

RECLAMATION

Managing Water in the West

Measuring the Transport of Sediment in an Ephemeral Stream

Research and Development Office
Science and Technology Program
(Final Report) ST-2017-9781-01



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Bureau of Reclamation
Research and Development Office

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Mission Statements

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The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Measuring the Transport of Sediment in an Ephemeral Stream

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Acknowledgements

The author is indebted to all project partners and stakeholders discussed in this report. However, two individuals deserve additional recognition for their involvement on this project; Dr. Jonathan Laronne and Robert Padilla.

Dr. Laronne is one of the preeminent researchers in the field of sediment transport in ephemeral streams, and his involvement in the project allowed us to hit the ground running, such that this research site did not have to reinvent the wheel. The project is grateful for all of Dr. Laronne's input, guidance, and effort.

Mr. Padilla has been supportive of this project from the beginning. His support has ensured that this project has continued to move forward and get to construction. Many obstacles presented themselves, and any one of them could have shut this project down. Mr. Padilla remained unflinching in his resolve and made certain that this project became a reality.

Acronyms and Abbreviations

AAO – Albuquerque Area Office

BGU – Ben Gurion University of the Negev

CNRS – Centre national de la recherche scientifique (National Center for Scientific Research; France)

DEES – Department of Earth and Environmental Science

GFZ – GeoForschungsZentrum (Geo-research Centre; Germany)

GSD – grain size distribution

IRIS – Incorporated Research Institutions for Seismology

LSPIV – large scale particle image velocimetry

NMIMT – New Mexico Institute of Mining and Technology

R&D – Research and Development

S&T – Science and Technology

SfM – Structure from Motion

UAV – unmanned aerial vehicle

USGS – United State Geological Survey

Executive Summary

There currently is no reliable, cost-effective way to quantify the volume and size gradation of sediment being delivered to a river by ephemeral tributaries during storm events. Volumetric flow rates of water and sediment shape the morphology of a river. The successful design of in-stream or streamside structures (e.g. water delivery features, erosion revetments) requires knowledge of channel morphology and its anticipated changes, therefore requiring reasonably accurate estimates of sediment delivery rates. When a river system has a significant number of ephemeral tributaries, sediment delivery to that river will be discontinuous, highly variable, and will likely cause significant morphological changes in a relatively short period of time.

There is a paucity of sediment transport data in ephemeral streams, leading to high levels of uncertainty associated with prediction or estimation of sediment fluxes. Primary reasons for this lack of sediment flux data is that: 1) ephemeral stream runoff events are driven by localized, short lived monsoonal rainstorms, making it difficult to reach and measure before the storm is over; 2) the typically intense nature of the storms can create safety concerns for those attempting to make measurements; and 3) storm events tend to cause quickly varying flow rates, such that it is difficult to specify the hydraulic conditions that are associated with the sediment measurements being made.

This research project is envisioned as a small portion of a larger multi-stage approach to providing practitioners the tools they need in order to quantify the volume and size gradation of sediment being delivered by ephemeral tributaries. One ephemeral stream was selected in Socorro County, New Mexico, that delivers flow and sediment to the Rio Grande during localized rainfall events. A world-class research facility has been designed and will be available to begin data collection in the fall of 2017. The research site will collect physical sediment samples, record data from surrogate technologies, as well as collect other hydraulic and hydrologic data. After multiple storm events have been monitored and data collected, a relationship between the physical measurements and surrogate signals will be developed, with the aim of being able to deploy the more cost-effective surrogate technology in other ephemeral tributaries to reduce the level of uncertainty on sediment flux estimates.

The research site will be ready for data collection in the fall of 2017. Data collection will commence with rainstorm events, and then data analysis and synthesis may begin. This research site should operate for at least a decade in order to provide the data necessary to meet the long term goals as well as ensuring that the initial investment has an acceptable benefit-cost ratio.

The partnerships that have developed around this research site include the Albuquerque Area Office (Reclamation), New Mexico Institute of Mining and Technology, local landowners, Ben Gurion University of the Negev, Rishin Hydrotech, Yamma & Ayyeka Companies, GFZ German Research Center for Geosciences, University of Grenoble Institute of Environmental Sciences / CNRS, Incorporated Research Institutions for Seismology, United States Geological Survey, U.S. Army Corps of Engineers, and the New Mexico Bureau of Geology.

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Introduction

River processes and resultant channel form are a response to the water and sediment supplied from the drainage basin. Quantification of water and sediment volume are necessary to understand river morphology. Extensive effort has been applied to quantifying water and sediment flux in perennial streams. This level of effort is not mirrored for ephemeral streams, which make up a large percentage of tributary systems in the arid Southwest. The southwestern U.S. also makes up a significant portion of Reclamation's jurisdiction.

Direct measurements of sediment delivery rates from ephemeral streams are difficult, if not impossible, due to safety concerns and the flashiness of flow events. Typical methods to estimate sediment delivery include using a soil loss equation for the wash load and a transport function for the bed material load. These methods tend to have a large amount of uncertainty associated with them, especially when taking into consideration that transport functions are based largely on empirical data from perennial systems.

This project partially funded the design and construction of a research site where both direct and surrogate measurements of sediment transport will be made. Data collection and analysis will be completed in the coming years and will help determine the relationship between surrogate and definitive sediment transport measurements. These will enable (1) determining the total sediment discharges in flashy conditions at the site and (2) the calibration of the unmanned indirect sensors to assess their potential use in other tributaries. These will ultimately serve to determine the method to predict bedload and suspended sediment loads under low discharge and flashflood conditions of tributaries in the arid Southwest.

This specific research project funded by Reclamation's Research and Development (R&D) Office is only a small part of the entire research project. Later sections will describe the work completed on this project by other project partners and stakeholders, funded outside of the R&D Office funding.

Background

A scoping proposal (literature review) was funded by the R&D Office as part of the FY13 Science and Technology (S&T) Program (project ID 2180). The result of this scoping proposal was a report discussing the existing literature on the topic, as well as an initial conceptual design of a research facility. A subsequent conducting proposal was submitted in FY14 for consideration as a 3-year project from FY15-FY17. This three year project (ID 9781) was funded and supported site selection, preliminary data collection, funding to a university for their support and assistance in project design (and partial funding of graduate student), acquisition of all instruments and sensors, ensuring functional data collection and recording from all sensors and instruments, and meetings with collaborators, stakeholders, and project partners.

The research questions stated for Project ID 9781 are:

Can a set of surrogate measurements be collected coincident with a definitive (physical) measurement of sediment flux in an ephemeral channel that will help

establish a relationship between surrogate data and sediment flux? What set of surrogate measurements needs to be collected in order to develop a relationship between surrogate data and definitive sediment flux? How do flow conditions affect the ratio of suspended load to bedload?

Site Description

The Arroyo de los Piños near Socorro, NM, has been selected as the research site. A location map of the site is presented in Figure 1. The drainage area is approximately 12.3 square miles with a watershed slope of 0.352 ft/ft (difference in maximum and minimum elevation within the watershed divided by watershed length). The arroyo drains the highlands east of the Rio Grande.

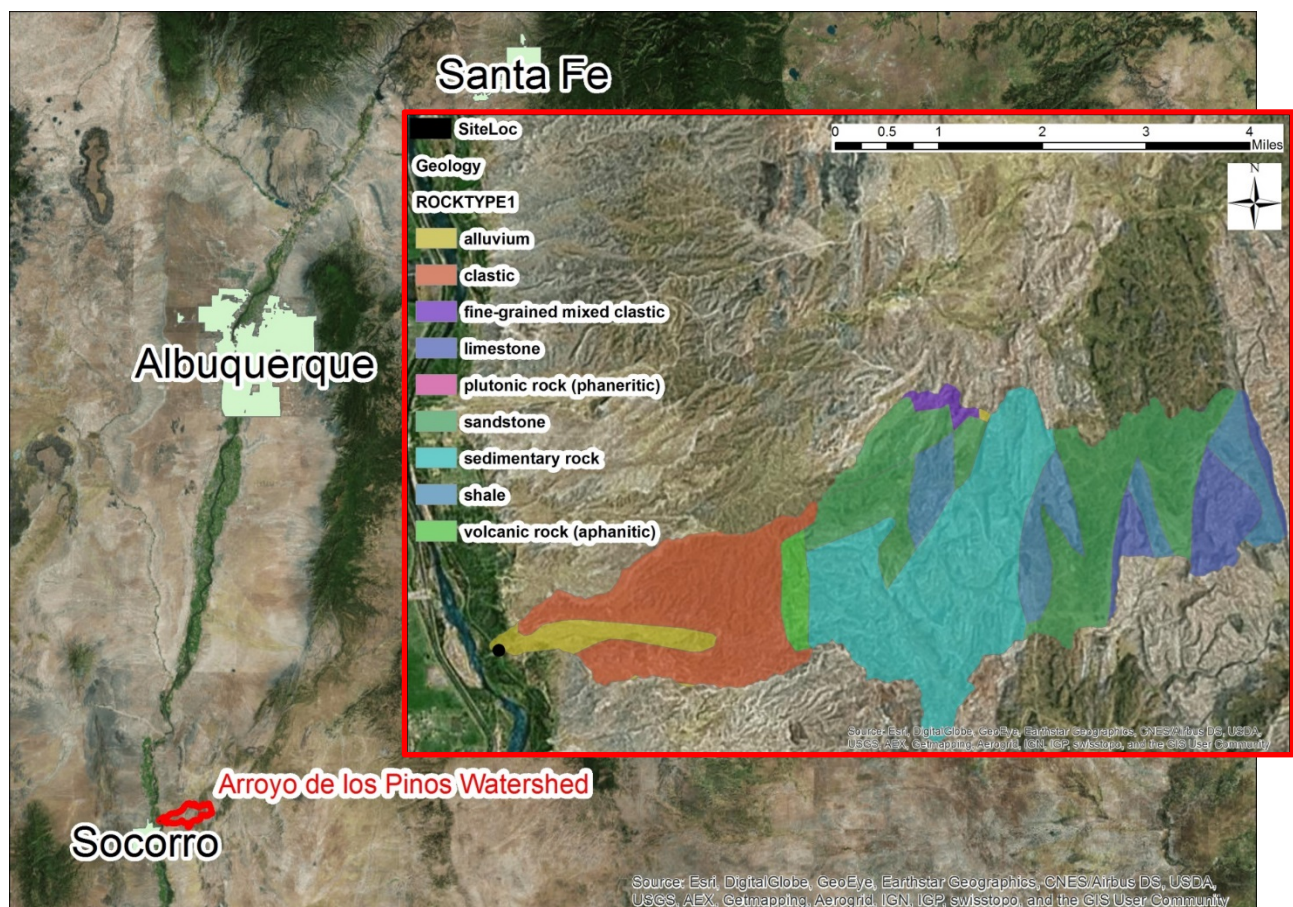


Figure 1. Location map of research site (indicated by the red polygon), along with an inset of drainage basin geology.

Preliminary Data Collection

The site selection occurred in the spring of 2015. In October 2014, a site visit was conducted by myself, representatives of Reclamation's Albuquerque Area Office (AAO), and Dr. Laronne of Ben Gurion University. During that site visit, 13 tributaries to the Rio Grande were visited and assessed for their potential as a research site. In the spring of 2015, three more sites were visited by Dr. Laronne and myself, and ultimately the Arroyo de los Piños was selected. Some preliminary data was collected in the spring of 2015, including an RTK-GPS survey of the arroyo and three sediment samples.

Geometric data

An RTK-GPS survey was conducted using Trimble survey gear. A local control point was established by driving a piece of rebar into soil and driving on a survey cap (Figure 2). This is not the most robust means of setting a control point, but this was intended to be temporary with the idea that a more permanent benchmark (set in concrete?) will be established when the instrumentation is installed.

An overview of the survey points collected on 31 March is presented in Figure 3. In general, the hollow circles are thalweg points, with a single thalweg identified through the study site, and two channels identified and surveyed upstream of the study site. The blue plus symbols are cross section surveys. The locations of the gabions were measured, along with the top and toe of the left and right banks being surveyed. The cross sections are numbered from 1 to 20 (downstream to upstream) and a culvert crosses under cross section 11.

Figure 4 presents a longitudinal profile of the arroyo, with 0 at the downstream end (on the alluvial fan at the Rio Grande's water's edge at the time of the survey) and stationing increasing in the upstream direction. In addition to the longitudinal (noted as thalweg) points (tw) being surveyed, the minimum elevation point from each cross section survey is included in the plot. The longitudinal and cross section minimum points tend to agree very well, with the exception of perhaps cross section 1. Reach slopes are presented in Figure 4, and in general the pattern (from upstream to downstream) is a relatively steep section where there are two channels (tw2 and tw3), a slightly less steep section upstream of the planned installation site (tw1.3), the steepest section through the planned installation site (tw1.2), and the flattest section downstream of the site where the channel becomes wider (tw 1.1). The planned installation will be discussed more in subsequent sections and will be approximately located at cross section 12 (~station 875 ft) in Figure 4.

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Figure 2. Base station set up over the control point for the RTK-GPS survey. Cap on control point is stamped "Pinos 1" and is located directly under the Trimble R8 receiver (pink flagging tied around rebar).

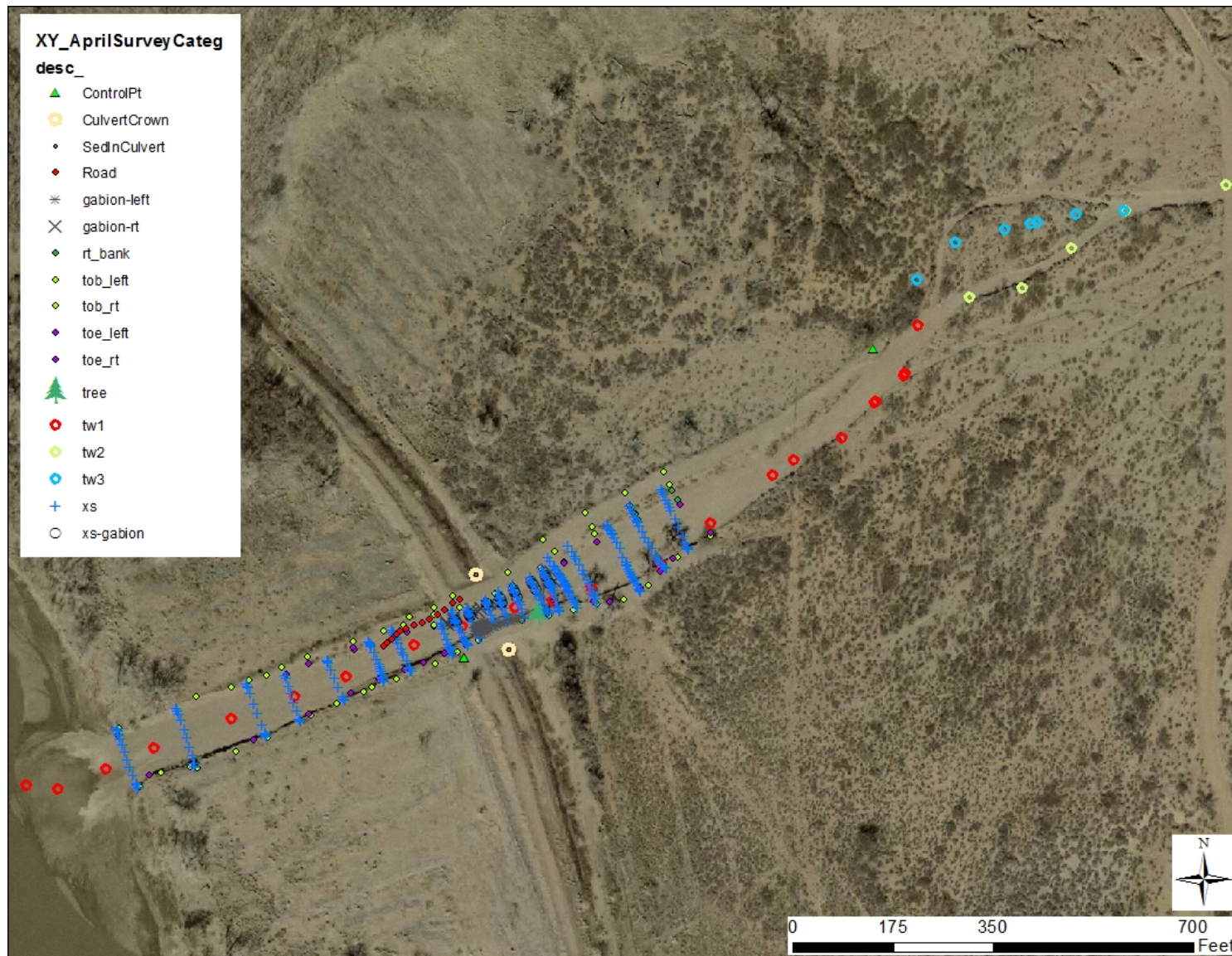


Figure 3. Plan view of all points surveyed during Spring 2015 data collection trip.

