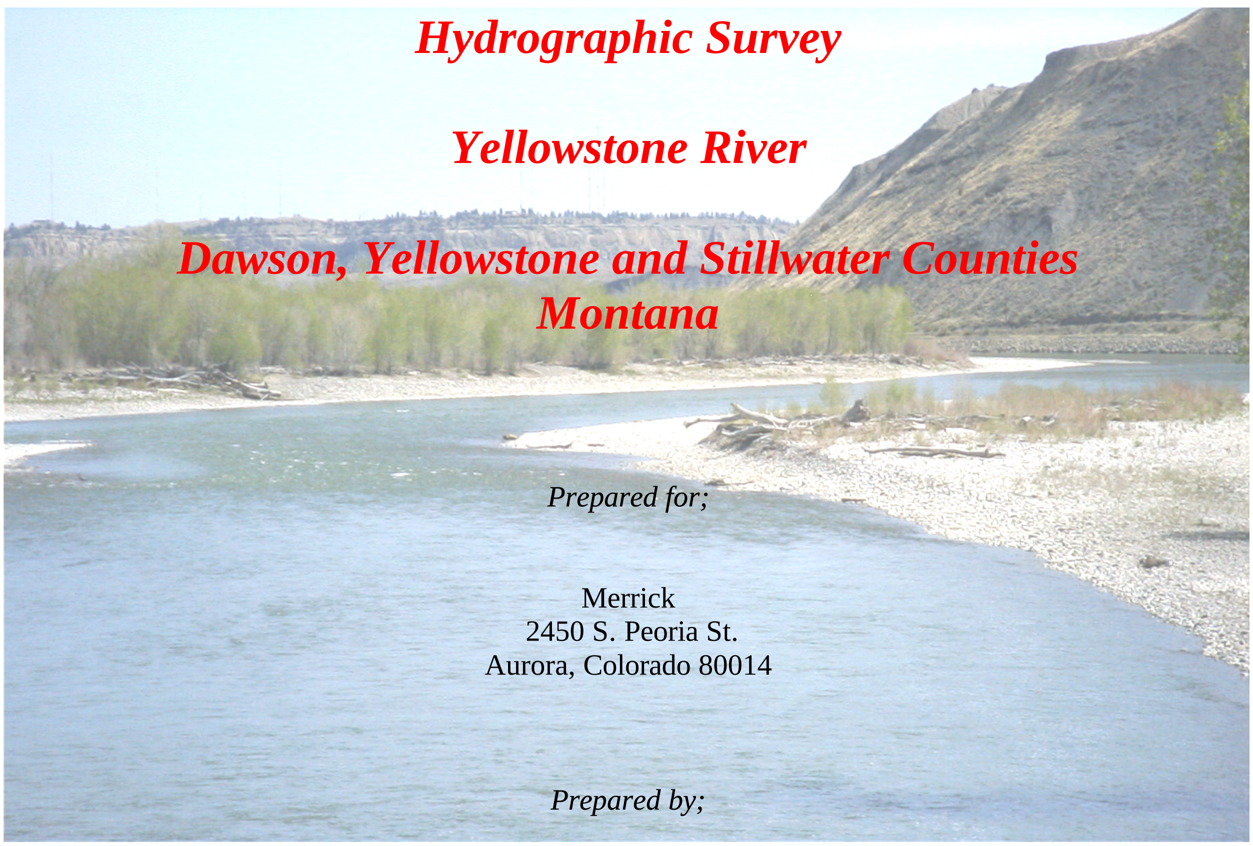
FINAL REPORT



Hydrographic Survey

Yellowstone River

Dawson, Yellowstone and Stillwater Counties Montana

Prepared for;

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CRA job # 04032

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1.0 Introduction

Chris Ransome & Associates (CRA) joined together with Merrick in late 2003 to carry out a combined aerial photography, Lidar and bathymetric survey of approximately 130 linear miles of the Yellowstone river and floodplain in Dawson, Yellowstone, and Stillwater Counties in Montana.

