UNIVERSITY OF ALASKA, FAIRBANKS
RIVER ICE STUDY PLAN

Prepared by Dr. J. Kasper, N. Konefal and
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In fulfillment of Milestone 2.1: System Requirements Analysis to inform ice study design. Study plan and equipment , deployment plan for over winter data collection,

DE-EE0007348

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ORPC, Inc.
October 11, 2016

As part of the US Department of Energy (DOE) funded Igiugig Village Council (IVC)-led project, the University of Alaska Fairbanks (UAF) will perform a study of over winter ice conditions in the Kvichak River at Igiugig, Alaska. UAF will deploy a mooring equipped with sensors to measure water column and surface ice velocities (a 1200 kHZ Teledyne RDI Workhorse Sentinel Acoustic Doppler Current Profiler) as well water column frazil ice and surface ice thickness (an ASL Environmental Sciences, Inc. Shallow Water Ice Profiler, or SWIP, owned by ORPC, Inc.). These sensors will be deployed by the first week of November 2016 and will be retrieved in May 2017.

1. Instrumentation:

The sensors will be mounted on an Ocean Science, Inc. “sea spider” fiberglass tripod and deployed on the river bottom in ~16 ft of water facing upwards. The instruments will be deployed near the location shown in Figure 1. The ADCP transmits sound at 1.2 MHz while the SWIP transmits a sound pulse at 542 kHz. The instruments and frame are shown in Figure 2.

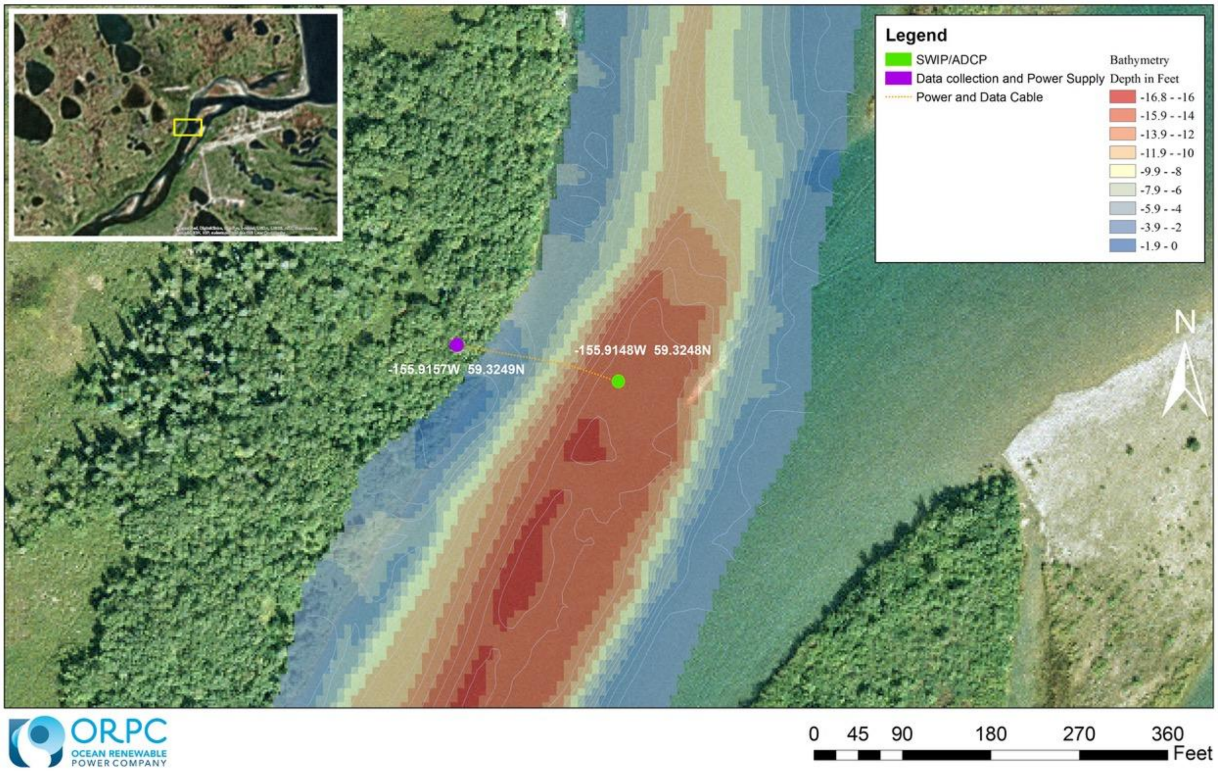


Figure 1 Map of SWIP/ADCP deployment in Igiugig on the Kvichak River.

The ADCP will be programmed to sample continuously at the maximum sampling rate (~1 Hz with ice tracking on, dependent on the water depth). Single ping data will be collected in beam coordinates and transformed to earth coordinates (N-S, E-W and vertical) during post processing. Collecting single ping data and applying coordinate transformations and ensemble averaging after the fact, allows the most flexibility in collecting and analyzing the data.

Ideally, the SWIP would be configured to burst sample at 1 Hz in profiling mode for 10 minutes at the start of every hour. This sampling rate is subject to change based on the throughput of the radio modem. Data throughput of the system will be verified prior to deployment.

Figure 2. Top Right: a TRDI Workhorse Sentinel ADCP. Image courtesy of TRDI, Inc. Top Right: An Ocean Science "sea spider" mooring frame. Bottom: An ASL Environmental Sciences SWIP with extended battery case. The Sea Spider frame will be equipped with 150 lbs of lead weights (50 lbs on each tripod leg) to keep the package moored to the river bed.