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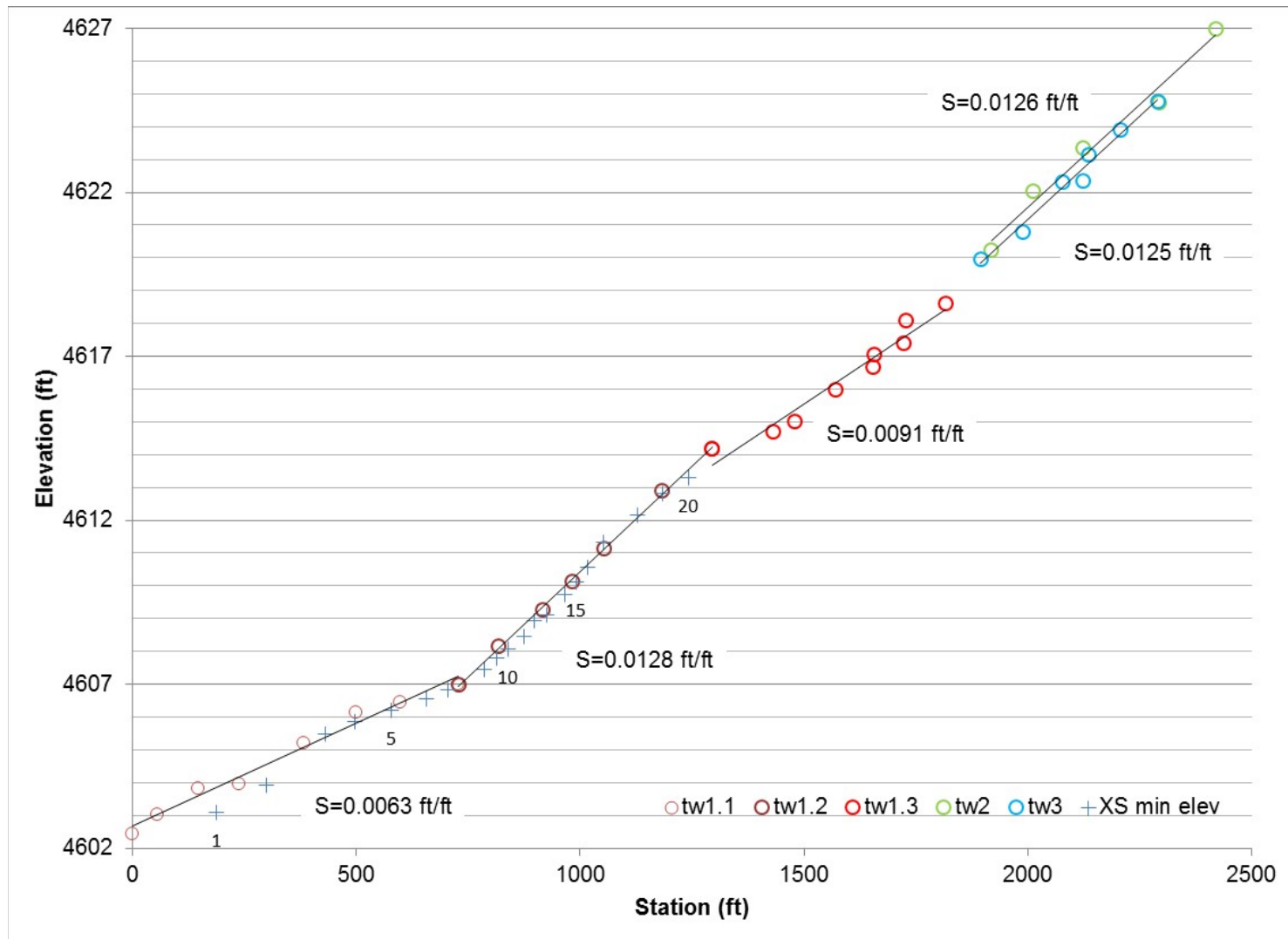


Figure 4 Longitudinal profile of Arroyo de Los Piños with reach slopes. Station 0 is the mouth of the arroyo at the Rio Grande. The planned measurement site is at station 875 ft. Numbers below “+” symbols indicate cross sections, and data collection site is at cross section 12.

Sediment samples

Three sediment samples were collected on 1 April 2015. The first two samples were surface and subsurface samples at location “A” (Figure 5), which was located approximately 140 meters upstream from the data collection platform. The third sample (“B”) was taken from the study reach, approximately 3m upstream of the sand eddy deposit within the damaged right gabion (Figure 5). There was no discernable surface vs. subsurface layer in the vicinity of the study reach due to cattle grazing and mixing the bed material. It will be necessary to control access to the study site, including people (on foot and in cars) and cattle. The samples were given to AAO for processing, and the grain size distributions (GSD) for the three samples are presented in Figure 5. All of the sediment samples are comparable, with a D50 in the range of 2.5 to 4mm, approximately 1/3 sand and 2/3 gravel, and all sampled material was less than 50mm.

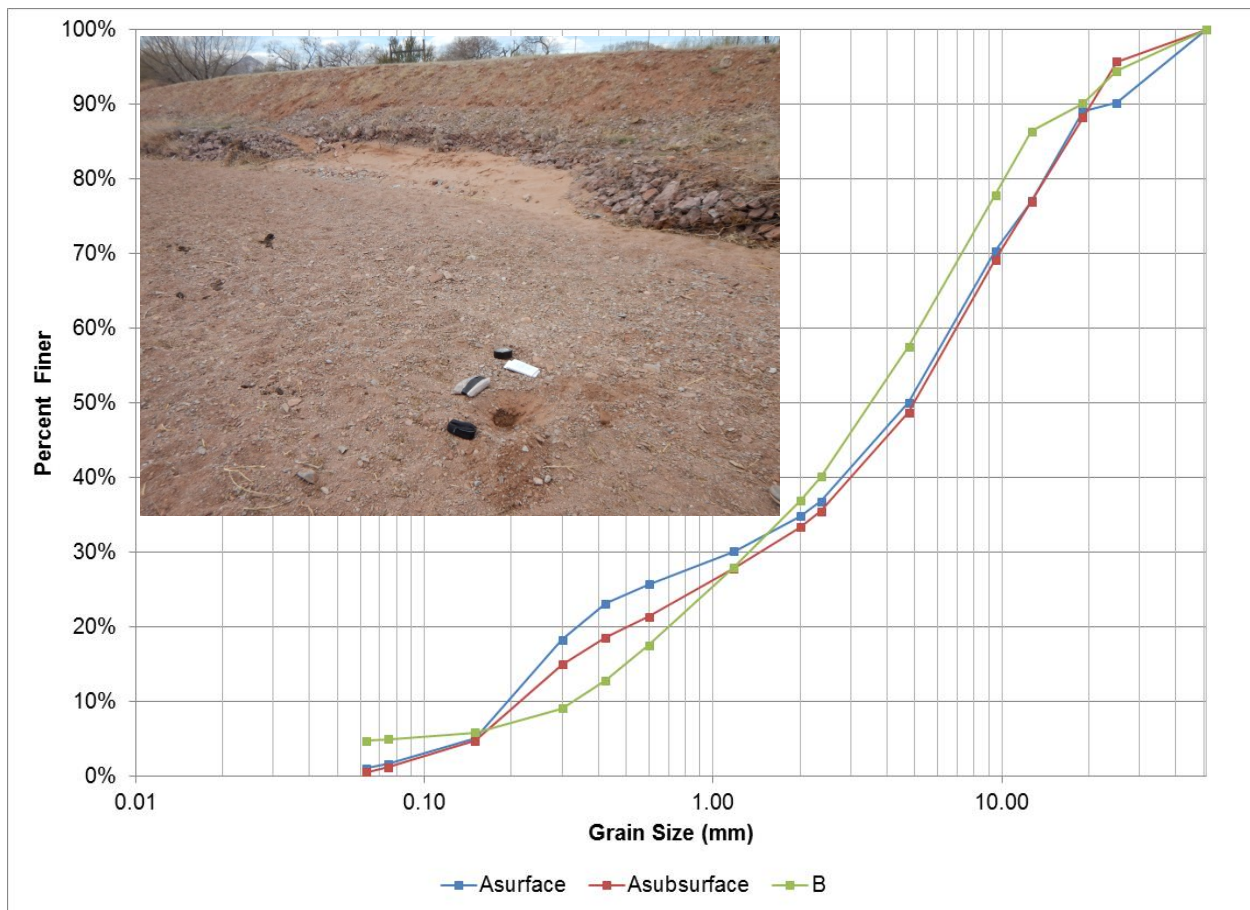


Figure 5. Grain size distribution of the three samples taken. Inset photo is of site "B" in the study reach, where the right bank is visible and the downstream direction is to photo left.

Instrumentation / Data Collection

Designing the research site was based upon the types of data that need to be collected and the instrumentation necessary to collect that data. Due to the infrequent nature of runoff events in ephemeral streams and their typically short duration, automation of the site was essential. Indeed, one of the primary reasons for the paucity in data for ephemeral streams in desert environments is their infrequent, short-lived nature. Powering the automated system was originally envisioned with solar panels, but concerns raised from our local partners related to vandalism has changed the method to car batteries, which will be maintained and recharged periodically. The project description was developed by our partners in the AAO and can be found in Appendix A. The design drawings, also developed at AAO, are in Appendix B. All of the instruments listed below have been purchased, tested, delivered, and will be deployed once construction is complete.

The main components of the data collection platform are as follows:

- Sediment traveling as bedload
 - Physical samples. The primary sampling will be with automatic slot samplers. If conditions permit, manual sampling will be conducted during the event as well.
 - Automatic. Three Reid-type slot samplers, which are a stainless steel inner box housed in a concrete outer box. The boxes have a lid with an adjustable-width slot opening. The stainless steel box rests on a pressure pillow attached to a load cell, which allows the time rate of filling (rate of bed load transport) to be measured and recorded. After the storm event, the stainless steel box can be removed, the sediment in the box sampled for GSD, and the box emptied and replaced in the concrete box, ready for the next storm event.
 - Manual. The BLH-84 is the standard bed load sampler used by the USGS and other federal agencies. This sampler will be housed on site and our project partners at New Mexico Institute of Mining and Technology will deploy the sampler if the in-stream conditions do not pose a safety hazard (if the flow rate is not too high).
 - Surrogate samples. Originally, acoustic methods were envisioned as the surrogate for bed load. In addition, seismological sensors will be used
 - Impact-type acoustic sensors. There will be two pipe microphones, one upstream of the left and right boxes, which will theoretically be struck by the moving bedload prior to the bed load falling into the Reid-type slot sampler. Upstream of the center slot sampler will be a plate affixed underneath with both a microphone and with a geophone. This is similar in principal to the pipe microphones, but with a different geometric configuration.
 - Non-contact acoustic sampler. The California Water Science Center (USGS) will deploy one of their portable, self-contained hydrophones at the site. Unlike the impact-type sensors, this underwater hydrophone does not register a signal from being struck by bed load, but rather receives a signal from one bed load particle colliding with another.

- Seismological sensors. A relatively new area of research is using seismological sensors to sense bed load. These sensors are extremely sensitive and there currently is one sensor deployed to measure background information at the site.
- Sediment traveling as suspended load
 - Physical samples. The primary sampling will be with automated pump samplers. If conditions permit, manual sampling will be conducted during the event as well.
 - Automated. Two ISCO pump samplers will be deployed at the site, with the intake tubes mounted at different elevations in a stilling well. These pumps will be programmed to sample at defined intervals during a storm event.
 - Manual. The DH-48 is the standard suspended sediment sampler used by the USGS and other federal agencies. One of these manual samplers will be housed on site and our project partners at New Mexico Institute of Mining and Technology will deploy the sampler if the in-stream conditions do not pose a safety hazard (if the flow rate is not too high).
 - Surrogate samples. Two high-end suspended solids sensors have been purchased and will be co-located with the pump sampler intakes. The Confab Instruments model 950 can be programmed to sample levels as high as 20% TSS.
- Hydraulics
 - Flow depth. Four pressure transducers will be deployed at the site. One will be housed in the stilling well, and three will be located in each of the slot samplers, in the gap between the outer concrete box and the inner stainless steel box.
 - Surface velocity. A large scale particle image velocimetry (LSPIV) system will be deployed. This method is based on a series of images (usually from video) that software can process to track the motion of particles on the water surface. A field of velocity vectors can be developed from the images.
- Geometry
 - Ground-based topography. An RTK-GPS survey of the site has been conducted twice over the last two years. A post-construction (as-built) survey will be conducted this winter
 - Aerial-based elevation.
 - The Corps of Engineers is overseeing photogrammetric data collection of the entire drainage basin. These flights will be conducted periodically. First flight with data collection took place in June. The Corps is also investigating the ability to process the imagery using Structure from Motion (SfM) software and technology.
 - The New Mexico Bureau of Geology has a drone and has completed a few test flights of the site. This method will use SfM processing to derive surface elevations. The spatial extent will be more along the local reach scale and not basin-wide.
 - The USGS also has an unmanned aerial vehicle (UAV) data collection program, although not out of the New Mexico Water Science Center. The NMWSC is working on developing a program like this in their office. Until then, the existing program out of Flagstaff may travel and conduct data collection flights.

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- Hydrology. Rainfall, wind speed, wind direction, air temperature, relative humidity, and air pressure are measured at two sites currently. One more will be deployed in the basin in the coming months.
- Control, Processing, and Storage. All of the signal processors, controllers, data loggers, and other necessary electronic equipment has been configured and tested. In addition, a multi-cellular transmitter will allow for mobile devices to monitor real-time data collection. NMIMT will download all raw data after each event. All data collected at this site during storm events will be stored at NMIMT and at Reclamation TSC. Appendix C provides labeled diagrams of the instrumentation as provided by Yamma Hydrometric Solutions, as well as photos/descriptions of other components of the data collection site.

Figure 6 provides a schematic of the data collection platform, including physical samplers and surrogate sensors.