CRA's responsibility was to carry out the automated hydrographic survey of the river. Data was to be reduced to the NAVD88 vertical datum. Coordinates were to be Montana State Plane NAD83 datum. All units were to be in meters. Final ascii x,y,z data files were to be forwarded to Merrick for inclusion in the Lidar terrain model and subsequent contour plots.

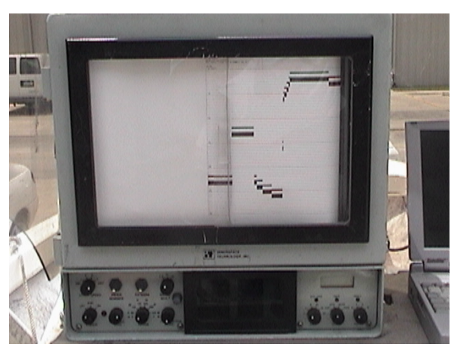
2.0 Equipment

CRA uses fully automated data acquisition techniques based on the following equipment;

2.1 Horizontal Positioning

Horizontal positioning for this project was achieved using the GPS (Global Positioning System) satellite system in "real time kinematic mode. This process involves the use of a GPS receiver located at a known point as a "reference" or "base" station. This unit compares its computed location derived from the satellites to its known (true) coordinates and computes range and integer corrections to each satellite in view. The latter are then transmitted over a UHF telemetry link to the receiver on the boat where they are applied to the same satellites. This improves the accuracy of the GPS system down to approximately 2 to 5 cms in the case of the high quality Trimble 5700 equipment used.

2.2 Depth Measurement



The Innerspace 448 survey fathometer was used for check measurements on this project. The 448 is a new, digital, single frequency unit operating at 200 kHz via a small transducer mounted to shoot through the hull of the boat. The unit is capable of measuring down to approximately 200 feet of water. In water less than 100 feet in depth the measurement accuracy is better than 4 inches at a rate of around 10 measurements per second. The 448 is connected directly to the computer system. It was calibrated using several measurements from an Odom “Digibar” velocimeter.

2.3 Data Acquisition System

Data from the horizontal positioning system and the fathometer are logged in a notebook PC. The software controlling data acquisition was Coastal Oceanographics “Hypack” which allows real time calculation of the boat's position and gives helmsman guidance information with respect to pre-programmed survey lines. It also matches single beam depth data with the correct horizontal position and records it on hard disk for later tidal corrections and editing of noise spikes, as well as the automatic generation of plan view charts and/or cross-sections. Hypack also has the ability to bring in both CAD files showing the intended coverage of the river, and aerial photo images, both of which were very useful in making sure that the boat operator got the desired coverage, and could locate himself on the river.

2.4 Vessel

Surveying during this project was carried out using two center console aluminum river boats. The main boat was a 19 ft center console design which had the fathometer transducer mounted through the hull and located coincidentally with the mast for the GPS system which eliminated any offsets.

3.0 Personnel

Project Manager for this project was Mr. Chris Ransome, President of CRA. The field Party Chief was Mr. Alex Howden. He was assisted by Mr. Michael Lahr (V.P. of CRA) and Mr. Victor Barrera (Operations Manager), as well as Mr. Iain Tyson, Mr. Michael Brasfield and Mr. Kyle Flyn.

