APPENDIX X
SPECIFIC SAMPLING PROTOCOLS AND PROCEDURES FOR TOPOGRAPHIC MAPPING

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TOPOGRAPHIC MAPPING

1.0 Background

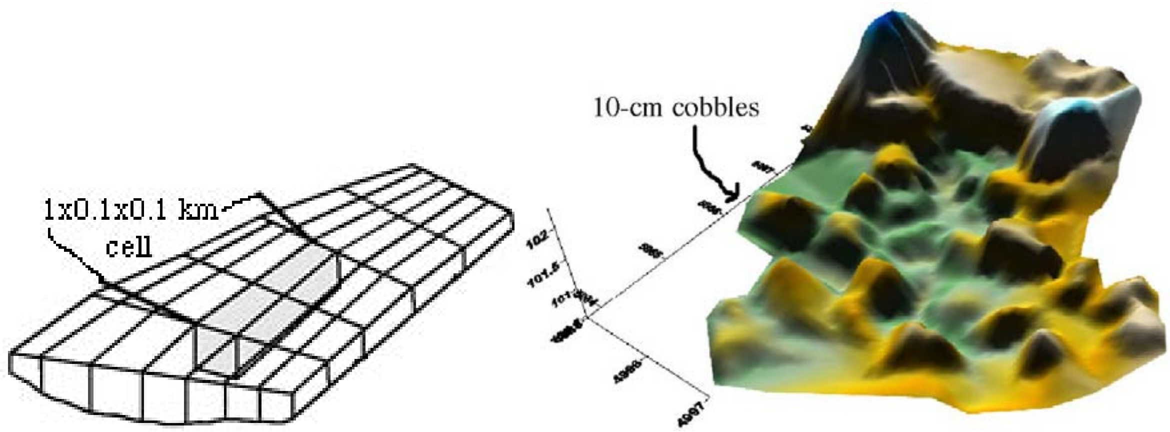
A topographic map is a representation of the elevation pattern of a land surface. Because topography is one of the most fundamental variables controlling ecosystem processes on Earth, it is essential to have a good topographic map to manage the landscape. In the case of rivers, topographic maps are particularly important, because the speed and direction of water flow and sediment transport is directed by landform configuration. In turn, flow and sediment help define instream habitat conditions and they can cause landform change. Repeated topographic mapping can be used to characterize how rivers change through time. Both habitat conditions and channel dynamics are important considerations in river management, particularly in regulated rivers that are actively managed to balance multiple needs and interests. Two common management activities that occur on regulated rivers and that would be greatly aided by a detailed topographic map include instream flow assessment and river rehabilitation.

1.1 Instream Flow Assessment Needs

Most instream flow studies of rivers involve either qualitative habitat assessment or empirical calculation at a limited number of cross-sections. However, a fish does not experience a cross-section or eve longitudinal “stream-tubes” (Fig. 1a). Fish are acutely tuned to the diversity of features in a river, even down to nooks and crannies that are only 10 cm dips in the bed surface (Fig. 1b). To understand and predict fish behavior, including spawning and rearing life stages, one has to view and analyze the river from the perspective that fish experience it, which is at the 0.1-1 m scale. There are three challenges with doing this. First, one has to know what a fish likes at this scale. A lot of data on fish preferences exists for many species, life stages, and rivers, including the Lower Yuba River (LYR)- with more data collection planned for the LYR in the next few years. Second, one has to have a map of a river with the same detail as fish experience it. In recent years the cost of very detailed aerial LiDAR mapping of terrestrial land

and boat-based echosounder mapping of channel bathymetry has dropped precipitously with the rapid pace of technological advancement. Third, one has to have significant computing power and an efficient river simulation algorithm to analyze many kilometers of river in this detail.

During the period 1990-2005, high-resolution 2D hydrodynamic modeling has been limited to the site scale of ~500-2000’. This forced managers to pick “representative” sites for modeling and then extrapolate the results to the rest of the river. However, site sampling and extrapolation is a highly questionable practice that is no longer justifiable. Just in the last few years new 2D hydrodynamic models, such as SRH-2D developed by the US Bureau of Reclamation, have come to the fore that are capable of accurately and quickly simulating many kilometers of river at a resolution of < 1 m. Modeling the whole river in one simulation and then performing habitat analysis on the system comprehensively eliminates the need for the pre-existing sampling and extrapolation method.



A B

Figure 1. Comparison of how rivers are normally conceived of in river assessment (a) versus how a fish actually experiences a river (b).

