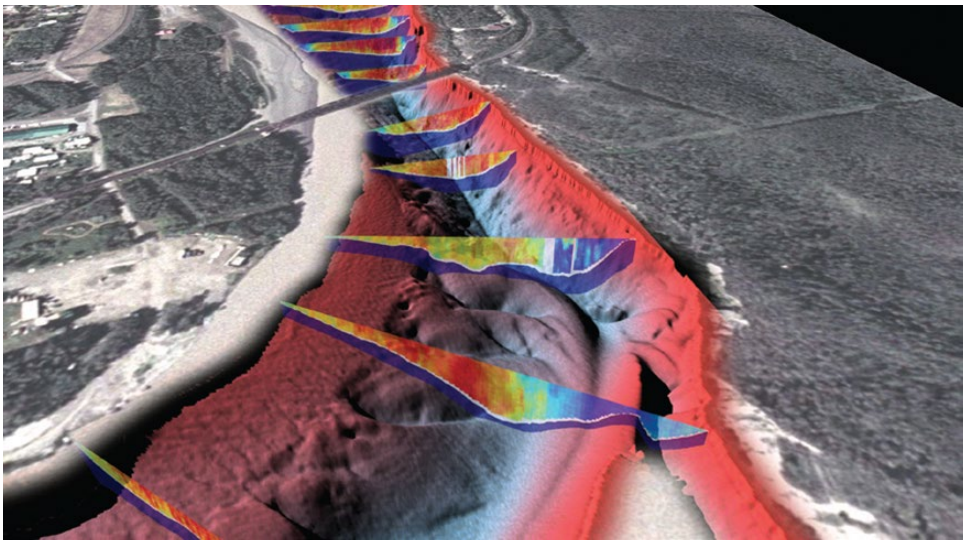
Tanana River Test Site (TRTS) - MHK Device Design Criteria

Alaska Center for Energy and Power (ACEP)

August 2020



The intent of this document is to concisely provide the site information and river characterization data relevant to the design and preparation of hydrokinetic energy devices for deployment at the Tanana River Test Site (TRTS). This report roughly follows IEC TS 62600-301:2019 “River energy resource assessment”.

Contents

Tanana River Test Site Description

The Tanana River Test Site is located 55 miles southwest of Fairbanks, Alaska in the road connected community of Nenana. A map of the area and driving route is shown in Figure 1.

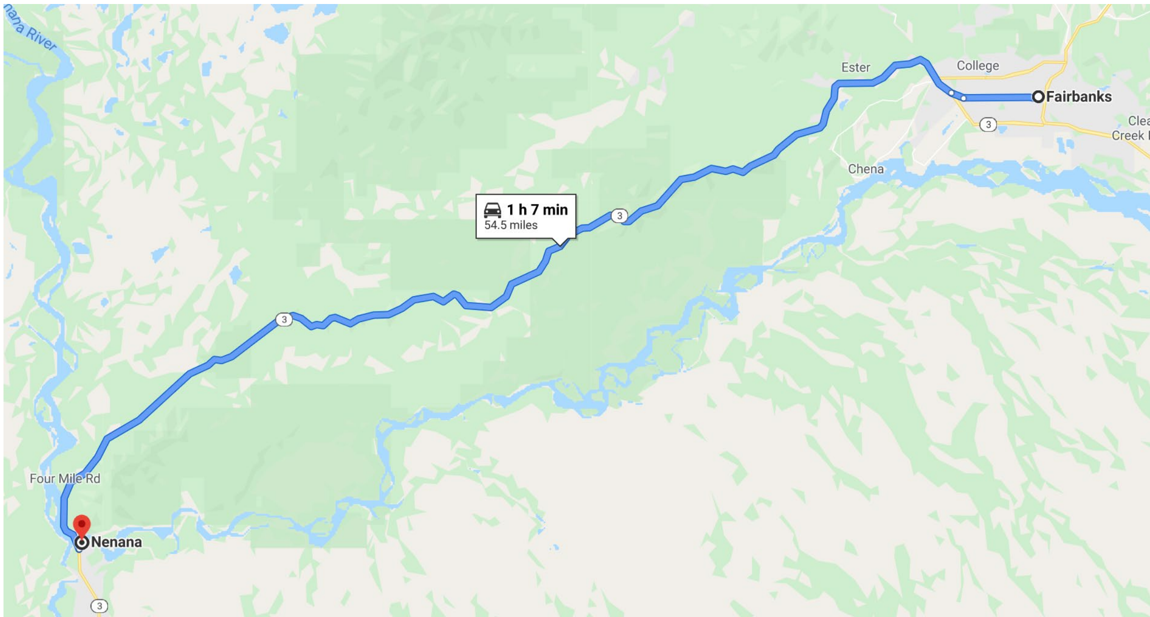


Figure 1. Map of Fairbanks to Nenana driving route.

Extent of Test Site Footprint

The characterized reach of river is approximately 1km in length and the river width at the barge deployment location is approximately 200m. The Research Barge provides a 40 foot by 24 foot working platform from which to deploy hydrokinetic energy systems into the river.

Proposed REC locations and blockage area (base area from which to determine blockage)

The test barge is moored off a permanent anchor as described below. The length of the mooring line can be adjusted to some extent to place the barge in different parts of the river. As a basis for determining blockage area, the mean cross-sectional flow area at the typical barge location is 1,279 m^2. All deployments possible from the Research Barge would be low blockage (<5%).

Bank-full river profile

A land survey of the banks has not yet been performed, but the river profile can be seen in the satellite imagery in Figure 2.

Project area bathymetry

Bathymetry of the Tanana River Test Site is overlaid on satellite imagery in Figure 2.

