCII coordinate positioning data (easting, northing, and elevation) useful in rendering a 3×3-foot point grid showing bed elevation and reservoir geomorphology. The underwater video mapping survey was conducted from RM 107.73 to 141.78 on the Snake River and RM 0 to 1.66 on the Clearwater River, along 61 U.S. Army Corps of Engineers established cross sections, and dredge material deposit transects. More than 900 videos and 90 bank photographs were used to characterize the sediment facies and ground-truth the multibeam echosounder data. Combined, the surveys were used to create a surficial sediment facies map that displays type of substrate type, level of embeddedness, and presence of silt.

Acknowledgments

The authors and field personnel offer a special thanks to the USACE Clarkston Natural Resources Office staff for their gracious support in providing boat mooring, equipment storage, and the use of their facilities for the duration of this study.

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Wentworth, C.K., 1922, A scale of grade and class terms for clastic sediments: The Journal of Geology, v. 30, p. 377–392.

Appendix A. Multibeam Echosounder Data and Sediment Facies Map

Snake and Clearwater River Multibeam Echosounder Data

ASCII XYZ position and elevation data Metadata

Snake and Clearwater River Sediment Facies Map

GIS files for map

Table A1. Survey benchmarks.

Point listing name	Northing	Easting	Elevation (feet)
R21-RA	410565.402	2513935.089	747.97
R24-LA	416395.56	2513025.92	743.82
R27A-RA	415223.29	2501208.87	745.85
R28A-RA	415109.67	2497368.67	746.65
R29D-RA	417580.451	2481859.809	748.38
R31-LA	413164.38	2473552.19	764.35

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Appendix B. Underwater Video Mapping Survey Transect Tables

Table B1. Underwater video mapping, Clearwater River, Idaho.

River mile	Type	Length (feet)	Easting (feet, Washington State Plane South)	Northing (feet, Washington State Plane South)
0.28	Cross section	1,310	2514558.108	417877.3041
0.41	Cross section	1,089	2515168.939	417818.9142
0.53	Cross section	1,130	2515783.093	417869.1791
0.67	Cross section	1,141	2516432.022	417492.1168
0.78	Cross section	748.9	2517019.141	417722.1255
0.92	Cross section	1,312	2517759.454	417280.8562
1.06	Cross section	1,367	2518167.193	416938.5179
1.16	Cross section	1,890	2518578.477	416488.9467
1.26	Cross section	1,427	2519071.113	416397.1885
1.36	Cross section	1,376	2519526.546	416213.3064
1.47	Cross section	1,610	2519954.69	416008.4692
1.56	Cross section	1,013	2520523.993	415947.9729
1.66	Cross section	1,094	2521074.225	415765.7706

Table B2. Underwater video mapping, Snake River, Washington.

River mile	Type	Length (feet)	Easting (feet, Washington State Plane South)	Northing (feet, Washington State Plane South)
107.73	Cross section	3,336	2412915.649	498263.0819
108.31	Cross section	3,280	2415041.396	497375.0198
110.00	Disposal line	14,050	2421886.205	495449.1141
111.24	Cross section	3,180	2422610.341	488148.1157
112.00	Disposal line	8,223	2423706.247	483667.758
113.12	Cross section	2,305	2426871.145	480340.8725
114.00	Disposal line	8,222	2430353.614	477579.0884
114.92	Cross section	2,801	2432785.091	473595.1037
117.00	Disposal line	23,210	2443999.23	470331.3617
119.56	Cross section	2,484	2452639.727	462208.8201
120.00	Disposal line	4,181	2454107.987	460527.9898
120.46	Cross section	2,731	2455978.219	459152.517
121.42	Cross section	1,665	2458714.545	454689.9359
122.69	Cross section	1,565	2460142.018	449702.9212
123.30	Cross section	1,756	2462311.381	445358.4231
124.94	Cross section	1,861	2463125.525	439871.907
126.07	Cross section	1,933	2462355.905	431585.1297
127.03	Cross section	2,126	2465565.422	428106.331
127.63	Cross section	2,117	2468000.434	426400.7354
128.27	Cross section	1,707	2469877.035	424065.6926
128.87	Cross section	1,629	2469865.525	421412.4978
129.27	Cross section	1,964	2469168.541	419409.8057
130.00	Cross section	2,066	2469368.937	415882.2926
130.44	Cross section	2,122	2470885.387	414174.117
130.66	Cross section	3,262	2471823.859	413224.3367
130.93	Cross section	3,807	2473487.722	412867.8886
131.62	Cross section	2,910	2477144.328	413829.3271