1.2 Riparian and Channel Rehabilitation Needs

Gold mining, flow regulation, and a variety of other human activities have dramatically altered river corridors in California. As a result, fish and wildlife habitats have been severely degraded, causing sustained inter-decadal declines in native populations and conditions favorable for non-native species’ invasions. For example, ~100,000 salmon ascended the Yuba River annually before impacts of mining and dams. After the construction of Englebright and New Bullards Bar Dams, the salmon runs averaged 15,000 fish per year. Current salmon runs have reached a critically low level, with the LYR supporting only 2,600 salmon in 2007. Also, not only has human activities affected aquatic populations, but it has also dramatically damaged riparian species. The LYR was physically re-located in many sections and the river valley was filled in with tens of meters of hydraulic mining debris. Historical photos show riparian forests along the LYR in some places, but those are now gone. The river’s floodplain is instead a hot, dry “moonscape” of largely unvegetated gravel and cobble. Lines of willows occur along present-day and abandoned base-flow channel banks. A few backwater areas have developed since the 1997 flood and are lined with cottonwoods.

River rehabilitation aims to undo enough of the physical degradation to promote a return of native species' populations to sustainable levels. The Yuba River Fisheries Technical Team (Yuba Accord) identified conditions of Habitat Complexity & Diversity to be one of the most important "stressors" to the Yuba salmon population. For the LYR, many rehabilitation ideas have been proposed over the years, including in-channel activities (e.g. enhancing salmon spawning riffles, widening riffles, building side channels for steelhead, building backwaters that are nutrient rich habitats for beavers, otters, and rearing fish, adding wood into the channel for habitat diversity, removing "shot rock" from the canyon below Englebright Dam, and performing gravel augmentation) and riparian corridor activities ("feather-edging" gravel/cobble bars to make them flood more frequently, removing roads and off-road tracks, placing soil, and planting trees). One visioning plan even exists to move the entire river corridor south back through the gold fields.

The USFWS Anadromous Fisheries Restoration Program supports projects related to both in-channel and riparian restoration projects on the LYR. These projects require detailed topographic maps for baseline assessment, design development, and eventual construction.

Because river rehabilitation involves re-engineering terrestrial and aquatic landforms, the keystone data underlying environmental analysis and engineering design is a high-resolution topographic map. The map provides the baseline for conceptual design, enabling the altering of topographic contours to obtain the desired ecological functionality. It also serves for detailed modeling and evaluation of design alternatives. No rehabilitation can be performed without a good map. Also, it would be difficult to prioritize among projects without a comprehensive map produced independently of the advocates of individual projects.

1.3 1999 Lower Yuba River Map

The last time the LYR was mapped was in 1999. Terrestrial land was mapped using aerial photogrammetry. The river bottom was mapped by boat. However, given the technology available at that time, the river bottom was only mapped with cross-sections spaced every 100-300'. Even worse, important areas with high habitat complexity and diversity were not mapped at all, because they could not be easily boated into. The 42,930 cfs flood (Yuba+Deer combined hourly peak) of May 2005 and the 109,090 cfs flood (Yuba+Deer combined hourly peak) of New Years' 2006 dramatically changed the river. The 1999 map is no longer representative of large sections of the river. Furthermore, it should be expected that major channel changing flood will occur on the Yuba every ~10 years, with several individual riffle sites likely experiencing significant morphologic change every 3-5 years. Consequently, it is necessary to re-map the river periodically to evaluate current habitat conditions and determine the long-term trajectory of channel evolution that is relevant for future river management.

1.4 2006 Timbuctoo Bend Map

To evaluate the scope of change 1999-2006 and its significance on fish spawning, UC Davis used funding from the USFWS to make a high-resolution map of the Timbuctoo Bend Reach on the LYR and compare it to the 1999 map. A boat-based method similar to that proposed for

2008 below was used for the river bottom survey and the terrestial land was mapped manually using a robotic total station and 4 months of student labor. The resulting map shows unprecedented details in the river (Fig. 2), and large-format plots were provided to all members of the Lower Yuba River Technical Working Group.

Figure 2. 2006 high-resolution topographic map of Timbuctoo Bend on the LYR.

By subtracting the digital elevation model of the 2006 map from that of the 1999 map, it was possible to determine that 605,000 cubic yards of gravel and cobble have been exported out of Timbuctoo Bend. Lacking a map of the downstream river, we do not know where that vast amount of material went. Furthermore, by combining the 1999-2006 change map with a geomorphic map of landforms in the river corridor, it was possible to evaluate how each landform changed over that time (Table 1). Every single landform in the river corridor eroded, except for medial bars, which grew slightly. Pools eroded more and deeper than riffles, which demonstrated a sustainable riffle-pool self-maintenance. The river's floodplain contributed the third most volume of sediment exported out of Timbuctoo Bend. This continual scour of the floodplain explains why a natural riparian corridor cannot establish itself in Timbuctoo Bend. Also, the topographic and geomorphic maps were combined with a redds survey to identify which aquatic landforms salmon were selecting for building redds (Table 2). These results show a strong mesohabitat control on salmon spawning in the LYR.