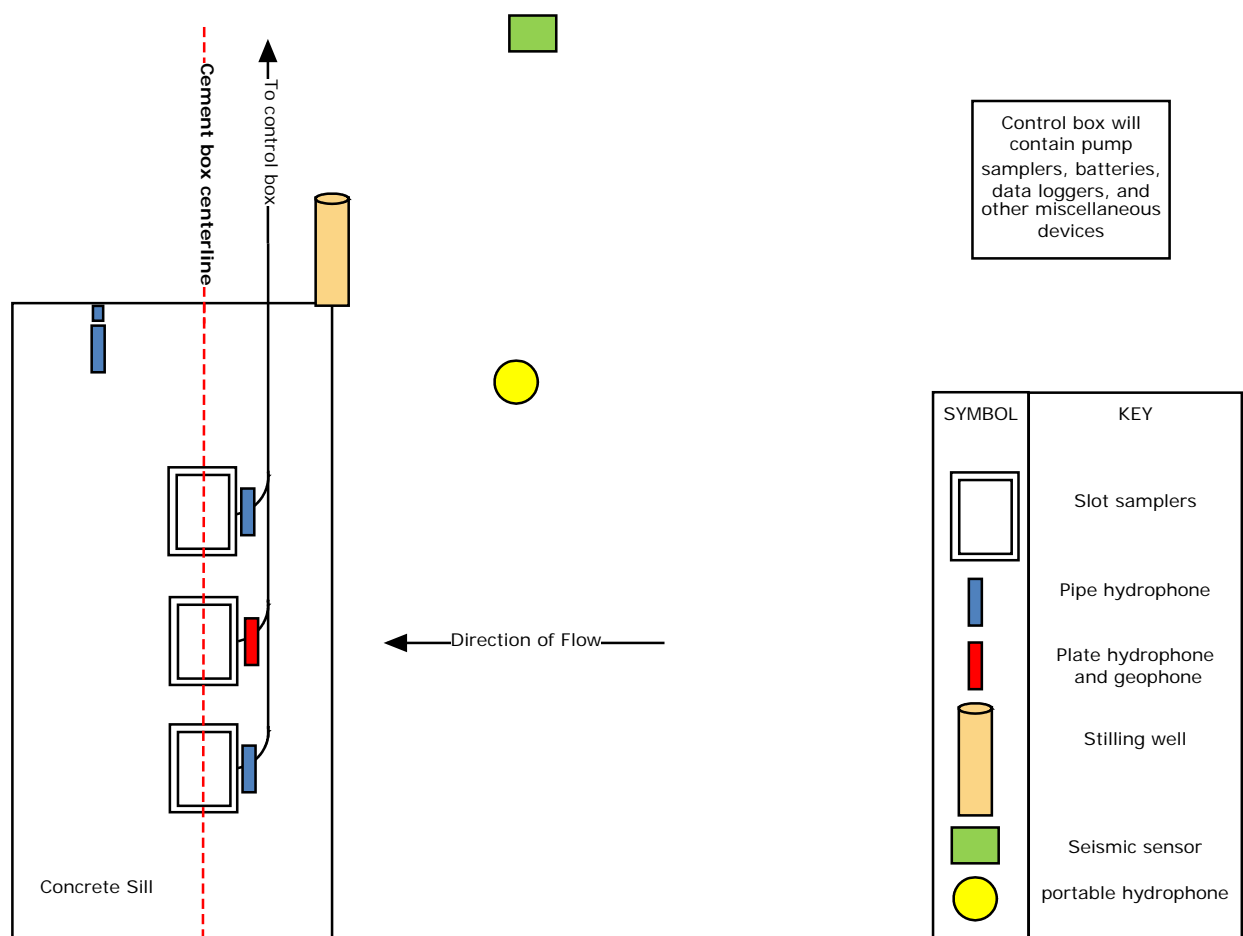


Figure 6. Schematic of the data collection platform.

Water and Sediment Data/Observations

Although the research site has not yet been constructed, other instruments have been deployed and data collection has occurred on location, largely by our project partners. In addition to the survey data and sediment samples discussed in the Site Description section (collected by myself and Dr. Laronne), the following instruments have been deployed and runoff events have been observed.

- Rain gauge / weather station at the research site was installed in August 2016 and has been collecting continuous data since.
- An up-basin rain gauge / weather station was installed in March 2017. Data collection has been continuous since installation
- Three pressure transducers deployed just below the river bed (one at the research site, two in the upstream basin) automatically record absolute pressure. A fourth pressure transducers, measuring barometric pressure, is used to correct the pressure transducers in the river so that stage can be calculated.
- Seismic device deployed at site. One malfunction has occurred. Other than that, continuous data since 10 July 2017. Some initial data collected prior to this.
- Runoff event in November 2016 (See Appendix D for report provided by NMIMT). Measurements of rainfall, stage, velocity, flow top width, suspended sediment, bed load (rate and grain size analysis), were collected for this event.
- Runoff event in January 2017 (See Appendix D for report provided by NMIMT). This event was smaller in size (less rainfall, short duration), such that sediment (suspended load, bed load) measurements could not be obtained. Velocity stage, and top width were measured. This is the first event where seismic data was collected as well.
- Runoff event 2 July 2017. Because of the holiday weekend, no manual samples were collected. Rainfall and automatic stage measurements were recorded.
- Runoff event 9 July 2017 event. Suspended sediment, stage and velocity data were collected for this event. However, a malfunction of the seismometer caused no seismic data to be collected for this event. Data processing (not including seismic) will be complete by 1 October.
- Runoff event 13 July 2017. Full complement of data including stage, velocity, suspended sediment, bedload, seismic, transducer, and rainfall data were collected. Data processing will be complete by 1 October.
- Runoff event 15 July 2017. This has been the biggest event since data collection began. Over ½ meter (~65cm) river stage measured. Full complement of data, and processing will be complete 1 October.
- Runoff event 22 July 2017. Full complement of data. Processing will be complete 1 October.
- Runoff event 1 August 2017. Two back-to-back events, both relatively small. Bed load measurement obtained on the falling limb of the second hydrograph. Stage, velocity, rainfall data recorded. Data processing will be complete 1 October.
- An initial gravity survey was conducted by New Mexico Bureau of Geology. This type of data collection can be used to infer bed infiltration and aquifer recharge. Subsequent surveys will be made in the future.

- Digital terrain data of the site location have been flown in March and in September 2017 through a partnership between NMIMT and the New Mexico Bureau of Geology. Another survey flight using the drone will occur post construction.
- The first aerial data collection by the Corps of Engineers along the drainage basin occurred on 13 June 2017. Data processing is occurring and a resulting surface should be available soon.
- Wolman pebble counts of the bed material were conducted by NMIMT. Photogrammetric software for bed material is being tested and will be compared to the manually collected data.
- Water presence sensors have been deployed. These indicate presence/absence of water. They are modified hobo light pendent sensors. There haven't been any events since these have been deployed but the goal is for them to be a cheap alternative to pressure transducers that will allow for constraining where flow is being generated in the watershed.

Project Partners and Stakeholders

This project has mushroomed in scope and partnerships beyond what I could have imagined when developing the original proposal for FY15. The interest and support would not have happened if the issues being addressed by this research were not a challenge being faced by others. This section will discuss the partnerships with and contributions from various agencies and institutions and how their input will promote this research site into a world class facility.

- **Albuquerque Area Office (Reclamation).** AAO has been instrumental in the design, permitting, contracting, and construction of this site. The staff at the AAO were involved in the site selection back at the beginning of the project, provided funding for the PI of this research project, developed the project description, created the design drawing required for construction, conducted all NEPA related investigations and documentation, obtained necessary land access and permitting, completed the contracting to hire the construction company, and will perform necessary QAQC as construction progresses. Further support during data collection and site management has been pledged as well.
- **New Mexico Institute of Mining and Technology (NMIMT).** Both the Department of Earth and Environmental Science (DEES) as well as the Seismic Observatory are providing in-kind services towards this project. The DEES have been, and will continue to be, the on-site manager and instrumentation steward, ensuring the site is functional and ready for the next storm event, as well as downloading and storing all data collected and recorded at the site. Manual sediment sampling during runoff events will also be conducted by DEES, which will help to validate the automated data collection systems. Reclamation has provided funding to NMIMT through a Cooperative Agreement to partially fund a graduate student (co-supervised by Dr. Daniel Cadol) in this department and the hope is to continue the funding of research assistants from this department on an ongoing basis. The development of a pedologic description of the entire drainage basin is being led by Dr. Harrison. The NMIMT Seismic Observatory (Dr. Sue Bilek) will also be involved in the deployment of seismic devices that can be used to collect additional surrogate data during a bedload-moving runoff event. This is a relatively new application

of seismic devices and the department will be coordinating with the GFZ and IRIS. NMIMT hosted Dr. Jonathan Laronne (BGU) during the summer of 2016 while he helped finalize the project plan and design drawings. Dr. Laronne is also co-supervising the current graduate student, both in traditional academic education as well as providing education of acoustic monitoring theory, literature, and proper deployment of the instruments.

- **Local landowners.** A number of local landowners have shown an interest in, and are supportive of, the project. One notable landowner is Mr. Bill Holms, who is not only supportive of the project but is also providing portions of his property for access and use during construction.
- **Ben Gurion University of the Negev (BGU).** Dr. Laronne is one of the premier researchers in the field of surrogate measurements of bedload transport. Dr. Laronne designed the instrumentation and construction specifically for the flashy nature and sediment size distribution of this site to ensure that project goals are achieved. Helping to identify the monitoring reach in previous visits, he spent the summer of 2016 in Socorro to see the design process to completion as well as to begin training the graduate student. Dr. Laronne will make an approximate one-month stay during the October 2017 to oversee and assist with instrument deployment in preparation for full functionality of the research site.
- **Rishin Hydrotech.** Mr. Michinobu Nonaka has worked closely with the project to produce a set of pipe and plate microphones for this specific deployment. The use of acoustic surrogates such as hydrophones, microphones, and geophones have typically been deployed in systems where bedload is comprised of material greater than 16 mm. Mr. Nonaka has developed some modified equipment with the aim of being able to detect smaller sediment sizes present in the Arroyo de los Piños system. Under ideal conditions the pipe microphones detect the motion of 2-4 mm sediment particles moving as bed load.
- **Yamma & Ayyeka Companies.** A state-of-the-art hydraulic-hydrologic transmitting system based on US, Japanese, German, UK, Australian and Israeli components has been assembled by these groups at the direction of Yaniv Munwes. The variety of instruments being deployed presented a challenge in data communication and storage which has now been resolved. Additionally, all data except seismic will be transmitted via cellular signals so that the system can be monitored remotely and data, including bedload discharge, can be observed in real time.
- **GFZ German Research Center for Geosciences.** The use of seismic devices as a means to collect surrogate bedload data is a relatively new field. Jens Turowski with the GFZ is a leader in this field, conducting research and publishing papers on the topic. He is providing guidance and expertise along with NMIMT, IRIS, and the University of Grenoble to develop a system to be deployed at the site.
- **University of Grenoble Institute of Environmental Sciences / CNRS.** Florent Gimbert is also a leader in the field of seismic devices being deployed to sense bed load transport in fluvial systems. He will be working with the other seismic researchers on the design and deployment of a seismic device array to improve data collection and processing for application as a surrogate for bed load transport.
- **The Incorporated Research Institutions for Seismology (IRIS).** This consortium of universities across the U.S. is dedicated to seismological data acquisition, management, and distribution. They are working with NMIMT, GFZ, and the University of Grenoble to

plan the deployment of an NSF-supported seismic system to be used as a surrogate measure of bedload.

- **United States Geological Survey.**
 - California Water Science Center. A portable hydrophone system has been developed by scientists in this group, and they are testing it in a variety of streams. They will deploy one of their systems at our site, to expand the range of conditions to which their system is exposed, evaluating it's applicability to an arid, ephemeral drainage basin.
 - New Mexico Water Science Center. Unique measurement systems for deployment in local drainage basins have been devised by this office in the past. Designing a system for this research site is ongoing. UAV flights for imagery collection will be conducted to develop digital terrain models of the research site. We are exploring the possibility of hosting the data collected at the site on the USGS website to ensure data quality and accessibility to other researchers.
 - The USGS Office of Surface Water has shown interest in collaborating in this long-term project. Representatives of the OSW will attend the stakeholder/partner meeting planned for the week of 23 October.
- **U.S. Army Corps of Engineers (Corps), Albuquerque District.** The Corps has developed a Large Scale Particle Image Velocimetry (LSPIV) system which will be deployed at Peralta Canyon near Cochiti Dam. They are planning to deploy another system at the Arroyo de los Piños research site. In addition, photogrammetric data of the entire drainage basin will be acquired on a periodic basis to assess basin-wide changes in elevation (erosion and deposition processes as sediment is transported downstream). The first flight was conducted on 13 June 2017, and another will be conducted when construction is complete. The Corps has also contributed significant funding in support of the graduate student at NMIMT.
- **New Mexico Bureau of Geology.** Repeat micro-gravity surveys of the drainage basin will be conducted to inform infiltration rates and groundwater recharge processes. An initial survey was conducted in July 2017.

Conclusions and Next Steps

A research site will be constructed in the Arroyo de los Piños by the end of October. The level of interest and support from other federal agencies (Reclamation AAO, Corps of Engineers, USGS), state agencies (NM Bureau of Geology), U.S. research organizations and institutes of higher learning (NMIMT, IRIS), international research organizations and universities (GFZ, University of Grenoble, BGU), exemplifies the interest in the research topic and the need to provide data to support theories and answers to the research question.

The next step is for construction to be completed. Construction is scheduled to be complete at the end of October. Even if construction isn't completed on that schedule, instrument deployment will take place at the end of October. The contractor will be constructing the research site first and then a significant portion of the construction is actually building and installing gabion baskets at and upstream of the research site. Instrument deployment at the site can be completed

while upstream gabion baskets are installed (see Appendix A for project description developed by AAO).

NMIMT will be hosting Dr. Jonathan Laronne during the month of October. Dr. Laronne will provide QAQC along with AAO staff during site construction. Dr. Laronne will also oversee instrument and sensor deployment, which will occur towards the end of October.

A meeting will be hosted by NMIMT for project partners and stakeholders. The meeting will include a visit to the research site, as well as presentations by various partners on what has been accomplished to date and what activities are upcoming. Depending on stakeholder/partner availability, there may be a second meeting hosted in Albuquerque at the AAO office.

Providing a few weeks for unforeseen circumstances, it is reasonable to expect the site to be ready for data collection by mid-November. At that time, NMIMT will maintain the site and ensure that instruments and sensors are ready for a runoff event. Based on data collection efforts from the last year and a half, it is possible for smaller runoff events to take place in the winter. However, the expectation is that the first significant runoff event will take place in the summer of 2018. Although the construction schedule isn't aligned perfectly with the targeted data collection season, this gap will ensure sufficient time to collect as-built data, including ground-based topographic survey using RTK-GPS gear, and aerial-based data collection by the Corps of Engineers, USGS, and New Mexico Bureau of Geology. This period of time will also be advantageous for the group spearheading the seismic data collection to deploy additional sensors as they see fit based on meetings and planning that occur during and subsequent to the October stakeholder/partner meeting.

Summer 2018 will be when significant data collection is expected to begin. This research site will then be ready to collect many years (decades?) worth of data. Although the data collected at this station will be site specific, the real long-term goal for this research is to understand how to deploy surrogate technologies to other drainage basins in a manner that provides a cost-effective, reasonably accurate estimate of suspended and bed load transport for different sized storm events.

There are other research stations worldwide that are collecting data similar to this site. The synthesis of this data with data from those other sites, identifying the basin-specific parameters (e.g., drainage area, basin slope, other) and storm-specific parameters (e.g., rainfall intensity, rainfall duration, discharge) that help to normalize the data, developing a hypothesis, and then testing that hypothesis by deploying a full data collection platform in another basin would be a future step of this research. The end goal for this field of research would be to have confidence that the only surrogates (acoustic, seismic, other) could be deployed in any basin and use basin- and storm-specific information to quantify sediment delivery rates from ephemeral streams. I believe that Reclamation's continued involvement in this effort is critically important and appropriate; ephemeral streams are abundant throughout Reclamation's jurisdiction. Quantifying the rate of sediment delivery from ephemeral streams to rivers on which Reclamation has facilities and or other river maintenance responsibilities, will make it easier and more efficient for Reclamation to meet its mission.

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Appendix A – Project Description (developed by Reclamation’s Albuquerque Area Office)

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RECLAMATION

Managing Water in the West

Arroyo de los Piños: Sediment Sampling Site

Project Description



*Department of the Interior
Bureau of Reclamation
Albuquerque Area Office
Technical Services Division
Albuquerque, New Mexico*



March 2016

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

RECLAMATION

Managing Water in the West

Arroyo de los Piños: Sediment Sampling Site

Project Description

prepared by

Technical Services Division

River Analysis Group

Anthony Lampert, P.E., Civil Engineer

Cover Photograph: Taken on January 19, 2016, on the Arroyo de los Piños, looking upstream at Escondida Drain.