2. Data collection and power supply:

The shore based data and communication package will consist of a propane fueled autostart generator and two 80W solar panels with sufficient fuel to power the entire 6 month deployment. Propane is available locally in Igiugig and UAF owns an autostart propane generator. A small battery bank will be installed as well to allow for time to service the power system in case of failure. The power system design was carried out by Mr. Andrew Cannavo, an undergraduate mechanical engineering student from Bucknell University and an intern with UAF from May-August 2016. Mr. Cannavo's report is included as Appendix A. Instrument data, battery bank voltage and generator output will be logged on-site using a Campbell Scientific, Inc. datalogger. Additionally, a radio modem will be used to transmit the data in real time to a laptop computer located inside a nearby IVC facility, ~0.5 miles distant. The laptop will be synced to a cloud service. Data will be available in near real time for quality control, analysis and for monitoring the operation of the instruments. Estimated power usage are shown in **Error! Reference source not found.**. Note solar, wind and hydrokinetic generation were considered as well to power the instrumentation system. However, the solar resource during winter was too small to be economic similarly while the small design loads and variable winds in the region made finding a suitable, cost effective wind turbine for the system problematic. While a small hydrokinetic system was considered, since we have no experience operating commercially available units such as Ampair 100W Water Turbine from ABS Alaska, Inc. we did not consider this a reliable solution.

Table 1. Estimated power usage for the instrumentation. The ADCP and radio modem are 24V instruments while the SWIP and data logger operate on 12V.

Watt Calculation (24V instruments)		
Estimated Watt Demand	18.1	Watt-hrs
Hours expected to run	24	hour/day
Total daily usage	434.4	Watt-hrs/day
Amp-Hour Calculation		
Battery loss correction (static average loss)	443.088	Watt-hrs/day
System Voltage (DC)	24	Volts
Amp-hours per day	18.462	Amp-hrs/day
Watt Calculation (12V instruments)		
Estimated Watt Demand	5	Watt-hrs
Hours expected to run	24	hour/day
Total daily usage	120	Watt-hrs/day
Amp-Hour Calculation		
Battery loss correction (static average loss)	122.4	Watt-hrs/day
System Voltage (DC)	12	Volts
Amp-hours per day	10.2	Amp-hrs/day
Total Amp-Hours per day	28.662	Amp-hrs/day

The number of 20 Amp-hour batteries required for 7 days of power to allow for time to service the system in case of a failure is estimated as 3. Calculations for this are shown in Table 2.

Table 2. Estimate of the number of batteries necessary for backup power

Battery Bank Calculation		
Approximate backup power required	7	days
Amp-hour storage required	200.634	Amp-hrs
Assume 50% depth of discharge	0.5	
Required Amp backup	401.268	Amp-hrs
20 Hr battery amp rating (needed)	64	fraction
Number of Batteries (parallel)	6.2698125	
Number of Batteries (series)	2	
Rounded number of Batteries Needed	3	

3. In field Operations:

   a. Personnel:

At least two personnel plus a vessel operator will be on site for deploying the instrumentation. All personnel on the vessel deck participating in the deployment will have appropriate safety equipment including safety shoes and personal flotation devices, at a minimum. Before the deployment operation begins on-site personnel will perform a job safety analysis, i.e. they will walk through the deployment in order to identify and mitigate any safety risks.

   b. Deployment Equipment:

The instrument package will be deployed in early November from an IVC chartered vessel (**Error! Reference source not found.**). The vessel will be equipped with a davit to aid in safely hoisting the ~200 lb mooring package (~1.2 m x ~1.2 m x ~0.7 m high) over the side of the vessel and for lowering the package to the river bed.

Figure 3 IVC Chartered vessel for deploying the monitoring, package and data and communications packages

c. Operations:

In preparation for deployment the mooring, its cable and chain bundle, and a temporary surface float attached to the deployment line will be laid out on the vessel deck and prepped for deployment. The SWIP cable is reinforced, jacketed and weighted while the RDI ADCP cable is a standard neoprene data and communication cable. Both are equipped with waterproof, impulse-type connectors suitable for long-term underwater deployment. The RDI cable will be jacketed in a nylon sleeve for additional protection. The cable bundle will be wrapped with chain to provide weight as well strain relief.

The Vessel will transit to the deployment location and hold position based on GPS coordinates of the desired deployment location. Once the crew is ready deployment operations will commence by lowering the mooring with its temporary surface float and cable and chain bundle attached to the river bed. Once it has settled into position, the deployment location and time will be recorded using a handheld GPS unit. After the placement of the mooring package on the riverbed, power and data cables bundled with the chain will be run from the vessel to shore. The chain will be connected to a temporary ground anchor where the cable bundle makes landfall. After running the cable to shore, the surface float will be replaced with a large chain link which will be lowered to the riverbed downstream of the mooring package. This line will provide a safe means of dragging for the mooring during recovery if it is not possible to retrieve the mooring using the chain alone.

The data collection and power supply equipment will then be installed on shore and the system will be commissioned, with successful data collection confirmation.

At the conclusion of the study in May 2017, all equipment will be removed including the temporary ground anchor. This primary means to accomplish this will be by retrieving the chain at the shore and using it to pull the mooring from the riverbed and into the vessel.

4. Data Collection and Analysis:

Since the data will be available in near real time, data will be monitored daily to ensure the equipment is operating continuously. Plots of time series of velocity, suspended ice acoustic return strength (in counts), temperature, surface ice draft (calculated as the acoustically measured distance between the ADCP and the water surface minus the height of the water column as measured by the ADCP's pressure sensor) and surface ice velocity will be updated at least monthly. Data will be summarized in the final deployment month so that when the equipment is removed the data analysis will be complete as well. A draft report summarizing the results of the ice study will be delivered to IVC in early June allowing a final version to be complete by June 30, 2017.