1.5 2007 Englebright Dam Reach Map and Model

In 2007, the Yuba River RMT funded a survey of the river bottom in the bedrock canyon between Englebright and the junction with Deer Creek. That canyon was not mapped in 1999, presumably because it was deemed un-navigable. To the contrary, in 2005 and 2006, UC Davis and Environmental Data Solutions successfully mapped two sections of that canyon and proved the feasibility of the overall mapping. Then in 2007 the rest of the canyon was fully mapped (Fig. 3). Subsequently, the map was used to make a 2D hydrodynamic model of the canyon for 855 cfs and 1600 cfs (i.e. the flows for which model-inputs are available at present) with a horizontal resolution of 3'. This map and 2D model is helping to guide gravel augmentation and evaluate proposed shot rock removal and riffle enhancement activities. Similar models of Timbuctoo Bend are underway at present and are planned for the entire LYR.

Table 1. Elevational and volumetric changes in Timbuctoo Bend organized by landform type.

Morphological Unit	Mean Cut/Fill (m)	StDev (m)	Cut/Fill Volume (m^3)
Backwater	-1.22	0.87	-3642
Chute	-1.21	1.44	-7412
Forced Pool	-1.22	1.05	-25268
Glide	-0.78	0.84	-87641
Pool	-1.45	1.28	-90623
Recirculation	-1.03	0.65	-732
Riffle	-0.54	0.86	-39532
Riffle Entrance	-0.73	0.69	-21938
Run	-1.03	0.74	-25392
Secondary Channel	-1.53	0.73	-19667
Lateral Bar	-0.55	0.92	-32100
Medial Bar	0.40	1.00	8485
Point Bar	-0.08	0.79	-2190
Cutbank	-0.95	1.57	-5892
Floodplain	-0.15	0.76	-58288
Hillside	-0.07	0.55	-12820
Tailings	-0.64	1.03	-22737
Terrace	-0.29	0.42	-8226
Tertiary Channel	-0.73	0.46	-4448
Tributary Delta	-0.15	0.47	-1960
TOTAL			**-462022**

Table 2. Distribution of observed redds among landform types in Timbuctoo Bend.

Morphological Unit	Redds	% Redds	Electivity
Backwater	0	0.00	0.00
Chute	0	0.00	0.00
Forced Pool	0	0.00	0.00
Glide	22	4.69	0.48
Pool	0	0.00	0.00
Recirculation	0	0.00	0.00
Riffle	322	68.66	9.38
Riffle Entrance	53	11.30	4.31
Run	39	8.32	3.87
Secondary Channel	19	4.05	3.50
Lateral Bar	7	1.49	0.27
Medial Bar	4	0.85	0.45
Point Bar	3	0.64	0.29
Cutbank	0	0.00	0.00
Floodplain	0	0.00	0.00
Hillside	0	0.00	0.00
Tailings	0	0.00	0.00
Terrace	0	0.00	0.00
Tertiary Channel	0	0.00	0.00
Tributary Delta	0	0.00	0.00
TOTAL	469	100.00	