4.0 Methodology

4.1 Boats and Fathometers

An advance party of the survey team arrived in Billings on May 30th to begin scouting the area, and setting up the survey boats with specially constructed transducer wells and antenna mounts which were fabricated locally. One boat, a 19 ft aluminum river boat with a 105 HP outboard jet-drive motor came in from Canada with Mr. Alex Howden, the nominal Party Chief, the other, a 17 foot “Tracker” flat bottomed aluminum boat with 40 HP outboard jet drive was purchased locally specifically for this project. Originally, it had been intended to use an airboat for this project due to it’s very shallow draft and the ease with which it could enter and leave the river, but when the river was seen, especially in flood, this was considered unsafe. The boats used were similar to those used by many other people and organizations on the Yellowstone. The transducer wells in both boats were built identically. They consisted of a 9 inch by 9 inch hole cut in the bottom of the boat just to the side of the keel line and approximately mid-way between bow and stern. Over this was fabricated a four sided aluminum box which was welded to the surrounding hull. At the top was a removable plate with a hole cut in it just larger than the diameter of the threaded transducer stem. At the bottom an inch-wide flange was welded around the circumference to allow a plexiglass plate to be bolted in so that it rested just above the hull line and so would be protected to some degree if the hull scraped over rocks or gravel. The bottom plate and transducer stem were sealed with waterproof caulking. The well was then filled with water and the transducer secured with collars above and below the top plate so that the face of the transducer was approximately 2 inches above the bottom plexiglass plate. See photos. Sound waves from the transducer would couple well with the surrounding water and pass easily through the plexiglass, hit the bottom of the river, pass back through the plexiglass and be detected again by the transducer. This design was primarily to protect the transducer, but also to try to enable the fathometer to work in shallower water. The limitation on any fathometer system in shallow water is the time necessary for the outgoing pulse to stop ringing in the transducer, and for the transmit circuitry to switch off and the receiver circuitry to start up. This translates into a finite number of milliseconds, and therefore distance, before any data can be detected after a pulse is sent out. Typically in most fathometers, this blanking distance is around 18 inches to 2 feet. Many fathometer systems provide shallow water options (which include reduced output power and different transmit/receive gain settings), and CRA uses Innerspace model 448 single frequency fathometers that have the shallow water option installed. In practice these units can be tweaked to work in just over a foot of water. The design of the transducer wells used up part of the blanking distance within the well itself, and the hope was that we would get close to be able to take data in 6 inches of water. At the start of the job, we tried the new Innerspace 455 fathometer which does not have a paper chart and records data internally for later download into a computer. This unit is much smaller and lighter than the 448, and came with a new transducer design that reduced ringing, and was modified for

shallow water operation. The manufacturer claimed that the unit would record in 6 inches of water. Unfortunately, this did not seem to happen in practice, and again, a foot (or just under) was all we could achieve, even with the new well design. Of more importance was the fact that this unit was processor controlled and all functions were controlled via repeated pressing of a couple of keys on the front panel. Often a fathometer will lose lock on the bottom, mostly due (in this environment) to air bubbles getting under the hull of the boat from turbulence. The older 448 had a switch that would immediately transfer operation from gated (bottom-tracking) mode to direct read, which clears this problem in a second or two. The menu structure on the new 455 made this much more time consuming, and significant distances were introduced over which no depth data could be recorded. Finally, it did not take long to realize that , due to the lower flow levels than normal on the river, and the rocky nature of the bottom, when the boats attempted to enter very shallow water, they would hit boulders which could vary from a foot or so up to several feet in diameter. This actually became the limiting factor for data collection on this river. The smaller boat was made of much thinner aluminum, and within two working days had sprung several leaks at the welds in the hull. This, and the fact that it was slightly underpowered for the river in flood, meant that it was not used for the rest of the project. The larger boat had a much thicker hull, and much more power, and so was quite well suited for this job, although it too sustained many dents to the hull and damage to the bottom of the outboard jet drive.

4.2 Positioning

The initial plan had been to use one of the high accuracy nation-wide GPS systems to provide decimeter level accuracy over the whole of the project area. Recordings of data from a monitoring station in South Dakota showed that the high accuracy “Omnistar” system (OmnistarHA) had the horizontal and vertical accuracy to meet the project requirements. Unfortunately, the satellite from which the Omnistar corrections are broadcast is quite low to the southern horizon at the latitude of the Yellowstone, and there are significant high bluffs along the river to the south in many places. It was therefore decided to switch to the back-up plan.