March 2016

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Project Background and Purpose

The Technical Services Center (TSC) of the Bureau of Reclamation (Reclamation) has identified the Arroyo de los Piños as the site where sediment transport research will be conducted. In October of 2014 and March/April of 2015, several ephemeral tributary (arroyo) sites were visited in order to find the location best suited for the sediment transport research investigation. The site chosen is located near Socorro, New Mexico, which has several advantages, including being located near New Mexico Tech University. Mr. David Varyu, from the Denver Office's Technical Services Center (TSC) River Hydraulics and Sedimentation Group under Reclamation's Science and Technology Program, has been working with the Albuquerque Area Office (AAO), Dr. Jonathan Laronne (Ben Gurion University of the Negev), and Dr. Dan Cadol (New Mexico Tech Professor) on the research and implementation of this project. Albuquerque Area Office (AAO), Technical Services Division (TSD) is providing design and logistical support for the selected research site project's components involving a concrete sill, sampling site bank protection, and data logging equipment housing.

A topographic survey was completed using Trimble RTK-GPS equipment by David Varyu and Dr. Laronne on March 31, 2015. During this survey, a temporary benchmark (Point Number 1) was established upstream of the project site on the right bank. This survey data is utilized for the site design for evaluation of the hydrology, hydraulics, and structural placement. A site visit was conducted by AAO TSD Staff on January 19, 2016, to review the design needs at the arroyo research site. The need for local bank stabilization on the left bank and partially on the right bank to establish a control cross section for sediment measurement was noted by AAO staff. Preliminary designs were completed by AAO staff for all facets of the research project with the exception of the measuring equipment. In addition, David Varyu, Jason Casuga, Dan Cadol, AAO Staff, and Bill Holm (adjacent landowner to the site) visited the project site on March 10, 2016, to finalize technical and design discussions for the installation of the field site. Lastly, AAO then re-surveyed the site using a Topcon total station to finalize the location and alignment of the project features utilizing the established temporary benchmark.

Project Components

In June 2007, Reclamation developed construction drawings for a drain maintenance project at the site that involved gabion mattresses on the left and right bank of the arroyo where the drain crossing is located. This 2007 drain maintenance project involved bank protection solely for the existing Escondida Drain that crosses perpendicular and underneath the selected Arroyo de los Piños sediment sampling site.

It was noted in the January 2016 AAO TSD trip that the arroyo channel bed degraded approximately two feet and the 2007 gabion mattresses on the left bank line have virtually all failed (rock displaced and wiring unraveled) and sloughed down the slope (Figure 1). This erosion on the left bank line will continue and would allow for channel migration away from the planned sediment measurement concrete sill location. It is necessary to have a control cross section at the sampling sill, so it will be necessary to replace the existing failed mattresses plus

Measuring the Transport of Sediment in an Ephemeral Stream

some additional upstream left bank projection work that will need to last for the duration of the arroyo sediment investigation.

The right bank line at the planned control section has a 44' section in length where the gabion mattresses have eroded from the bank toe up to the top of bank (Figure 2). This project description and construction plan include information for the concrete sill, the sampling boxes, continuous bank protection on both left and right bank, and the data collector equipment housing units.



Figure A 1: September 2016 photo of gabionmats eroding at toe on the left bank



Figure A 2: September 2016 photo of right bank 44' eroded section, looking upstream

Sampling Boxes

Specifications and drawing plans for the concrete and stainless steel boxes are being produced by AAO TSD. The concrete boxes are 4'-8" long, 3'-3" wide, and 3'-8" deep. The concrete boxes will be 6" thick with #4 rebar inside all the walls and base. There are two options for the cables coming into the concrete boxes. The first option is a block out and the second option is 3" diameter PVC pipe. The stainless steel boxes will be 3'-4" wide, 1.98' long, and 2.63' deep. The stainless steel boxes will be made up of be 3/16" thick ASTM 304 stainless steel plates. Due to the estimated cost of these boxes, they will need to be purchased under a new supply contract. A contract will need to be issued by the Denver or Upper Colorado Regional Acquisition offices as appropriate. It is recommended that both the concrete and stainless steel boxes be awarded to a single vendor to ensure that the steel boxes will fit as required within the concrete boxes. Once the three concrete and three stainless steel boxes are fabricated, the vendor will need to transport them to the Socorro Field Division office (Socorro). They will need to be stored there until construction at the site is ready to begin. Socorro will install the boxes as the first part of construction.



Figure A 3: Example of sampling stainless steel box sitting inside of concrete box (Varyu)

Concrete Sill

The concrete sill design consists of reinforced concrete. The sill is 30' wide, 15' long, and is 6" thick. There will a 3' deep cutoff on the upstream end and an angled cutoff on the downstream end that extends 3'-8" downstream and dips 2' into the ground. The concrete sill placement will be approximately 14 cubic yards of 4500-psi concrete, with expansion joints, and 1,125 pounds of #4 steel rebar. The necessary site preparation, earth compaction and wetting, and form work will be performed by Socorro. The installation procedure for the three prefabricated concrete boxes consists of excavation, followed by placing the boxes in the locations and elevations identified in the drawings. These locations will be staked in the field by TSD AAO staff. Once the concrete boxes are installed, the cement for the sill can be placed in the forms with the reinforcement bars. A concrete supplier with delivery capability will need to be contracted to truck in the cement for placement of the sill. The cement will need to be placed so that the top of the sill elevation is level with the current arroyo elevation. The form and concrete pour for the sill will also need a vertical cutoff on the upstream end and a graded cutoff on the downstream end. Backfill soil will be filled to the existing elevation after the downstream cutoff concrete has set. The sill will also extend underneath either the Options A or B on the right bank (described below). Vibratory compaction and saturation of the soil will take place underneath the sill.

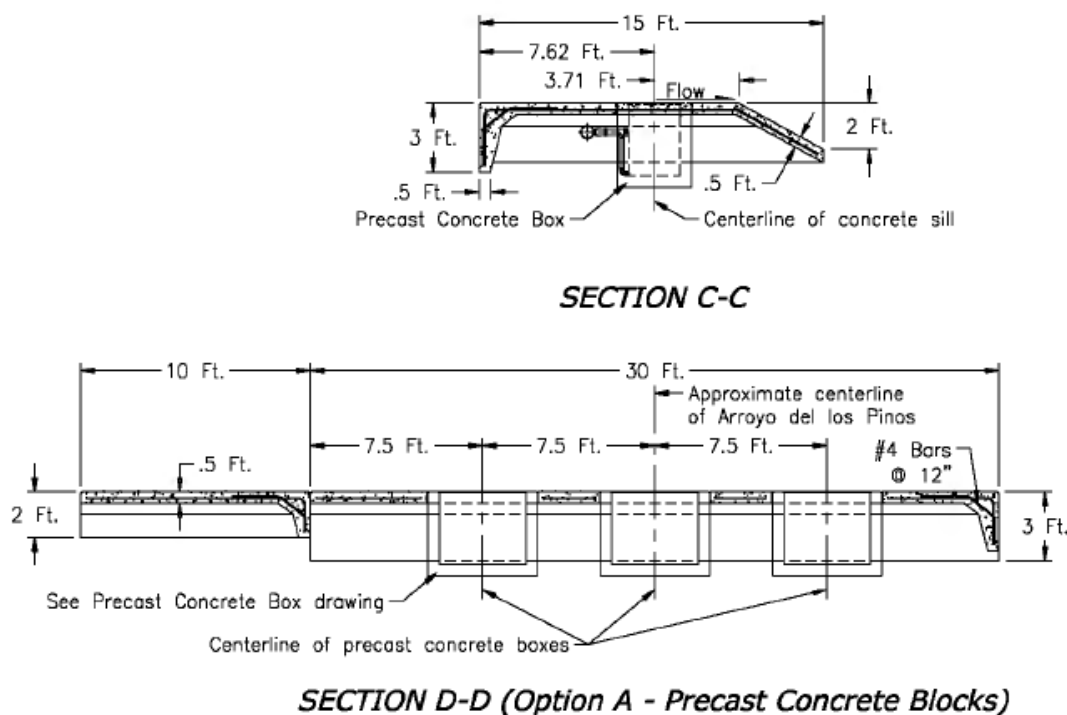
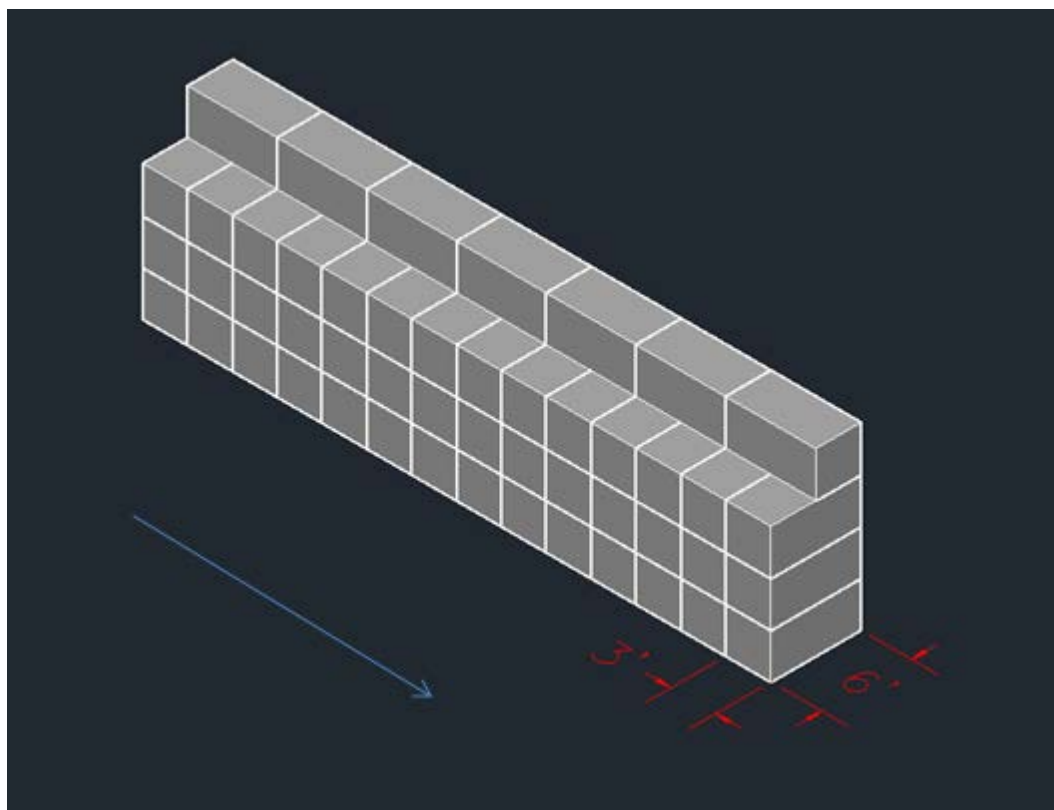


Figure A 4: Cross Section of Concrete Sill with box sitting in bottom (upstream to the left) and profile of concrete sill (Everetts)

Left Bankline Gabion Baskets

At the planned control section, the left bank has eroded significantly, and the arroyo is widening directly upstream of where these 2007 constructed gabion mattresses protection begins. These gabion mattresses will be replaced with new 3' x 3' x 6' gabion baskets. The total height of all the gabions stacked will be 12' (four rows of baskets). The first three rows will sit perpendicular to the arroyo (6' wide) and the top row will sit parallel to the arroyo (3' wide). The gabion baskets will be keyed 3' into the ground below the existing grade of the arroyo so that the first row will be completely buried underground. The gabion baskets that are directly above the culvert will bend and sit on top of the culvert. The gabion baskets will be filled with 4"-6" riprap material. Geotextile will be placed with pins underneath and behind the gabion baskets to prevent soil erosion underneath the baskets. The alignment of the gabion baskets will be staked in the field by AAO TSD staff and would be similar to the previous layout along the bank. The gabion baskets will cover a length of 120' (140 baskets) along the left bank and transition into an 84'-long wing wall (98 baskets) on the upstream end of the control section. For the downstream portion of the left bank, a 30' wing wall (35 baskets) will need to be placed. This comes to a total of 218 baskets. Vibratory compaction and soil saturation will take place underneath the gabion baskets. The start, end, and elevations of the gabion mattresses for the bank line and the upstream wing wall alignments will be staked in the field by AAO TSD staff.



FigureA 5: 3-D layout of the typical layout of gabion baskets

Right Bankline Freestanding Blocks (Option A)

At the sediment sample control section, the portion of the ledge of gabions on the right bank toe has a 44' section that has eroded. This 44' section will need to be reinforced to protect against arroyo flows during flood events due to current arroyo alignment and the planned upstream wing wall installation that was described above. Freestanding blocks made by Redi-Rock International will be used on the right bank for bank stabilization. The four different blocks that will be used are Straight Bottom, Corner Bottom, Straight Top, and Corner Top. The blocks will be stacked two high, five deep, and twelve wide. The total dimensions will be 46.1' long, 3' tall, and 10' wide. There will be 2 Corner Bottoms, 58 Straight Bottoms, 2 Corner Tops, and 58 Straight Tops for a total of 120 blocks. The blocks will lie on top of a concrete pad which will lie adjacent to the sill. The concrete pad will be 46.12' long, 10' wide, and 6" deep. There will be 2' cutoff wall on the upstream, downstream, and arroyo side of the pad. The blocks have preinstalled hooks which will make them easily placed by an excavator with a chain and hook. The start and stop locations, alignment, and elevations for the freestanding blocks will be staked in the field by AAO TSD staff.

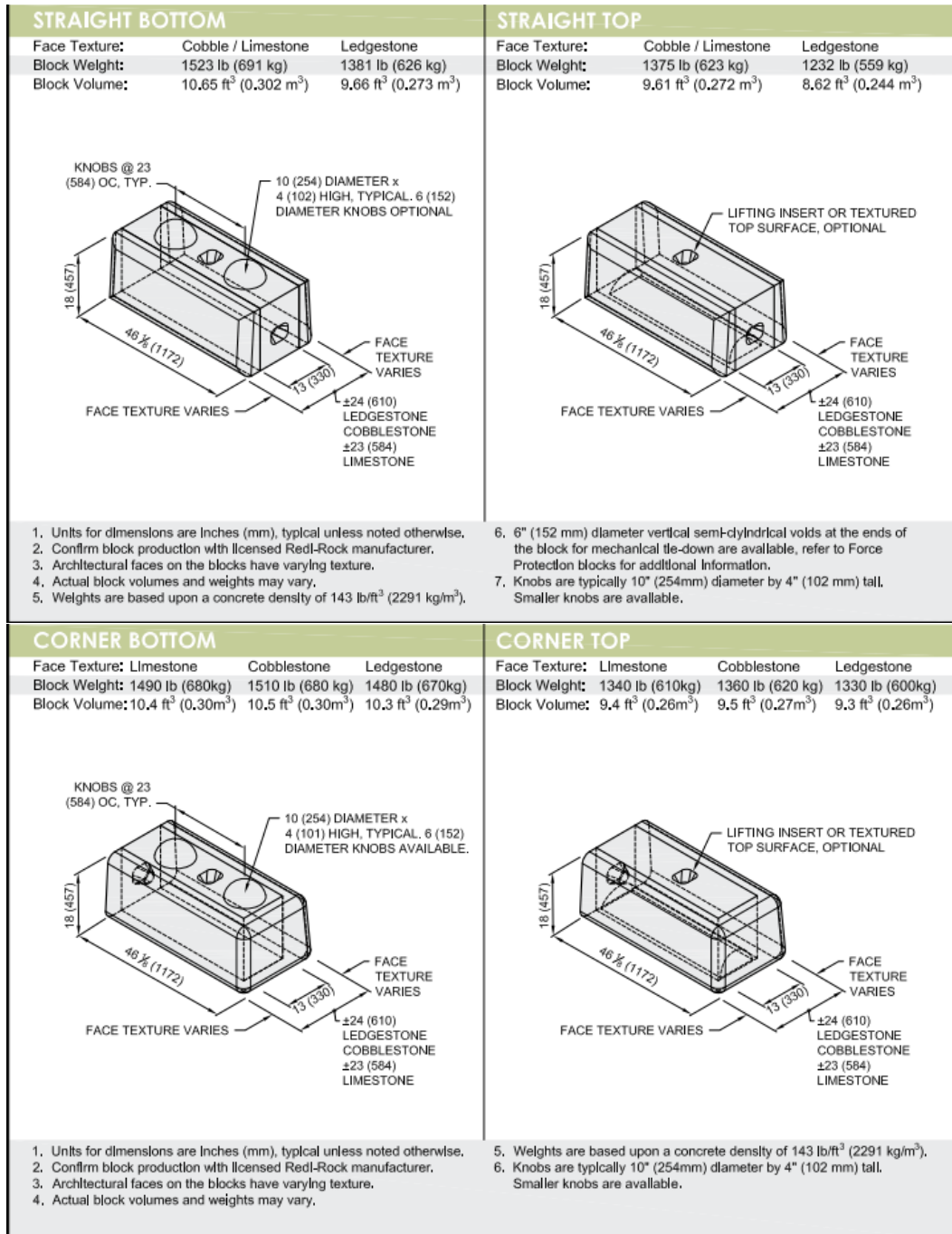


Figure A 6: Example of Freestanding blocks (Option A)

Right Bankline Gabion Baskets with Concrete Top (Option B)

The other option for the right bank would be gabion baskets. This would use the same 3' × 3' × 6' baskets described for the left bankline and would have the same 4"–6" riprap inside them. The feature would be eight gabion baskets long and three baskets deep towards the bank and only one basket high. This would consist of 24 gabion baskets. The start, end, alignments, and elevations of the gabion baskets for the bank line and the upstream wing wall will be staked in the field by AAO TSD staff.