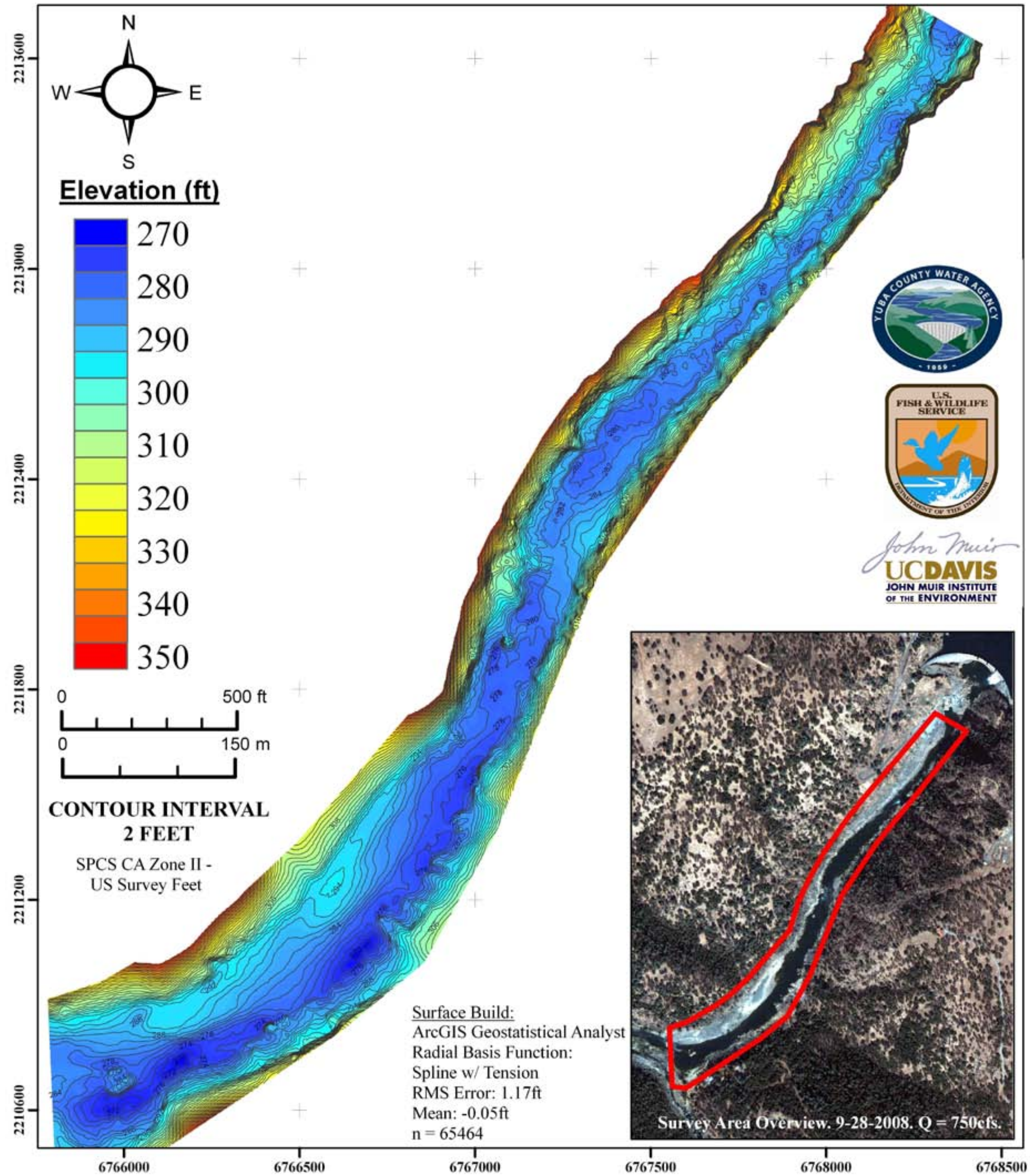


Figure 3. 2007 map of the Englebright Dam Reach of the lower Yuba River.

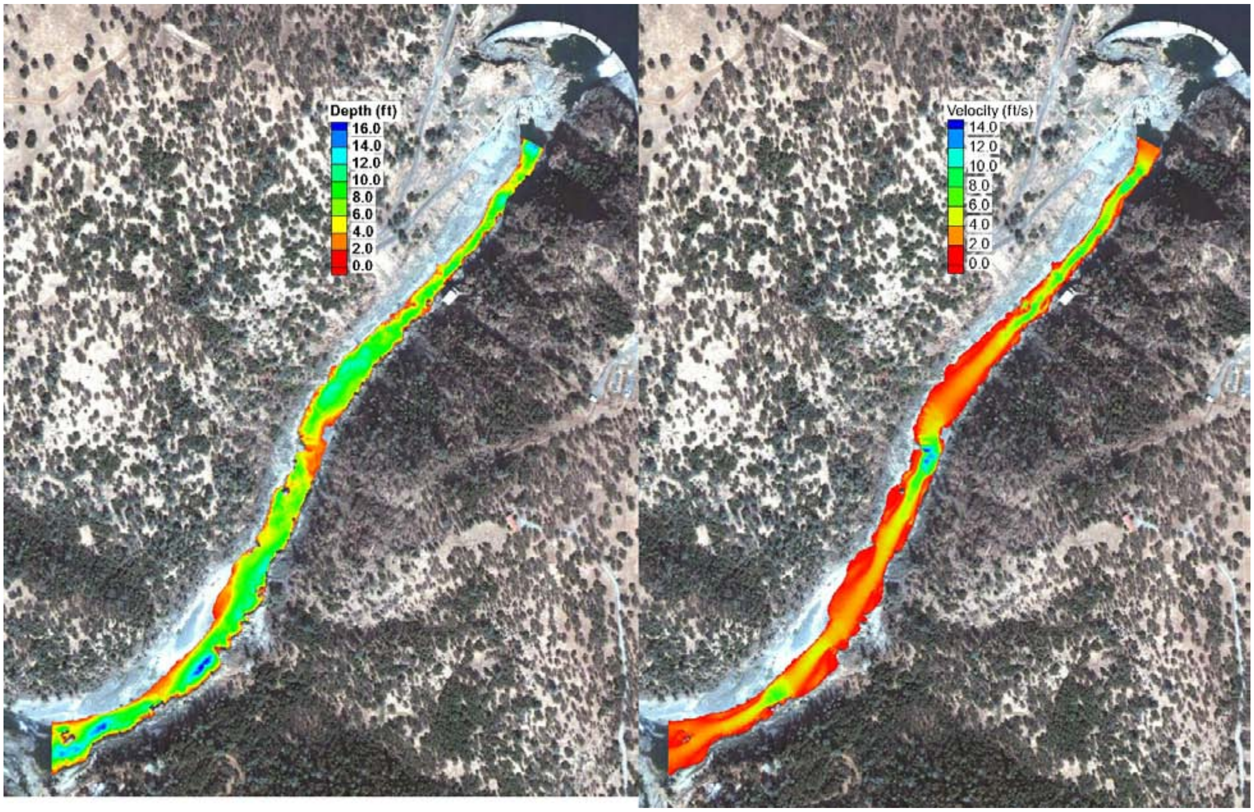
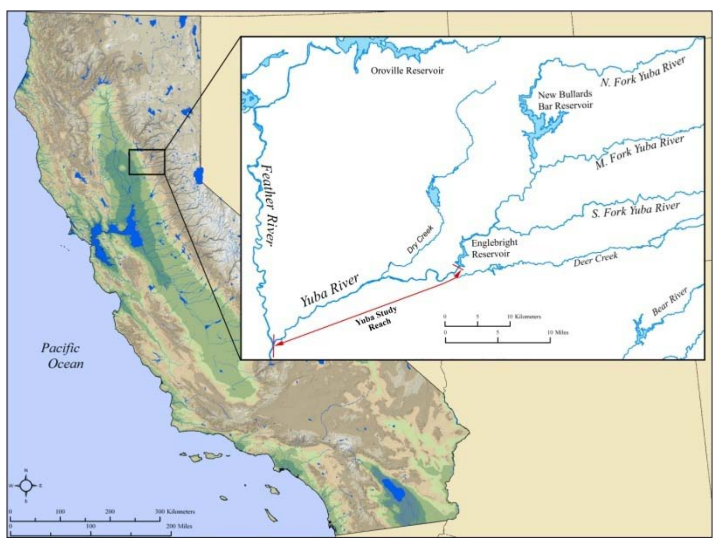