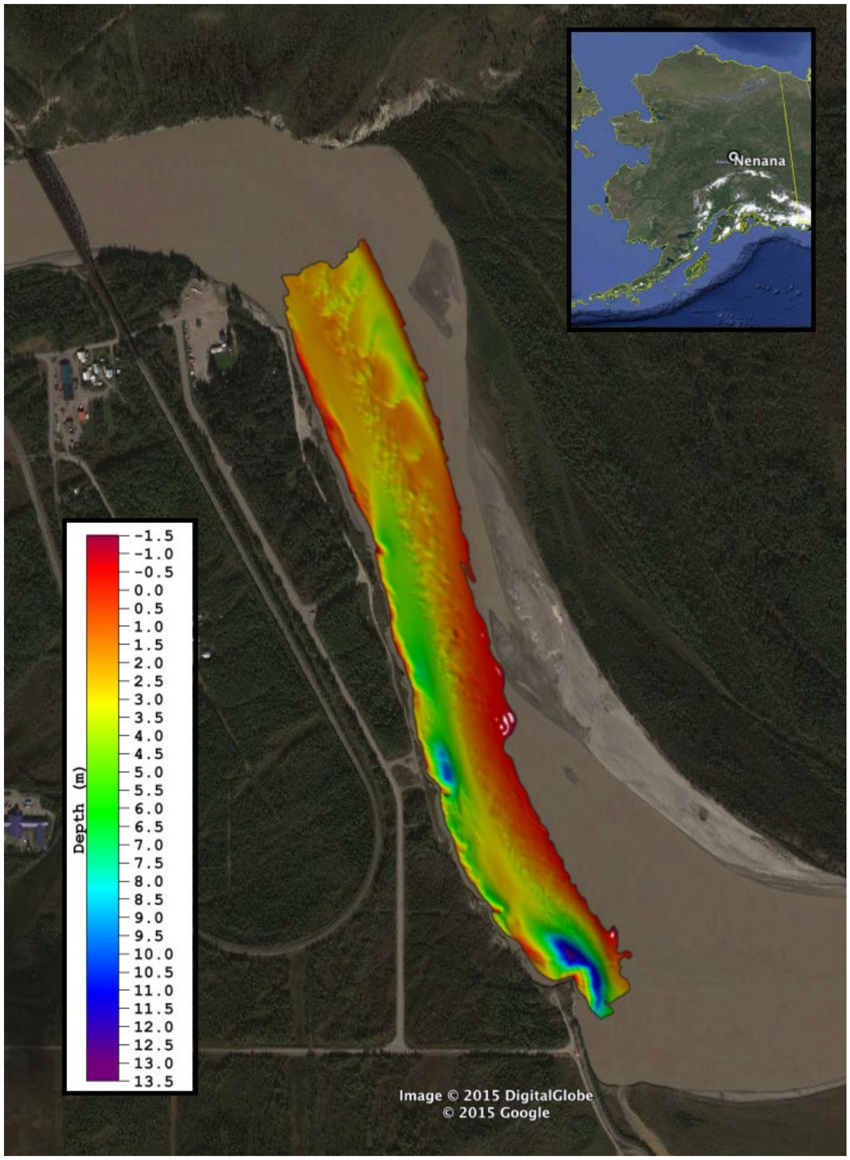


Figure 2. TRTS Bathymetry overlay on satellite imagery. Source: image from Google Earth. Bathymetry from Terrasond (2010). Nenana Hydrokinetic Energy Research Site Physical Characterization Survey.

Water depth or water-surface elevation including a reference elevation (water level / stage)

The river depth from an arbitrary datum is noted on the bathymetry in Figure 2. This data was collected with a river stage of 2.8m above the gage. Normal range of river stage is 1m to 4m above the gage, as shown in Figure 7 below.

Nearby hydrographic or environmental monitoring stations

USGS 15515500 TANANA R AT NENANA AK is located just downstream of the TRTS. Discharge measured at this gage matches data collected during ADCP transects at the test site. 10 years of 15-minute stage and discharge data during open water season is available at the USGS website, and is summarized in this document.

Any other notable feature or infrastructure in proximity to the test location

The town of Nenana offers limited lodging, basic grocery, and limited dining. Fairbanks, 55 miles north on the Park Highway, offers an international airport and significant industrial, commercial, and fabrication capacity.

Identification of the cross-channel transect and current profiler (CP) measurement locations used during the river resource assessment.

The cross-channel transects performed during the 2009 river characterization campaign are shown in Figure 3. New transects were performed in July 2020 and updated transect data will become available.

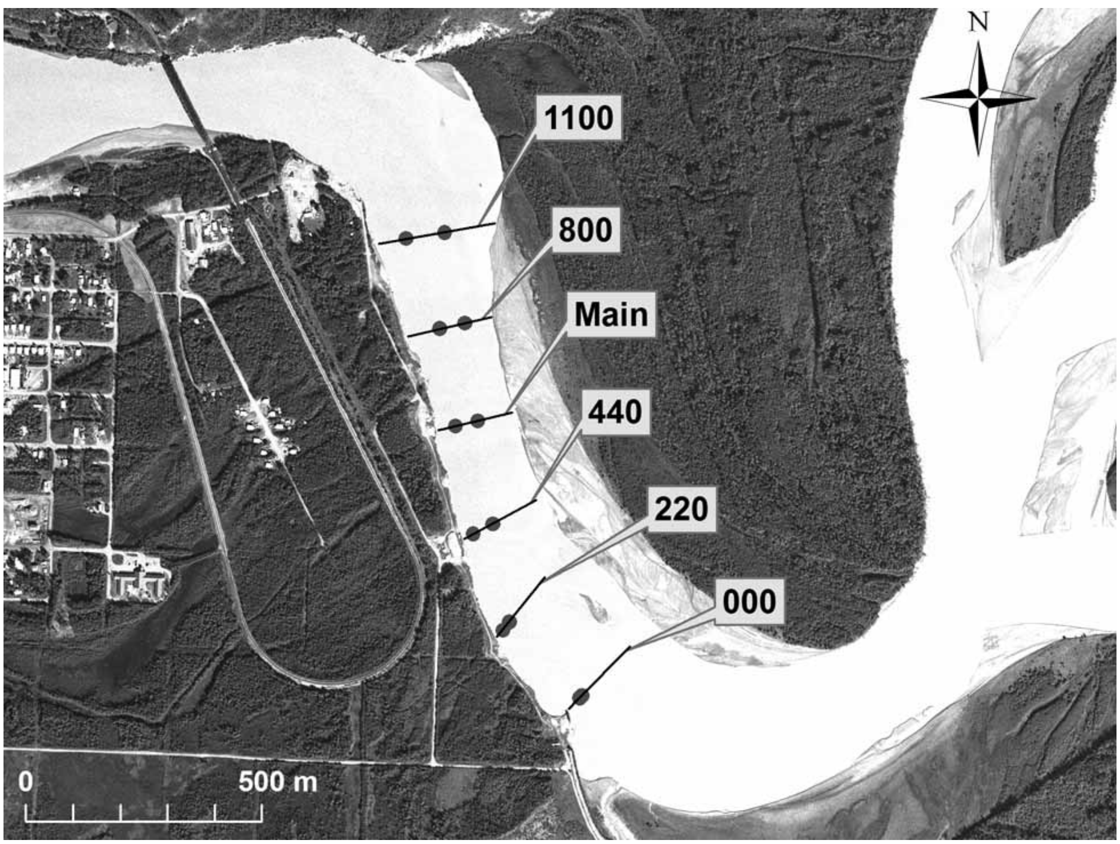


Figure 3. 2009 ADCP transect locations.