Right Bankline Gabion Mattress

A gabion mattress will be installed on the slope directly above either Option A or B to replace the existing 2007 eroding gabion mattresses. The gabion mattress will be installed on the existing right bank slope for a length of 48' going downstream and extending 12' from the bank toe the up the existing slope. This gabion mattress will be set at a 2:1 (Horizontal: Vertical) slope, where it will run 11' horizontally and rise 5.5' vertically. The Gabion Mattress will also be filled with the 4"–6" riprap. The mattresses are sized at 12' long, 6' uphill, and 1' deep. There will need to be eight of the mattresses to fill the slope. The sides of the mattress will be tied into the existing adjacent 2007 gabionmats. The start, end, alignment, and elevation of the gabion mattresses for the bank line and the upstream mattress will be staked in the field by AAO TSD staff.

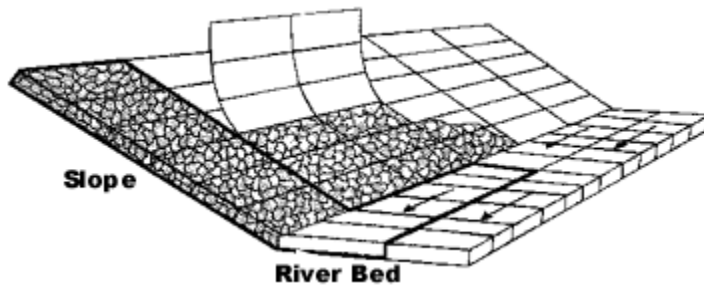


Figure A 7: Example of Gabion Mattress layout (Geosolutions, 2016)

Housing Units

Cables for the sediment measure equipment will exit all three of the concrete underground boxes (described in Sampling Boxes above) and stay underground until they reach the top of the right berm embankment where they will go into a utility vault or stilling well. Their position will be underneath the area that will be disturbed under the Option A or B and the gabion mattresses on the slope. The two ISCO samplers (to be acquired by the Denver TSC) will be housed up in the housing unit along with solar panels and other pieces, which will be identified later. At present, the stilling well is expected to be downstream of the sill, but this will be planned at a later date.

Crane

A tripod crane will be used that can be moved to the site after a flow event. Decisions can be made at a later date as to what crane exactly will be purchased.

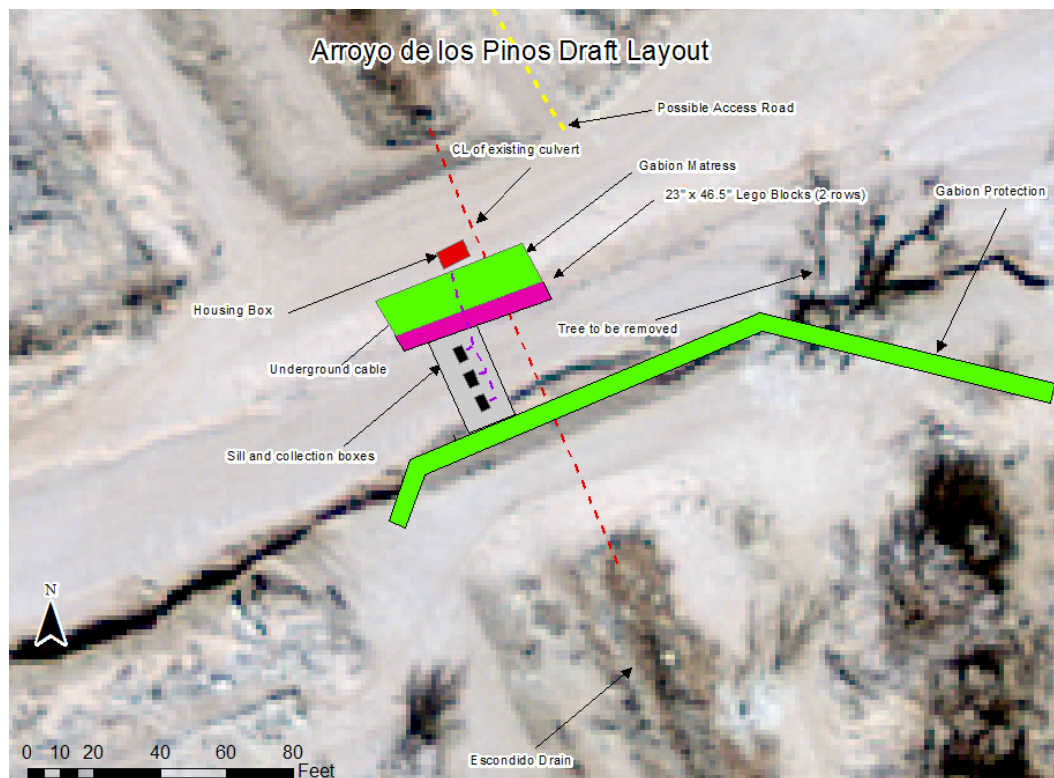


Figure A 8: Draft Plan Layout for planned construction

Access

During construction the Primary Access route will be used to work on site. Once construction is complete, the Secondary Access will be the preferred method of access if access is granted by the landowner. The landowner, Sue Conklin, will be contacted by Dr. Cadol. Using the Secondary Access will minimize disturbance to the arroyo upstream of the sampling site.

Measuring the Transport of Sediment in an Ephemeral Stream



Figure A 9: Vicinity Map displaying Primary and Secondary Access Routes and Project Site with proximity to Socorro, NM

If necessary to ensure safe and convenient access, road improvements (e.g. clearing, mowing and trimming, blading, widening, gravel cap placement, etc.) may be made to the access routes.

Staging/ Site Disturbance

The Primary Access route will be used during construction and it is known that disturbance will take place to soil upstream of the site. Once construction is complete, if the secondary access is allowed, site disturbance will be at a minimum when collecting data from the boxes.

Construction Operations

To facilitate the interim construction at this site, the following sequence and BMPs will be observed. To avoid the migratory bird season, work is not anticipated to occur between April 15 and September 1.

Expected Construction steps, although not in the exact sequence are as follows: Some of these steps may be concurrent.

1. Mobilize: Use Primary Access Road to bring construction equipment to the site.
2. Site Preparation, Remove tree on left bank and pile along berm on East side of Escondido Drain.
3. Diversion and Care of Los Pinos Arroyo.
4. Excavation for concrete pad and sampling holes for concrete boxes.
5. Backfill and compacting backfill about sampling concrete pad
6. Excavate for reinforced concrete box sampling vault.
7. Removed gabionmats from right and left bank.
8. Install cables from gauging station installed by others to the concrete box sampling vault.
9. Furnish and Install reinforced concrete box sampling vault.
10. Furnish and place reinforced concrete sill apron.
11. Haul in components of option A or B and begin installing the blocks or gabions and riprap. If Option B is utilized pour concrete on top of gabions.
12. Haul gabion baskets and riprap in and begin placing on the left bank.
13. Complete the housing box and all facets together.

The following Best Management Practices (BMPs) would be used at the site.

1. *Management of water runoff* – Dirt berms, straw bales, silt fences, silt curtains or other appropriate material will be placed at strategic locations to manage water runoff at the site.

2. *Minimize impact of hydrocarbons* – To minimize potential for spills into or contamination of aquatic habitat:
 - a. Hydraulic lines will be checked each morning for leaks and periodically throughout each work day.
 - b. All fueling will take place outside the active floodplain. Fuel may be stored on site overnight, but not near the river or any location where a spill could affect the river.
 - c. All equipment will undergo high-pressure spray cleaning and inspection prior to initial operation in the project area.
 - d. Equipment will be parked on pre-determined locations on high ground away from the river overnight, on weekends, and holidays.
 - e. Spill protection kits will be onsite, and operators will be trained in the correct deployment of the kits.
3. *Vegetation clearing* – Vegetation clearing will be completed after September 1 and before April 15. Any need for deviations from this work window would be considered on a project-specific basis in the tiered consultations for each river maintenance project at a later date. Work after April 1 would be accompanied by appropriate surveys. Reclamation coordinates monitoring and work activities with the Service, as appropriate, if bird nests are found. Nonnative vegetation at the project site will be mulched, burned, or removed offsite to an approved location. If a project requires removing native vegetation, where possible, this material will be removed or harvested at the appropriate season to use in revegetation at another location in the project area or at another project site. If it is not possible for native vegetation to be replanted, material will be mulched, temporarily stockpiled and used to create dead tree snags or brush piles in the project area upon completion, or cut to lengths for use by the Pueblo.
4. *Implementation waste* – All project spoils and waste will be disposed of offsite at approved locations. All river maintenance projects will have a contract in place for the rental of porta potty facilities during the duration of the project.

Material Quantities

Expected and maximum quantities for the original Arroyo de los Piños Sediment Sampling Site project are shown in Table 1.

Table A 1: Expected Material Quantities for Arroyo de los Piños Sediment Sampling Site Project (Bernal)

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Acknowledgments

The original project was a concept developed in house by Bureau of Reclamation. Design information for construction is based on data derived from designs and reports developed by TSD, TSC, Dr. Laronne, and Dr. Cadol.

Document Revision History

April 26, 2016: The final version is distributed.

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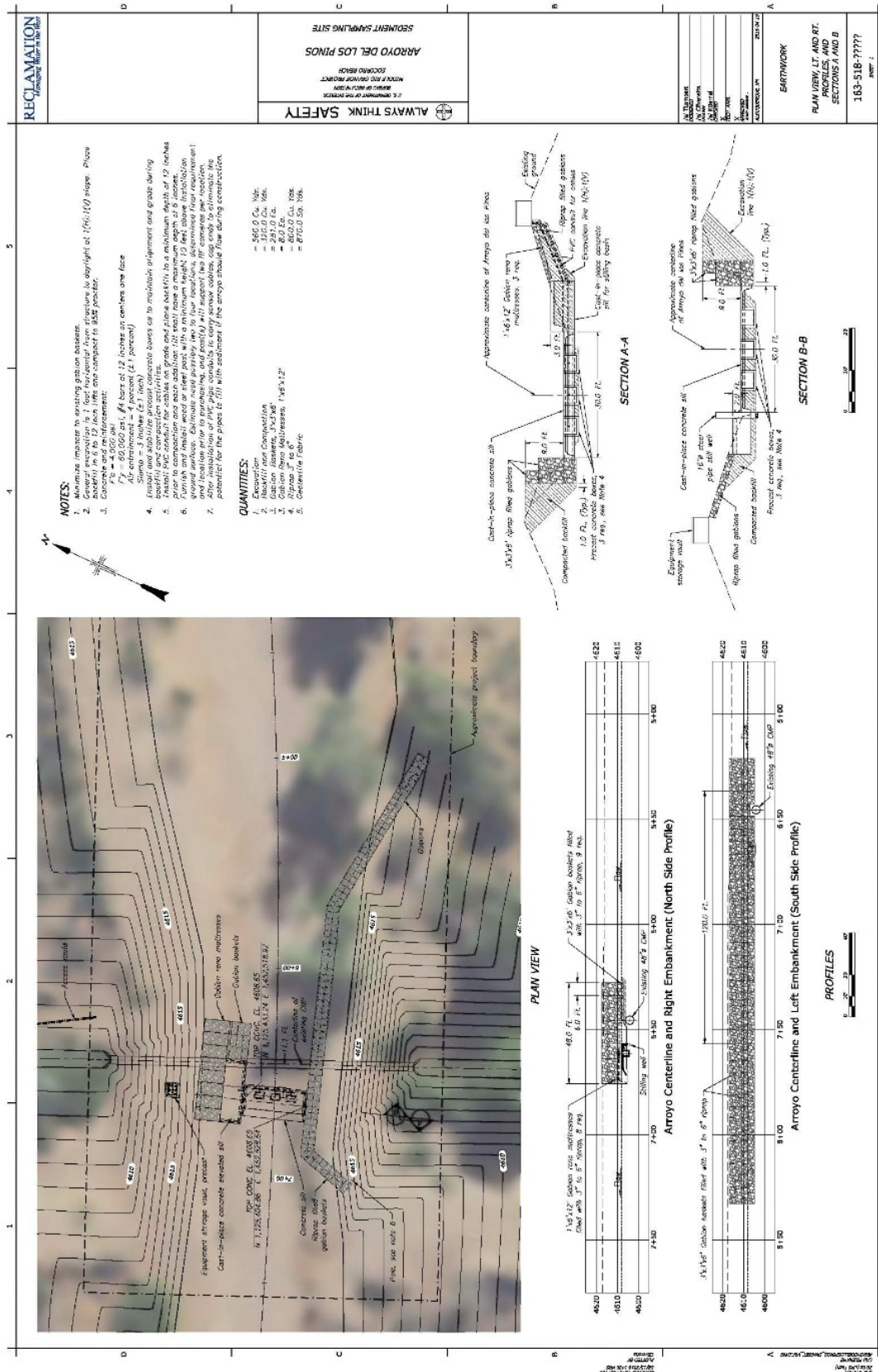
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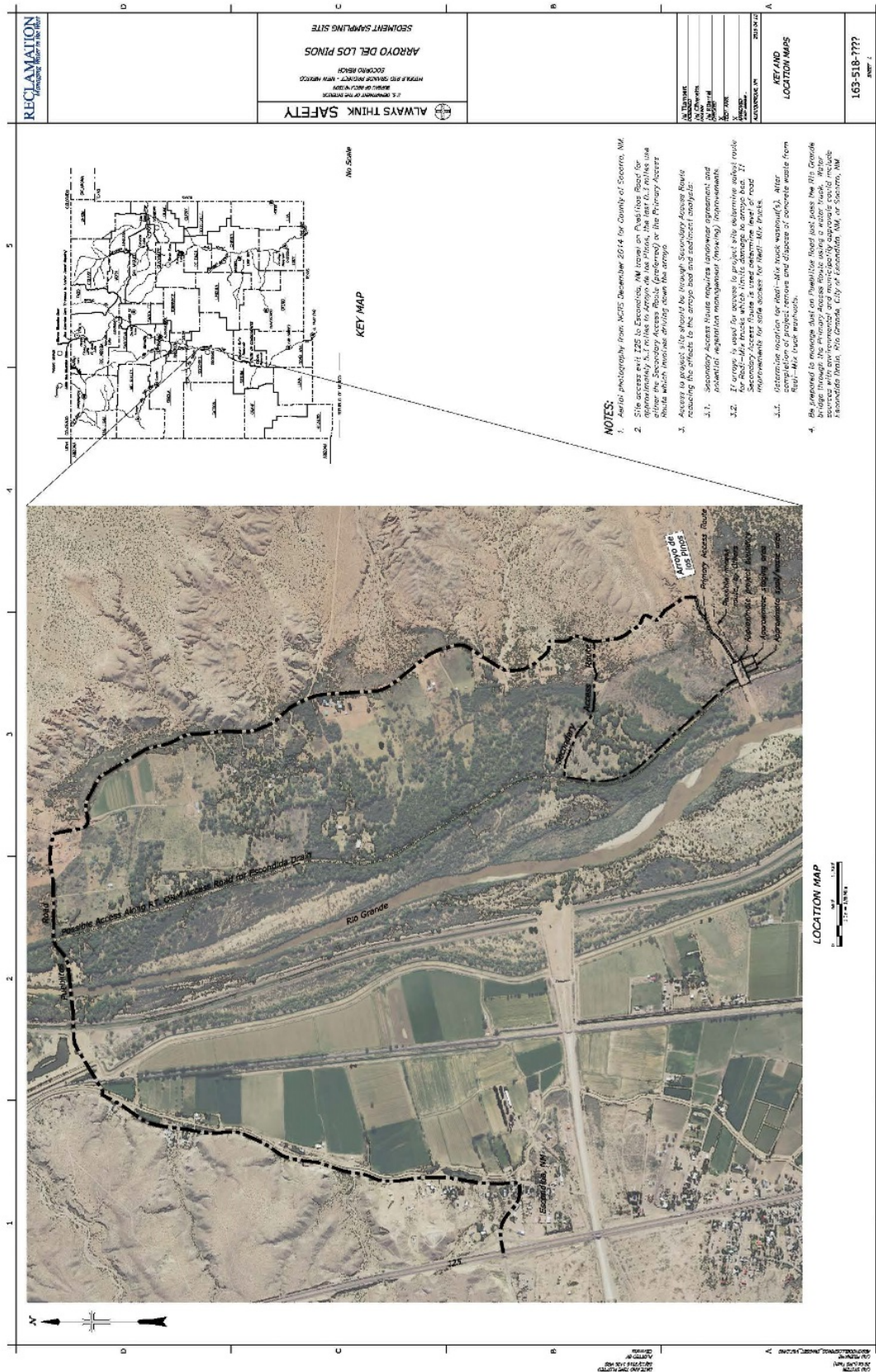
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Appendix B – Design Drawings (developed by Reclamation’s Albuquerque Area Office)