Table B2. Underwater video mapping, Snake River, Washington.—Continued

River mile	Type	Length (feet)	Easting (feet, Washington State Plane South)	Northing (feet, Washington State Plane South)
132.05	Cross section	2,148	2479188.89	415323.0343
132.71	Cross section	1,508	2482183.778	417030.3178
133.41	Cross section	1,676	2485753.914	417787.6633
133.98	Cross section	1,881	2488262.078	417740.6446
134.58	Cross section	2,221	2491484.273	416732.1745
135.15	Cross section	1,860	2493916.474	415403.1546
135.76	Cross section	1,655	2497120.087	414373.0329
136.29	Cross section	2,153	2499947.688	413917.833
136.69	Cross section	1,519	2501598.19	414622.2821
137.17	Cross section	2,211	2503894.728	415850.9087
137.69	Cross section	1,604	2505944.024	417545.031
137.94	Cross section	1,584	2506938.931	418253.5856
138.07	Cross section	1,575	2507593.291	418451.1655
138.34	Cross section	1,895	2508786.328	418586.1987
138.52	Cross section	2,251	2509885.094	418603.3159
138.71	Cross section	2,420	2510836.798	418576.519
138.94	Cross section	2,737	2512123.787	418309.8488
139.22	Cross section	2,483	2512976.353	417722.8096
139.29	Cross section	2,866	2513520.537	417544.379
139.43	Cross section	1,488	2513607.366	416528.4698
139.64	Cross section	1,178	2513698.334	415196.6179
139.91	Cross section	1,260	2513933.03	413932.7433
140.22	Cross section	916.6	2513876.90	411988.059
140.51	Cross section	1,022	2513556.897	410720.6452
140.75	Cross section	1,588	2513500.822	409394.7468
141.21	Cross section	1,619	2513167.011	406918.5852

Appendix C. Underwater Video Mapping Survey Videos

Table C1. Underwater videos, Clearwater River, Idaho, October 20, 2009.

[Maps and associated videos can be viewed in figures C1–C26, available at http://pubs.usgs.gov/sir/2012/5089]

10202009-2.mp4	10202009-23.mp4	10202009-44.mp4	10202009-65.mp4
10202009-3.mp4	10202009-24.mp4	10202009-45.mp4	10202009-66.mp4
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10202009-20.mp4	10202009-41.mp4	10202009-62.mp4	
10202009-21.mp4	10202009-42.mp4	10202009-63.mp4	
10202009-22.mp4	10202009-43.mp4	10202009-64.mp4	

Table C2. Underwater videos, Snake River, Washington, October 21, 2009.

[Maps and associated videos can be viewed in figures C1–C26, available at http://pubs.usgs.gov/sir/2012/5089]

