Quarterly Progress Report
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Period of Report:	July 2012, through September 2012.

Introduction

The debris mitigation project goals are to:

(1) Develop a test debris mitigation platform that will allow us to test various debris mitigation technologies and methods. (completed)
(2) Prepare the Nenana test site infrastructure (e.g., anchoring/mooring system) to be able to accommodate the debris mitigation platform tests (completed) and possibly retest the New Energy Turbine, as appropriate (Cost estimates to refurbish the New Energy Turbine and our work on debris testing indicates that it is beyond the scope of this project retest the turbine as part of this project).
(3) Obtain necessary permits and conduct the necessary baseline studies to prepare for the debris mitigation testing. (completed)
(4) Conduct the debris mitigation technology and debris management methods testing (completed).

Note: With all major tasks of the project completed we are now analyzing data with the intention of completing project reports and providing recommendations on debris mitigation technology and methods.

Refer to previous quarterly reports for a general description of the project and activities to-date. Previous quarterly reports were submitted on 10/15/2011, 1/16/2012, 4/3/2012, and 7/24/2012.

Activities and Progress

During June and late July the Research Debris Diversion Platform (RDDP) was deployed at the Tanana River Test Site (TRTS) at Nenana. A shore mounted time-lapse camera system was installed to observe surface debris in the river along with pressure sensors to measure river stage. . Forward and aft looking time lapse cameras were mounted on the RDDP to provide a video record of RDDP/debris interactions. Videos of the tests were also taken from an observer boat holding parallel to the debris and RDD). River current velocity was measured both with and without the RDDP being deployed at the TRTS. These measurements were made to analyze the effect of the RDDP and the mooring buoy

on water flow conditions that could affect the performance of a hydrokinetic turbine mounted behind the RDDP.

The RDDP was attached to a mooring buoy by a line that ran parallel to the surface of the water (Figure 1). The mooring buoy was connected to an anchor set into the riverbed. This system was designed to minimize the number lines exposed to either surface or subsurface debris. Only the anchor line that runs from the riverbed to the mooring buoy is directly exposed to intercepting debris in the river. In two years of use, there have been few instances of debris becoming caught on the buoy system. In each instance the debris eventually self-cleared or was easily cleared. The dynamic motion of the buoy in the current appears to dislodge most debris over time.

Tests to determine the effectiveness of the mooring buoy and the RDDP to divert debris were conducted in late July by collecting woody debris of different types and directing them separately into the buoy and RDDP. River discharge was about 70,000 cubic ft. per second and the gauge height was around 19 ft. during the testing period. For comparison, the mean high water discharge is around 60,000 cubic ft. per second and flood stage gauge height is about 12.2 ft. This means that our tests were conducted at fairly high water discharge and current velocities that provided a severe test of the RDDP to deal with debris. While the analysis of the data is currently in progress, as our field season has just ended, we have already learned a great deal about what works and what does not work for debris diversion methods and where and when debris exists in the water at the TSTS.

Tests of the RDDP consisted of directing straight and twisted logs (without branches), trees (with branches) and small leafy branches into the front of the RDDP. The logs and trees were configured to impact the mooring buoy and RDDP crosswise to the current. This produces the most severe impact forces and difficulty in diverting the path of the debris (Figure 2). Tests were conducted with two different RDDP noses: a solid angle piece covered with high density plastic and a cylindrical nose that was free to turn. The purpose of the fins was to cause the cylinder to turn, thus, preventing the accumulation of small debris in the backwash in front of the cylinder. The cylindrical nose was tested with three different configurations: (1) fins that deployed in one direction around the cylinder to use the water current to turn the cylinder, (2) pinning the fins such that they did not deploy (reducing the rate of cylinder rotations) and (3) with the pinned fins covered with a high-density plastic and no rotation of the cylinder due to river current. The high density plastic provided a low friction surface to any debris in contact while the fins dug into the debris holding it on the cylinder. The cylindrical nose with exposed fins is shown in Figure 3. The cylindrical nose with the fins covered by plastic sitting alongside the fixed angle plastic covered nose is shown in Figure 4.