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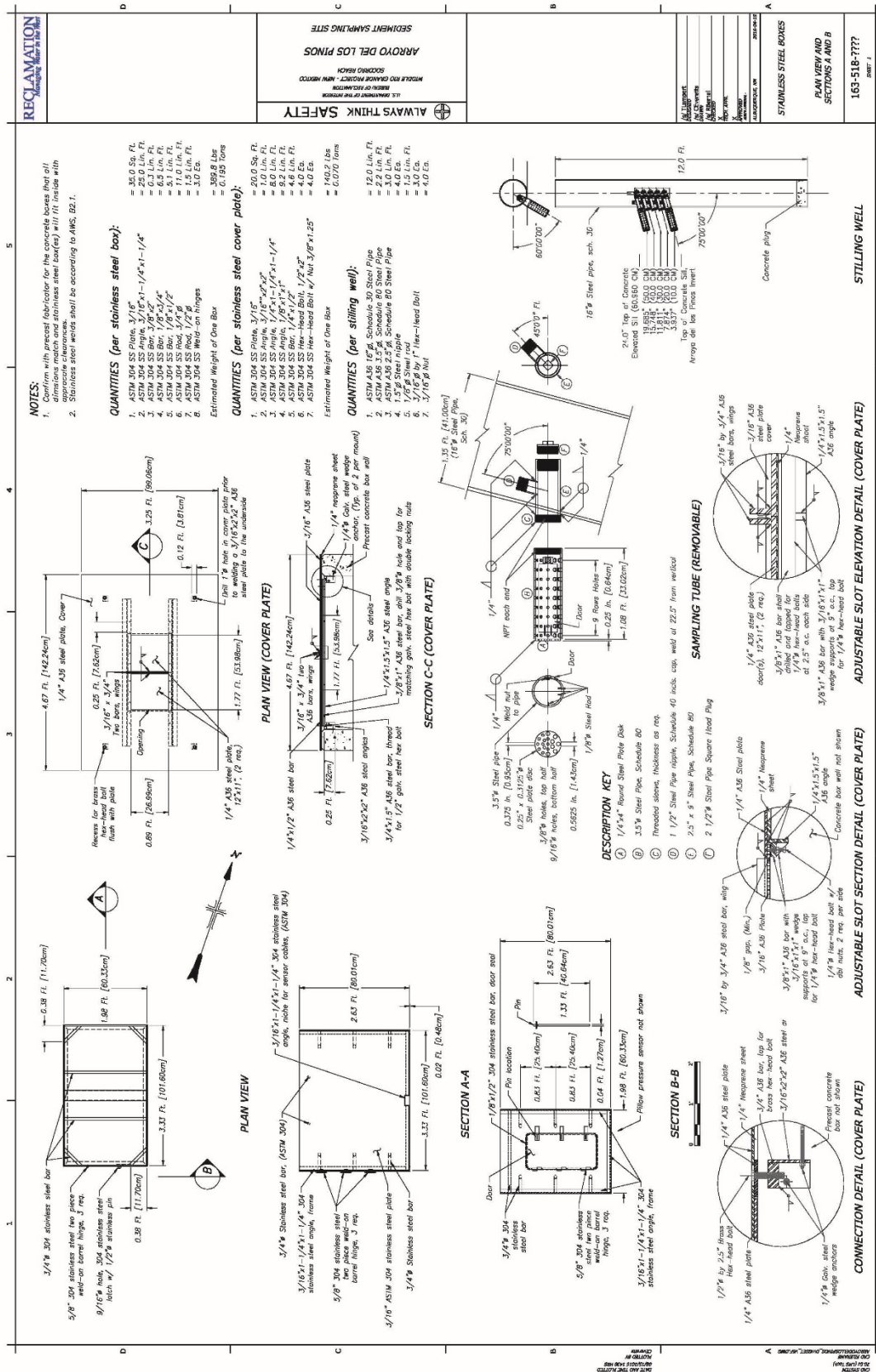
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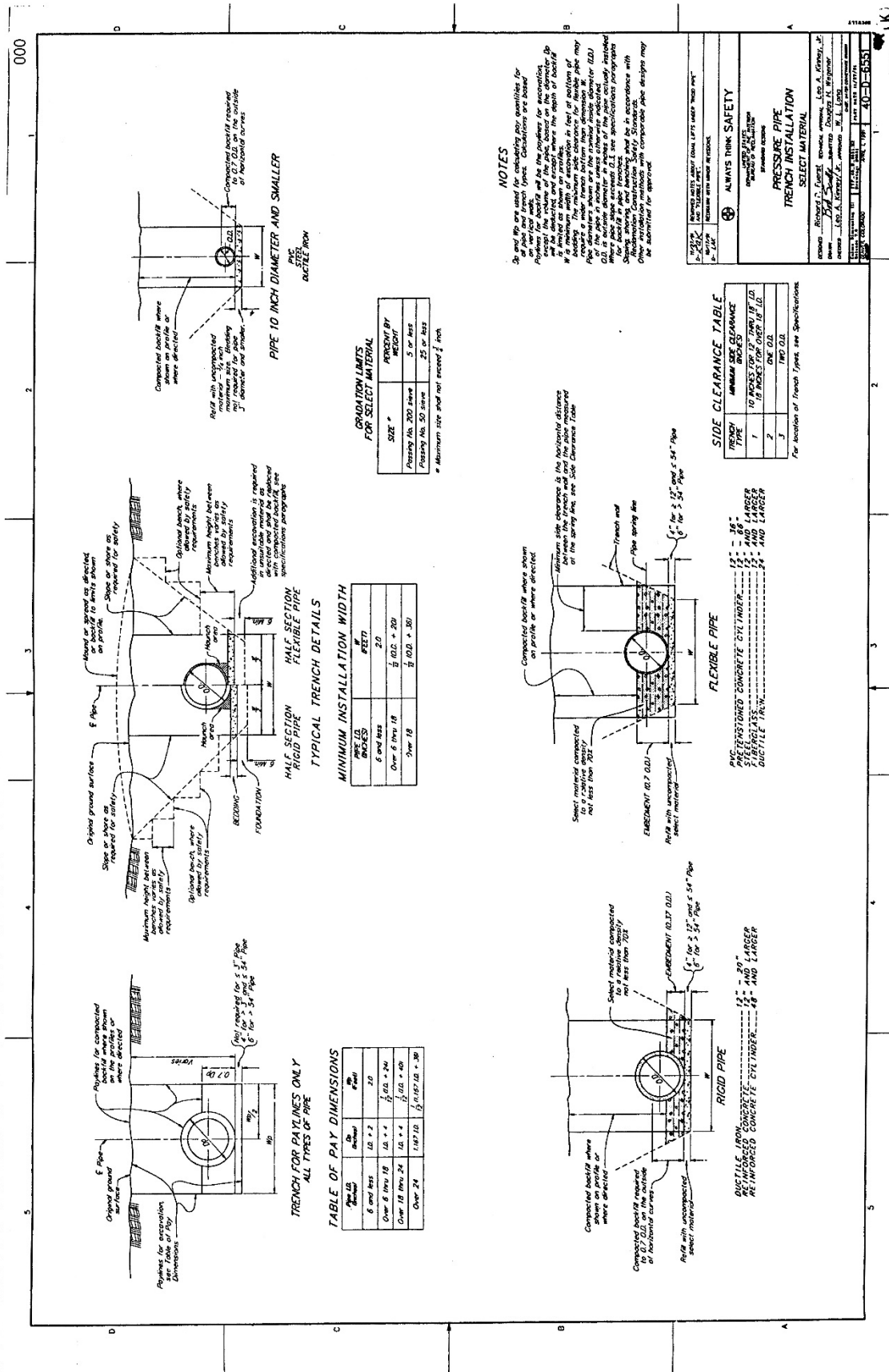
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Appendix C – Hydrophone System Schematic (provided by Yamma Hydrometric Solutions)

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 www.yamma-hydro.co.il | info@yamma-hydro.co.il

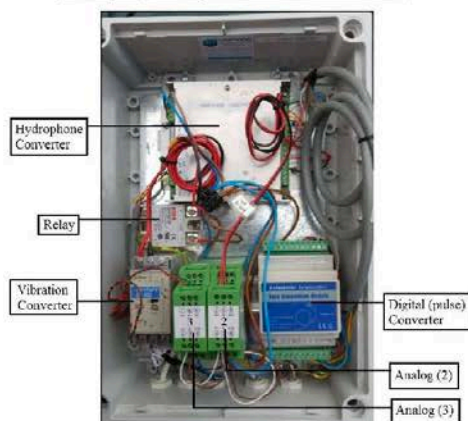
ימה פתרונות הידרומטריים

Hydrophone System

Pipe Hydrophone System



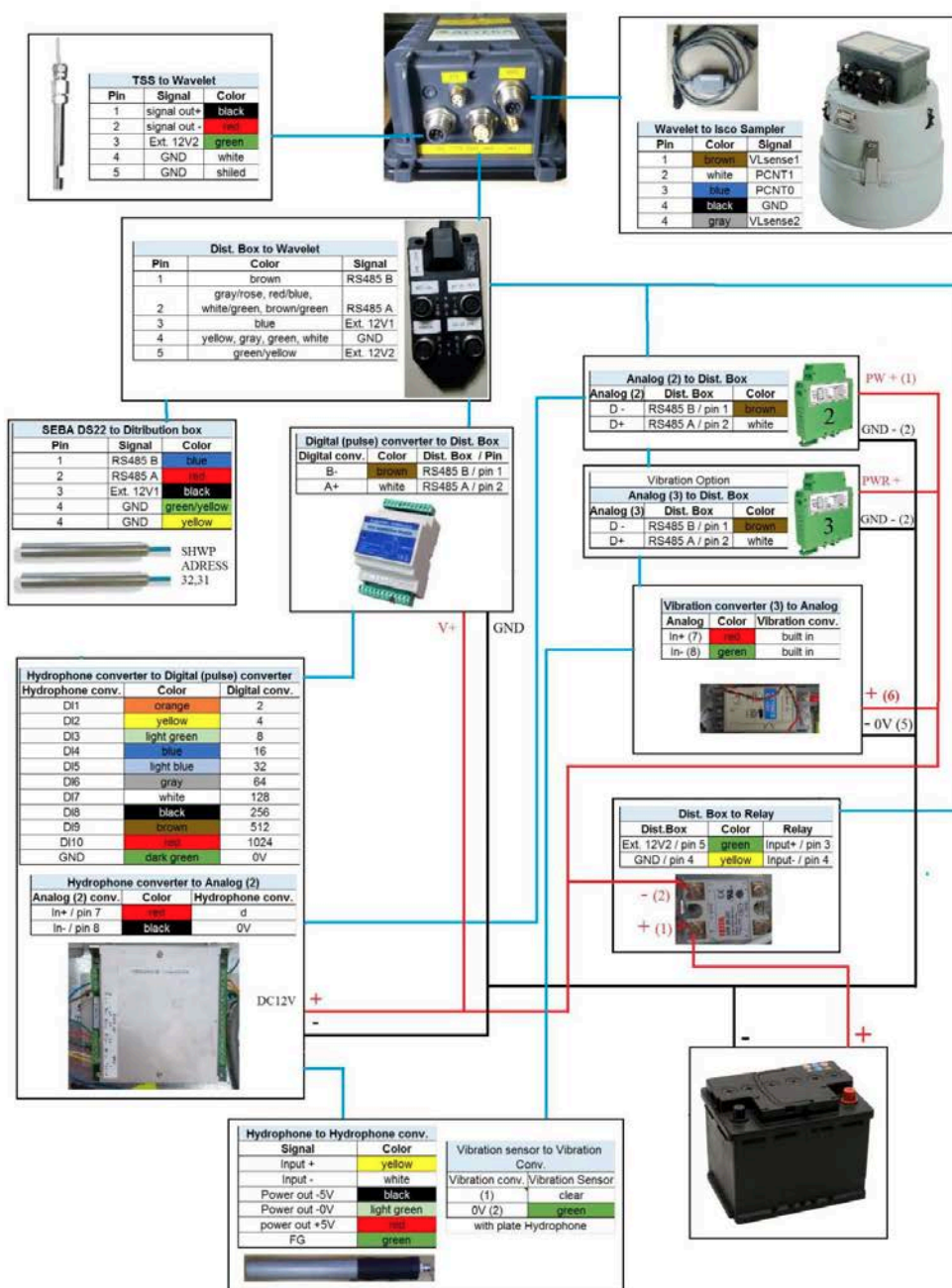
Plate Hydrophone System with Vibration Sensor





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ימה פתרונות הידרומטריים



Appendix D – Pinos Flow Summary Reports (provided by New Mexico Institute of Mining and Technology)

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November 4th, 2016 Arroyo de los Piños flow event summary

Flow was recorded in the Arroyo de los Piños following a storm early on November 4th, 2016 (Figures D 1 and D 2). Twenty millimeters of rain in twenty hours primed the basin for smaller flows later on. Flow reached the sampling site three times (at 1230, 2030, and 2300). Flow reached a maximum measured height of 0.18 m and extended up to 2.0 m from river right. Discrete velocity measurements were recorded throughout two events (Table D 1). In total 45 mm of rain fell over 30 hours.

Three transducers (one in the upper reaches of the basin, one in the middle part of the basin, and one at the installation site, near the Piños output into the Rio Grande) recorded how the basin reacted to the storm. Maximum flow at the up-basin location was 0.06 m (Figure D 3). Water pooled near the transducer and slowly infiltrated into the ground over the course of a few hours. Flow wasn't recorded at the mid-basin transducer (Figure D 4). This is likely due to the flow path of the runoff which may have missed the stilling well. The site transducer recorded three flows: the first two were complemented with data collected in the field while the last flow occurred very early in the morning (Figure D 5). A manning's roughness coefficient was determined using velocity and cross-sectional area measurements (Table D 1). In general, the calculated values are representative of a stream like the Piños, where sand and small gravel dominate the channel bed.