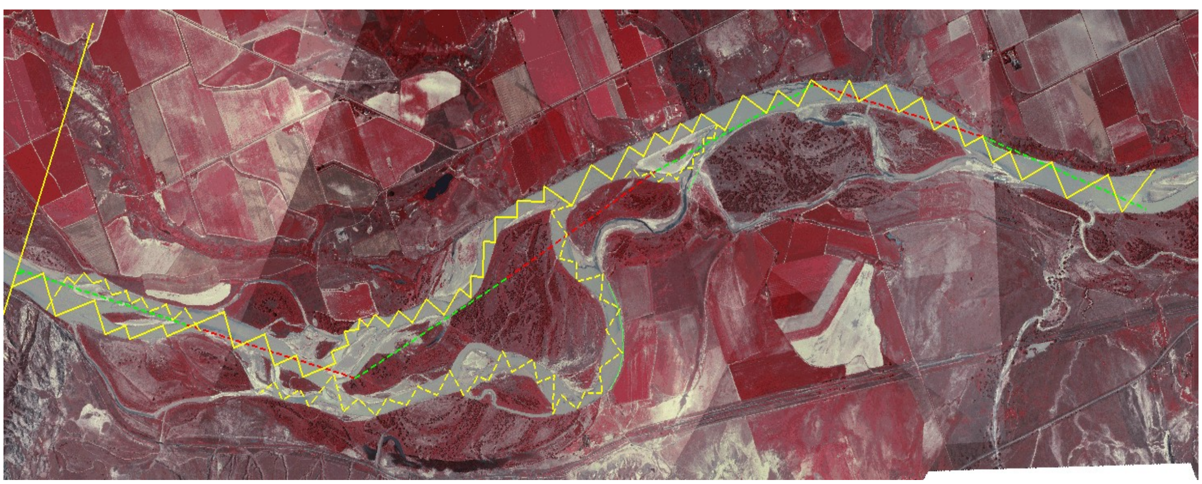
The Real Time Kinematic(or RTK) method has been around for some while in GPS satellite positioning for high accuracy land surveying. Like the Omnistar system, it requires the use of a base station located over a known point, and some form of telemetry to take the corrections generated over to the mobile GPS unit on the boat. While the Omnistar system uses many base stations around the country and telemetry via satellite communications, the RTK method still relies on one base station that is set up over known points within 5 miles (approx.) of the work area, and telemetry via UHF frequency radio modems. Unlike the Omnistar system which is based on code measurements augmented with carrier phase data, the RTK method uses code measurements as only a starting point to determine the integer count of wavelengths of the carrier signal from each satellite. As a result, the RTK method is capable of measurement accuracies of only 3 to 5 centimeters in x,y, and z relative to the base station. This level of accuracy is more than adequate for this project, but the method has some practical draw-backs for long river sections, which raises costs and complicates the operation. Due to a combination of sinuous river, high bluffs in some areas, and larger trees at the river banks, base stations with their UHF radiotelemetry units face a practical limit of only 2 to 3 miles before the signal can no longer be received on the boat with reliability. Given a project with around 130 linear miles of river, this means many base station set-ups. Each base station needs accurate coordinates and must be scouted in advance, and usually needs a dedicated attendant to set up the equipment, protect it from theft, and take it down at the end of the day. Getting accurate coordinates used to be the main technical problem. To survey into local control takes time, as does a large static GPS survey using two or three receivers (or more) simultaneously. For this survey, CRA decided to use the new "OPUS"service from the National Geodetic Survey (NGS). Here, a user would submit a minimum of 4 hours dual frequency GPS data from a given base station site, and the NGS computers automatically find the closest three Continuously Operating Receivers (CORS) sites* (see note below) and process the data to a very accurate solution. In our case, most base stations would be operating for up to 8 or 9 hours per day, and we were confident that a good position would be determined. Since the base station was set up initially using a "here", or code only, position, the absolute accuracy on the boat for that day could be up to 5 meters out. This did not really matter for getting coverage of the river, and all data would be corrected in post-processing once the x,y,z offset from the "here" position to the OPUS solution had been determined. Using the RTK method, the ellipsoidal height** of the GPS antenna on the boat is being fixed in space to a high degree of accuracy. This means that the change in elevation of the water surface along the river due to either;

