

# Section 1

## Objectives and Methodology

---

### 1.1 Background

Alaska has over 300 rural villages that are located near a river. The Electric Power Research Institute (EPRI) has performed conceptual feasibility studies for sites which showed that the economics for River In-Stream Energy Conversion are quite promising, potentially reducing the cost of electricity by 50-70%. The economics of a hydrokinetic energy plant are a direct function of river velocities and associated power densities at the river sites near these villages. Velocity data for most of these sites is non-existent.

Hydrokinetic technology manufacturers and energy project developers require information on the water velocity and depth. This project provides critical information for determining the feasibility of extracting hydrokinetic energy at 24 rural villages in Alaska. All results will be available to the public and private entities such as consultants, in-stream tidal companies, communities and the state of Alaska. Any organization interested in evaluating the potential of in-stream renewable energy technologies will be able to select a system that is appropriate for the water body in question. It will also enable a “market pull” by informing device developers of the site conditions (i.e. water depth, velocity distribution and infrastructure availability) and therefore allow them to optimize their device technology to meet a majority of the site conditions in Alaska.

Providing the necessary preliminary information on a large number of sites suitable for hydrokinetic power generation will demonstrate to the state and the manufacturers the hydrokinetic potential within Alaska. This may help the development of small scale hydrokinetic plants for communities and organizations such as the University of Alaska School of Engineering (UAA-SOE) Renewable Energy Test Station in Girdwood, Alaska. Similarly, this study possesses the potential to assist the state in developing a comprehensive hydrokinetic research, study and implementation plan ultimately improving the state’s ability to become more self sufficient in the development of its own renewable energy resources.

Currently, this project has acquired data and begun to assess the potential hydrokinetic energy resources for seventeen sites in rural Alaska (six on the Kuskokwim River and eleven on the Yukon River). This is being conducted through the analysis of velocity, bathymetric and topographic data. In addition, fifteen water level gauges were placed at selected locations to remain for the duration of the open water season to help determine the range of water levels. Existing gauging stations managed by the United States Geological Survey (USGS) in relative close proximity to project sites were used to validate the collected data for discharge

measurements and water levels throughout the year. The collected data will provide the ability to make estimates of the long term hydrologic (i.e. velocity/depth) conditions at the selected rural sites. Long-term depth and velocity distribution data obtained will be used to determine the hydrokinetic energy available for power generation, thus facilitating the development of low cost, carbon neutral energy technologies, leading to a reduction of energy costs in the future.

## **1.2 Objectives**

The amount of energy that is available for hydrokinetic power generation is a direct function of river velocities and associated power densities therein. The dynamic nature of river characteristics vary with water levels, which makes it necessary to predict these characteristics for varying water levels throughout the year at each prospective site. This can theoretically be achieved through the use of the Manning's Equation, which states that velocity is a function of the river slope, hydraulic radius, and the manning's roughness coefficient. The velocity, hydraulic radius and slope of any river can be determined within an acceptable degree of accuracy by using Acoustic Doppler Current Profilers (ADCP) in conjunction with Global Positioning Systems (GPS), leaving the roughness coefficient as the only unknown variable. By making the general assumption that the roughness coefficient will remain constant throughout the yearly river cycle, predictions pertaining to discharge at various river stages can be made. The goals of this project are to (1) use average velocity, topographic, and bathymetric data obtained at each site to determine the Manning's roughness coefficient, (2) use data from deployed water level monitors and information from USGS gauging stations to determine a typical range of river stages, (3) correlate yearly discharge predictions with velocity distributions, (4) determine the locations of highest energy density, and (5) to evaluate the economic feasibility of hydrokinetic power generation at each site.

## **1.3 Methodology**

### **1.3.1 Logistics**

Ambitious research such as this hydrokinetic feasibility study requires a great deal of effort and coordination during the planning phase, due to the remote nature of the project. It was necessary to initially meet with rural proponents of renewable energy development to decide which sites to be study. Dr. Nyree McDonald, formerly an Assistant Professor for the UAA-SOE, attended the Galena Renewable Energy Conference on April 2<sup>nd</sup> through the 4<sup>th</sup> of 2009 to establish local relationships to facilitate potential research. At this conference, flyers were circulated informing

representatives for each attending community of the intent of the research. Additionally, surveys were distributed not only for those in attendance but for other local conferences in an effort to characterize the interest and public opinion of a hydrokinetic project. This survey covered such topics as the local energy cost, level of interest, and possible concerns of the community. These surveys coupled with the Galena conference and the rural connections that were forged gave the research a point of origin. A list of prospective research sites was compiled and evaluated, based on but not limited to: the site's proximity to a power grid, anticipated river depth and velocity, the local need for alternative energy, and general community interest.

Originally, the research was to be limited to 8 sites for the first years' research. However, it quickly became evident that it would be more efficient and cost effective to pick sites that had a higher number of surrounding communities that were sequentially located along a river that was easily accessible by boat. Initially Erin Eggleston, a Research Technician for the UAA-SOE, had correspondence with Jody Malus of the Bethel Alternative Energy Council to begin making arrangements for studies on the Kuskokwim River. Another key contributor to the logistical process for the Kuskokwim project was David Griso, the Executive Director of the Kuskokwim Watershed Council. He was instrumental in the selection process for locations of potential research, offering his recommendations as well as providing the necessary contacts for communication in the various villages.