Figure 4. 2D hydrodynamic model simulation of the Englebright Dam Reach at 1600 cfs showing depth (left) and velocity (right) predictions at 3' resolution.

2.0 Survey Location



The study area for this protocol is the river corridor of the LYR from Englebright Dam to the confluence of the Yuba and Feather Rivers (near Marysville, California). Englebright Dam is the first completely impassable barrier on the river, though Daguerre Point Dam (~12 miles downstream of Englebright) may bar fish migration in low flows or when ladders clog with debris. The river corridor is defined as the channel, associated floodplains, and a buffer of the valley walls well above the 150,000 cfs flow level. The study area certainly encompasses all habitat accessible to anadromous fish during the range of flows addressed by the Yuba Accord. The extent has been reviewed and approved by UC Davis and RMT participants. The polygon shapefile of the map boundary is available upon request.

Because the Englebright Dam and Timbuctoo Bend Reaches were mapped in 2006 and 2007, respectively, they are not proposed for repeat mapping in 2008-2009, but should be included in future implementation of this protocol.

3.0 Data Collection

The methods for topographic data collection have rapidly progressed in the last decade, so that now highly detailed datasets may be obtained by low-cost remote methods. The preferred remote methods recommended in this protocol are airborne LIDAR mapping of the terrestrial river corridor and boat-based echosounding of the submerged river channel. Each of these methods is capable of obtaining very high densities of data, with the majority of the individual point measurements being within 0.15 m vertical accuracy, which is the level of resolution prescribed by the U.S Army Corps of Engineers' rigorous Class 1 standard.

3.1 Half-Foot Accuracy Terrestrial Survey

Airplane-based Light Detection And Ranging (LIDAR) technology offers one of the most accurate, expedient and cost-effective ways to capture wide-area elevation information for terrestrial land. By merging laser ranging, GPS positioning, and inertial attitude technologies, airborne laser mapping directly measures the shape of the earth's surface beneath the aircraft's flight path. Elevation data is generated at the rate of thousands of points per second, with individual points representing the average elevation over an area of ~0.3x0.3 m^2 (~1 ft^2). After hitting the tree-canopy (where present), the laser beam finds a hole between the foliage and reaches the ground. The returns are registered and a digital dataset is created instantly. After the flight, data is directly processed and reduced to obtain a detailed "bare earth" only dataset with a vertical accuracy of ~0.15 m. The spatial resolution depends on the number of passes, and for this protocol a level of 1 point every 0.738 m (1 pt per ~2 ft) was selected . In addition to the topographic data, the LIDAR survey will also yield the intensity of the LIDAR return signal at each point, and this can be rasterized to yield a black and white image of the river corridor. This image may serve as a base map for GIS and it can be used to construct a polygon shapefile of the water's edge, since the intensity of LIDAR returns from water are dramatically lower than from land.

LIDAR contractors perform QA/QC on their data primarily by performing conventional topographic mapping on a flat stable surface, such as a road, and reporting the deviations between ground-measured points and LIDAR-measured points> In addition, it is wise to have a local contractor perform a similar comparison for sloped and rough surfaces, to constrain uncertainty in how LIDAR performs in more complex settings.