Vertical current-speed profiles at the noted transects are shown in Figure 4. New transects were performed in July 2020 and updated data will become available in the coming months. A transect of the normal testing location is shown in Figure 5.

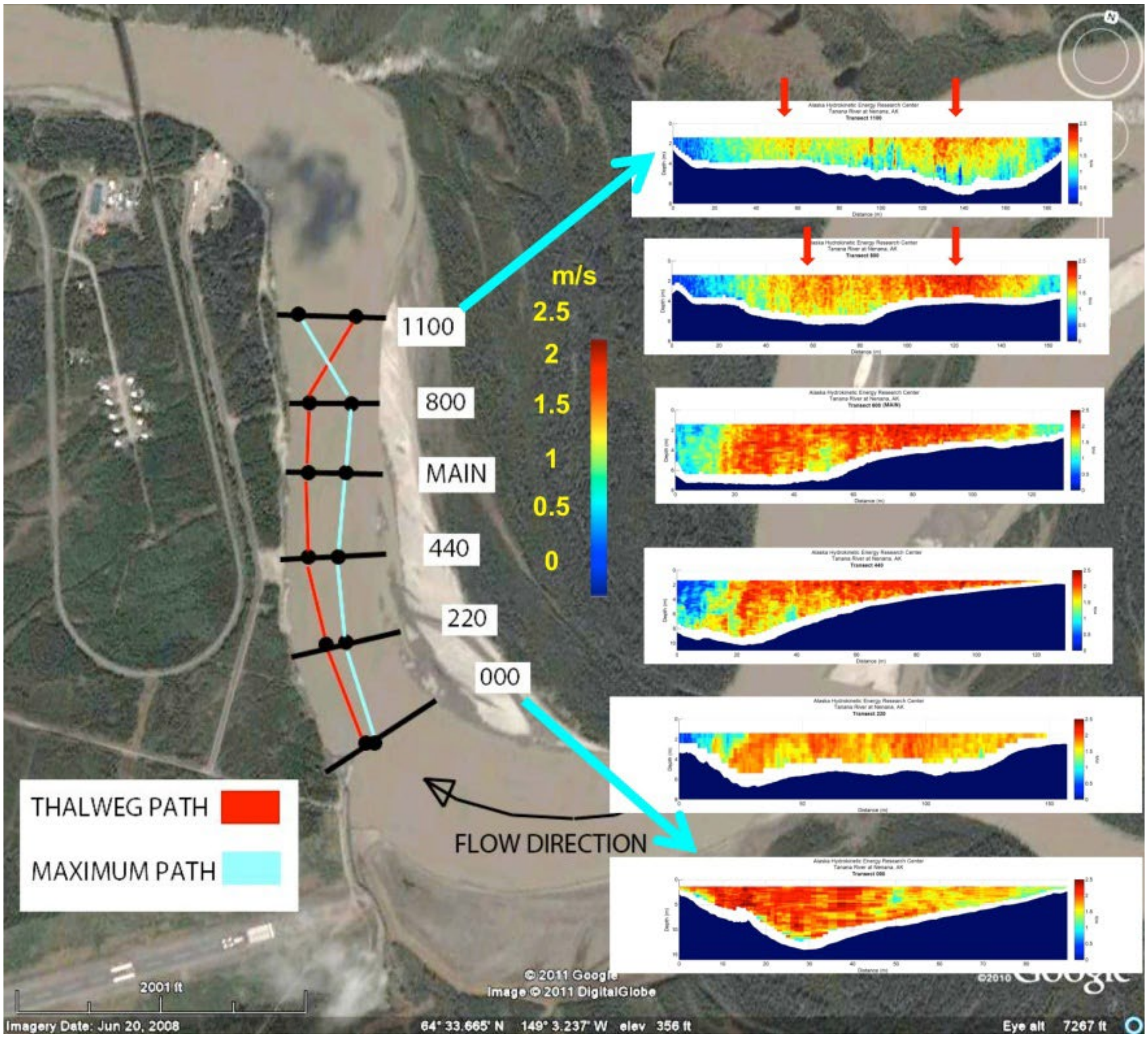


Figure 4. Depth and current of ADCP transects.

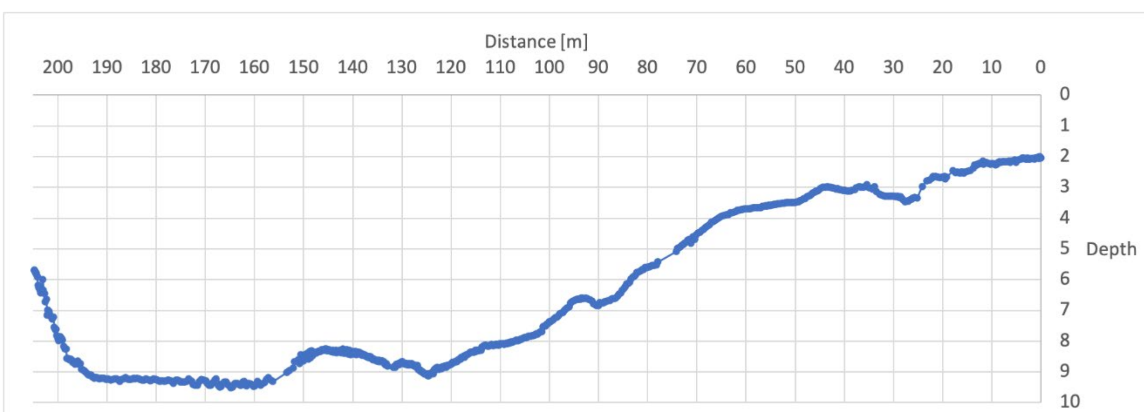


Figure 5. Transect at normal testing location.

River Characterization

River characterization has been performed utilizing a combination of bathymetry, stream gage data, transect data, and hydrodynamic modeling.