The inflated expense of travel to rural Alaska deemed it necessary to make as few roundtrips to and from Anchorage as possible. The result was an effort to orchestrate arrangements to visit 6 sites from Bethel to Napaimute over a span of 14 days, 7 sites from Galena to Holy Cross in 16 days, and 4 sites from Marshall to Mountain Village in 8 days. Not only was this the most economical solution for personnel transport, but also for the 1000 plus pounds of equipment that the project required. Because of the relative inaccessibility of many of the sites, the teams' main cargo handler, Northern Air Cargo (NAC), could only deliver to certain sites on certain days of the week. This played a vital role in determining the order of site visits, as it was necessary for the equipment to be awaiting the arrival of the research team. Other options for equipment transport were considered and utilized as well. Knowing that the research team was going to visit Marshall, AK after a short return to Anchorage, Teddy Heckman, the vessel operator for the Lower Yukon research, was contracted to transport equipment from Holy Cross to Marshall. This proved a very efficient and economical decision as opposed to shipping the gear back to Anchorage, as NAC does not directly operate through Marshall.

Once the project sites were determined, it was necessary to begin arranging for accommodations, travel arrangements, and vessels with skilled operators to perform survey work and provide transportation. The key requirements for accommodations at each site included relative close proximity to the project site (the river) and electricity for charging the numerous batteries that powered the instruments. The high value associated with the equipment being used necessitated proper storage on a nightly basis. Hand carrying large volumes of equipment to and from lodgings each day was a last resort option, as it was time consuming and generally inefficient.

For this reason, it was necessary to also secure ground transportation within each village, where possible.

In addition to accommodations, travel between the project sites was considered. Due to the high volume and weight of the equipment necessary to perform the research, flying between sites had to be minimized, for cost considerations. This meant ensuring that travel by boat was obtainable to shuttle equipment from village to village, in the required time frame. Ideally, the aim was to utilize a minimum number of vessel operators, thus using one boat and captain for as many consecutive project sites as possible. Not only does this ensure that the research team has reliable transportation available, but it reduces the necessary training time involved in acquainting each operator with the navigational system and the overall process of collecting bathymetric data. Ultimately, it was necessary to use air transportation for personnel and equipment between Kaltag and Grayling, because the distance between the two villages made boat travel impractical and uneconomical.

When planning for remote projects, communication with supervisors and communities is essential. With the general lack of infrastructure at a majority of these sites, the only option for communication is most often a satellite phone. Cellular phone service is still only available in select locations, and in the case of an emergency, there is an urgent need for a reliable means of communication. As a general rule for field work, issues with software or hardware are bound to propagate themselves. Contact with manufacturers and supervisors must be maintained to avoid costly project delays.

As is the case for any project, unforeseen last minute changes occur where lodging or transportation arrangements fall through. If this is the case, coordinators must make quick decisions as to not leave the research team marooned, as field time is a relatively expensive expenditure. At the end of the day, all of the aforementioned considerations must be methodically arranged so that the intended work is performed in the most efficient manner possible.

### **1.3.2 Equipment**

High precision equipment is necessary to accurately measure and position river velocity, bathymetry, and topographic data. River velocities and bathymetry were measured using an ADCP. Navigation and positioning was conducted using Real Time Kinematic GPS, as was the upland topography of the river banks. The integration of these systems requires researchers to become well acquainted with equipment configuration settings, as well as various data interchange formats. Equipment trials were conducted prior to field work to ensure equipment compatibility and operator experience.

### 1.3.2.1 Acoustic Doppler Current Profiler

Previous to this study, the UAA-SOE either owned or had access to a single-beam sonar, Acoustic Doppler Velocimeters, and an ADCP that was allocated for measuring the velocities at a hydrokinetic site in Ruby, AK for the duration of the summer. It was deemed necessary to acquire a unit that had all the capabilities of collecting the desired bathymetry and velocity data in one package. Turning attention to the instruments used by the USGS and from recommendations from experts in the field, alternatives were considered.

There are several ADCP's available on the market that all promise accurate readings when used according to their respective design specifications. There are subtle differences in each manufacturer's design that may suit the varied needs of the research to be conducted. For this particular hydrokinetic assessment, two ADCP models offered by two separate manufacturers were considered: the SonTek M9 RiverSurveyor and the Teledyne RDI Rio Grande Workhorse.

The SonTek M9 River Surveyor features nine transducers, with a dual 4-beam 3.0MHz/ 1.0MHz Janus arrangement. The remaining transducer is a .5MHz vertical beam. This instrument claims to have a velocity profiling range from 0.06m to 30m, with a resolution of 0.001m/s. In addition, it has a depth measurement range of 0.20m to 80m, with a resolution of 0.001m. It has an internal memory capacity of 8GB and is available with an optional SonTek RTK GPS package, thus eliminating the need for more costly equipment, when the use of GPS is necessary.

Teledyne's 600kHz Workhorse Rio Grande ADCP has a single 4-beam Janus transducer array that is capable of measuring velocity profiles between .7m to 75m with a comparable resolution of 0.001m/s. It is capable of making depth measurements up to 100m for typical river water conditions. However, the Rio Grande has only 2GB of internal memory and does not come with the RTK GPS option.