1) The natural grade of the river
2) changing flow volume
3) Sharp changes in bottom topography such as ledges and rapids
4) Changes in the draft of the boat due to changing weights of fuel or personnel.

would all be taken into account. The fathometer would then measure the distance from the transducer to the river bottom, which, together with the fixed offset from the GPS antenna to the transducer would allow a direct measurement of the ellipsoidal height of the river bed. Since the final product was required to be in orthometric heights reference the NAVD 88 datum, a translation was required. This was achieved by taking the final edited and cleaned data into Trimble Navigation's Geomatics Office software where it was converted from ellipsoidal heights to Orthometric heights using the GEOID03 model produced by the NGS.

After the initial few days of start-up had produced a more or less smooth work flow using just one boat, the extra personnel were then assigned to using the spare GPS rover to find existing NGS vertical control points and to take a reading over them to check the accuracy of the OPUS solution.

One of the great unknowns at the start of this project, was how much of the river could be surveyed in one day by one boat. In an attempt to determine the best way of covering the river such that the maximum amount of useful data could be obtained in the shortest time, CRA analyzed three different approaches during the project proposal stage, three longitudinal lines, cross-sections every 100 feet, and our own suggestion of steering a sinusoidal or z-line down the river. We were able to show that the z-line approach cut the river contours better than the longitudinal lines, and was far more rapid then cross-sections. The final proposed line structure was made in CAD trying to keep internal angles around 90 degrees. This was then used in the Hypack data acquisition software to guide the field crews (see below).



5.0 Results

5.1 Boat and Fathometer

The main reason for scheduling the hydrographic survey during peak run off was that the survey would cover a wider area of the river and be able to sample places which would later be exposed during the low flow late summer when the Lidar work would take place.

This would give overlap between the two systems, and be the last link in the QC chain. This was a problem of timing as the beginning of the snow melt in the mountains could only be guessed at, and having so much equipment and personnel sitting around would be very expensive. Ultimately, we managed to hit the peak flow during the month of June, which was historically the month in which the melt occurred. Unfortunately, however, the snow pack was much smaller than in previous years, and the flow levels were much lower than anticipated. In one way, this was not a bad thing. Several areas of the river become quite dangerous for surveying during very high flows, with standing waves of over (sometimes substantially over) 4 feet in height. The low flows did mean that some tributaries or river braids could not be surveyed, and that areas of potential overlap with Lidar were reduced. Figure 3 shows the flow levels for the river during the survey period, together with historic average levels. The top graphic in this figure shows the discharge before, during and after, the survey period and the median daily average based on 75 years observations. In the middle is a more detailed plot of the discharge just during the survey itself, again with the average historic values, and the bottom image shows the river gage height in feet during the survey period.

The fathometer system proved that depths could be obtained on a regular basis in as little as 1.8 feet (approx. 0.5 m) of water. Since the river was always at least two feet higher than it would be when the Lidar was flown, this should give the required overlap. The fathometer system was calibrated by using a Odom "Digibar" velocimeter to take direct measurements of the speed of sound in the river. An average reading of 1480 meters per second with a variation of only plus or minus 2 meters per second. In waters as shallow as this river, the velocity of sound would have to be off by several tens of meters per second to show any measurable difference.

One of the project requirements was to survey across the river above and below each bridge at a distance of approximately 50 feet. In practice, during periods of higher flow, surveying above a bridge proved very difficult and dangerous.

5.2 Positioning

The RTK positioning system worked well, and the OPUS system provided good accurate positions. Figure 4 shows the base station sites and the vertical results from OPUS. It is interesting to note from this data that the elevations determined from the "here" solution were generally within a meter or three of the final OPUS solution. Only 5 stations out of the total 34 used showed a difference of 10 to 12 meters. Of all the OPUS solutions only one had a standard deviation exceeding 10 cm (a 14 cm s.d.). The average, even including this larger value, was still under 4 cm. Even though a standard deviation of 14 cm was a little high, this did not necessarily mean that the value for this station (TCP8-1) was off significantly. We did examine the OPUS solution and tried re-processing, but it seems the data is just a little more noisy on that day. This site was essentially re-occupied the following day (within 2cm by 4 cm horizontally), and the ellipsoidal height came in to within 5 cm of the prior days value and with a standard deviation back down to under 7 cm.