Flow Duration Curve (FDC)

A flow duration/exceedance curve is being developed.

The monthly average, maximum, and minimum discharge for the Tanana River at Nenana are shown in Figure 6. The minimum discharge year occurred in 1996, and the maximum average discharge year occurred in 1967. Discharge data can be accessed from the USGS gaging station on the Tanana River in Nenana. River stage for the open water season is correlated to the USGS average, maximum, and minimum measured discharge and is shown in Figure 7. The correlation between stage and discharge is shown in Figure 8.

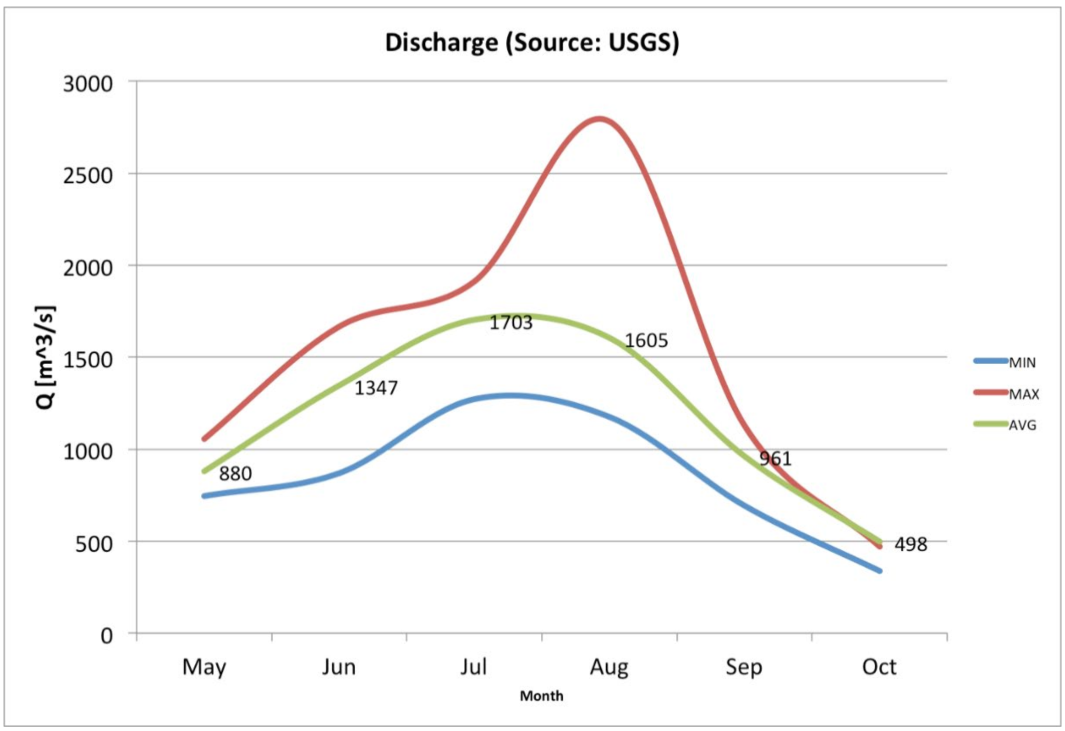


Figure 6. Monthly discharge range and average. Source: USGS data available at: http://waterdata.usgs.gov/nwis/inventory/?site_no=15515500

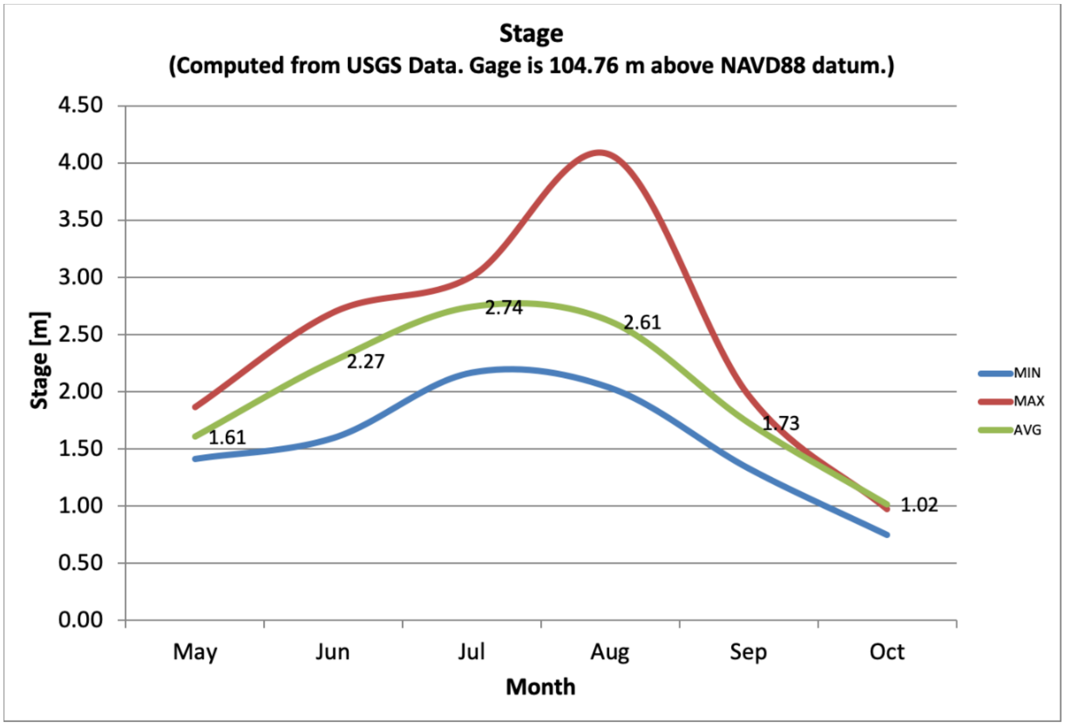


Figure 7. Monthly stage range and average. Source: USGS data available at: http://waterdata.usgs.gov/nwis/inventory/?site_no=15515500.