The final decision on which ADCP to choose was not determined by the available options that each instrument offered, but rather the instrument's availability. SonTek could not deliver the instrument within a two month timeframe, whereas Teledyne RDI could have the instrument assembled and shipped in a matter of weeks.

Due to the anticipation of high sediment conditions in the Alaskan rivers, the 600 kHz ADCP was preferred over the 1200 kHz model that Teledyne RDI offers. This is due to the fact that the lower frequency ADCP's have a greater capacity to penetrate water with a high concentration of suspended particulates. There are, however, a number of drawbacks to the lower frequency model. Although the lower frequency ADCP will measure deeper than the high frequency models, they require larger depth cells and



Figure 1: Teledyne RDI Rio Grande ADCP (Teledvne. 2009).

have a larger blanking distance. This may become inconvenient in waters that are relatively shallow (less than 1m).

The Rio Grande features a user specified input which allows for the modification of critical settings for data acquisition when default settings result in unsatisfactory results. This input, the WS mode, modifies the bin size that the ADCP will collect while the instrument is pinging. River conditions in which the water is relatively deep will require a much larger bin size than shallow water. As a consequence, choosing the proper WS mode is very site specific. Rivers with long sweeping banks followed by deep channels are especially challenging. In order for the ADCP to collect discharge measurements in the shallow banks, the bin size must be relatively small. Conversely, the deep channel requires a greater bin size. Since the Teledyne Rio Grande does not have the capacity to automatically adjust the bin size during a transect, often several test transects must be completed in order to determine the appropriate WS mode. If the bin size is too small, discharge measurements will not be recorded in the deeper portion of the channel. Ultimately, it is the responsibility of the researcher to ensure that the data collected is of the quality that is required.

### 1.3.2.2 Global Positioning System

Relative positioning of the hydrography and upland topography were critical in accurately defining the river cross-sections and georeferencing the velocity data. Originally several pieces of survey equipment were considered for positioning and navigation. A survey level was ruled out because although it can be quite accurate for vertical control, it does not collect horizontal data nor provide positioning for the hydrographic work. A total station was also considered for the project, but for the volume of work to be completed in a small window of time, it was deemed inadequate. In addition, neither of these instruments allows their direct integration into the ADCP.

All positioning data for this assessment was completed using Trimble 5700, 5800 and R8 models, utilizing Real Time Kinematic (RTK) GPS mode. The 5700 and the 5800 receivers as well as the necessary ancillary equipment was provided by the Geomatics Department of the UAA-SOE, while the R8 model was purchased in part for this project. For the required precision needed for this project, standalone GPS was not an option, as this mode only provides for accuracies typical of handheld GPS receivers. RTK systems use a single base station receiver and a number of mobile roving receivers. The base station re-broadcasts the phase of the carrier that it measures, and the mobile units compare their own phase measurements with the ones received from the base station.



Figure 2: Trimble 5700 GPS Receiver (Trimble, 2009).

This differential in carrier phase allows for accuracies on the order of a few centimeters both horizontally and vertically.



Figure 3: Trimble R8 GPS Receiver (Trimble, 2009).

In addition to their precision capabilities, integration of RTK GPS was desired for ADCP operations. By streaming the National Marine Electronics Association's (NMEA) 0183 string into the ADCP software, it was possible to geo-reference all the collected bathymetric and hydrographic data to the upland topography. This was imperative for interpreting data at a later time.

Although integrating the GPS receivers with the ADCP is not always necessary, certain flow conditions make it preferable. When not using GPS as navigational reference, the ADCP computes observed velocities using "Bottom Tracking" (BT). As a consequence of the instrument vessel moving as the ADCP records measurements, the software must subtract the speed of the boat to obtain accurate velocity measurements. Under some conditions BT is an acceptable method for this process. However, if the river bed is dynamic (moving bed), the vessel velocities observed by BT will be biased low, resulting in inaccurate water velocity measurements. Due to the uncertainty of such conditions along the Yukon and Kuskokwim Rivers, it was decided to err on the safe side and integrate GPS into the ADCP software, using the GGA data as a reference to accurately compute flow velocities.

### 1.3.2.2 HYPACK- Navigation

A majority of the transects were pre-planned in Anchorage using geo-referenced tiff images. This allowed the research team to target the areas where the highest flow velocities were anticipated. These rivers can easily surpass one mile in width, requiring a navigational aid to stay true-to-course. HYPACK was selected as the navigational tool and was integrated with the GPS rover receiver to provide RTK quality navigation of the vessel.

Although HYPACK is typically used for port and harbor applications, it is a very versatile program that works exceedingly well for its intended use for this project. As was the case with most of the GPS equipment, the UAA-SOE has access to a version of this software, making it the most economical option for navigation. Use of this software is instrumental in ensuring that the vessel operator does not venture far from the pre-planned transects, as it provides a real time location of the vessel and its proximity to the transect being studied. Not only does this streamline the collection of bathymetric data, it also ensures that the data is as close to a linear specimen as is intended.

### 1.3.2.3 HOBO Water Level Gauges

One of the key objectives for this study is to accurately predict flow behavior (i.e. velocity and discharge) for various river stages throughout a rivers' yearly cycle. Accurate water level data must be available in order to make flow predictions. Unfortunately, the USGS has no gauging stations located near the reaches that are being studied, with the exception of the gauge at Pilot Station. To obtain the necessary water level information that is needed to create an accurate model, the research team must place gauges at each site which are to remain for the duration of the open water season.