Figure 5 shows the results of using these base stations with the OPUS positions to check into local control points using an RTK rover. This was done, in most cases, using the base station operating with a “here” position, and then correcting the observed position using the x,y,z offset determined later for that site from the OPUS data. As noted earlier, five sites did not get done because this check was carried out later in the project and the field crew could not find the rebar used to mark the original base station locations. Results were generally good in the Billings area with an average difference of only 5 cm. TCP20 did come in at just over 12 cm, but the OPUS solution looked good at around 5 cm. Data from this point were scrutinized more with regards to overlap with adjacent data but no increase in error was observed. The results for the Glendive area were a little worse with an average of just over 10cms, but one site (TCP29) accounted for most of that with a difference of over 16 cm. The OPUS standard deviation for this site was just over 2cm. Again, final results from this site were examined for overlap with data from adjacent sites and no significant anomalies found. It is interesting to note that all ties to NGS point in the Glendive area and all but two in the Billings area showed consistently that the OPUS elevations were lower than the published NGS values.

No attempt has been made to modify any of the elevations produced by OPUS for this project based on comparisons to NGS points. This was done for several reasons;

1) To keep consistency of data
2) The couple of points showing large errors could have instability in the NGS monuments
3) More independent checks on the NGS and CRA points would be needed to be sure of the source of any errors.

Had any of these sites shown abnormal differences with respect to adjacent data sets, more investigations would have been performed.

One further source of potential error would be the amount of time the RTK signal lost lock and the fixed solution began to revert to a float solution (differential accuracies). This would potentially degrade centimeter level elevation accuracy to several meters, depending on the length of time it took for the GPS receiver to re-establish lock. The Trimble 5700 receivers used by CRA have a relatively rapid re-acquisition time, and the field crews are trained to spot loss of a fixed position solution and to abort the line if it does not rectify itself almost immediately. Loss of a fixed solution occurs either when the GPS antenna is blocked from signals by large trees at the river’s edge, or if the limits of the data telemetry system are exceeded. Figure 6 shows a bar graph of the percentage of raw data that was RTK fixed quality, as well as the other 4 fix types of GPS fix. The table on the same figure shows that over 98% of the Glendive area data was RTK fixed quality, compared to over 99% in the Billings area.

Figure 7 shows the final table that was used to correct the data files from each base station to an accurate position and ellipsoidal elevation. Coordinates in the field data were acquired using meters as the horizontal unit of measurement, however, in order to preserve as much measurement accuracy as possible, the fathometer was run in feet. Although the read out on the fathometer itself appears to give 2 decimal places of meters, the data in the output string to the computer is only to one decimal place, i.e. 10 cm. Conversely, one place of decimal feet is 3 cm. Note that Figure 7 shows elevations in feet. Later in the process, all elevations were converted to meters using the relationship ***feet*0.3048=meters***. At this point after all data had been corrected, it was brought into "Surfer" software from Golden Software as a convenient way to map the overlap areas between adjacent base stations and to try to detect any consistent bias. In practice, some overlap areas were better than others and a couple had no overlap at all, although only one, at the highway bridges in Billings, had a gap of over a few meters. Although sometimes difficult to do to more than a few tenths of a foot (due to the rocky, boulder strewn river floor and often steep sides), this process did reveal several problems in the data which allowed us to go back in and make the necessary changes. The problems varied from plain typographical errors, to wrong base stations being ascribed to a data set, wrong antenna heights, and errors in data editing in Hypack, to name a few. Once a clean data set had been obtained the data was input to Trimble Geomatics office first for conversion to orthometric heights reference NAVD88 datum using the Geoid03 model, and then from elevations in feet to meters. Finally it was decided to thin the data for submission to Merrick for inclusion in the Lidar terrain model and subsequent contouring. Original field data was obtained at various densities along each line according to boat speed, but could be as much as multiple depth readings per linear foot of travel. Accordingly it was decided to develop software to thin the data to approximately one point every 2 meters, which should still provide enough detail, but would mesh more easily with the data density of the Lidar system. Both thinned and full data sets were sent to Merrick, however, as part of the final deliverables. The final QC stage is to observe the overlap between the hydrographic and Lidar data for differences large enough to influence the required 1.5 meter contour interval in the river. Figures 8 and 9 show the location of the base stations with respect to the work area for both the Billings and Glendive areas.