Three suspended sediment samples and one bedload sample were collected throughout the first two flow events. The flow was highly turbid, which is typical of semi-arid ephemeral streams. Total suspended sediment (TSS) concentration ranged from 4000 mg/L to 14000 mg/L; as stage increased TSS increased such that the highest concentration sample was collected during the highest stage (Table D 2). A BLH-84 sampler was used to collect one bedload discharge sample. The BLH-84 has a square opening that is 76 mm. Seventy six grams of sediment were collected over 60 seconds. Bedload discharge was 1.67gram/meter-second. Grain size distribution is provided in Figure D 6 The sample was taken in the highest discharge part of the stream and is likely to decrease away from the thalweg.

In summary, antecedent conditions from early morning storm cells primed the watershed for smaller cells that arrived later in the day. Three flow events were recorded at the Piños site; suspended sediment and velocity measurements were recorded during two of them. Total suspended sediment concentration ranged from 4000 mg/L to 14000 mg/L. One bedload sample was collected; discharge was 1.67 gram/meter-second. Flow was recorded up basin as well, albeit at a lower stage. In general, this was a very small flow on the Arroyo de los Piños; rain intensity was moderate which generated small flows. These data are a good starting point; techniques and procedures were established that can be refined and improved on for future flows.

Photographs from the events can be found at: <https://goo.gl/photos/rQNHZEPBUbD5FWxr9>

Measuring the Transport of Sediment in an Ephemeral Stream

Table D 1 Velocity and depth measurements from the Arroyo de los Piños sampling site. Transducer indicates sampling directly adjacent to the site transducer. Velocities were measured at 0.6 water depth.

date time	depth	Sampling location from river right	velocity	Flow Width	Discharge	Calculated mannings n
	m	m	m/s	m	m ³ /s	
11/4/16 12:25	0.14	1.0	0.6	1.5	0.126	0.05
11/4/16 12:27	0.14	1.0	0.65	1.5	0.1365	0.04
11/4/16 12:29	0.18	0.5	0.97	2.0	0.3492	0.03
11/4/16 12:33	0.15	0.5	0.77	2.0	0.231	0.04
11/4/16 12:34	0.08	1.0	0.27	1.0	0.0216	0.07
11/4/16 12:42	0.15	0.5	0.57	1.5	0.12825	0.05
11/4/16 12:44	0.12	Transducer	0.33	1.0	0.0396	0.07
11/4/16 13:03	0.06	Transducer	0.31	1.0	0.0186	0.05
11/4/16 20:34	0.07	Transducer	0.31	1.0	0.0217	0.06
11/4/16 20:35	0.1	0.5	0.48	1.5	0.072	0.05
11/4/16 20:36	0.1	Transducer	0.27	1.0	0.027	0.08
11/4/16 20:40	0.06	Transducer	0.29	1.0	0.0174	0.06

Table D 2 Suspended sediment sample results. TSS ranged from 4036 – 14220 mg/L.

Sample #	Sample Location	Sample Time	River Stage (m)	Volume Collected (mL)	TSS (mg/L)
1	1 m from river right	1230	0.15	323	14220
2	Site Transducer	1245	0.12	275	7236
3	Site Transducer	2040	0.06	332	4036

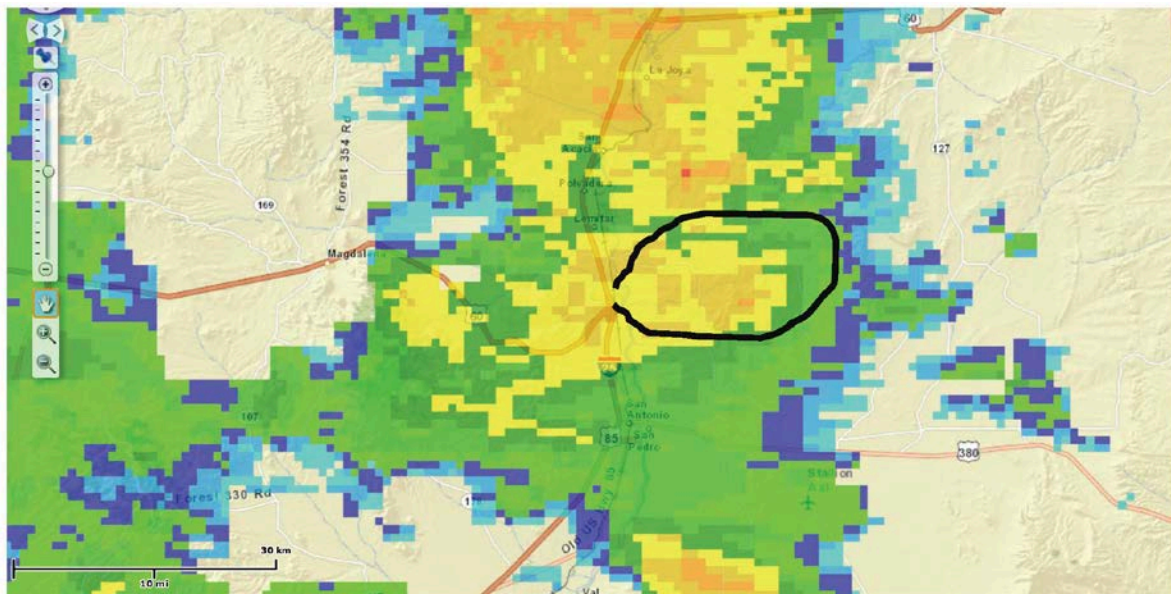


Figure D 1 Radar BACKSCATTER representation of the November 4th storm at 6am. The black outline represents the Piños watershed. This part of the storm was slow moving and of moderate intensity that lasted about 20 hours. Data from the National Centers for Environmental Information, gis.ncdc.noaa.gov.

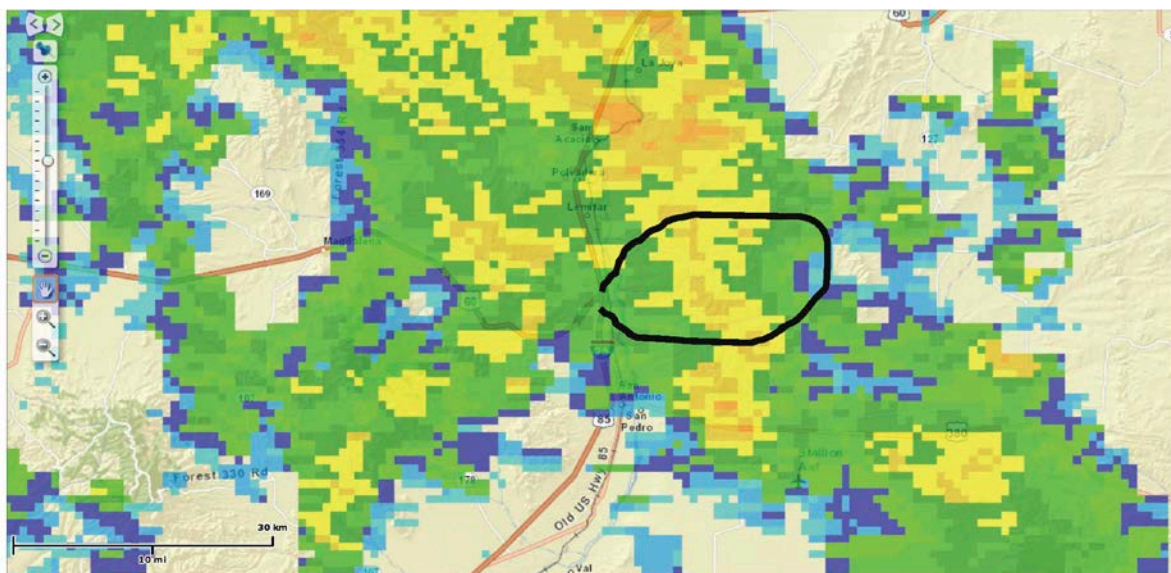


Figure D 2 Radar BACKSCATTER representation of the November 4th storm at 11:30 am. The black outline represents the Piños watershed. This part of the storm was slow moving and of moderate intensity that lasted about 2 hours. Data from the National Centers for Environmental Information, gis.ncdc.noaa.gov.

Measuring the Transport of Sediment in an Ephemeral Stream

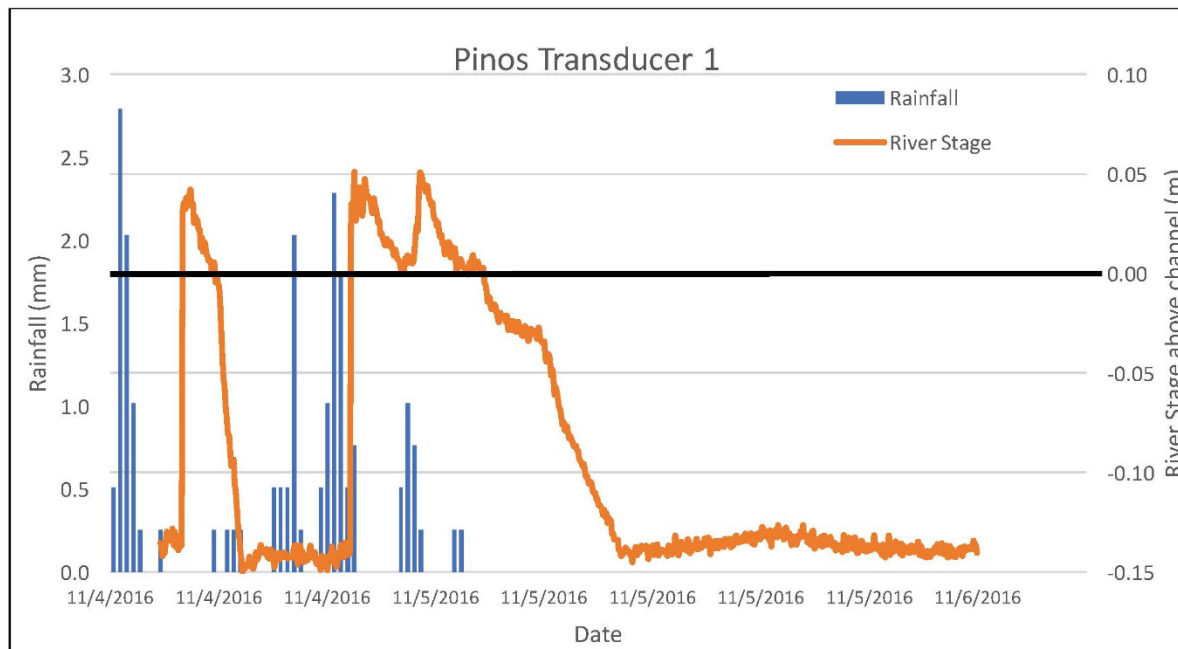


Figure D 3: Up basin transducer. Only small flows were recorded. The negative values represent the depth at which the transducer was below the ground surface (13.6 cm). Values below 0.00 reflect infiltration while positive values reflect overland flow.

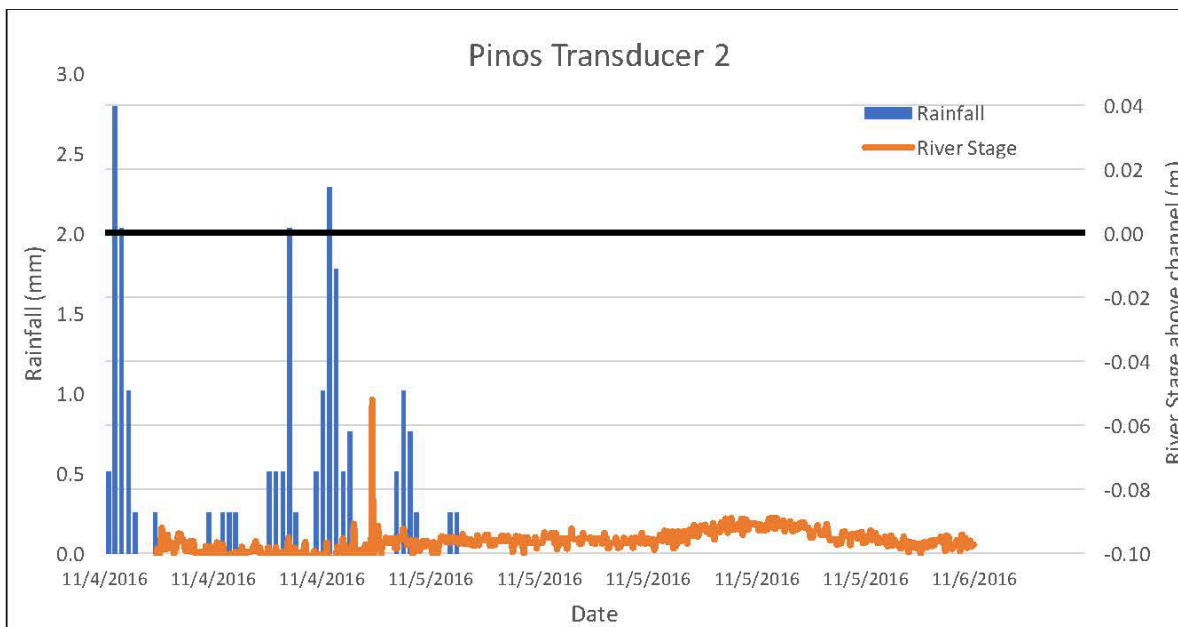


Figure D 4 Mid-basin transducer. No Flows were recorded at this location. The negative values represent the depth at which the transducer was below the ground surface (10 cm). Values below 0.00 reflect infiltration while positive values reflect overland flow.

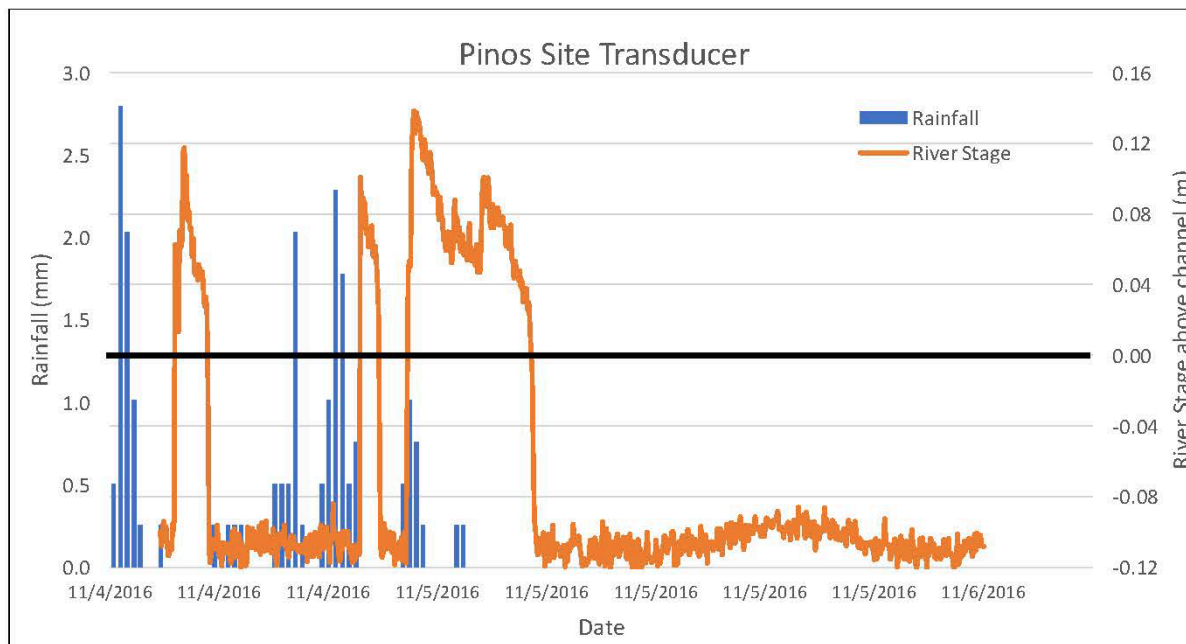


Figure D 5 Site Transducer. Three separate flows were recorded at this location. The first two are complemented by data taken in the field. The negative values represent the depth at which the transducer was below the ground surface (10 cm). Values below 0.00 reflect infiltration while positive values reflect overland flow.