10212009-2.mp4	10212009-44.mp4	10212009-87.mp4	10212009-130.mp4
10212009-3.mp4	10212009-45.mp4	10212009-88.mp4	10212009-130.mp4
10212009-4.mp4	10212009-46.mp4	10212009-89.mp4	10212009-131.mp4
10212009-5.mp4	10212009-47.mp4	10212009-90.mp4	10212009-132.mp4
10212009-6.mp4	10212009-48.mp4	10212009-91.mp4	10212009-133.mp4
10212009-7.mp4	10212009-49.mp4	10212009-92.mp4	10212009-134.mp4
10212009-8.mp4	10212009-50.mp4	10212009-93.mp4	10212009-135.mp4
10212009-9.mp4	10212009-51.mp4	10212009-94.mp4	10212009-136.mp4
10212009-10.mp4	10212009-52.mp4	10212009-95.mp4	10212009-137.mp4
10212009-11.mp4	10212009-53.mp4	10212009-96.mp4	10212009-138.mp4
10212009-12.mp4	10212009-54.mp4	10212009-97.mp4	10212009-139.mp4
10212009-13.mp4	10212009-55.mp4	10212009-98.mp4	10212009-140.mp4
10212009-14.mp4	10212009-56.mp4	10212009-99.mp4	10212009-141.mp4
10212009-15.mp4	10212009-57.mp4	10212009-100.mp4	10212009-142.mp4
10212009-16.mp4	10212009-58.mp4	10212009-101.mp4	10212009-143.mp4
10212009-17.mp4	10212009-59.mp4	10212009-102.mp4	10212009-144.mp4
10212009-18.mp4	10212009-60.mp4	10212009-103.mp4	10212009-145.mp4
10212009-19.mp4	10212009-61.mp4	10212009-104.mp4	10212009-146.mp4
10212009-20.mp4	10212009-62.mp4	10212009-105.mp4	10212009-147.mp4
10212009-21.mp4	10212009-63.mp4	10212009-106.mp4	10212009-148.mp4
10212009-22.mp4	10212009-64.mp4	10212009-107.mp4	10212009-149.mp4
10212009-23.mp4	10212009-65.mp4	10212009-108.mp4	10212009-150.mp4
10212009-24.mp4	10212009-66.mp4	10212009-109.mp4	10212009-151.mp4
10212009-25.mp4	10212009-68.mp4	10212009-110.mp4	10212009-152.mp4
10212009-26.mp4	10212009-69.mp4	10212009-111.mp4	10212009-153.mp4
10212009-27.mp4	10212009-70.mp4	10212009-112.mp4	10212009-154.mp4
10212009-28.mp4	10212009-71.mp4	10212009-113.mp4	10212009-155.mp4
10212009-29.mp4	10212009-72.mp4	10212009-114.mp4	10212009-156.mp4
10212009-30.mp4	10212009-73.mp4	10212009-115.mp4	10212009-157.mp4
10212009-31.mp4	10212009-74.mp4	10212009-116.mp4	10212009-158.mp4
10212009-32.mp4	10212009-75.mp4	10212009-117.mp4	10212009-159.mp4
10212009-33.mp4	10212009-76.mp4	10212009-118.mp4	10212009-160.mp4
10212009-34.mp4	10212009-77.mp4	10212009-119.mp4	10212009-161.mp4
10212009-35.mp4	10212009-78.mp4	10212009-120.mp4	10212009-162.mp4
10212009-36.mp4	10212009-79.mp4	10212009-121.mp4	10212009-163.mp4
10212009-37.mp4	10212009-80.mp4	10212009-122.mp4	10212009-164.mp4
10212009-38.mp4	10212009-81.mp4	10212009-123.mp4	10212009-165.mp4
10212009-39.mp4	10212009-82.mp4	10212009-124.mp4	10212009-166.mp4
10212009-40.mp4	10212009-83.mp4	10212009-125.mp4	10212009-167.mp4
10212009-41.mp4	10212009-84.mp4	10212009-126.mp4	10212009-168.mp4
10212009-42.mp4	10212009-85.mp4	10212009-127.mp4	10212009-169.mp4
10212009-43.mp4	10212009-86.mp4	10212009-128.mp4	10212009-170.mp4
		10212009-129.mp4	

Table C3. Underwater videos, Snake River, Washington, October 22, 2009.

[Maps and associated videos can be viewed in figures C1–C26, available at http://pubs.usgs.gov/sir/2012/5089]