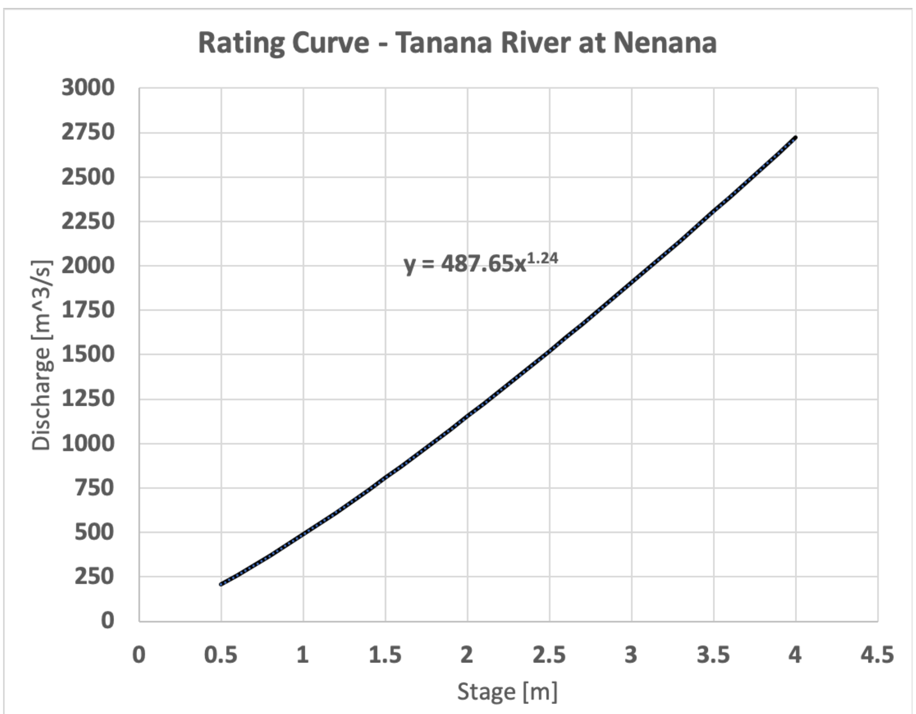


Figure 8. Rating curve - Tanana River at Nenana

Velocity Duration Curve (VDC)

Velocity is modeled using USGS gage stage and discharge measurements and a model of the velocity discharge relationship. The velocity distribution curve is plotted in Figure 9. This plots the percentage of time that river flow is likely to equal or exceed some velocity of interest. An estimation of the typical seasonal variation of river current velocity is obtained by entering the measured seasonal discharge into a 2D hydrodynamics model for the TRTS and is shown in Figure 10.

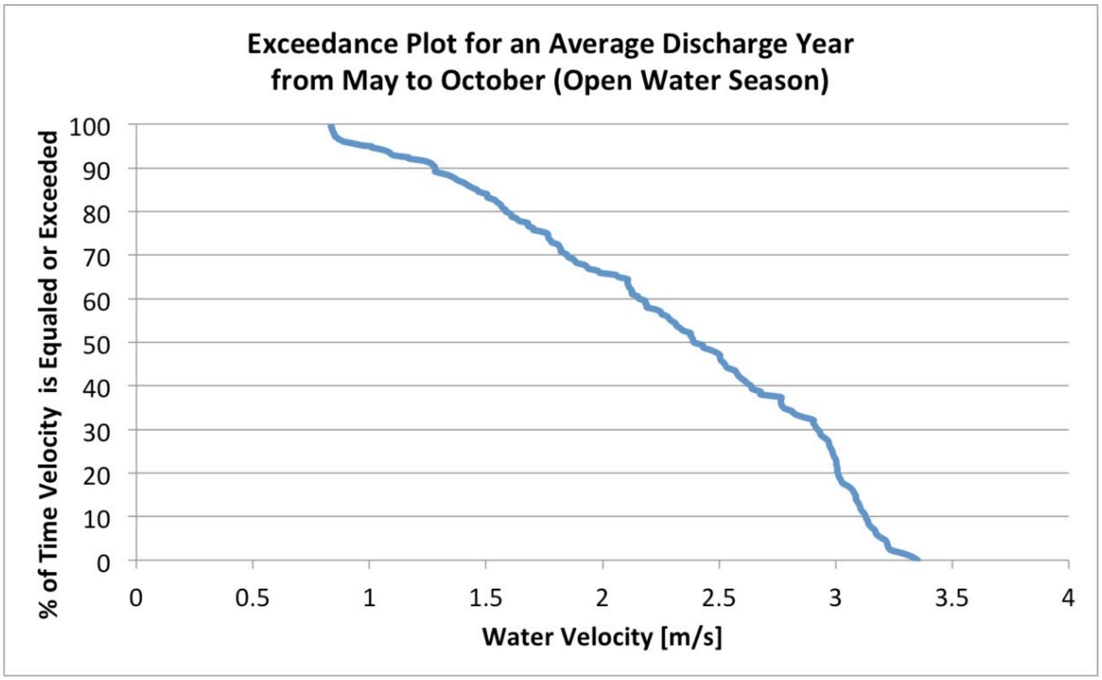


Figure 9. Velocity distribution curve (VDC). Source: modeled velocities from: Duvoy, P., & Toniolo, H. (2012). HYDROKAL: a module for in-stream hydrokinetic resource assessment. Computers & Geosciences, 39, 171-181.