A total of 15 HOBO gauges manufactured by Onset were set during the summer of 2009 with the exception being Pilot Station and Upper Kalskag. Initially, each gauge was inserted through the end of a 25-30 foot PVC stilling well that was assembled at the project site. The gauge was tethered to a stationary object on the river bank using vinyl coated non-stretch steel wire. Typically, a large angular rock was tied to the end of the stilling well meant to be submerged in the river, so as to resist movement throughout the data collection period. The goal of the process was to deploy the device in an area where it was unlikely to be disturbed, and in an area of sufficient depth so as to record data for the entirety of the season.



Figure 4: HOBO Water Level Logger manufactured by Onset Computer Corporation (Onset, 2009).

Being that these rivers are dramatically dynamic, their water level may drop as much as 20 or more feet from the spring months to the beginning of ice formation. Reports from various communities began streaming in that there was very little water covering the stilling wells as early as late July and the method above was deemed insufficient.

A revised method was designed to deploy these gauges involving creating a “basket” using PVC as a frame. The PVC was then wrapped with wire mesh and the basket was filled with rocks. The water gauge was then attached to the outside of the basket and the entire apparatus was tethered to shore using the same wire as mentioned above. This made deployment much easier, as it enabled the team to drop it from the side of the boat some distance from shore, ensuring sufficient depth for deployment. The basket design also significantly reduced the amount of PVC being transported to the sites, and proved to be a much lighter, efficient system.

At each site, contacts were made for retrieval of these devices before ice formed, which would make recovery unlikely using the described methods. Shipping materials including padded shipping boxes and prepaid shipping labels were given to each volunteer who were then advised on the methods for retrieval and told to await word from the research team for when to remove the gauges. This process was overall the most cost efficient for the water level data that is required.

### 1.3.2.4 Laptop

In order to integrate all three systems (GPS, HYPACK, ADCP), it was necessary to purchase a computer that was adequately robust for field work as well as possessing a parallel port. HYPACK requires that a hard-lock key be inserted into the parallel port of the computer being used for the software to run. Unfortunately, most modern laptops no longer come equipped with this feature. In addition to the parallel port, the field computer had to possess serial, VTG, and USB ports. With the need of all of these features, it made it necessary to purchase a port replicator to satisfy all of these requirements.

The VTG port was essential to enable the use of a second monitor for vessel navigation. HYPACK was displayed on the second monitor for the vessel operator to navigate the preplanned transects, while the researcher simultaneously monitored the status of the ADCP. The serial port was required for the uplink to the ADCP, to enable data acquisition. Finally, the 2 USB ports were required to stream the GPS data into HYPACK and WinRiver II simultaneously.

Due to the nature of the work, it was necessary to purchase a Panasonic Toughbook, which is both impact and water resistant. The process of shuffling equipment on a daily basis as well as the fact that work was being performed mostly in open hull vessels on open water necessitated these features.



Figure 5: Panasonic Toughbook (shown without port replicator) (Panasonic, 2009).

### 1.3.2.5 ADCP Mount

When deploying an ADCP there are several options available. One method for data collection is the bow-mounted approach. This method puts the instrument at greater risk, being as it will undoubtedly be the first thing to hit bottom when traversing a transect. This consideration along with the fact that the bow-mount design would be relatively complicated encouraged further alternatives. Another possible method is the stern-mount concept. This method was quickly abandoned for two reasons: (1) The



Figure 6: UAA-SOE ADCP side mount fitted to research vessel (Yager, 2009).

cavitations created by the prop on the motor was likely to interfere with data collection and (2) the battery for the vessel can potentially cause magnetic interference, thus fouling data. The option that seemed to best suit the needs of the research team was the side-mount deployment.