Appendix A

Design of the shore power system

MEMO

To: Director Jeremy Kasper, AHERC
From: Intern Andrew Cannavo, AHERC
Subject: Design of a system for powering instrumentation for measuring river ice and velocities
Date: 15 July, 2016

Assignment (from Scope of Work):

"As part of the Igiugig Village Council led DOE project to deploy ORPC's Rivgen® hydrokinetic turbine in the Kvichak River near Lake Iliamna, AHERC is funded to complete a frazil ice study of the deployment site. The study requires the deployment of an Acoustic Doppler Current Profile (ADCP), a Shallow Water Ice Profiler (SWIP) and possibly an underwater time lapse camera system. Before deployment of these instruments, the costs associated with deploying the instruments in real time (preferred) versus in autonomous, internally logging mode need to be quantified."

Considerations (from Scope of Work):

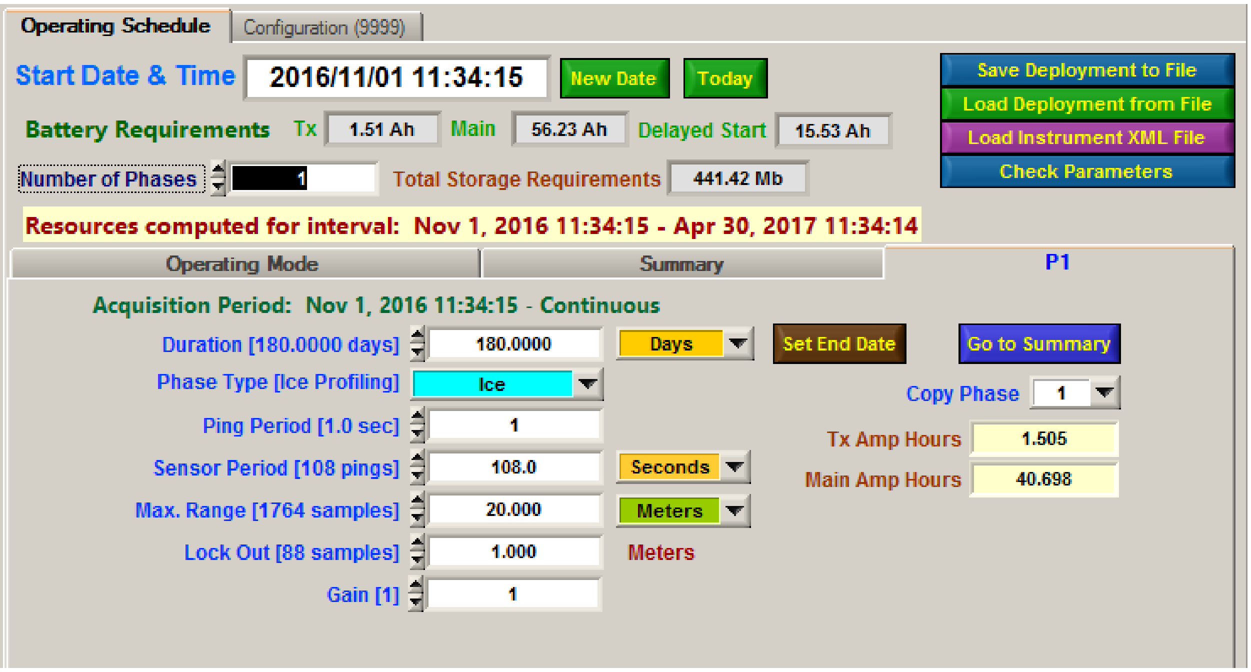
"Deployment in real time mode requires the purchase of a serial cable for conveying power from shore and data transfer from the bottom mounted ADCP to shore. (The SWIP is already equipped with the necessary cabling.) Additionally, the electrical load of each instrument needs to be quantified in order to determine the design of the power system. The electrical load will be determined by the sampling scheme of each instrument. Additionally, real time mode will require the use of a pair of radio modems to transmit data from where the instrument cables make landfall to an IVC owned building 0.5 miles distant from the site."

Scenario 1:

Both the ADCP and SWIP are capable of being deployed with internal data logging and operating in battery powered mode. The period of the study however is long, about 6 months, and being able to support the power and data loads for this length of a period will require the right sampling schemes and external batteries to supplement the internal battery pack of each instrument. While the sampling schemes can be made to fit both requirements of power and data for the intended time period, the amount of data they collect may not be optimal due to the infrequency of measurements.

Shallow Water Ice Profiler:

Using the IPS5Link River software that is used to deploy the SWIP, it was shown that using the standard sampling scheme for the instrument meets both our power and data requirements for a 180 study. It can be seen in Figure 1 that over the 180 day period 441 MB of data will be collected using only 56 amp hours of power. The typical internal battery used to deploy with the SWIP has about 120 amp hours. Of the estimated 56 Ah use, this leaves a considerable margin of unused power. If deploying the SWIP at the start study is done, an additional 15 Ah of power will not be used in delaying the start of data collection, reducing power needs even more.