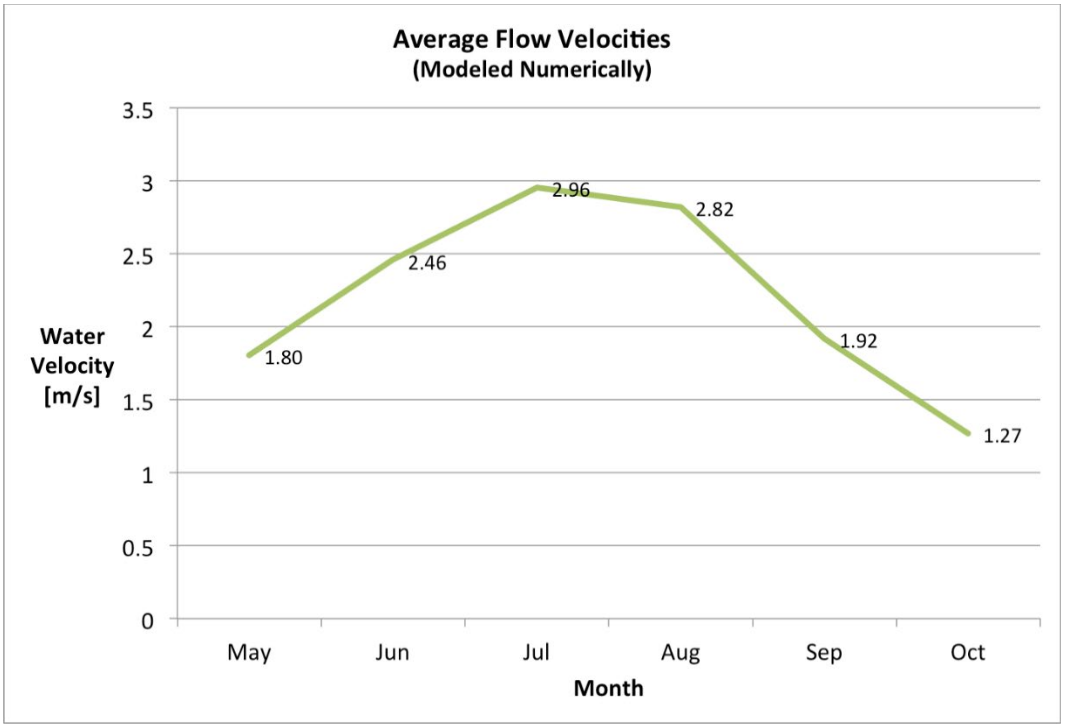


Figure 10. Monthly modeled average flow velocity. Source: modeled velocities from Duvoy, P., & Toniolo, H. (2012). HYDROKAL: a module for in-stream hydrokinetic resource assessment. Computers & Geosciences, 39, 171-181.

Annual Energy Production (AEP) calculation

AEP is turbine specific, but can be estimated using the water velocity data in Figure 10

Discussion of Limitations and Additional Factors

The water at the test site is highly loaded with sediment in the form of glacial silt and this has not been explicitly included in any modeling.

Turbulence is highly variable spatially in the characterized reach of the river. Power density as a function of location in the Tanana River Test Site river reach, with notations about turbulence and placement of hydrokinetic power generating devices is shown in Figure 11.

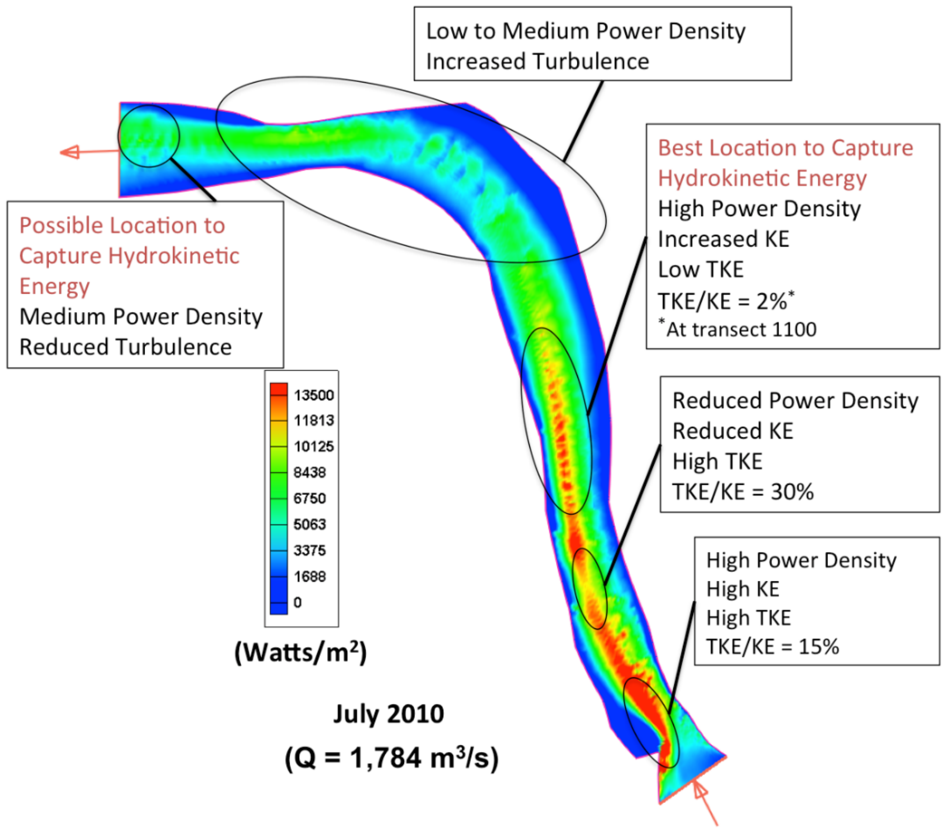


Figure 11. Modeled power density. Source: figure modified from Duvoy, P., & Toniolo, H. (2012). HYDROKAL: a module for in-stream hydrokinetic resource assessment. Computers & Geosciences, 39, 171-181.

Floating and submerged debris are also an important factor at the Tanana River Test Site. The River Debris Diversion Platform, described below, helps mitigate debris for equipment deployed from the research barge. Debris prevalence tends to be highest during periods of rising water levels as accumulated debris are floated into the river and bank erosion occurs. Data from a study of river debris in 2011 are presented in Figure 12. Load cell data on the RDDP mooring line have recorded peak impulse loadings of less than 2,000 lbf and peak continuous drag loads due to snagged trees of up to 6,000 lbf for durations of minutes to hours.