The RDDP performance tests indicated that all three cylindrical nose configurations were more effective at diverting debris than the solid angle. When the cylinder was used with deployed fins and pinned fins some debris would become torque balanced on the front of the RDDP. Torque balance is the condition where the torque exerted on the cylinder by the force of water flow against the debris does not cause the cylinder to turn with the

result that the RDDP will not clear debris. Preliminary analysis indicates that this occurs because the fins dig into the debris holding it on the cylinder and the turbulence of the river current causes the torque from the debris to alternate between clockwise and counterclockwise with a frequency that is too fast to overcome the inertia of the cylinder. As a result, the cylinder oscillates back and forth rather than spinning in one direction to clear the debris.

Torque balancing did not occur when plastic was used to cover the cylinder. The plastic provides a low friction surface that allows debris to slide on its surface even when the cylinder is not turning. As a result, the torque exerted by the log can cause the log to rotate without the need to overcome the cylinder's inertia (because the debris can slide over the plastic without the cylinder turning). Once the debris starts sliding on the cylinder it then begins to turn, further facilitating diversion of the debris.

Tests also demonstrated that debris in contact with the RDDP starts to roll in the upstream direction due torque from water flowing under the debris; debris with branches exhibit a stronger torque as the leaves and branches provide more surface area on which the flowing water acts. This rolling motion can result in twisted logs, trees with branches, and larger diameter logs to roll under the RDDP and either hang up under the RDDP or continue along its original path rather than being diverted. This indicates that the depth of the RDDP in the water (which was only about 12 in (0.3 m)) needs to be increased to prevent debris from rolling underneath the front cylinder and pontoons.

Since the primary purpose the RDDP is to divert debris around a hydrokinetic device it is important to know how rapidly debris fills in behind the RDDP after clearing the diversion pontoons. To examine this qualitatively we released weighted sealed plastic tubes in a line in front of the buoy/RDDP system and observed their path in the flow behind the RDDP. We also observed the flow paths of diverted logs and branches with leaves. From these observations, we conclude that the RDDP produces a turbulence induced vortex curl at the end of the diversion pontoons. The vortex curl acts on low inertia debris, such as the plastic tubes, to pull them quickly into the flow behind the RDDP when they slide off the end of the diversion pontoons. The vortex curl behind the RDDP less affects high-inertia debris and branches than the low inertia plastic tubes. The flow path behind the RDDP can remain clear of debris for tens of meters (intermediate sized debris) to hundreds of meters (for large sized debris) before natural river drift of debris begins to move into the flow behind the RDDP.

The features of the cylinder front end on the RDDP that help with debris removal are:

- The cylinder's large diameter reduces the likelihood that branches, root balls, or mixed debris can span the front of the RDDP to hang up (this is a significant problem for solid angle front ends).
- The cylinder turns in the direction of torque applied by debris to clear debris.
- Debris can slide off of the low friction plastic.
- Inducing cylinder rotation using river current prevents the accumulation of small debris in a dead flow zone in front of the RDDP.

- The possibility exists to motorize the cylindrical nose if a torque balance conditions occurs to facilitate clearing debris that does not self-clear.

In addition to tests where debris was intentionally guided into the RDDP, we left the RDDP deployed unattended behind the buoy throughout the summer. The RDDP load cell that was attached to the mooring line recorded a number of "hits" (high load events) indicating that debris impacted the RDDP, with no adverse effect to the RDDP.

Debris tests were also conducted on the mooring buoy to which the RDDP was attached. In one test, a very large spruce tree hung up on the buoy bending downstream until in broke in two pieces. Other trees that impacted the buoy were deflected by the buoy or reoriented to flow with their long axis parallel to the current. Thus the buoy acted as a first level of debris protection by causing debris to be oriented such that it would either miss the RDDP or impact it end on, which is easier to deflect than when the debris impacts crosswise to the RDDP.

A preliminary examination of river current velocities behind the RDDP and mooring buoy indicate that the presence of the mooring buoy and RDDP create reduced flow velocities behind them that may affect the efficiencies of hydrokinetic turbines in converting river kinetic energy into electricity. Quantitative assessment of the effect of the RDDP and buoy on water flow hydrodynamics will need to wait for our analysis of the summer 2012 current velocity data. Actual assessment of how such RDDP generated turbulence affects hydrokinetic device performance will require testing using a hydrokinetic device that can be placed behind the RDDP.