10222009-2.mp4	10222009-53.mp4	10222009-105.mp4	10222009-157.mp4
10222009-3.mp4	10222009-54.mp4	10222009-106.mp4	10222009-158.mp4
10222009-4.mp4	10222009-55.mp4	10222009-107.mp4	10222009-159.mp4
10222009-5.mp4	10222009-56.mp4	10222009-108.mp4	10222009-160.mp4
10222009-6.mp4	10222009-57.mp4	10222009-109.mp4	10222009-161.mp4
10222009-7.mp4	10222009-58.mp4	10222009-110.mp4	10222009-162.mp4
10222009-8.mp4	10222009-59.mp4	10222009-111.mp4	10222009-163.mp4
10222009-9.mp4	10222009-60.mp4	10222009-112.mp4	10222009-164.mp4
10222009-10.mp4	10222009-61.mp4	10222009-113.mp4	10222009-165.mp4
10222009-11.mp4	10222009-62.mp4	10222009-114.mp4	10222009-166.mp4
10222009-12.mp4	10222009-63.mp4	10222009-115.mp4	10222009-167.mp4
10222009-13.mp4	10222009-64.mp4	10222009-116.mp4	10222009-168.mp4
10222009-14.mp4	10222009-65.mp4	10222009-117.mp4	10222009-169.mp4
10222009-15.mp4	10222009-66.mp4	10222009-118.mp4	10222009-170.mp4
10222009-16.mp4	10222009-67.mp4	10222009-119.mp4	10222009-171.mp4
10222009-17.mp4	10222009-68.mp4	10222009-120.mp4	10222009-172.mp4
10222009-18.mp4	10222009-69.mp4	10222009-121.mp4	10222009-173.mp4
10222009-19.mp4	10222009-70.mp4	10222009-122.mp4	10222009-174.mp4
10222009-20.mp4	10222009-71.mp4	10222009-123.mp4	10222009-175.mp4
10222009-21.mp4	10222009-72.mp4	10222009-124.mp4	10222009-176.mp4
10222009-22.mp4	10222009-73.mp4	10222009-125.mp4	10222009-177.mp4
10222009-23.mp4	10222009-74.mp4	10222009-126.mp4	10222009-178.mp4
10222009-24.mp4	10222009-75.mp4	10222009-127.mp4	10222009-179.mp4
10222009-25.mp4	10222009-76.mp4	10222009-128.mp4	10222009-180.mp4
10222009-26.mp4	10222009-77.mp4	10222009-129.mp4	10222009-181.mp4
10222009-27.mp4	10222009-78.mp4	10222009-130.mp4	10222009-182.mp4
10222009-28.mp4	10222009-79.mp4	10222009-131.mp4	10222009-183.mp4
10222009-29.mp4	10222009-80.mp4	10222009-132.mp4	10222009-184.mp4
10222009-30.mp4	10222009-81.mp4	10222009-133.mp4	10222009-185.mp4
10222009-31.mp4	10222009-82.mp4	10222009-134.mp4	10222009-186.mp4
10222009-32.mp4	10222009-83.mp4	10222009-135.mp4	10222009-187.mp4
10222009-33.mp4	10222009-84.mp4	10222009-136.mp4	10222009-188.mp4
10222009-34.mp4	10222009-85.mp4	10222009-137.mp4	10222009-189.mp4
10222009-35.mp4	10222009-86.mp4	10222009-138.mp4	10222009-190.mp4
10222009-36.mp4	10222009-87.mp4	10222009-139.mp4	10222009-191.mp4
10222009-37.mp4	10222009-88.mp4	10222009-140.mp4	10222009-192.mp4
10222009-38.mp4	10222009-89.mp4	10222009-141.mp4	10222009-193.mp4
10222009-39.mp4	10222009-90.mp4	10222009-142.mp4	10222009-194.mp4
10222009-40.mp4	10222009-91.mp4	10222009-143.mp4	10222009-195.mp4
10222009-41.mp4	10222009-92.mp4	10222009-144.mp4	10222009-196.mp4
10222009-42.mp4	10222009-93.mp4	10222009-145.mp4	10222009-197.mp4
10222009-43.mp4	10222009-94.mp4	10222009-146.mp4	10222009-198.mp4
10222009-44.mp4	10222009-95.mp4	10222009-147.mp4	10222009-199.mp4
10222009-45.mp4	10222009-96.mp4	10222009-148.mp4	10222009-200.mp4
10222009-46.mp4	10222009-97.mp4	10222009-149.mp4	10222009-201.mp4
10222009-47.mp4	10222009-98.mp4	10222009-150.mp4	10222009-202.mp4
10222009-48.mp4	10222009-99.mp4	10222009-151.mp4	10222009-203.mp4
10222009-49.mp4	10222009-100.mp4	10222009-152.mp4	10222009-204.mp4
10222009-50.mp4	10222009-101.mp4	10222009-153.mp4	10222009-205.mp4
10222009-51.mp4	10222009-102.mp4	10222009-154.mp4	10222009-206.mp4
10222009-52.mp4	10222009-103.mp4	10222009-155.mp4	10222009-207.mp4
	10222009-104.mp4	10222009-156.mp4	

Table C4. Underwater videos, Snake River, Washington, February 1, 2010.