5.3 Comparison of Hydrographic and Lidar Data

By design, the hydrographic data was taken during high river flows to maximize the coverage, and the Lidar data was obtained later in the year during relatively low flow conditions, also to maximize coverage. It was hoped that this would result in some overlap between the two sensors along the entire length of the survey area. Figures 10 through 12 show the amount of overlap finally obtained. The final QC test was to compare the data sets from these overlap areas. Table 1 below summarizes the results.

Project File	Yellowstone_River_Bathymetry_Report
Date	7-Dec
Vertical Accuracy Objective	
Requirement Type	Accuracy(z)
Accuracy(z) Objective	0.5
Confidence Level	90%
Control Points in Report	61967
Elevation Calculation Method	Interpolated from TIN
Control Points with Lidar Coverage	61963
Control Points with Required Accuracy (+/- 0.50)	60619
Percent of Control Points with Required Accuracy (+/- 0.50)	97.83
Average Control Error Reported	0.08
Maximum (highest) Control Error Reported	2.66
Median Control Error Reported	0.07
Minimum (lowest) Control Error Reported	-0.93
Standard deviation (sigma) of Z for sample	0.18
RMSE of Z for sample (RMSE(z))	0.19 PASS
FGDC/NSSDA Vertical Accuracy (Accuracy(z))	0.32 PASS
NSSDA Achievable Contour Interval	0.7
ASPRS Class 1 Achievable Contour Interval	0.6
NMAS Achievable Contour Interval	0.7

TABLE1

As can be seen, the average difference between the data sets was only 8 cm with a standard deviation of about 18cm. The total number of overlapping hydro points was almost 62,000 which represents 17.6% of the over 350,000 points in the thinned data files used for the terrain model integration. The full hydro data set comprises almost 2,600,000 points.

A few points are worth mentioning here with respect to comparing these two data sets, and the final accuracies achieved. Given that these were two different surveys conducted with different techniques spaced over 4 months apart in time and at very different rive flow levels, the level of agreement obtained is very good. An examination of the larger differences show that many are grouped in just a few locations. In one example over 30 points showed an average difference of around a meter. These all plotted at one end of one specific sand bar. As was noted during the pre-mobilization meetings, the higher flow conditions during snow melt would undoubtedly make some changes in the river bed morphology, and if that area was sampled by the hydro crew before a particularly high flow event, then there would inevitably be a difference with the Lidar data. In some instances, it would only take a large boulder to be rolled a few feet downstream.

For a few larger events, this is almost certainly the explanation.

The fathometer system only reads out to a tenth of a foot (3cm). Given other potential errors in horizontal position and timing between sensors, the U.S. Army Corps of Engineers quotes a repeatable vertical accuracy for their most accurate surveys in protected shallow waters using an automated data acquisition system to be 0.5 feet (see Table 2 below). In this particular survey we estimate the best theoretical accuracy would be about 0.2 feet (6 cm) vertically.