We know from the experiences of the hydrokinetic demonstration projects at Eagle, Ruby, and Ft. Simpson during summer 2010 that debris can exist at any depth in the water column. Additionally, observations at the TRTS during 2012 also indicated that debris can be present both on and under the surface of the river at any location across the width of the river. For example, a subsurface small tree was pulled up with our anchor recovery line and another small tree rode up the anchor chain to the mooring buoy. We also used a high-resolution sonar (Blueview) to observe underwater stationary debris. Observing moving debris is much more difficult than static debris since the time of observation is very short and the heavy silt in the river creates scattering noise in the sonar beam. To adequately characterize subsurface debris, a combination of mechanical capture/detection of debris and blueview monitoring of the debris that pile up against the capture mechanisms may be necessary.

Observation of surface debris (personal observation and observations from our time-lapse debris monitoring system) indicate that debris location in the river is affected by the mass, buoyancy and type of debris. River channel cross section shape and the shape of the reach of the river (river bends and straight sections) can also affect how debris moves downriver and changes its location in the current flow. Debris amount generally increases with river stage. During the heavy rains at the end of September the Tanana River stage increased to very high levels (in excess of 10 cubic ft. before the gauge stopped

measuring, we have not analyzed our pressure sensor gauge data yet) producing extensive surface and subsurface debris. In some instances subsurface debris was observed to come to the surface in river boils and then sink under the surface again as the boil dissipated (Holmgren, personal communication). The mooring buoy floatation during normal high-velocity summertime flow and during the late Sept. 2012 flood stage flow is shown in Figure 5.

Planned activities for the next quarter

During the next quarter we will close down the TRTS removing the RDDP and buoy for the winter. Both the RDDP and buoy will be moved to Fairbanks. We will also start analysis of data in preparation for reporting and to provide recommendations for debris mitigation technology, methods, and future work to further improve mitigation methods and technology.

Figures

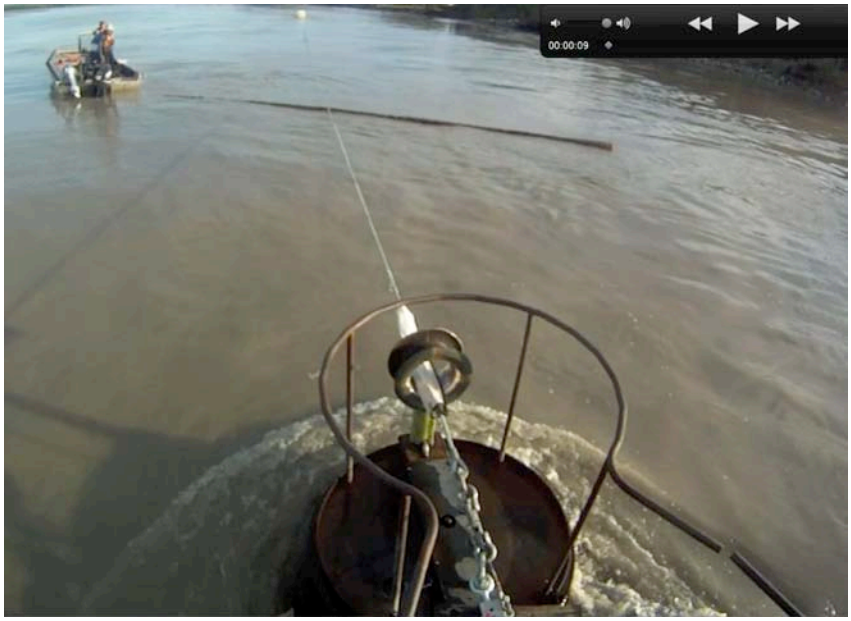

Figure 1. A debris impact test on the RDDP. The mooring line runs from the mooring buoy (in the distance) to the front of the RDDP.

Figure 2. Sequence of pictures of a debris impact test on the RDDP: just prior to debris impact (a); immediately upon impact of the cylindrical nose of the RDDP (b); debris sliding on the cylindrical nose after impact (c); debris sliding along the RDDP lateral pontoon after the debris cleared the nose (d); debris clearing the pontoon (e); debris clearing the RDDP (f). The cylinder nose for this test was covered with high density plastic.

Figure 3. RDDP cylindrical nose with unpinned fins.

Figure 4. RDDP forward frame (background) with plastic covered cylindrical nose (forward-right) and fixed angle plastic covered nose (forward-center).

a b

Figure 5. Mooring buoy floatation during midsummer high-water stage flow at the TRTS (a), and during the late Sept. 2012 flood stage flow (b).