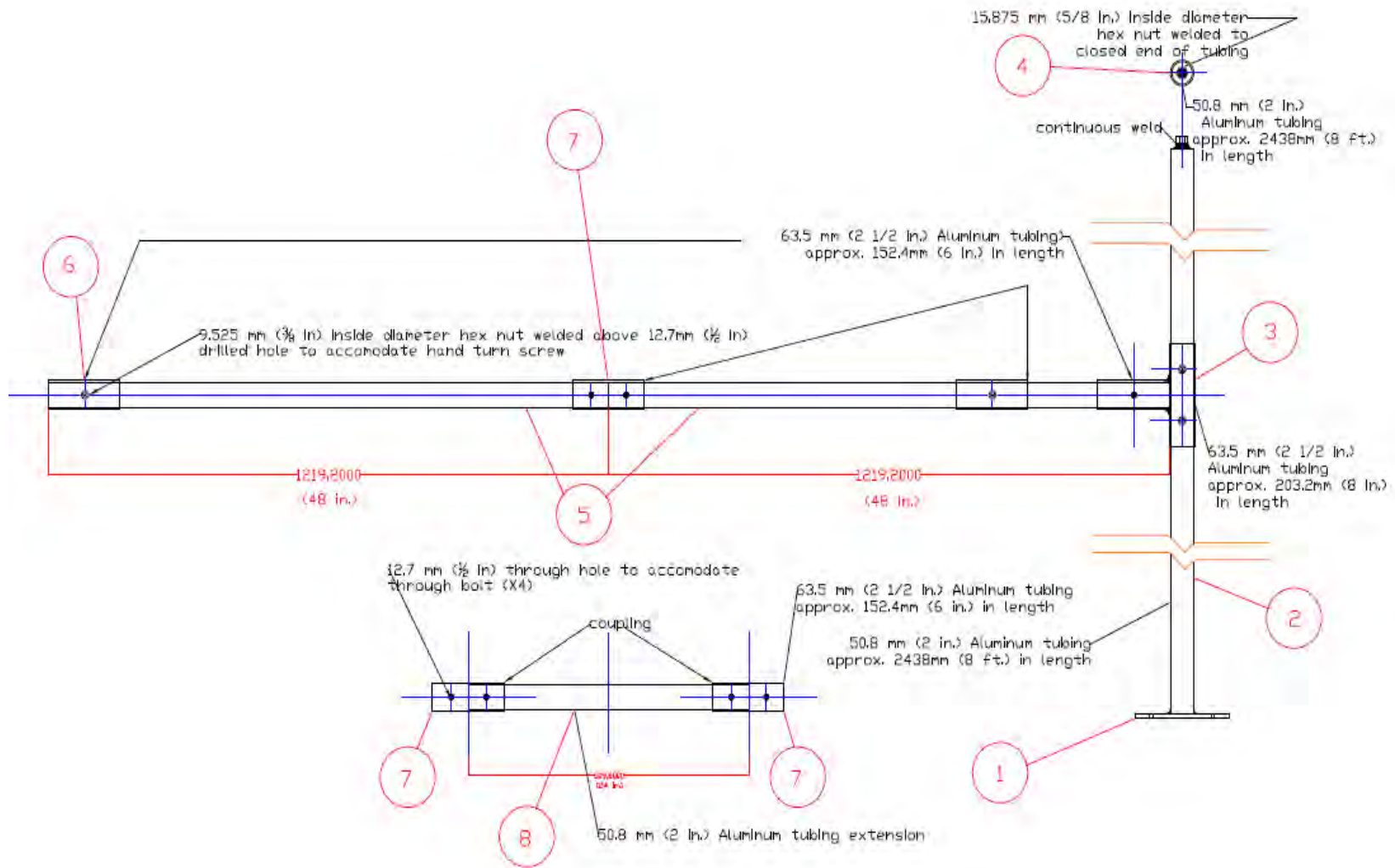


Figure 7: Construction schematic of ADCP boat side mount (Harper, 2009).

After deciding on a concept, research revealed that the mount was required to be made entirely from non-ferrous material, as to not create a local magnetic field that would interfere with the instrument. The design was conceived by the research team and was fabricated free of charge by the UAA Welding Department. The mount featured a telescoping cross beam that allowed for adjustment to vessels of a broad range of widths. This was an essential feature, as the research team was to use several different vessels throughout the course of the project. The ADCP was mounted to the bottom of a vertical post that was joined to the cross beam via a “T” fitting, and was allowed to slide freely for both easy deployment and removal. In addition, a Zephyr GPS antenna was co-located on a length of all-thread fitted to the top of the post to reduce the need for measuring horizontal offsets for post processing considerations. Finally, the entire apparatus was fixed to the gunwales of the vessel via two large clamps and a tag line running from the top of the vertical post to the stern, to resist rotation. This design proved to be very reliable and was quite cost efficient.

### 1.3.3 Preplanning

Aside from coordinating lodging, transportation, etc., there was a great deal of time spent analyzing aerial photography of the selected sites. Given the fact that very little, if any data existed for these sites, decisions had to be made as to where the highest velocities were likely to be observed. Ideally, it would be most beneficial to plan transects very close together in order to capture a denser set of data. However, a process such as this would require a great deal of time, and much more than the research team would be able to spend at each site. Following this realization it was determined that the aim of the work should be to cover a longer reach of the river, thus producing more generalized results.

One of the general criteria for choosing a set of transects for each site was that they had to be in relatively close proximity to one another. This was mainly due to the fact that the GPS base station radio has a limited range to which it can broadcast GPS corrections, roughly 1.5 to 2 miles with limited

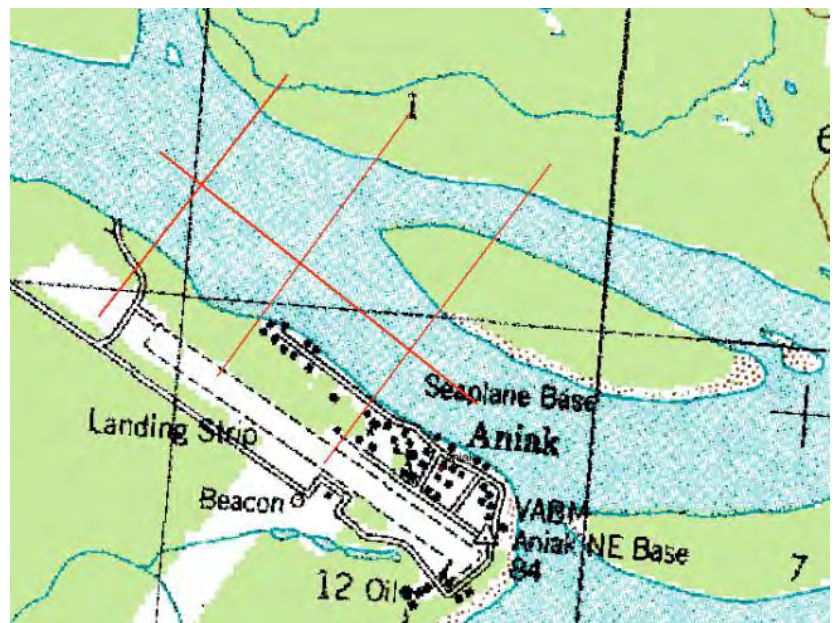


Figure 8: Preplanned transects for Aniak, AK (UAA-SOE, 2009).

