Guayaramerin-Porto Velho Reservoir Reach Hydrodynamics and Sediment Transport: Field Report

Trey Crouch, PhD Student, Environmental Engineering Sciences Dept., University of Florida

Landerlei Almeida Santos, PhD student, Institute of Geosciences and Exact Sciences, Universidade Estadual Paulista

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Abstract:

Sedimentation behind “run-of-the-river" (ROR) dams is expected to be limited and quickly stabilized because of the preserved energy gradient available to move sediment through these systems. However, this assumption may not hold for large, seasonal rivers with high sediment loads. For example, the environmental licensing process for the Madeira Hydroelectric Complex (MHC) in Brazil used empirical methods and 1-dimensional hydro-sedimentological modelling to estimate low sedimentation rates upstream from the in-series Jirau and Santo Antonio dams. However, third party reviews of the Environmental Impact Assessment (EIA) concluded that these estimates lacked a physical basis and rigorous uncertainty analysis. A recent observational study, based on field-calibrated remote sensing of surface suspended sediment concentration (SSSC), demonstrated that the MHC reservoirs are trapping at least 20% of surface suspended sediment, but this study only used a two-year post-dam period to draw this conclusion. All of the above confirm that a more detailed and holistic analysis is needed to estimate the impacts of the MHC and other ROR dams on sediment transport. Here, we report the results of a field-based data collection and modeling study that complements information from the EIA and the French Research Institute of Development’s HYBAM program. The field campaign included surveys of flow, sediment, bed morphology, and sedimentation since flooding of the Jirau reservoir in 2013. Acoustic Doppler Current Profiler (ADCP) surveyed cross-sections were compared against cross-sections and sedimentation estimates from the EIA. From these comparisons, we expect to show that more sedimentation has taken place in the reservoir and further upstream compared to the EIA’s predicted “direct area of impact”. We also predict that bed material, SSSC, and integrated suspended sediment samples will suggest sedimentation rates of coarse and fine sands higher than those predicted in the EIA. Results from this study will be used, along with additional pre- and post-dam, multidimensional hydraulic and sediment transport modeling and rigorous uncertainty analyses, to show that a more accurate estimate of sedimentation rates can be made with the same field effort.

Summary:

The following is a brief description of the May 2018 field campaign along the Mamore and Madeira Rivers between Guajara-mirin and Porto Velho, Rondonia, Brazil. A month was spent in Brazil, with 15 days on the Mamoré and Madeira Rivers. The fieldwork was in collaboration with UT Austin's Edgardo Latrubesse's lab (interested in the use of sediment samples to better correlate to remote sensing images mentioned above) and with the tremendous support of Dr. Carol Doria's Laboratório de Ictiologia e Pesca (Fish and Fisheries lab) at the Universidade Federal de Rondônia (UNIR). Tatiane Checchia, professor of hydrology at UNIR, and Fabio Carvalho, technician with Brazil's Geological Survey - CPRM, were also critical for lending their sediment sampling expertise and equipment. The Tinker Foundation funding was crucial to making this work possible. The following is a brief outline of what is included below:

1. Summary of data collected;
2. Summary of the sampling instruments;
3. Summary of general observations along the different river reaches;
4. Future Work

Field team from left: *Landerlei Santos, Roberval Ribeiro, Trey Crouch, Fabio Carvalho*

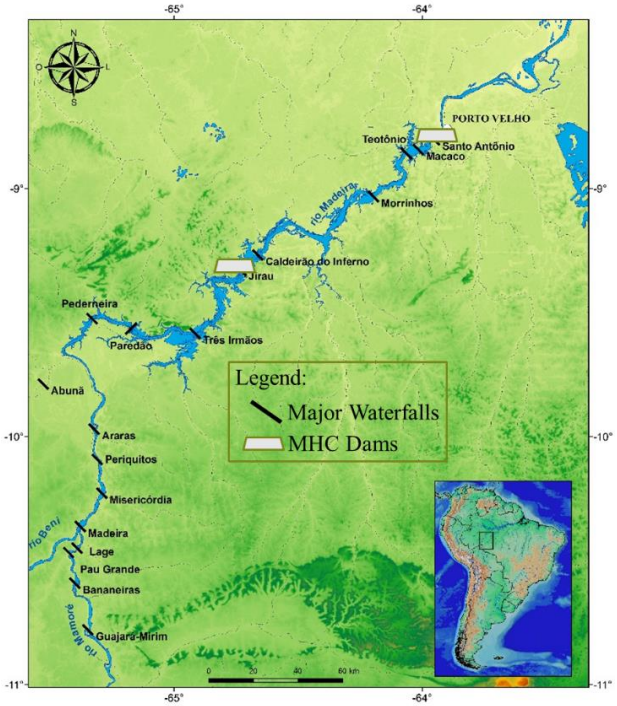


Figure *– Map showing the location of the Madeira Hydroelectric Complex (MHC) dam locations.*

Data Collected:

During the 14-day campaign we collected the following, up and downstream of the dams, for explicitly comparing cross-sections and hydraulic and sediment transport modeling purposes.