[Maps and associated videos can be viewed in figures C1–C26, available at http://pubs.usgs.gov/sir/2012/5089]

02012010-2.mp4	02012010-36.mp4	02012010-71.mp4	02012010-106.mp4
02012010-3.mp4	02012010-37.mp4	02012010-72.mp4	02012010-107.mp4
02012010-4.mp4	02012010-38.mp4	02012010-73.mp4	02012010-108.mp4
02012010-5.mp4	02012010-39.mp4	02012010-74.mp4	02012010-109.mp4
02012010-6.mp4	02012010-40.mp4	02012010-75.mp4	02012010-110.mp4
02012010-7.mp4	02012010-41.mp4	02012010-76.mp4	02012010-111.mp4
02012010-9.mp4	02012010-42.mp4	02012010-77.mp4	02012010-112.mp4
02012010-10.mp4	02012010-43.mp4	02012010-78.mp4	02012010-113.mp4
02012010-11.mp4	02012010-44.mp4	02012010-79.mp4	02012010-114.mp4
02012010-12.mp4	02012010-45.mp4	02012010-80.mp4	02012010-115.mp4
02012010-13.mp4	02012010-46.mp4	02012010-81.mp4	02012010-116.mp4
02012010-14.mp4	02012010-47.mp4	02012010-82.mp4	02012010-117.mp4
02012010-15.mp4	02012010-48.mp4	02012010-83.mp4	02012010-118.mp4
02012010-16.mp4	02012010-49.mp4	02012010-84.mp4	02012010-119.mp4
02012010-17.mp4	02012010-50.mp4	02012010-85.mp4	02012010-120.mp4
02012010-18.mp4	02012010-51.mp4	02012010-86.mp4	02012010-121.mp4
02012010-19.mp4	02012010-52.mp4	02012010-87.mp4	02012010-122.mp4
02012010-20.mp4	02012010-53.mp4	02012010-88.mp4	02012010-123.mp4
02012010-21.mp4	02012010-54.mp4	02012010-89.mp4	02012010-124.mp4
02012010-22.mp4	02012010-55.mp4	02012010-90.mp4	02012010-125.mp4
02012010-23.mp4	02012010-56.mp4	02012010-91.mp4	02012010-126.mp4
02012010-24.mp4	02012010-57.mp4	02012010-92.mp4	02012010-127.mp4
02012010-25.mp4	02012010-58.mp4	02012010-93.mp4	02012010-128.mp4
02012010-26.mp4	02012010-59.mp4	02012010-94.mp4	02012010-129.mp4
02012010-27.mp4	02012010-60.mp4	02012010-95.mp4	02012010-130.mp4
02012010-28.mp4	02012010-61.mp4	02012010-96.mp4	02012010-131.mp4
02012010-29.mp4	02012010-62.mp4	02012010-97.mp4	02012010-132.mp4
02012010-30.mp4	02012010-63.mp4	02012010-98.mp4	02012010-133.mp4
02012010-31.mp4	02012010-64.mp4	02012010-99.mp4	02012010-134.mp4
02012010-32.mp4	02012010-65.mp4	02012010-100.mp4	02012010-135.mp4
02012010-33.mp4	02012010-66.mp4	02012010-101.mp4	02012010-137.mp4
02012010-34.mp4	02012010-67.mp4	02012010-102.mp4	02012010-138.mp4
02012010-35.mp4	02012010-68.mp4	02012010-103.mp4	02012010-139.mp4
	02012010-70.mp4	02012010-104.mp4	
		02012010-105.mp4	

Table C5. Underwater videos, Snake River, Washington, February 2, 2010.