Start Date & Time 2016/11/01 11:34:15

Battery Requirements Tx 1.51 Ah Main 56.23 Ah Delayed Start 15.53 Ah

Number of Phases 1

Total Storage Requirements 441.42 Mb

Resources computed for interval: Nov 1, 2016 11:34:15 - Apr 30, 2017 11:34:14

Acquisition Period: Nov 1, 2016 11:34:15 - Continuous

Duration [180.0000 days] 180.0000 Days

Phase Type [Ice Profiling] Ice

Ping Period [1.0 sec] 1

Sensor Period [108 pings] 108.0 Seconds

Max. Range [1764 samples] 20.000 Meters

Lock Out [88 samples] 1.000 Meters

Gain [1] 1

Copy Phase 1

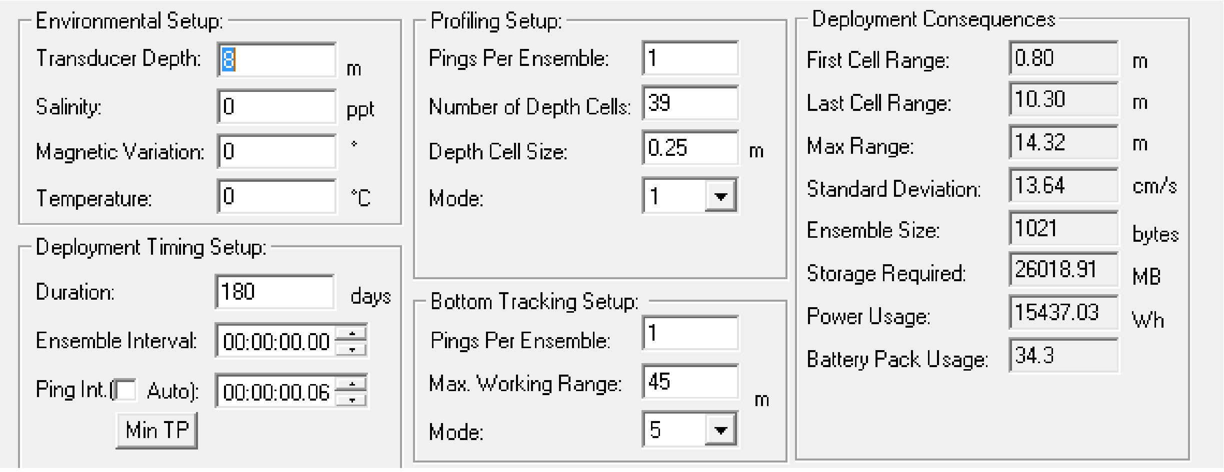
Tx Amp Hours 1.505

Main Amp Hours 40.698

Figure 1. Example sampling scheme for the SWIP

Acoustic Doppler Current Profiler:

The software used to program the ADCP for deployment, PlanADCP, allows full user control over the conditions it will see and characteristics necessary for the deployment. For a deployment of six months, the time period of the intended frazil ice study, a measurement of 1 ping at a frequency of 10 Hz will provide more than sufficient data. This amounted to a power usage of about 85 Wh per day and 26 GB of data over the course of the 180 days. Using this amount of data and power means the ADCP could not be deployed internally with the current settings, but for the purpose of the study this frequency of measurements is required. A hybrid between internal and externally driven will have to be created for a successful deployment.



Environmental Setup:
Transducer Depth: 8 m
Salinity: 0 ppt
Magnetic Variation: 0 °
Temperature: 0 °C

Deployment Timing Setup:
Duration: 180 days
Ensemble Interval: 00:00:00.00
Ping Int.(☐ Auto): 00:00:00.06

Profiling Setup:
Pings Per Ensemble: 1
Number of Depth Cells: 39
Depth Cell Size: 0.25 m
Mode: 1

Bottom Tracking Setup:
Pings Per Ensemble: 1
Max. Working Range: 45 m
Mode: 5

Deployment Consequences:
First Cell Range: 0.80 m
Last Cell Range: 10.30 m
Max Range: 14.32 m
Standard Deviation: 13.64 cm/s
Ensemble Size: 1021 bytes
Storage Required: 26018.91 MB
Power Usage: 15437.03 Wh
Battery Pack Usage: 34.3

Figure 2. Example sampling scheme for deployment scenario

Scenario 1 Summary:

While the data collection schemes for the instruments being internally logged are not be ideal for the intention of the study, they do show that it is at least plausible to deploy them for the 180 day period and to be both internally powered and store data. While this would be good for the independence of the study, there are some other considerations. Internally logging the data would mean it would not be accessible until the end of the study. This could mean that if something would to happen that would hinder or stop data collection altogether, it would not be known until the data was retrieved. The potential loss of data is great since it would not be monitored remotely. Remote monitoring of the data could recognize a problem with the data after only a few days and address the issue. The frequency of data required for the purpose of the study is also large, especially for the ADCP. The sampling scheme shown above for the ADCP showed that it was not possible to internally manage the instrument for the course of the 180 day period. Thus, a hybrid plan must be achieved between internally and externally powering the system.

Scenario 2:

Analysis:

In order to deploy this system in real time mode, meaning constant data collection over the designated period of study, there are two main considerations. These being how to power the system during this time period and how to effectively transmit the collected data. Through the use of a power system consisting of a battery bank and some sort of recharge device (i.e. solar array, wind turbine, hydrokinetic turbine, or generator) the instruments can be powered. The use of cabling, Campbell data logger, and radio modem will transmit data from the SWIP and ADCP to shore, couple the data, and then transmit it the half mile from the site through the radio and to an offsite computer.

Power Calculations:

In order to determine the power required to run the instruments and associated system, estimates were made for individual device's consumption based on the maximum possible usage for the radio modem and data logger. The estimates for each instrument were the power each would draw due to a sampling scheme that allowed for maximum data collection. Table 4 shows the calculated power demands for both the 24 V powered devices (ADCP and radio modem) and the 12 V devices (SWIP and data logger).