Minimum Performance Standards for Corps of Engineers Hydrographic Surveys (Mandatory)

PROJECT CLASSIFICATION		Navigation & Dredging Support Surveys Bottom Material Classification Hard	Soft	Other General Surveys & Studies (Recommended Standards)
RESULTANT ELEVATION/DEPTH ACCURACY (95%)				
System	Depth (d)			
Mechanical	(d<15 ft)	± 0.25 ft	± 0.25 ft	± 0.5 ft
Acoustic	**(d<15 ft)**	**± 0.5 ft**	**± 0.5 ft**	**± 1.0 ft**
Acoustic	(15>d<40 ft)	± 1.0 ft	± 1.0 ft	± 2.0 ft
Acoustic	(d>40 ft)	± 1.0 ft	± 2.0 ft	± 2.0 ft
OBJECT/SHOAL DETECTION CAPABILITY				
Minimum object size (95%		> 0.5 m cube	> 1 m cube	N/A
Minimum number of acoustic hits		> 3	3	N/A
HORIZONTAL POSITIONING SYSTEM ACCURACY (95%)		< 2 m (6 ft)	2 m (6 ft)	5 m (16 ft)
REPORTED FEATURE HORIZONTAL LOCATION ACCURACY (95%)				
Plotted depth location		2 m (6 ft)	5 m (16 ft)	5 m (16 ft)
Fixed planimetric features		3 m (10 ft)	3 m (10 ft)	3 m (10 ft)
Fixed navigation aids		3 m (10 ft)	3 m (10 ft)	3 m (10 ft)
Floating navigation aids		10 m (30 ft)	10 m (30 ft)	10 m (30 ft)
SUPPLEMENTAL CONTROL ACCURACY				
Horizontal Control		3rd order (I)	3rd order (I)	3rd order (I)
Vertical Control		3rd order	3rd order	3rd order
WATER SURFACE MODEL ACCURACY		[½ depth accuracy standard]		½ depth accuracy
MINIMUM SURVEY COVERAGE DENSITY		100% Sweep	NTE 200 ft or 60 m	NTE 500ft (150m)
QUALITY CONTROL & ASSURANCE CRITERIA				
Sound velocity QC calibration		> 2/day	2/day	1/day
Position calibration QC check		1/day	1/project	1/project
QA performance test		Mandatory	Required (multibeam)	Optional
Maximum allowable bias		+ 0.1 ft	+ 0.2 ft	+ 0.5 ft

Reproduced from the U.S.A.C.E. Hydrographic Survey Manual EM 1110-2-1003

TABLE 2

6.0 Conclusions

By the time the field crews had become proficient at obtaining data on this river, it became obvious that the original projections on productivity were easily surpassed. This means that future projects on this, and similar rivers, can either obtain the same data density for less cost, or provide greater density. The one task that would need more time and money would be to do more to scout GPS base stations in advance and perhaps to carry out a static GPS survey including nearby first order vertical control points to tighten up the vertical component.

For projects requiring 0.5 meter contour intervals, this project proved that the equipment and methodology used, and the productivity obtained, could complete the work satisfactorily within the allotted budget.

***Note**

The National Geodetic Survey (NGS), an office of NOAA's National Ocean Service, coordinates two networks of continuously operating reference stations (CORS): the National CORS network and the Cooperative CORS network. Each CORS site provides Global Positioning System (GPS) carrier phase and code range measurements in support of 3-dimensional positioning activities throughout the United States and its territories (map).

Surveyors, GIS/LIS professionals, engineers, scientists, and others can apply CORS data to position points at which GPS data have been collected. The CORS system enables positioning accuracies that approach a few centimeters relative to the National Spatial Reference System, both horizontally and vertically.

The CORS system benefits from a multi-purpose cooperative endeavor involving many government, academic, commercial and private organizations. New sites are evaluated for inclusion according to established criteria. See our newest sites and their coordinates.

All national CORS data are available from NGS at their original sampling rate for 30 days. After that time, the data are *decimated* to a 30 second sampling rate. Cooperative CORS data are available from the participating organization that operates the respective site. Links to Web pages containing the Cooperative CORS data are provided from the NGS CORS Map and the Cooperative CORS Web page. Please note: Cooperative CORS members are only required to keep the latest 30 days of data.

APPENDIX ‘A’

Equipment Brochures

APPENDIX ‘B’

Data Coverage Maps

Yellow = Planned Coverage

Red = Actual Coverage