[Maps and associated videos can be viewed in figures C1–C26, available at http://pubs.usgs.gov/sir/2012/5089]

02022010-2.mp4	02022010-45.mp4	02022010-89.mp4	02022010-133.mp4
02022010-3.mp4	02022010-46.mp4	02022010-90.mp4	02022010-134.mp4
02022010-4.mp4	02022010-47.mp4	02022010-91.mp4	02022010-135.mp4
02022010-5.mp4	02022010-48.mp4	02022010-92.mp4	02022010-136.mp4
02022010-6.mp4	02022010-49.mp4	02022010-93.mp4	02022010-137.mp4
02022010-7.mp4	02022010-50.mp4	02022010-94.mp4	02022010-138.mp4
02022010-8.mp4	02022010-51.mp4	02022010-95.mp4	02022010-139.mp4
02022010-9.mp4	02022010-52.mp4	02022010-96.mp4	02022010-140.mp4
02022010-10.mp4	02022010-53.mp4	02022010-97.mp4	02022010-141.mp4
02022010-11.mp4	02022010-54.mp4	02022010-98.mp4	02022010-142.mp4
02022010-12.mp4	02022010-55.mp4	02022010-99.mp4	02022010-143.mp4
02022010-13.mp4	02022010-56.mp4	02022010-100.mp4	02022010-144.mp4
02022010-14.mp4	02022010-57.mp4	02022010-101.mp4	02022010-145.mp4
02022010-15.mp4	02022010-58.mp4	02022010-102.mp4	02022010-146.mp4
02022010-16.mp4	02022010-59.mp4	02022010-103.mp4	02022010-147.mp4
02022010-17.mp4	02022010-60.mp4	02022010-104.mp4	02022010-148.mp4
02022010-18.mp4	02022010-61.mp4	02022010-105.mp4	02022010-149.mp4
02022010-19.mp4	02022010-62.mp4	02022010-106.mp4	02022010-150.mp4
02022010-20.mp4	02022010-63.mp4	02022010-107.mp4	02022010-151.mp4
02022010-21.mp4	02022010-64.mp4	02022010-108.mp4	02022010-152.mp4
02022010-22.mp4	02022010-65.mp4	02022010-109.mp4	02022010-153.mp4
02022010-23.mp4	02022010-66.mp4	02022010-110.mp4	02022010-154.mp4
02022010-24.mp4	02022010-67.mp4	02022010-111.mp4	02022010-155.mp4
02022010-25.mp4	02022010-68.mp4	02022010-112.mp4	02022010-156.mp4
02022010-26.mp4	02022010-69.mp4	02022010-113.mp4	02022010-157.mp4
02022010-27.mp4	02022010-70.mp4	02022010-114.mp4	02022010-158.mp4
02022010-28.mp4	02022010-71.mp4	02022010-115.mp4	02022010-159.mp4
02022010-29.mp4	02022010-72.mp4	02022010-116.mp4	02022010-160.mp4
02022010-30.mp4	02022010-73.mp4	02022010-117.mp4	02022010-161.mp4
02022010-31.mp4	02022010-74.mp4	02022010-118.mp4	02022010-162.mp4
02022010-32.mp4	02022010-75.mp4	02022010-119.mp4	02022010-163.mp4
02022010-33.mp4	02022010-76.mp4	02022010-120.mp4	02022010-164.mp4
02022010-34.mp4	02022010-77.mp4	02022010-121.mp4	02022010-165.mp4
02022010-35.mp4	02022010-78.mp4	02022010-122.mp4	02022010-166.mp4
02022010-36.mp4	02022010-79.mp4	02022010-123.mp4	02022010-167.mp4
02022010-37.mp4	02022010-80.mp4	02022010-124.mp4	02022010-168.mp4
02022010-38.mp4	02022010-81.mp4	02022010-125.mp4	02022010-169.mp4
02022010-39.mp4	02022010-82.mp4	02022010-126.mp4	02022010-170.mp4
02022010-40.mp4	02022010-83.mp4	02022010-127.mp4	02022010-171.mp4
02022010-41.mp4	02022010-84.mp4	02022010-128.mp4	02022010-172.mp4
02022010-42.mp4	02022010-85.mp4	02022010-129.mp4	02022010-173.mp4
02022010-43.mp4	02022010-86.mp4	02022010-130.mp4	02022010-174.mp4
02022010-44.mp4	02022010-87.mp4	02022010-131.mp4	02022010-175.mp4
	02022010-88.mp4	02022010-132.mp4	

Table C6. Underwater videos, Snake River, Washington, February 3, 2010.