Table 3. Power Demand of Instruments

Watt Calculation (24V instruments)		
Estimated Watt Demand	9.37	Watt-hrs
Hours expected to run	24	hour/day
Total daily usage	224.88	Watt-hrs/day
Amp-Hour Calculation		
Battery loss correction (static average loss)	229.3776	Watt-hrs/day
System Voltage (DC)	24	Volts
Amp-hours per day	9.5574	Amp-hrs/day
Watt Calculation (12V instruments)		
Estimated Watt Demand	0.568	Watt-hrs
Hours expected to run	24	hour/day
Total daily usage	13.632	Watt-hrs/day
Amp-Hour Calculation		
Battery loss correction (static average loss)	13.90464	Watt-hrs/day
System Voltage (DC)	12	Volts
Amp-hours per day	1.15872	Amp-hrs/day
Total Amp-Hours per day	10.71612	Amp-hrs/day

While these power requirements are larger estimates for the instruments they are still relatively low in terms of daily usage. Ideally, a renewable device would be able to power the system continuously with a battery bank used as backup power. Taking a look at the number of batteries required for a given number of days of sufficient power (Table 4) gives a safe working power allowance for the system in the case something the bank isn't able to be continuously powered.

Table 4. Examining the number of batteries necessary for sufficient power

Battery Bank Calculation		
Approximate backup power required	7	days
Amp-hour storage required	229.37	Amp-hrs
Assume 50% depth of discharge	0.5	
Required Amp backup	458.74	Amp-hrs

20 Hr battery amp rating (needed)	85	fraction
Number of Batteries (parallel)	6	
Number of Batteries (series)	2	
Rounded number of Batteries Needed	3	Series/parallel

Power Recommendations:

- Based on power requirements of about 300 W-h/day for the system in question

Battery Bank:

The battery bank will be made up of 8 12V batteries connected in series/parallel to make the bank 24V. It was decided to increase the number of batteries from the calculated 6 (Table 2) to 8 in order to account for the lower power availabilities from the cold temperatures likely to be encountered. This bank is thus made up of 8 batteries connected in series in pairs of 2 to create the 24 V power. These 4 pairs are then connected in parallel to increase the available power of the battery bank to about 400 Ah based on standard 12 V battery ratings (Table 5).

Table 5. Determining the power of the battery bank

Battery Bank Capacity		
Number of 12 V Batteries	8	batteries
Batteries in Series/Parallel configuration	4	pairs
Battery Bank Voltage	24	Volts
Available Power (20 hr)	85	Amp-hrs
Current	4.25	Amps
Current used daily	102	Amp-Hours
Power of Bank	408	Amp-Hours

Solar:

Having two 80W solar panels available, powering the instruments with solar energy is the first thing to examine. These power ratings given by the manufacturer for the panels were from testing of sun conditions at 1 kW/m^2 test conditions. For Igiugig however, these conditions are often unlikely. Because the test period for these instruments occurs in the winter, the limitation for this power option is already cut to about 4 hours of sun per day (Figure 3). Based on preliminary power calculations, this could still provide the necessary power for all the instruments. However, examining the solar irradiance data for the area around Igiugig, found from the National Renewable Energy Lab's NSRDB Data Viewer, the average direct solar irradiance averages to about 2.5 kWh/m^2/day (Figure 4). This translates to only about 1/10 of the available power, 100 W/m^2, that the panels are rated for.

Based on this data it seems that solar will not be an adequate stand-alone power source for the instrumentation required in this system. There is also about 50% cloud cover in the winter time when the study is to be conducted and snow is prevalent. This would require the panels to be swept off if covered, reducing the independence of a solar system even further. However, since the study is over the course of 6 months, the last half of the study could provide adequate sun to offset the overall power consumption of the system. Since the solar panels and equipment are already available to us they should be incorporated into the power system to be created in order to help offset power needs when the sun increases later in the study. The low power requirements of the devices should make any solar production relatively significant though later in the study. Even at a tenth of the available power production of the panels due to the low solar irradiance, 16W of power for a couple hours a day could provide the required 10W/hr for the instruments. The remaining 6W of power could be used, while minimally, to recharge the battery bank and offset propane use.

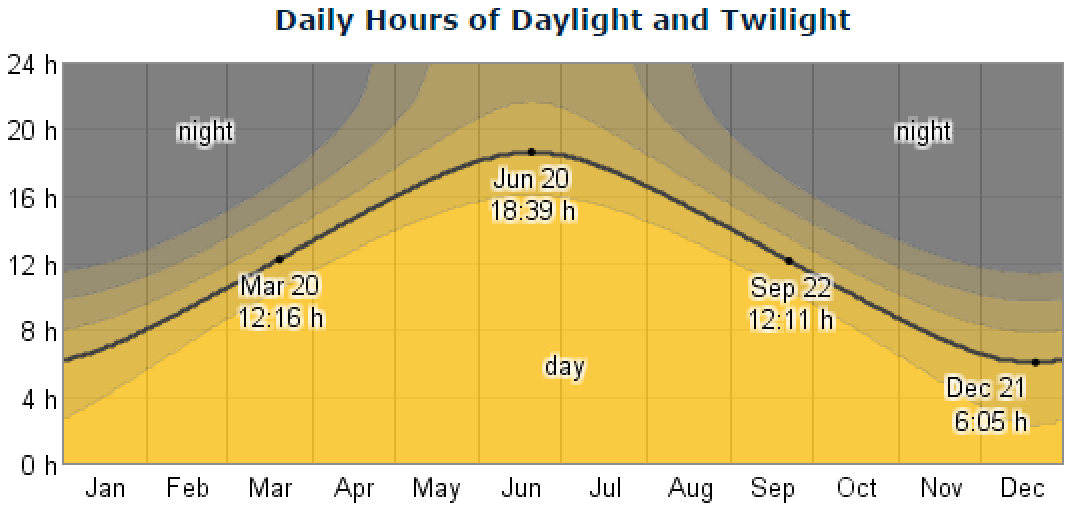


Figure 3. (https://weatherspark.com/averages/32974/Igiugig-Alaska-United-States)