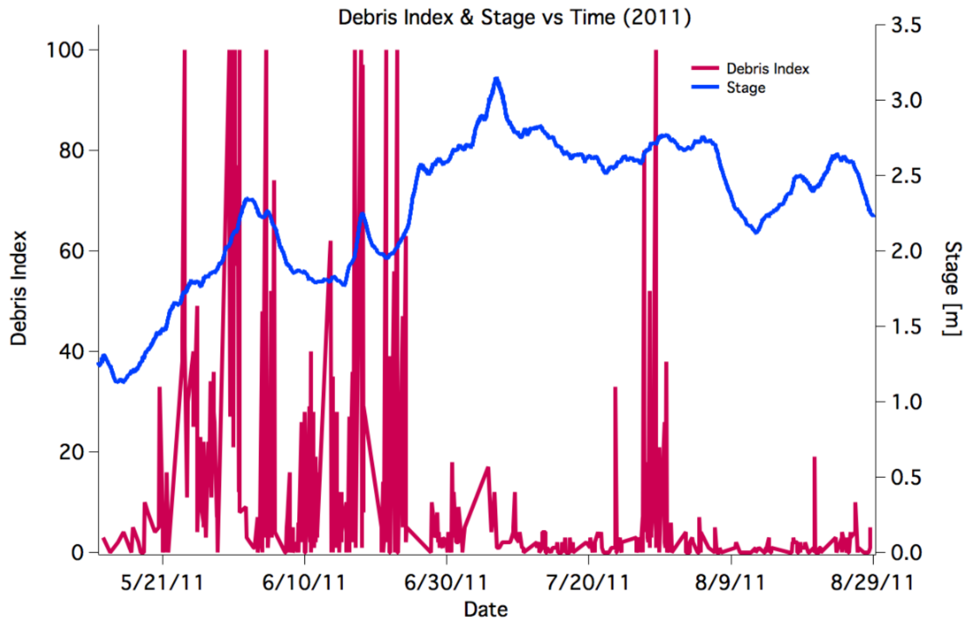


Figure 12. Debris incidence during 2011 field season. Source: Johnson, J. B., Schmid, J., Kasper, J., Seitz, A. C., & Duvoy, P. (2014). Protection of In-River Hydrokinetic Power-Generating Devices from Surface Debris in Alaskan Rivers. Fairbanks, Alaska, University of Alaska, Fairbanks: 61.

Test Site Infrastructure

The TRTS is an easily accessible site, providing a valuable opportunity to test and develop systems under realistic deployment conditions.

On shore infrastructure

Equipment for moving and transporting large and/or heavy equipment is limited to locally available assets including an extending forklift and a front-end loader equipped with forks. Device manufacturers seeking to test here need to plan ahead to successfully test at the site. Note, these conditions are similar to what developers will encounter in rural Alaska.

Limited office space in an ATCO-type portable building is available on the river bank adjacent to the barge mooring point. There are two shipping containers on-site for temporary storage of equipment. Three phase, 208V electrical service is available on-site as are other limited amenities (an outhouse, low bandwidth/cellular based internet access). Aside from what can be easily transported to the site by personal vehicles, there is currently no treated water available at the site.

On water infrastructure

The on-the-water testing infrastructure is all moored to a single permanent anchor as shown in Figure 12. From the lead buoy, the Research Debris Diversion Platform (RDDP) is the first floating component downstream. The Research Barge is connected behind the RDDP and is the platform from which turbines are deployed and retrieved. The barge includes a data collection shelter and a hydraulic winch system. The inclined plane fish trap is deployed immediately behind the Research Barge to comply with fish monitoring requirements. An overhead view of the RDDP, Research Barge, and inclined plane fish trap is shown in Figure 14.

Two powered boats are available on site for transporting personnel and assets (including pushing the barge) to and from the mid-river mooring site; a ~26 ft. Munson equipped with a 90 hp outboard with a low-pitch prop and a ~25 ft. jon boat equipped with 50 hp outboard. A third power boat is also typically on-site during testing to support mandatory fish monitoring.

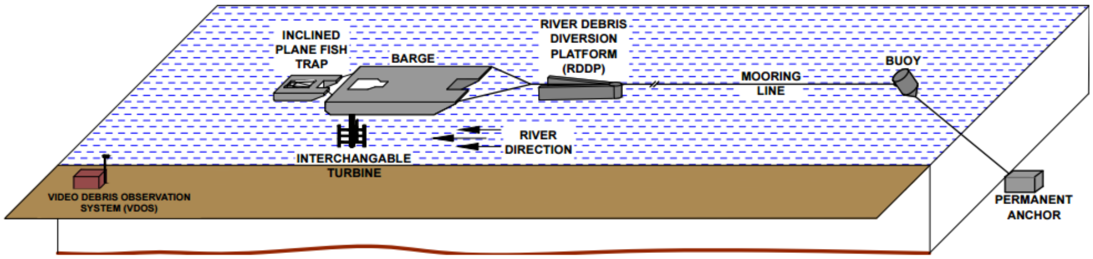


Figure 13. Schematic of TRTS turbine testing assets.

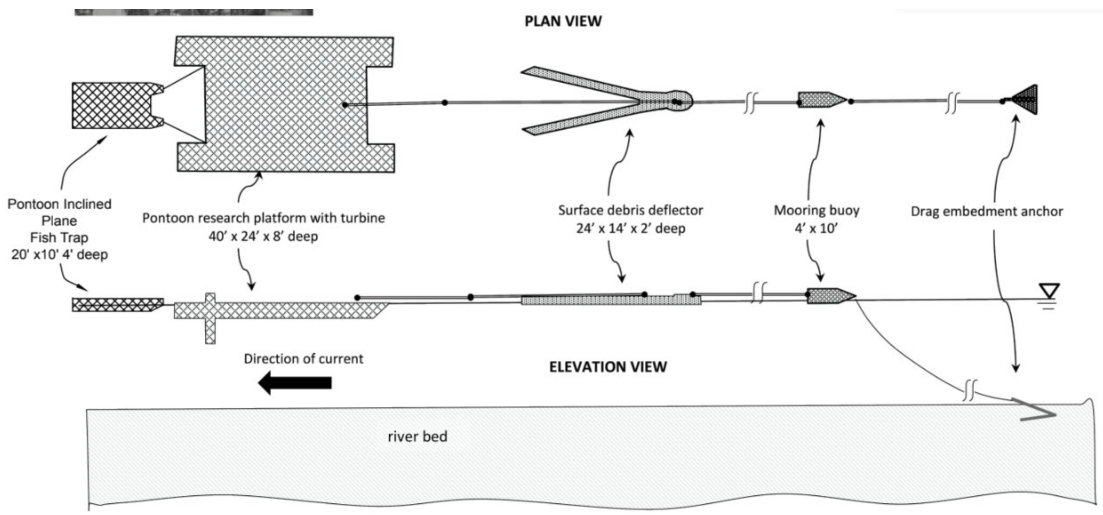


Figure 14. Plan and elevation views of TRTS infrastructure.

Figure 15. Overhead view of RDDP, Research Barge, and Inclined Plane Fish Trap.

The River Debris Diversion Platform (RDDP), depicted in Figure 15, is approximately 30' x 20' x 1.5' (length x width of widest opening x approximate submerged keel depth). The RDDP width is adjustable from between 14' to as narrow as ~3'. The RDDP is expected to be replaced with an upgraded system in 2021.