obstructions. Using the aerial maps, obvious locations for problematic transects were immediately ruled out based on this criteria. Another criterion for choosing transects was that they also had to be relatively close to the actual village, for transmission line considerations. At many locations, islands and sand bars are clearly visible from the imagery and where possible, placing transects that traversed straight through these obstructions was discouraged, mostly to ensure that the team maintained a signal from the base station. This is not to say that these types of transects weren't decided on, because at several locations there was no other option. In order to collect the densest set of data, often several river channels were surveyed. On occasion, transects were placed based on the recommendations of the local townsmen, as they were more familiar with the sites.

After relative locations for transects were decided, there was discussion as to how many could be traversed in the time allotted for each site. Taking into consideration setup time and allowing for unforeseen complications, it was determined that 7 to 10 transects could conceivably be completed in a single work day, while yielding the desired quality. With the transects drawn onto the geo-referenced tiff images, the coordinates could then be keyed into the HYPACK software for navigation at each site.

There were occasions when the preplanned transects were either impossible to complete or finished ahead of schedule. In the event that transects were finished early, it became the responsibility of the research team to determine locations for additional transects. As was often the case, new transects were placed between the preplanned lines to collect a more dense set of data. Some reasons for the decision to abandon certain transects included water too shallow for boat navigation, loss of base station radio contact, and inclement weather that made conditions unsafe on the river.

Also considered during the preplanning phase were the potential locations for the water level gauges. This was difficult to plan from Anchorage, as there was little data available for review that would potentially aid this process. Ultimately, the placement of the HOBOS was at the discretion of the research team while in the field and the decision was made after evaluating each project site.

During the preplanning phase the research team investigated the location of any and all NGS (National Geodetic Survey) monuments that had been placed at the various sites. The hope was to utilize these control points as a location for the base station, being that their location was well documented and of control quality. Upon arriving at each site, it quickly became obvious that most if not all of the NGS monuments would not aid the research team. Most of the control points were located at great distance from the project site (the river), thus making it an impractical location for a base station due to the range limitations of the base station radio. One particular monument in Aniak that was potentially within range of the project site was located beneath heavy tree cover, making it virtually unusable for GPS applications.

As part of the control search, researchers obtained magnetic declination adjustments for each site that was to be visited. This was important for the ADCP measurements as the internal compass of the instrument must be calibrated at each site. Additionally, at the start of each measurement WinRiver II prompts the user for a local magnetic declination as to accurately interpret the vessel course as well as the direction of river flow.

### 1.3.4 Equipment Trials

When integrating various survey systems, it is paramount to test all equipment before any field work is commenced. This is even more important for research in rural Alaska, as replacement parts generally will have to be flown out to the site, which is very costly and inefficient. With the added uncertainty of communication with technical support, it is essential to become as familiar as one can be with the various systems in order to significantly reduce the need for such measures.

As preplanning operations were taking place, the survey team began testing all the various GPS components from wires to receivers. Researchers spent several days on the phone with technical support or in the school parking lot running tests and familiarizing themselves with the equipment. This was instrumental in both troubleshooting procedures and equipment malfunctions. Several times throughout the course of the research the survey team was required to rely on knowledge obtained from these very trials, undoubtedly saving both time and money. The next task for the research team involved integrating the GPS data with both the ADCP software and the navigational software.

Using a base station located on the roof of the UAA Engineering Building, the team first tested the navigational software. This was done by attaching a Trimble 5700 receiver and antenna to a rolling cart serving as the “vessel”. The HYPACK software could then verify its position at a certain point, which was then compared to the land survey team’s RTK rover. This allowed the team to be certain that the navigational software was accurate and could be used as part of the project.

Being that none of the research team was familiar with the Rio Grande ADCP, it was decided that testing the device in the UAA pool was possibly the best way to become acquainted with both its hardware and software. A mount was specifically constructed for this test which would allow a research member to pull the ADCP from one end of the pool to the other. At the same



Figure 9: Research members prepare the ADCP for a trial run in the UAA pool (Yager, 2009).

time another member wheeled a cart with the battery and computer for the ADCP alongside and ensured that data was being collected and that all systems were running properly. This test was very useful for the researchers performing the bathymetric survey, as it acquainted them with the setup and user commands for the ADCP.