PSM Direct Normal Irradiance 4 nearby results

Result 1 of 4

Average DNI: 2.6330762

Result 2 of 4

Average DNI: 2.6042829

Result 3 of 4

Average DNI: 2.6259134

Result 4 of 4

Average DNI: 2.6166127

SUNY India Direct Normal Irradia... 0 nearby results

Figure 4. (https://maps.nrel.gov/nsrdb-viewer/)

Wind:

The winter time is the peak of the year for wind speeds. Igiugig sees its highest average wind speeds at this time when the study is to be conducted. As seen in Figure 5, the average daily wind speed is about 10 mph, with a range from 2 – 17 mph during the winter months. With this large range of wind speeds a turbine with a low cut in speed would be required to ensure reliable power throughout the range of velocities. Not already having a turbine that fits these requirements would mean one would have to be purchased and installed. One such turbine that fits these requirements is the Bergey XL 1, offered from Remote Power Inc; it has a cut in speed of 5.6 mph and a power rating of about 1300 Watts. The price of the turbine itself is about $4,250 not including the cost of the tower or installation costs. For the purpose of this study, these costs seem high and unnecessary expenses to complete it effectively.

Given the high cost of having to buy new equipment to power the system and the general unreliability of wind, using it as an effective resource to meet the power needs of the system during the course of the study seem unlikely.

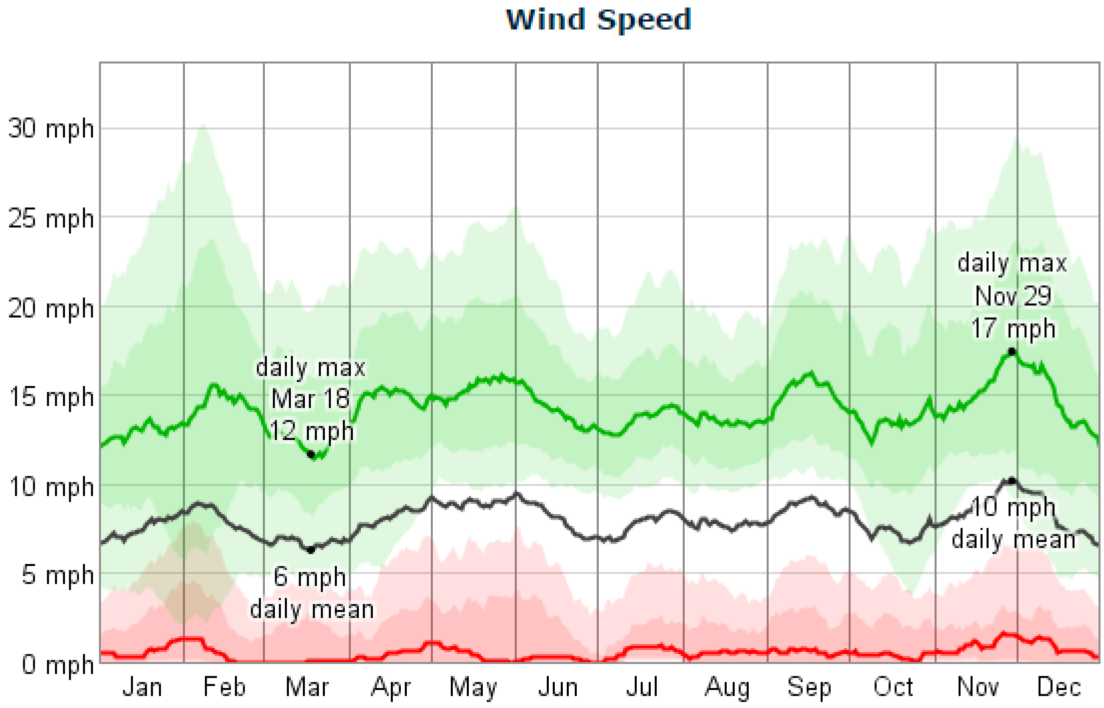


Figure 5. (https://weatherspark.com/averages/32974/Igiugig-Alaska-United-States)

Hydro:

Being at the mouth of the river leading from Lake Iliamna, the use of a hydrokinetic turbine could be significant. One such turbine is the Ampair 100W Water Turbine from ABS Alaska, Inc. This 100 Watt turbine can provide up to 4 amps per hour. The amp requirement of our system is only about 1.25 amps per hour, but the 4 amp rating is the maximum it can produce. There is a recommendation for the turbine that water speed be at least 1.8 m/s and be at a depth of at least 16 inches or else the power production of the turbine will be negligible. Not knowing the conditions for the river at Igiugig leaves the question of whether these requirements can be met.

Given the troubles encountered at Nenana with the 5kW New Energy turbine these minimal requirements, especially velocity, seem like they could be a problem. The small amount of power the turbine is rated for could conceptually meet our consumption needs, but that was for ideal conditions at the turbine, something we most likely will not have. Since the system will be deployed over the winter, water velocities will likely be reduced and the introduction of frazil ice could introduce other problems to the performance of the small turbine. With a cost of $2,200 and the associated risks of unreliability, using a marine turbine such as this one from ABS does not seem like an effective, independent solution to powering the system.

Autostart Generator:

The most reliable of the options available to us to power the system would be through the use of an autostart generator. Recommendations from Greg Egan of Remote Power Inc. suggested this course of action due to the low power requirements of our system. Through the use of a battery bank, needed regardless of the power option chosen, the generator would only need to be turned on every 4 or 5 days for about 5 hours (Table 6) in order to recharge the batteries spent. This interval could be set and then the only involvement necessary would be someone needed to refill the propane tanks every few months depending on the size of the tank. Through the use of a propane autostart generator and tanks storing propane onsite, there is the possibility of the system still being able to sustain itself throughout the testing.