Data points from the LIDAR survey are then imported into ArcGIS to create a digital elevation model of the terrestrial land around the river using a standard TIN-based approach with breaklines and additional quality assurance measures. This method is described in detail in section 4.

The plan for the proposed 2008 airborne LIDAR survey is to map the river at a low flow (~700-900 cfs) with maximal exposed river bed. Alternately, it may be desirable in the future to do the mapping at a typical spawning habitat discharge to obtain a water's edge shapefile for use in mapping the spatial pattern of water depth at that spawning discharge without having to simulate it with a hydrodynamic model.

****Lower Yuba River LIDAR data was acquired on September 21, 2008. On that day, the Yuba River discharge at Smartville was constant at 860 cfs, Deer Creek was at 3 cfs, and Marysville was at 622 cfs.

3.2 Half-Foot Accuracy Bathymetric Survey

In 2005-2007 a private hydrography firm (Environmental Data Solutions, San Rafael, CA) was contracted to partner with UC Davis to produce map of sections of the LYR between Englebright Dam and highway 20 bridge. A similar approach will be used for the 2008-2009 mapping, but instead of using a single echosounder, this time multiple echosounders will be deployed simultaneously across the bow of the boat. A customized aluminum jet-boat is outfitted with up to five Odom Hydrotrack survey-grade fathometers (each with a 3°, 200-kHz transducer) and a TSS 335B motion sensor that adjusted for roll/pitch of the vessel. Position data for the fathometers are collected using real-time kinematic (RTK) GPS receiving corrections by radio from an on-site base station located on one of the pre-established benchmarks. These benchmarks were established by long-duration static surveys with an RTK GPS and then waiting to obtain "ultra precise" solutions through NOAA's Online Positioning User Service (OPUS). Both streams of data (depths and positions) are recorded onto a laptop running Hypack Max 4.3 (Hypack, Inc., Middletown, CT).

Ideally, the boat survey is done at a higher discharge and the airborne LiDAR survey at a lower discharge, so the two dataset overlap and can be intercompared, but that is not always possible. Water depth must be more than ~1' for the boat to access a location and the echosounder cannot record accurate depths in water <0.5'. Where depth permits, the boat makes cross sections on a ~3-m interval and performs six longitudinal transects approximately evenly spaced across the channel. To account for the water surface slope and its changes through time, Mini Troll 400 vented pressure transducers (In-situ, Inc., Fort Collins, CO) are placed in the river along the survey area and their elevations are surveyed using RTK GPS. An algorithm within Hypack (tide adjustments) is used to interpolate water surface slopes based on the distance between the pressure transducers.

Position data is recorded every 1 s, but to reduce data quantity to simplify processing and reduce redundancy, the total amount is reduced. In post-processing, a radial filter is applied to the boat-based data to obtain a 0.6-m spacing between points. This achieves the goal of obtaining bathymetric data at a resolution of 1 point per m^2 along the boat tracks. Ideally, the boat would be run in parallel tracks to obtain complete coverage of the channel, but in practice there may be areas that are not mappable by boat. Some common problem areas include areas <1' depth (commonly along banks and on riffle crests), boulder-strewn banks, bank and side channels with woody debris or submerged aquatic vegetation, and floodplain ponds that are not connected to the channel. If these areas are desired for mapping, they have to be done by a separate ground survey with RTK GPS (or total station) or by mounting a single echosounder and RTK GPS onto a small tethered pontoon and walking or swimming it around.

Quality assurance and quality control information beyond the scope of this summary is kept on file with the contractor. Independent surveys of stable sections of the river bed are performed using a robotic total station to evaluate the accuracy of the bathymetric data. The obtained results meet U.S. Army Corps of Engineers' rigorous Class 1 standard (±0.15m vertical accuracy). Data points are then imported into ArcGIS 9 to create a digital elevation model of the river using a standard TIN-based approach with breaklines and additional quality assurance measures.

In receiving the deliverables for the bathymetric data, it is important to ask for an additional data set containing positions, dates, times, and water depth observations using a 20' radial filter. These water depths may be used to create water surface maps and/or validate hydraulic models.

***Bathymetric data was acquired on multiple dates: August 19, 20, 22, 25, and 26, 2008; September 16, 17, 18, and 19, 2008; March 4-6, 2009; May 6, 15, 20, 2009.

4.0 Map Production in ArcGIS

To create the topographic map, the following items are assumed to have been obtained through data collection: LIDAR flight and data file tiling scheme polygon shapefile, LIDAR data coverage polygon shapefile, LIDAR intensity images (all returns), LIDAR ground-return point file (ASCII format), boat-based echosounder/RTKGPS point file filtered to 2-foot spacing, total station point data.