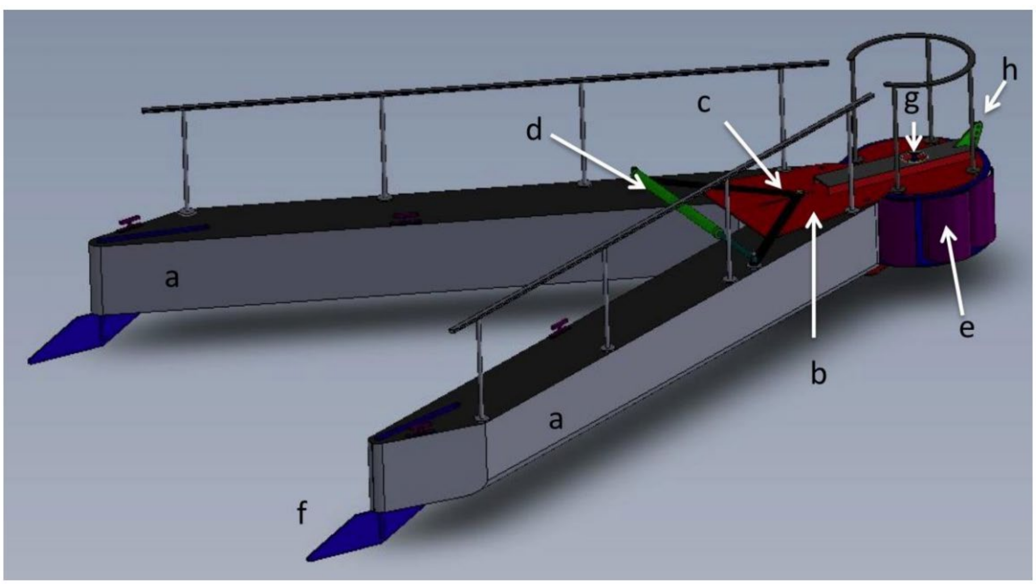


Figure 7. Research debris diversion platform showing the various components including the pontoons (a), the connecting plate between the sweeper and pontoons (b), the reinforcing U-bracket and centering bars (c), the hydraulic ram (d), debris sweep with hinged vanes (e), rudders (f), debris sweep axel head nut (g), and mooring attachment point (h).

Figure 16. CAD depiction of RDDP

The TRTS Research Barge can accommodate a payload up to 8,000 lbs (turbine + electronics + instrumentation, research staff and misc. equipment) while the anchor system can accommodate up to 45,900 lbf (force of debris impacts + hydrodynamic drag on the RDDP, barge, etc). The force acting on the RDDP, barge and any monitoring equipment due to hydrodynamic drag is typically on the order of ~600 lbf. There is no grid connection on the barge, moored in mid-river, and generator power output is limited by how much energy can be dissipated on site (e.g. using a load bank or other means).

The research barge from which hydrokinetic energy converters are typically mounted to is 40' x 24' x 5" (length x width x approximate submerged depth). As illustrated in Figure 16, there is a test section opening between the research barge pontoons through which turbines are typically mounted. The test section is approximately 111" wide and 144" long. Turbines may also be deployed from the stern of the Research Barge if necessary.

The research barge is equipped with a mobile hydraulic unit and three hydraulic winches rated between 2,000 lbs and 10,000 lbs. A shelter to house data collection and other electronics is visible on the starboard side in Figure 14.

Description of test equipment used during field data collection.

Velocity data are collected during field testing using both ADCP (50cm beam) and ADV instruments. These instruments can be deployed statically from the Research Barge or can be deployed from motor boat for transect measurements.

Campbell Scientific CR1000 and CR6 data loggers are available to capture data from MHK system specific sensors and can be configured for all standard sensor voltage, current, and pulse outputs.

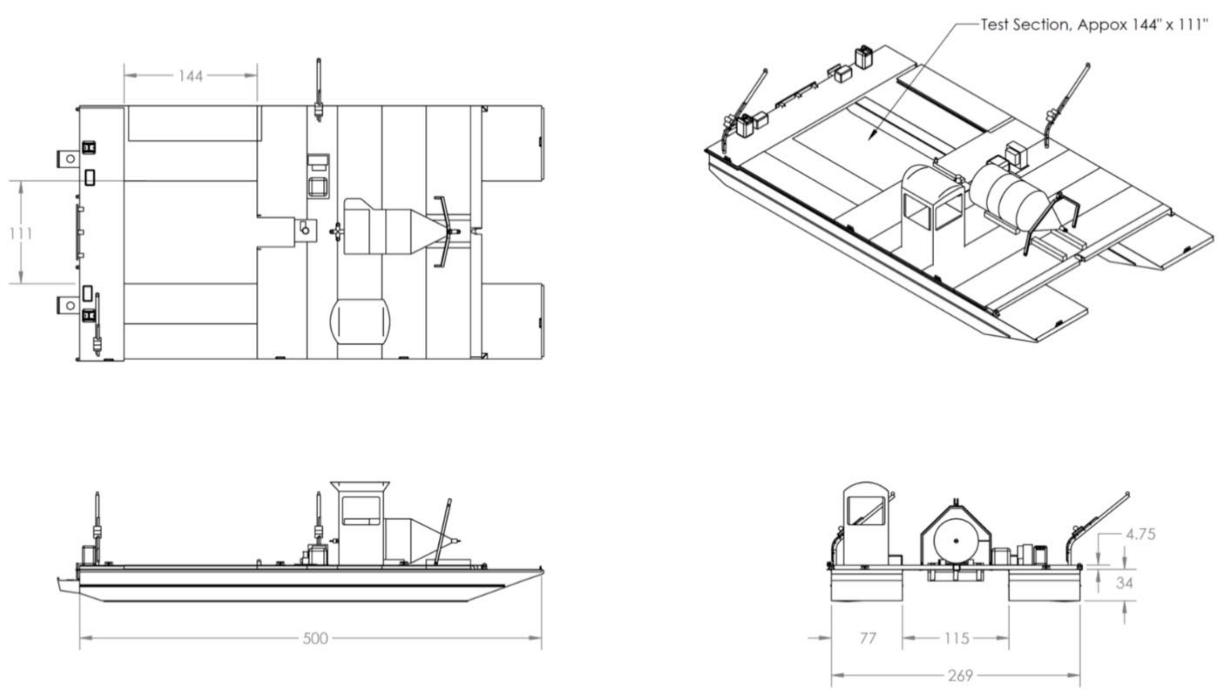


Figure 17. Nominal Research Barge dimensions. Deployment of larger systems off the stern of the barge is also possible.