[Maps and associated videos can be viewed in figures C1–C26, available at http://pubs.usgs.gov/sir/2012/5089]

02032010-3.mp4	02032010-42.mp4	02032010-83.mp4	02032010-125.mp4
02032010-4.mp4	02032010-43.mp4	02032010-84.mp4	02032010-126.mp4
02032010-5.mp4	02032010-45.mp4	02032010-85.mp4	02032010-127.mp4
02032010-6.mp4	02032010-46.mp4	02032010-86.mp4	02032010-128.mp4
02032010-7.mp4	02032010-47.mp4	02032010-87.mp4	02032010-129.mp4
02032010-8.mp4	02032010-48.mp4	02032010-88.mp4	02032010-130.mp4
02032010-9.mp4	02032010-49.mp4	02032010-89.mp4	02032010-131.mp4
02032010-10.mp4	02032010-50.mp4	02032010-90.mp4	02032010-132.mp4
02032010-11.mp4	02032010-51.mp4	02032010-91.mp4	02032010-133.mp4
02032010-12.mp4	02032010-52.mp4	02032010-92.mp4	02032010-134.mp4
02032010-13.mp4	02032010-53.mp4	02032010-93.mp4	02032010-135.mp4
02032010-14.mp4	02032010-54.mp4	02032010-94.mp4	02032010-136.mp4
02032010-15.mp4	02032010-55.mp4	02032010-95.mp4	02032010-137.mp4
02032010-16.mp4	02032010-56.mp4	02032010-96.mp4	02032010-138.mp4
02032010-17.mp4	02032010-57.mp4	02032010-97.mp4	02032010-139.mp4
02032010-18.mp4	02032010-58.mp4	02032010-98.mp4	02032010-140.mp4
02032010-19.mp4	02032010-59.mp4	02032010-99.mp4	02032010-141.mp4
02032010-20.mp4	02032010-60.mp4	02032010-100.mp4	02032010-142.mp4
02032010-21.mp4	02032010-61.mp4	02032010-101.mp4	02032010-143.mp4
02032010-22.mp4	02032010-62.mp4	02032010-102.mp4	02032010-144.mp4
02032010-23.mp4	02032010-63.mp4	02032010-103.mp4	02032010-145.mp4
02032010-24.mp4	02032010-64.mp4	02032010-104.mp4	02032010-146.mp4
02032010-25.mp4	02032010-65.mp4	02032010-105.mp4	02032010-147.mp4
02032010-26.mp4	02032010-66.mp4	02032010-106.mp4	02032010-148.mp4
02032010-27.mp4	02032010-67.mp4	02032010-107.mp4	02032010-149.mp4
02032010-28.mp4	02032010-68.mp4	02032010-108.mp4	02032010-150.mp4
02032010-29.mp4	02032010-69.mp4	02032010-109.mp4	02032010-151.mp4
02032010-30.mp4	02032010-70.mp4	02032010-110.mp4	02032010-152.mp4
02032010-31.mp4	02032010-71.mp4	02032010-111.mp4	02032010-153.mp4
02032010-32.mp4	02032010-72.mp4	02032010-112.mp4	02032010-154.mp4
02032010-33.mp4	02032010-73.mp4	02032010-113.mp4	02032010-155.mp4
02032010-34.mp4	02032010-74.mp4	02032010-114.mp4	02032010-156.mp4
02032010-35.mp4	02032010-75.mp4	02032010-115.mp4	02032010-157.mp4
02032010-36.mp4	02032010-76.mp4	02032010-116.mp4	02032010-158.mp4
02032010-37.mp4	02032010-77.mp4	02032010-117.mp4	02032010-159.mp4
02032010-38.mp4	02032010-78.mp4	02032010-118.mp4	02032010-160.mp4
02032010-39.mp4	02032010-79.mp4	02032010-119.mp4	02032010-161.mp4
02032010-40.mp4	02032010-80.mp4	02032010-120.mp4	
02032010-41.mp4	02032010-81.mp4	02032010-121.mp4	
	02032010-82.mp4	02032010-122.mp4	
		02032010-123.mp4	

Table C7. Underwater videos, Snake River, Washington, February 4, 2010.