1. **33 ADCP cross-sections** for discharge and channel geometry (see below example figure of preliminary data);

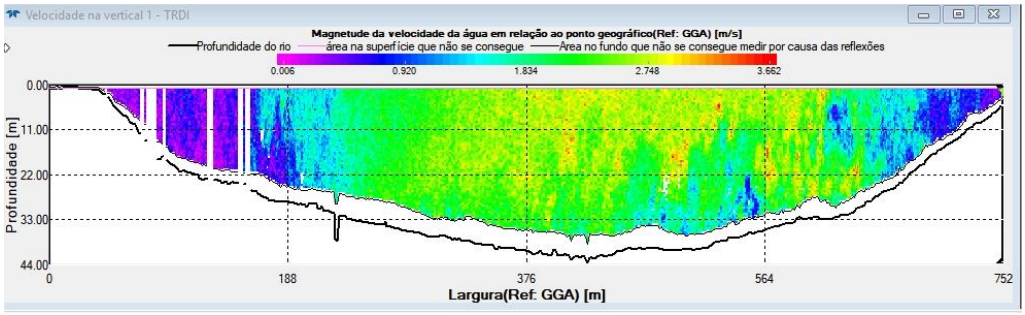


***Figure** - Example ADCP data used for velocity, discharge, and channel geometry data.*

2. **7 longitudinal ADCP profiles;**
3. 2-4 surface sediment **grab samples** at 24 different cross-sections - **76 in total** - with 500ml water bottles
4. **17 bulk samples** of surface sediment with a 12L bucket;
5. **point samples** at 3 depths were collected at 8 of 24 sampled sections, **25 in total**;
6. **2 depth-integrated** sampling (with AMS-8) both at official ANA stations.
   i. upstream of the reservoirs near the town of Abuna,
   ii. downstream of the reservoirs near Porto Velho
7. **16 samples of bottom material** up, between, and downstream of the dams

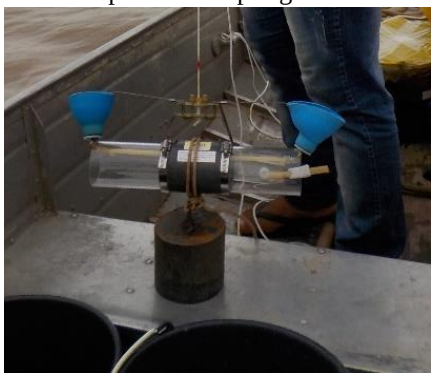
Sampling Methodology

Before embarking on the field exhibition, we came up with a sampling protocol based on the borrowed equipment and planned methodologies. Arriving in Porto Velho, we had the following for sampling purposes (see accompanying photos of equipment):

1. Rio Grande 600khz ADCP profiler, which uses the Doppler effect of sound waves scattered back from particles in the water to measure velocities and channel geometry. The instrument was fastened to an Oceanscience Group Riverboat:

Two personal laptops and a trimble GPS were connected to the ADCP for navigation and data acquisition.

2. Point sampler for sampling sediment at different depths in the water column *(1L LaMotte model JT-1)*



3. 2 Handheld GARMIN GPS;
4. Rangefinder for estimating bank and riparian vegetation height;
5. Depth finder for bottom sampling;
6. Make-shift bottom material and bedload sampler using a sock, funnel and weight.

After coordinating with Tatiane Checchia, Professor of Hydrology with the Geography Department at UNIR, we arranged with a technician from the Brazilian Geological Service (*CPRM*), Fabio Carvalho, to come with us on the 14-day exhibition. We also hired an experienced boatman, Roberval Ribeiro, who we contacted through our institutional partner Dr. Carol Doria, professor of Biology at UNIR. Fabio Carvalho helped us arrange the rental of the 10 ft. aluminum boat, trailer, and car for the trip and we borrowed the following equipment from *CPRM* for sampling purposes:

7. USBM-54 (AMF-1) Bottom material sampler and 5L AMS-8 collapsible bag depth-integrating sampler with manual winch (~30 m cable).



General Observations

The following is short summary of a few major observation made during the campaign. Detailed observations were made in notebooks, with photos, and described in the metadata report.

Potential for implementing USGS continuous sediment sampling: There are definitely possibilities for the use of acoustic techniques for continuous sediment measurements on the Madeira now that a second bridge at the Abuna, RO ferry is being built, making it possible to monitor both up- and downstream of the dams. The commitment and security logistics, of course, would have to come from Brazilian colleagues. This is the hard part, as I heard from the many hours I had in conversations with the other Brazilian PhD student of Dr. Latrubesse, Landerlei Santos, and the CPRM technician, Fabio Carvalho. Fabio also talked about his experience with other USGS consultants, Bill Hazell and others in 2015. He mentioned the trouble ANA and CPRM have had keeping telemetered water and meteorological stations maintained and working in Rondonia.

Gold dredging: It is quite the operation the "garimpeiro" gold-miners have going, with hundreds, if not thousands of these dredging along the Madeira River and its tributaries (see below photos, these are two story homes on small barges with dredging capabilities up to 40m). Some are informal, illegal operations. Talking with numerous former fisherman, we were told that many people have moved to gold-mining as a supplementary income source, now that catch numbers have changed in the area. This activity is sure to change bed-forms (that could be used to estimate sediment bedload) and local suspended sediment concentrations.


Future Work:

Now that samples and ADCP data has been collected, the following is what needs to be done in the next year to get out results (in form of a publication).

1. Process ADCP data into georeferenced modeling format
2. Extrapolate above cross-sections to bankfill level based on field observations and photos
3. Interpolate between sections based on previously surveyed cross-sections.
4. Dam reach model selection.
5. Lab analysis of sediment samples
6. Selection of model input data.

The following is a short list of work that could be done to complement the above.

7. Considering the recession period that we sampled (May 2018), it would be interesting to sample on the rising end of the hydrograph as well as during its peak and lowest points.

8. As suggested by Dr. Latrubesse, it would be interesting to take some cores for Pb210 analysis to demonstrate some “excessive” sedimentation in secondary circulation-backwater zones identified by geophysics and remote sensing.
9. Classify changes in riparian vegetation using remote sensing images based on in-field observations.