4.1 Create Important Point and Polygon Shapefiles

1. View the LIDAR intensity imagery and manually draw the following: A) a shoreline polygon, B) a set of polygon covering any isolated ponds or channels not connected to the main channel, and C) a set of polygons covering any islands in the river.
2. Rename the ASCII lidar point files to end with .csv and then use a text or spreadsheet editor capable of hablding the full size of each file to add a row with the following text column headers to the first line of the file: {X,Y,Z}. Use ArcCatalog to create a 3D point shapefile from each lidar point file. Be sure to assign the correct horizontal and vertical datums.
3. Viewing the echosounder data and LIDAR data, manually draw a set of polygons covering areas devoid of data. Back-channels and side-channels are easily delineated where devoid of points. For bank areas devoid of points, it is necessary to use judgment to determine if interpolation is acceptable in that area or if a critical data gap exists.
4. Cut the shoreline polygon with the island polygon file to created a wetted channel polygon.
5. Merge the wetted channel and pond polygons to create a wetted area polygon shapefile.
6. Cut the LIDAR data coverage polygon with the wetted area polygon to obtain a land area polygon shapefile.
7. Divide the total map area into a set of smaller mapping units, with each containing 8-10 lidar tiles. This is necessary, because ArcGIS cannot handle building a map of the whole set at once. Use the autotrace tool in the Editor toolbar to create a boundary for each

mapping area; be sure the boundary exactly matches the data boundary for the overall map or there can be edge effects when creating TINs and contours.

8. Divide the echosounder point file into subsets that match the map area boundaries. Make sure the points include a small amount of channel outside the end boundaries or else there may be undesirable edge effects in the map. This also helps, because when you QA/QC individual echosounder points later on using the Editor Toolbar in ArcGIS, this ensures that any corruption to a file does not lose all the edits you make.

4.2 Process LIDAR Points

1. Extract LIDAR points that are on land into "landshp_tile#" file for each tile using the Spatial Analyst->Extract->Clip tool.
2. Extract LIDAR points that are on water into "watershp_tile#" file for each tile using the Spatial Analyst->Extract->Clip tool.

4.3 Intercompare Overlapping LIDAR, Ground, and Echosounder Points

Each dataset is obtained using a unique method that makes it difficult to say with certainty that any one represents the true elevation. LIDAR and echosounder "point" elevations are actually averages over an area that is hit with a signal, while total station and RTK GPS points are locations where the tip of a pole touched the ground. Commonly, averaged areas tend to be higher than points, because people tend to push tips down between particles and because the average covers a larger protruding area. That difference is not an error, just a measurement difference.

For a gravel bed surface with particle sizes ranging from 1-20 cm, it is likely that deviations in measurements could be in this range. The mapping goal of having points within 0.5' (0.15 cm) is within the noise of the bed roughness, though on the high side of it. Thus, the goal of this step is to look for any large deviations and try to account for them, but generally to ensure that the data conforms to the goals of the project.

1. Identify the lidar and ground point files that will be intercompared and create 3D point shapefiles of each dataset.
2. Add a field to each shapefile's attributes table that contains the elevation data for the points. This is the field that will be compared.
3. Perform a spatial join (Arctoolbox->Analysis Tools->Overlay->Spatial Join) to create a new point shapefile that contains comparable points and both elevation fields. The "target" is the point shapefile you want to end up with, the "feature set" is the data you want to merge", set a gorizontal distance or intersection of 5 cm to find matching points in the datasets.
4. Add a new field to the merged shapefile.
5. Use field calculator to difference the two fields and obtain the deviation value.
6. Perform statistics on raw deviations and absolute values of deviations to determine how much of the data falls within 0.5' and 1' difference thresholds.
7. Repeat steps 1-6 for boat and ground point files.

4.4 Build Preliminary TIN

1. Create boundary area shapefiles that isolate 8-10 LIDAR tiles, because ARCGIS cannot handle processing more than that at one time.
2. Create a shapefile within each boundary area with just the echosounder data for that area.
3. Build preliminary TIN using 3D analyst.
   a. Use the LIDAR landshp tile files, the echo file for that area, and any total station point files.
   b. Use the boundary area polygon as a “hard clip”, the shoreline polygon as a “hard line”, the pond polygons as a “hard erase”, and the data gap polygons as a “hard erase”.
4. Create a shapefile of 1-foot contours

4.5 QA/QC Contours For Each Boundary Area

1. View contours and points together.
2. Delete any outlier individual point that is more than 3 feet different than the points around it.
3. When data is collected over the same area at different times and large flows or long time intervals have passed, then it is necessary to check to see if the lines of data are significantly different due to erosion or deposition. If that is the case, then one or the other data much be deleted. Usually, I prefer to delete the set that has fewer points to yield a robust representation of the surface as it was at the time of greater data availability. Alternately, one might choose the more sparse data if it was newer and the most recent surface was desirable over a more accurate one.
4. Where in-channel data has a small data gap along the bank, such as when the boat data undulates, then it is acceptable to augment a few points to fill in the small gap and prevent the lidar data from interpolating irregularly into that space. To do so, add an augmented data point shapefile (with Z), add points in the gap, interpret the boat data around it to identify the suitable elevation, and then assign that elevation to the augmented points by double clicking on each point, then right clicking, choosing properties, and typing the elevation..
5. Re-build TINS and 1’ contours and then repeat steps 1-4 as many times as necessary to resolve evident problems.
6. Build final TIN and 1’ contour shapefile.