[Maps and associated videos can be viewed in figures C1–C26, available at http://pubs.usgs.gov/sir/2012/5089]

02042010-2.mp4	02042010-10.mp4	02042010-23.mp4	02042010-34.mp4
02042010-3.mp4	02042010-11.mp4	02042010-29.mp4	02042010-35.mp4
02042010-4.mp4	02042010-12.mp4	02042010-30.mp4	02042010-39.mp4
02042010-5.mp4	02042010-13.mp4	02042010-31.mp4	02042010-40.mp4
02042010-6.mp4	02042010-14.mp4	02042010-32.mp4	02042010-41.mp4
02042010-8.mp4	02042010-15.mp4	02042010-33.mp4	02042010-42.mp4

Appendix D. Bank Photographs

Table D1. Geo-tagged bank photographs, Clearwater and Snake Rivers, October 21–22, 2010.

Click on a file name to view the photograph.

102109_074718_tag.jpg	102109_134448_tag.jpg	102209_083243_tag.jpg	102209_132242_tag.jpg
102109_081505_tag.jpg	102109_135039_tag.jpg	102209_083629_tag.jpg	102209_132521_tag.jpg
102109_082226_tag.jpg	102109_140644_tag.jpg	102209_012235_tag.jpg	102209_133505_tag.jpg
102109_083838_tag.jpg	102109_141019_tag.jpg	102209_090734_tag.jpg	102209_134028_tag.jpg
102109_084317_tag.jpg	102109_142431_tag.jpg	102209_091100_tag.jpg	102209_134433_tag.jpg
102109_085349_tag.jpg	102109_142747_tag.jpg	102209_092450_tag.jpg	102209_135750_tag.jpg
102109_090108_tag.jpg	102109_144017_tag.jpg	102209_092907_tag.jpg	102209_140049_tag.jpg
102109_090913_tag.jpg	102109_144425_tag.jpg	102209_020951_tag.jpg	102209_141820_tag.jpg
102109_091627_tag.jpg	102109_150216_tag.jpg	102209_021642_tag.jpg	102209_143401_tag.jpg
102109_092605_tag.jpg	102109_151053_tag.jpg	102209_100048_tag.jpg	102209_145226_tag.jpg
102109_093115_tag.jpg	102109_152803_tag.jpg	102209_100150_tag.jpg	102209_145844_tag.jpg
102109_093947_tag.jpg	102109_153406_tag.jpg	102209_100639_tag.jpg	102209_151753_tag.jpg
102109_094639_tag.jpg	102109_154535_tag.jpg	102209_103840_tag.jpg	102209_152251_tag.jpg
102109_100042_tag.jpg	102109_155108_tag.jpg	102209_104517_tag.jpg	102209_153657_tag.jpg
102109_103514_tag.jpg	102109_160534_tag.jpg	102209_104531_tag.jpg	102209_154331_tag.jpg
102109_110124_tag.jpg	102209_073220_tag.jpg	102209_033617_tag.jpg	102209_160204_tag.jpg
102109_110438_tag.jpg	102209_074629_tag.jpg	102209_033923_tag.jpg	102209_160439_tag.jpg
102109_113235_tag.jpg	102209_075258_tag.jpg	102209_115010_tag.jpg	102209_162218_tag.jpg
102109_113813_tag.jpg	102209_080633_tag.jpg	102209_123723_tag.jpg	
102109_120724_tag.jpg	102209_080645_tag.jpg	102209_125121_tag.jpg	
102109_130517_tag.jpg	102209_081343_tag.jpg	102209_125416_tag.jpg	
102109_132302_tag.jpg	102209_082747_tag.jpg	102209_130852_tag.jpg	
102109_132302-1_tag.jpg	102209_082747-1_tag.jpg	102209_131219_tag.jpg	
102109_132630_tag.jpg	102209_082845_tag.jpg	102209_131236_tag.jpg	

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For more information concerning the research in this report, contact the
Director, Idaho Water Science Center
U.S. Geological Survey
230 Collins Road
Boise, Idaho 83702
http://id.water.usgs.gov

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Williams and others— **Bathymetric and Underwater Video Survey of Lower Granite Reservoir and Vicinity, Washington and Idaho, 2009–10**—Scientific Investigations Report 2012–5089