Finally, it was necessary to test all of the various components together as they would operate during the field work. The team first considered conducting a full scale test on a local Anchorage lake, but reconsidered due to the fact that no flow would be measured, nullifying one of the objectives to the equipment trial. The Knik River was deemed an appropriate test location for the scope of the research study, as it was the largest and most accessible river for the team. On June 5, 2009 the team set out with a 14 foot inflatable Zodiac and all the necessary equipment to perform a trial survey on the Knik River. The land survey team set up two monuments, one on either side of the Glenn Highway Bridge, and performed a static survey. At the same time, the hydrographic survey team fitted the vessel with the ADCP mount and all the navigational hardware, as well as the ancillary equipment needed to carry out the research. While the team was awaiting the results of the static survey, one of the HOBO water gauges was placed to ensure its proper functioning, as well as the function of the stilling well that it was housed in.



Figure 10: Knik River equipment trial on June 5, 2009 (Mills, 2009).

The bathymetric research members quickly realized that something was not operating correctly with the ADCP. After exhausting all other troubleshooting methods, the manufacturer was contacted. The information that was conveyed to the research team was that WinRiver II, the

ADCP software, has a default bin size setting for the depth at which measurements will be taken. Since the Knik River is relatively shallow (4 to 5 feet), custom user commands had to be input which would shrink the bin size down to a point where it would begin reading current velocities. This piece of information proved useful throughout the summer, as many of the sites had long, sweeping deposit banks that could not have been surveyed using the default setting. Overall, this trial run proved to be an enormous step forward and was very valuable for the research that was conducted throughout the summer.

### 1.3.5 Data Acquisition

Upon arriving at each site, the first consideration was always where to locate the GPS receivers for the static survey so that not only did they have a clear view of the sky, but also a clear view of a relatively large reach of the river. Additionally, it was favorable to locate the receivers at a distance of several hundred meters apart, to achieve the longest baseline possible. For monuments at each site, two 2 inch aluminum rebar caps similar to the one shown in Figure 11 were used. The

monuments were labeled with the project name, followed by the site and monument number and ending with the year.

This method of monumentation was used because it required the minimum amount of materials when compared to digging holes and filling them with concrete as is needed for brass monuments. With the rebar driven and the caps placed, the GPS

receivers were set up over the monuments and the static survey began.



Figure 11: 2 inch aluminum cap set flush to ground on rebar at Chuathbaluk, AK (Harper, 2009).

With the receivers mounted on their respective tripods, they were then leveled and the antenna heights were measured and recorded. For each control point, a static survey log sheet was filled out documenting the time, monument name, and approximate location, as well as several other required fields of information. With the receivers acquiring their position fix from the satellites overhead, they were left to collect data for a minimum of two hours, although typically they were allowed roughly four hours to observe.

While the GPS receivers were conducting the static survey, typically the team then evaluated the most appropriate location for placement of the water level gauge. The gauge should be located relatively close to the project site, as to provide pertinent water level data to be used in post processing. Additionally, the location of the gauge must be well documented by taking a survey shot at its location immediately after deployment, as well as noting the time at which it was deployed. This survey shot will then serve as a reference water level for further analysis, to be conducted at a later time. When launching the HOBO prior to deployment, the individual whose task it was typically took a screen shot of the launch screen, not only as a time reference for post processing, but to ensure that all the required fields in the launch window were properly filled out. With the HOBO ready for deployment, the stilling well used to house the instrument was assembled from various lengths of PVC tubing using slip couplings and PVC cement. After approximately 10 minutes, the cement was dry enough to insert the instrument and place the apparatus into the river. Figure 12 shows the HOBO apparatus used in Bethel, AK, located on a sea wall that skirts the Kuskokwim River there.



Figure 12: HOBO water level gauge deployed on seawall at Bethel, AK (Yager, 2009).

Contacts were made at each site occasionally for the sole purpose of retrieving these devices. A detailed set of instructions for removing the gauge was given to each contact, as well as prepaid shipping labels and padded boxes, to send them back to Anchorage for

processing. This method proved quite effective and surpassed the expectations for the safe return of the instruments, as there were only two that were lost over the course of the summer. With the water gauges set and the static survey completed, the receivers were then connected to the

computer and their information was downloaded into TGO. After verification that the static survey was a success the team was able to proceed with the scheduled work for that site.

As the land survey team began conducting the topographic survey, the bathymetric crew fitted the vessel with the ADCP mount and prepared all necessary systems for the intended work. With the mount in place, the ADCP was securely fastened to the base plate of the mount via four nuts and bolts, paying close attention to make sure that the bolts were tight enough as to not risk losing the instrument during deployment. With the ADCP in place, the Zephyr GPS antenna was then screwed into its position at the top of the mount and all the proper cables were connected to their respective ports. At this point, the ADCP is lowered into position so that two important measurements can be taken. The distance from the water surface to the center of the transducer face on the ADCP must be measured and recorded so that the proper value may be entered when the configuration wizard prompts the user. Similarly, the distance from the water surface to the bottom of the GPS antenna must be accurately measured and recorded not only for river slope measurements, but for post processing considerations. All values are then recorded in the field book for quality assurance. After setting up the second monitor for HYPACK navigation, instrument calibrations could begin.