Using the generator as the means to power the system seems to be the most reliable of the power methods stated, as it does not have to rely on unsteady environmental conditions for power production. The cost would be minimal as we already have the autostart generator and the system for the instruments would be greatly simplified down to only distribution boxes and a DC-DC converter for the two different power requirements of the two instruments. The battery bank will no longer be used for backup power, but for powering the instruments with the generator recharging the bank periodically. While the cost is reduced and the system is greatly simplified, the power source is not renewable. However, in the interest of completing the study and having reliable and consistent data throughout the test period, this method seems like the most reasonable option.

Table 6. Amount of fuel needed for 180 day study

Depletion and Charging		
Available Power (60% availability)	244.8	Amp-hrs
Amp-Hours per day Used	10.71612	Amp-hrs/day
Assume 40% Depth of Discharge	0.4	
Days before depletion	9.137635637	days
Power of Bank	9792	Watts
Charging Capacity of Generator	2500	Watts/hr
Assume 80% efficiency	2000	Watts/hr
Full capacity recharge time	4.896	Hours

Fuel Consumption Rate	2.3	lb/hr
Fuel used per recharge	11.2608	lbs
Number of Recharges over 180 day study	19.69875	recharges
Fuel used over 180 day study	221.823684	lbs

After considering the inclusion of the solar panels into the system, the power consumption calculations were redone (Table 7). Assuming only a tenth of the rated power production of the panels and only an average of 3 hours of operation per day over the course of the 180 day period reduced fuel consumption of propane to about 180 lbs (Table 8). This means that coupling two 100 lb propane tanks would give enough fuel to power the system throughout the whole study.

Table 7. Power consumption after considering production from solar panels

Corrected Power Consumption (with Solar Panels)		
Estimated Solar Production	16	Watt
Average Hours of Sun over 180 days	3	hour/day
Daily Solar Production	48	Watt-hrs/day
Voltage	24	Volts
Amp-Hours per day	2	Amp-hrs/day
Total Amp-Hours per day (original - solar power produced)	8.71612	Amp-hrs/day

Table 8. Fuel Consumption after considering offset power produced from solar panels

Corrected Depletion and Charging (with Solar Panels)		
Available Power (60% availability)	244.8	Amp-hrs
Amp-Hours per day Used	8.71612	Amp-hrs/day
Assume 40% Depth of Discharge	0.4	
Days before depletion	11.2343566	days
Power of Bank	9792	Watts
Charging Capacity of Generator	2500	Watts/hr
Assume 80% efficiency	2000	Watts/hr
Full capacity recharge time	4.896	Hours
Fuel Consumption Rate	2.3	lb/hr
Fuel used per recharge	11.2608	lbs
Number of Recharges over 180 day study	16.0222794	recharges
Fuel used over 180 day study	180.423684	lbs

System Diagram:

The diagram shown in Figure 6 is the system design for use with the autostart generator and integrated solar panels. The generator is connected to the 24V battery bank and recharges it at set intervals as it is depleted. Using at most 15 Ah of power a day and assuming 60% of available power due to the cold temperatures means the bank could power the instruments 9 days before having to be recharged by the generator.

From the bank the instruments are connected as the load. There is a fuse and switch on the positive power cable for protecting the instruments and the DC-DC converter converts the power from the 24V of the battery bank down to 12V for the SWIP and Campbell logger. The rest of the instruments can be powered directly with 24V.

The incorporation of the solar panels was done due to the fact that the panels and associated equipment are already available to us. The panels may not provide considerable power until later in the deployment when daily sun increases. However, since the power requirements of our system are so low, they could offset the amount of propane used to run the generator considerably as the daily sun increases. With two 100 pound tanks of propane onsite and the addition of the solar panels to supplement the generator, the whole 180 day deployment could be achieved without having to have any tanks refilled or replaced.