4.6 Point Density Analysis

1. Merge all point data into a single shapefile using the Data Management->general->Merge tool.
2. Use Spatial Analyst’s point density tool to obtain a point density raster for each area (radius 30’; grid cell size 10’, reporting in pts/ft^2)
3. Use zonal statistics to separate out the channel and floodplain areas to calculate their constituent densities.
4. Classify quality zone as follows: Dark Green is >1/1 ft2 = 1, Light Green is >1/(2*2 ft^2)=0.25, Dark Blue is >1/(5*5 ft2)=0.04, Light Blue is >1/(10*10 ft2)=0.01, Yellow is >1/(20*20 ft2)= 0.0025, Orange is >1/(50*50 ft2)=0.0004, Red is <1/(50*50 ft2)=0.0004.

5.0 Logistics

5.1 Personnel

Snorkel survey personnel will be responsible for conducting snorkel surveys in the field as per the protocols and duties described in **sections 3.0 - 3.3** above. All staff are expected to complete survey data sheets and notes required for data collection. Experienced field staff are expected to assist in the training of newly hired staff.

5.1.1 Qualifications

To effectively conduct field data collection required by this survey, the lead biologist should meet the following minimum requirements: a 4-year degree in fisheries biology or a related field and at least 2 years professional experience conducting field surveys. Experience with snorkel surveys and juvenile salmonid identification are also highly recommended for the lead biologist.

Crew members should have completed at least 2 years of education working towards a 4-year degree in fisheries biology or a related field or have at least one year experience conducting field surveys.

Data collection methods presented in **sections 3.0 - 3.3** above assume work will be conducted by a 4 person team to facilitate safe and efficient surveys.

5.1.2 Training

This plan should be made available to all survey personnel to promote consistence among snorkelers and to address safety concerns. All personnel should be trained in swift water rescue, basic first aid, with an emphasis on CPR and recognition and treatment of hypothermia. Crew members should be trained to identify potential in-river hazards (debris jams, swift water, turbulent areas, etc.) before entering the river and beginning to survey the unit.

All crew members should be trained to clear masks and snorkels of excess water while underwater, to accurately identify fish life stages and species. All crew members must be trained to be competent in the use of all other equipment used during sampling (GPS units, flow meters, thermometers, etc). If boats or 4WD vehicles are used to access sampling locations, crew members must be competent in the operation of such equipment.

5.2 Costs

Proposal for High Resolution Mapping The Lower Yuba River From Highway 20 Bridge to Feather River Junction

Greg Pasternack's Consulting Fee = $130 per hour

Task	hours per project site	cost
1. Aerial LiDAR Survey (Aero-Metrics, Inc)		
1a. Lidar Acquisition and Processing (~0.75 m resolution data)		$29,940
1b. Lidar System Mobilization, Installation, and Calibration		$9,150
2. Bathymetric Survey (Environmental Data Solutions, Inc.)		
2a. Planning & Mobilization		$3,200
2b. Singlebeam Swath Survey (~1-5 m resolution data)		$26,595
2c. Data Reduction & Reporting		$9,800
2d. RTK GPS Base Station "babysitter"		$600
3. Ground Truthing (Greg Pasternack)		
3a. Use RTK GPS and/total station to independently map two different areas to check the accuracy of the aerial LiDAR survey	8	$1,040
3b. Use RTK GPS and/total station to independently map two different areas to check the accuracy of the bathymetric survey	8	$1,040
3c. Install permanent surveying benchmarks using RTK GPS	16	$2,080
3d. Infill surveying to address data gaps	16	$2,080
4. Map Production (Greg Pasternack)		
4a. QA/QC aerial LiDAR dataset	16	$2,080
4b. QA/QC bathymetric dataset	16	$2,080
4c. Integrate all data sets and produce digital elevation model	16	$2,080
5. Project Management (Greg Pasternack)		
5a. Coordinate with surveying subcontractors	16	$2,080
5b. Coordinate with Yuba River RMT	8	$1,040

Total	120	$94,885

The otal cost estimates for the topographic map is $94,885. In addition a 16% contingency cost option is highly recommended to cover the need for repeat boat surveys during different flows and periods in light of the complexity of mapping on the lower Yuba River.

6.0 Data Management

Each contractor will retain the raw data collected in the field. Derived points, polygons, TINs, rasters, contours, etc will be organized and maintained by the project manager. In addition the complete set will be delivered to the RMT for distribution to project sponsors and other stakeholders.