Before the process of collecting transect data can begin, the ADCP must first run through a general diagnostic test followed by a compass calibration test. The diagnostic test ensures that all of the sonar beams are functioning properly as well as several other vital systems on the instrument. The compass must be calibrated at each site as well, for reasons



Figure 13: Base station location at Kaltag, AK overlooking the Yukon River Project Site (mills, 2009).

discussed previously. With these calibrations completed and after checking to make sure that the base station is communicating with both HYPACK and WinRiver II, a test transect can be run. The test transect provides several pieces of information that are used throughout data collection at each site. From this test, the researcher can observe the maximum depth, water speed, water temperature, and any problematic sandbars that may be present along the river. At the completion of this process, this data can be entered into the configuration wizard in WinRiver II and any user commands may be entered to adjust bin sizes where necessary.

When beginning a transect it is of utmost importance to have the vessel operator maneuver onto the start of the preplanned line and maintain position in an area of sufficient depth until the ADCP has acquired 2 “good” bins. At this time, it is important to remain stationary with the ADCP pinging for at least 10 seconds observing those 2 bins so that the instrument can calibrate itself for flow conditions and make more accurate estimations of the discharge on the starting bank where the water is too shallow to take measurements. It is also necessary at this time to key in an “edge estimate” into WinRiver II. At that point in data collection it is merely a rough estimate. During post processing these estimates are corrected by using the topographic survey information coupled with the bathymetric data in TGO, yielding much more accurate outputs from the software. With this achieved, the vessel can then begin traversing across the river. In doing this it is equally important to monitor the vessel speed as indicated by WinRiver II to ensure that the boat is not traveling any faster than the velocities that are being observed by the instrument. Not only does this provide a more dense data set for a transect, but it make velocity calculations more accurate in the software. Much like the process undertaken at the beginning of each transect, at the conclusion of a run the vessel must remain stationary for at least 10 seconds while observing 2 bins, as to better estimate the discharge in the section that cannot be observed by the ADCP. At the end of each transect WinRiver II also prompts the user for another “edge estimate” for the distance to the water line, and is handled precisely as stated above. It was typically the practice of the researcher to make two passes on a single transect to obtain an average for the sought values, as well as to identify any obviously erroneous data. After completing a transect and before moving on to the next, an ADCP log sheet is filled out and any notes were recorded for future review.

While the hydrographic survey is being conducted, the topographic survey was also being undertaken on the river banks. With the base station set over one of the two placed monuments, the survey team records an initial check shot over the unused monument. This will serve as quality check at the conclusion of the survey when the very same point is observed again and the two shots are compared and analyzed for any misclosures. With the initial check shot recorded in the data logger, the survey team set out to start observing on the river banks by staking out to the preplanned lines, first taking a shot at the water line to provide a reference water level and working up the banks from there. Typically 4 to 5 survey shots were taken for each bank on each transect observing any and all major grade changes and noting the height of the cut banks where present. This method was used throughout the summer and provided the topographic information

that was needed. At each survey point, the name of the point and a brief description were recorded for cross-reference at a later time where needed. After completing one river bank, the survey team was shuttled across the river by the boat crew to begin work on the opposite side of the river. Where the depth of the river allowed, shots were taken in knee deep water in an attempt to complete the bathymetry that could not be recorded by the ADCP, due to shallow conditions. At some locations this was not possible due to the abrupt drop in river bed elevation, making it unsafe to wade into the river.

Usually the final step in data collection involved “floating” the vessel downstream to acquire the data necessary for determining the river slope at each location. This was done by attaching the data logger to the Zephyr antenna atop the ADCP mount, keying in the vertical offsets, and setting it to record data points at 100 foot intervals. This was conducted over a distance of 7500 to 8000 feet with boat at idle speed to obtain enough data points to accurately determine the slope of the river. During this process, the occupants of the vessel were sure to be as still as possible as to maintain stability of the boat in the water so as to not disturb the height of the antenna during acquisition.

With the topographic data collected, the survey team set out to locate landmarks and permanent structures to be used as control shots, in the event that a research team returned to the site in the future. This would allow any future data collected to be tied to the same coordinates and as well as serving as a check shot.

Lastly, a final check shot on the unoccupied

monument set earlier was taken for quality assurance. At the conclusion of work at a particular site, the base station was taken down, the ADCP was dismantled and all equipment was stowed in its respective hard cases. Upon returning to the lodgings for the night, all GPS receivers and data loggers were downloaded and the information was backed up using an external hard drive. The ADCP data was likewise copied to the external hard drive and the various batteries used were plugged in to their respective chargers for work the following day.



Figure 14: Survey team locating local permanent control monuments (Butterer, 2009).

Throughout the process of both the land survey and the bathymetric survey, researchers were faced with many challenges. On the hydrographic side, long, sweeping, shallow deposit banks made it very difficult to set user commands that captured not only the shallow portions of the river, but the deepest portions as well. This can be overcome to a certain extent with the previously mentioned test transects, but ultimately it is left to the judgment of the researcher to determine an appropriate course of action for capturing the data that best represents flow at a particular location. Likewise, the land survey crew had many challenges on the river banks. Often times, the banks were nearly impassable due to very soft silty clay, making for very exhausting conditions and slow data collection. Also, the land survey team was occasionally forced to cut their own view of the sky due to a dense tree canopy. Additionally, a small number of transects had to be abandoned due to loss of base station radio contact as well as inclement weather that posed substantial risk to the equipment and research team.

Using the methods described above, the research team was able to collect a wealth of information at each one of these sites, where little or none existed before. The following steps in the research involved the task of combining all the data and resolving it into a product that may be used for a variety of analysis.