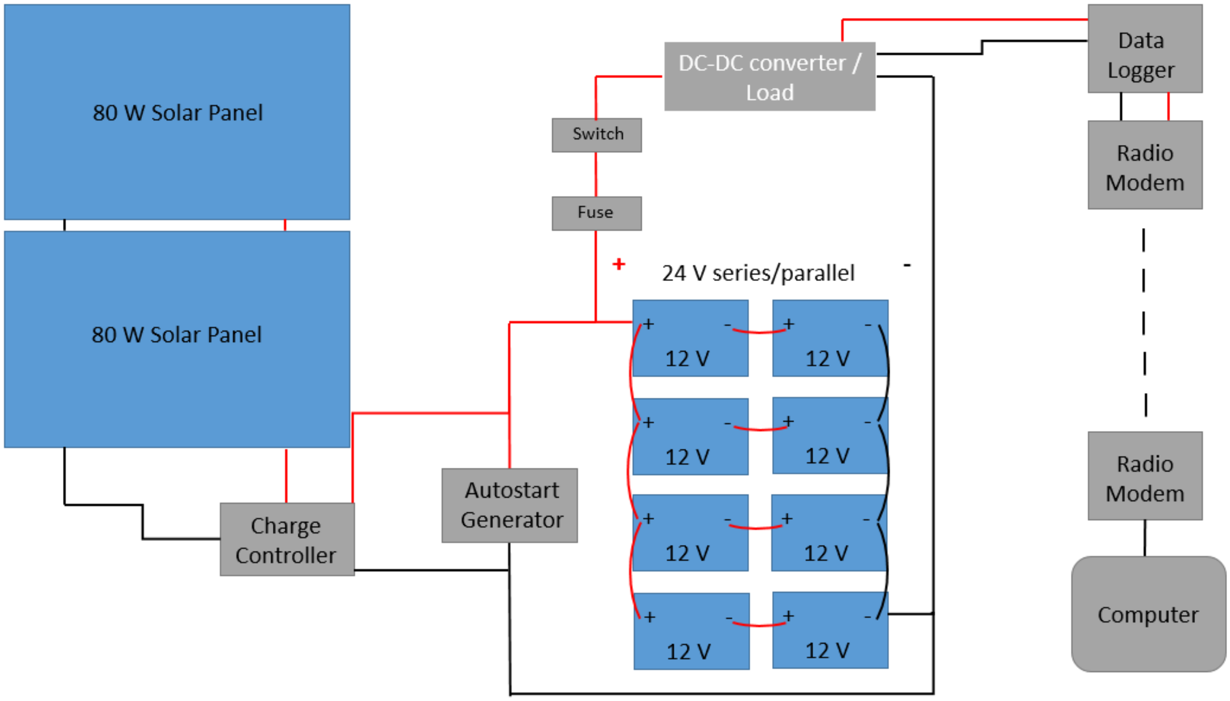


Figure 6. System Diagram for system with autostart generator supplemented with solar panels

Recommendation:

Adjusting the sampling scheme so that less frequent measurements are made by the instruments could reduce the power demands of the system from the max estimated in scenario 2. Since the time period of the study is so long, less frequent measurements would have significant impact on the power, but coupling the system with the external battery bank should reconcile this issue. However, the purpose of the study requires a larger sampling scheme for both instruments. Externally powering the instruments and offloading the data through the use of the data logger and modem to a computer is thus necessary.

To get the most reliable system and thus the highest possibility of complete data over the course of the 180 day study it is recommended to use the propane autostart generator system with onsite propane storage tanks to externally power the instruments and offload data to the offsite computer. Coupling this power source with the two available solar panels will allow for offset power production from the generator later in the term of the study, as more sun becomes available. Installing internal battery packs to the instruments can also be done in order to provide backup power if required in the case of a drained or malfunctioned battery bank. Both instruments are cabled with RS422 connections, allowing simultaneous power and data transmission. The use of this external powered system allows the data collected from the instruments to be coupled through the use of the Campbell data logger and transmitted with a radio modem offsite. The use of the data logger will also allow the monitoring of the power and charging of the battery bank. Overall, this system seems to be the most efficient and independent of all the options examined while still providing the large amount of data required for the purpose of studying the frazil ice in the river.

Append B: Power Calculations

Watt Calculation (24V Instruments)

Estimated Watt Demand	9.37	Watt
Hours expected to run	24	hour/day
Total daily usage	224.88	Watt-hrs/day

Amp-Hour Calculation

Battery loss correction (static average loss)	229.3776	Watt-hrs/day
System Voltage (DC)	24	Volts
Amp-hours per day	9.5574	Amp-hrs/day

Watt Calculation (12V Instruments)

Estimated Watt Demand	0.568	Watt
Hours expected to run	24	hour/day
Total daily usage	13.632	Watt-hrs/day

Amp-Hour Calculation

Battery loss correction (static average loss)	13.90464	Watt-hrs/day
System Voltage (DC)	12	Volts
Amp-hours per day	1.15872	Amp-hrs/day

Total Amp-Hours per day	10.71612	Amp-hrs/day

Battery Bank Capacity

Number of 12 V Batteries	8	batteries
Batteries in Series/Parallel configuration	4	pairs
Battery Bank Voltage	24	Volts
Available Power (20 hr)	85	Amp-hrs
Current	4.25	Amps
Current used daily	102	Amp-Hours
Power of Bank	408	Amp-Hours

Depletion and Charging

Available Power (60% availability)	244.8	Amp-hrs
Amp-Hours per day Used	10.71612	Amp-hrs/day
Assume 40% Depth of Discharge	0.4	
Days before depletion	9.137635637	days
Power of Bank	9792	Watts
Charging Capacity of Generator	2500	Watts/hr
Assume 80% efficiency	2000	Watts/hr
Full capacity recharge time	4.896	Hours
Fuel Consumption Rate	2.3	lb/hr
Fuel used per recharge	11.2608	lbs
Number of Recharges over 180 day study	19.69875	recharges
Fuel used over 180 day study	221.823684	lbs

24 V Instruments Usage

ADCP	3.57	Watt-hrs
RF Modem	5.8	Watt-hrs

12 V Instruments Usage

SWIP	0.232	Watt-hrs
Campbell Logger	0.336	Watt-hrs

Corrected Depletion (with Solar Panels)

Estimated Solar Production	16	Watt
Average Hours of Sun over 180 days	3	hour/day
Daily Solar Production	48	Watt-hrs/day
Voltage	24	Volts
Amp-Hours per day	2	Amp-hrs/day

Total Amp-Hours per day	8.71612	Amp-hrs/day

Battery Bank Capacity

Number of 12 V Batteries	8	batteries
Batteries in Series/Parallel configuration	4	pairs
Battery Bank Voltage	24	Volts
Available Power (20 hr)	85	Amp-hrs
Current	4.25	Amps
Current used daily	102	Amp-Hours
Power of Bank	408	Amp-Hours

Depletion and Charging

Available Power (60% availability)	244.8	Amp-hrs
Amp-Hours per day Used	8.71612	Amp-hrs/day
Assume 40% Depth of Discharge	0.4	
Days before depletion	11.2343566	days
Power of Bank	9792	Watts
Charging Capacity of Generator	2500	Watts/hr
Assume 80% efficiency	2000	Watts/hr
Full capacity recharge time	4.896	Hours
Fuel Consumption Rate	2.3	lb/hr
Fuel used per recharge	11.2608	lbs
Number of Recharges over 180 day study	16.0222794	recharges
Fuel used over 180 day study	180.423684	lbs