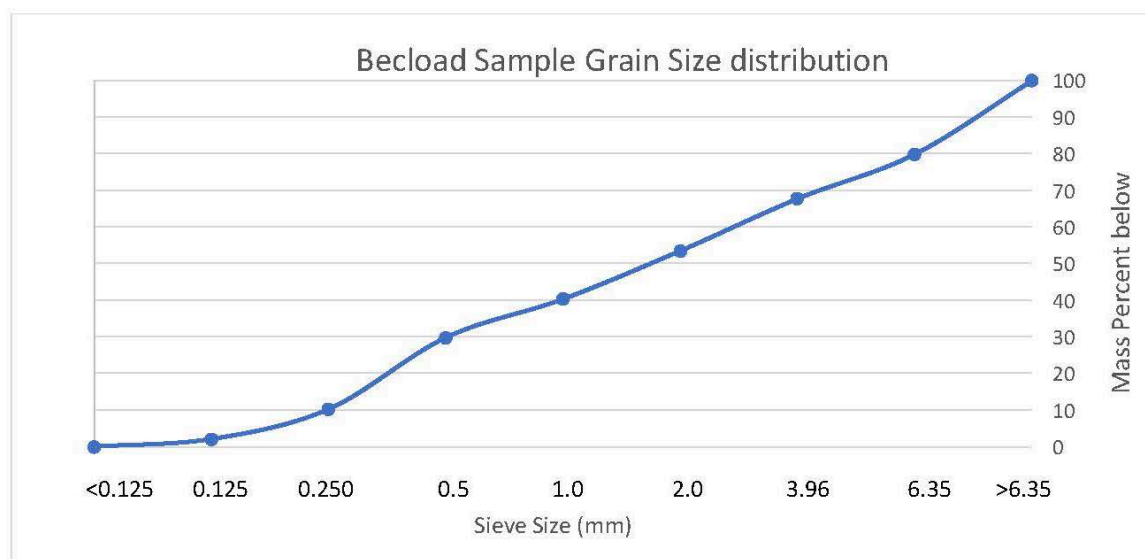


Figure D 6 Grain size distribution from the bedload sample collected on 11/4/16. 47% of the sediment mass had a grain size diameter greater than 2mm.

January 15th, 2017 Arroyo de los Piños flow event summary

Flow was recorded in the Arroyo de los Piños following a storm January 14th - January 15th, 2017 (Figure D 7 and Figure D 8). Ten millimeters of rain fell over eleven hours, followed by 12 millimeters in in two hours (Figure D 9). This moderate intensity storm produced a small flow at the Piños site (observed to be ~4.0 cm at 0645). The flow was too small to sample bedload or suspended load.

Estimates of peak stage, velocity, and stage height are presented in Table D 3. A seismometer was deployed to record seismicity induced by bedload. The seismometer recorded data at a frequency of 500 Hz and will be compared to the background dataset collected in 2016.

Transducers were placed throughout the basin to record flow. These transducers are not vented; they record absolute pressure and are corrected using an ambient barometric pressure transducer. Due to the imprecise nature of this correction, flows were not reflected in the corrected stage height graph (Figure D 10). This issue will occur only in extremely small flows of less than ~7.0 cm. Future equipment deployments at the Piños site will utilize vented transducers, where pressure data is immediately corrected. This will increase the accuracy of flow data and allow detailed stage analysis, even in these small flows.

In summary, antecedent conditions from slow moving, low intensity storms saturated soils in the Arroyo de los Pinos watershed enough to produce an extremely small flow on January 15th, 2017. This flow was too small to sample. Due to the small nature of the flow, data from the deployed pressure transducers did not accurately record the flow when corrected for barometric pressure. Seismic data collected to indirectly measure bedload will be analyzed and compared to the background dataset collected in 2016.

Photographs from the event can be found at: <https://goo.gl/photos/BNwYvHUxrdCzjkZv9>

Table D 3 Peak flow estimates from the Arroyo de los Pinos site. These data were collected at 0645.

Parameter	Highest estimate
Stage (m)	0.04
Velocity (m/sec)	0.15
Flow Extent (m from river	1.5

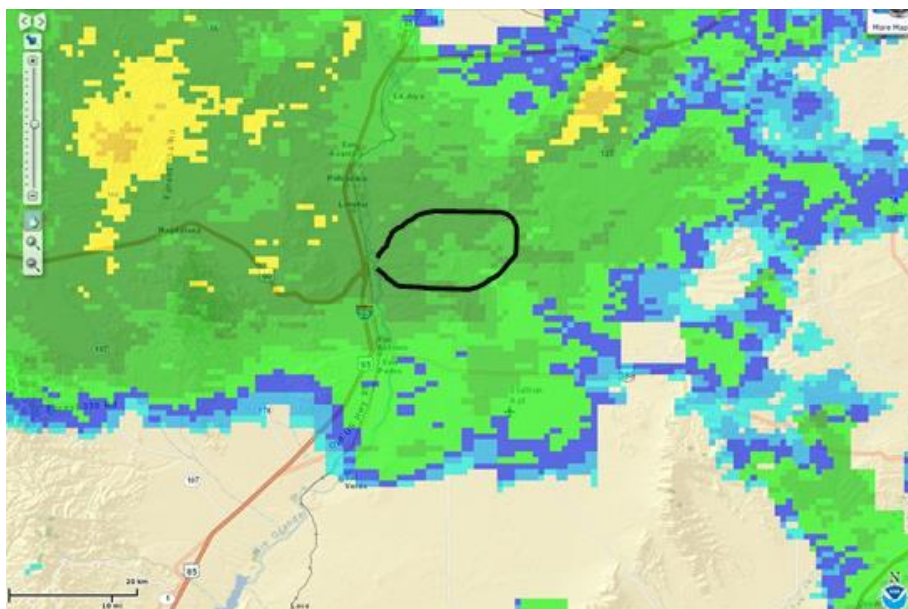


Figure D 7 Radar BACKSCATTER image of the January 15th storm at 23:45. The black outline represents the Piños watershed. This part of the storm was slow moving and of low intensity that lasted about 11 hours. Data from the National Centers for Environmental Information, gis.ncdc.noaa.gov.

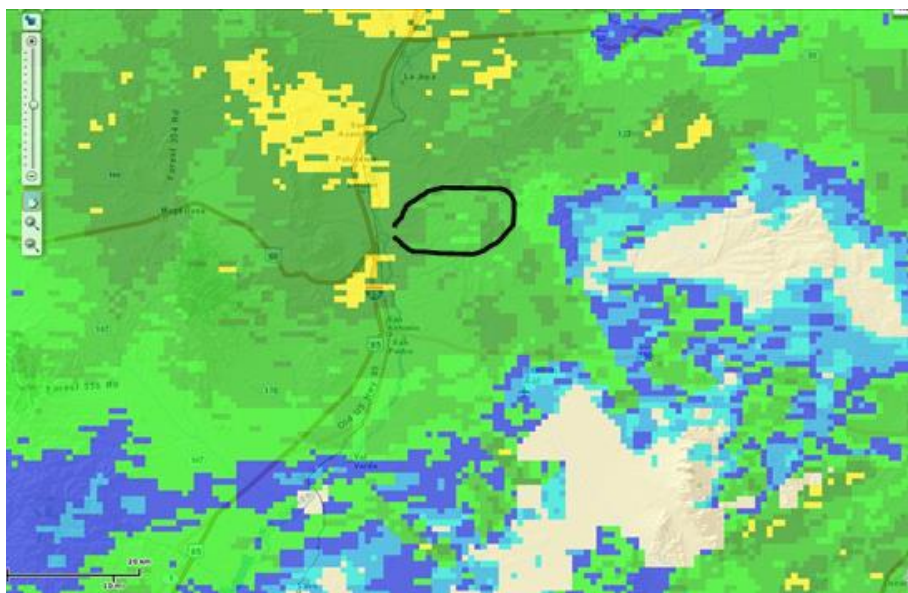


Figure D 8 Radar BACKSCATTER image of the January 15th storm at 0615. The black outline represents the Piños watershed. This part of the storm was also slow moving and of low intensity that lasted about 2 hours. Even though this part of the storm was also fairly low intensity, ambient conditions caused overland flow. Data from the National Centers for Environmental Information, gis.ncdc.noaa.gov.

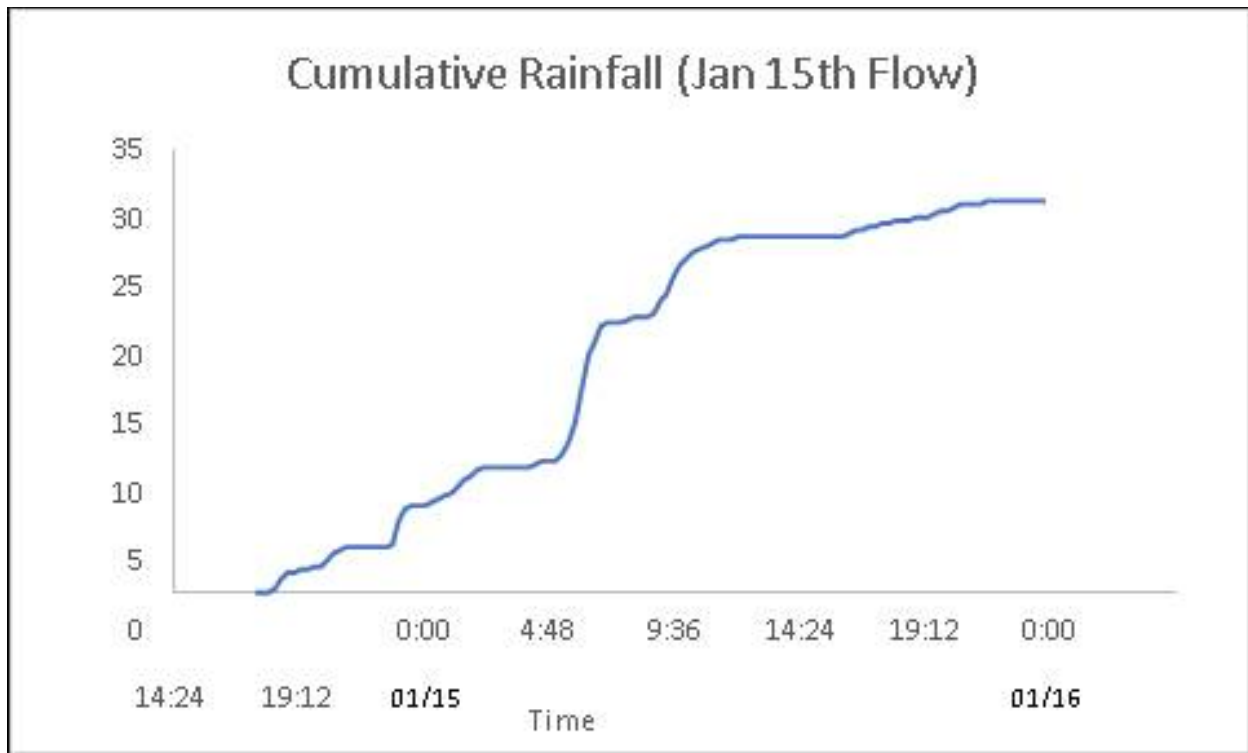


Figure D 9 Cumulative rainfall during the Jan 15th storm. Flow was recorded at the Piños site at 0645 on 01/15/17.

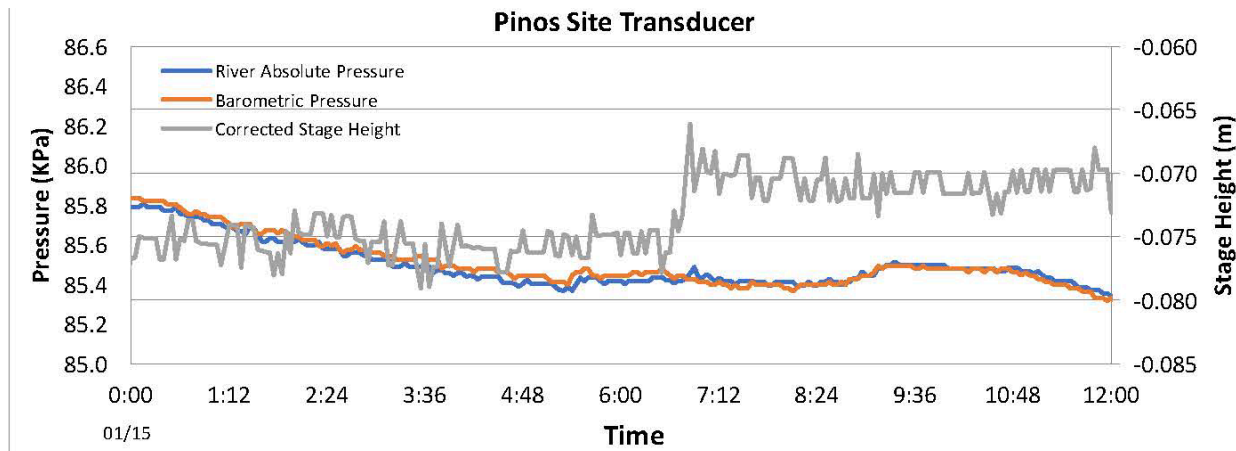


Figure D 10 Corrected stage height and pressure transducer data (absolute and barometric). The negative values represent the depth at which the transducer was below the ground surface (7.6 cm). Values below 0.00 reflect infiltration. There is a noticeable increase at the initiation of flow (0645). However, the magnitude is inaccurate due to imprecisions caused by the barometric correction.

July 2017 Arroyo de los Piños flow events summary

Individual Event Summaries

Flow was recorded within the Arroyo de los Piños six times during the 2017 monsoon season. A variety of data were collected including stage, velocity, suspended sediment, bedload, and seismic data. Continuous stage height was recorded at the basin outlet and farther up-basin, near the headwaters of the watershed (Figures D 11 and D 12). Two rain gauges are deployed in the watershed, one at the basin outlet and one up-basin in steep, exposed bedrock hills. (Figure D 13).

Ten bedload samples and 20 suspended sediment samples were collected (Table D 4). Below is a brief summary of each event, the type of data collected, and a description of the storm that caused the flow. Following the event summaries is a more in depth analysis of the data collected.

A photolog of all of the events can be found here:

<https://photos.app.goo.gl/VlaE5ZyCTxtEVCMY2>

July 2nd flow

Characterized by a small, very intense storm cell that caused overland flow in the lower part of the basin (Figure D 14). Fourteen millimeters of rain fell over 30 minutes at the basin outlet while none was recorded up-basin. Limited data were collected during this small event; only transducer stage and rain data was collected because no one was present during the event.

July 9th flow

Another small flow event from a fast-moving storm cell moving south across the entirety of the basin (Figure D 15). Over thirty minutes, five millimeters of rain was recorded at the basin outlet while 10 millimeters of rain was recorded by the up-basin gauge. Rain earlier in the day created antecedent conditions that allowed for this relatively small storm to produce flow within the basin. Two suspended sediment samples were collected. The seismometer was deployed but malfunctioned.

July 13th flow

A moderate sized flow event from a slow-moving storm cell moving southwest across the entirety of the basin (Figure D 16). Over 1.5 hours, two millimeters of rain was recorded by the up- basin gauge and 27 mm of rain was recorded by the basin outlet rain gauge. A full complement of data were collected including two bedload and five suspended sediment samples.

July 15th flow

The largest recorded flow event to date (Figure D 17). River stage was recorded in excess of 0.64 meters. One large storm cell moving southwest caused 18.5 mm of rain at the basin outlet and 6 mm of rain up-basin. A full complement of data were collected including seven suspended sediment and one bedload sample were collected. Most of the samples and direct measurements of stage and velocity were collected from the river bank due to the extreme nature of the flow.

July 22nd flow

Antecedent conditions tempered the July 22nd flow event; three full days of dry conditions were sufficient to dry the entire watershed. Two large cells moving southwest produced 22 mm of rain up-basin and 29 mm of rain at the basin outlet (Figure D 18). Six bedload and six suspended sediment samples were collected in addition to stage, velocity, and seismic data.

August 1st flow

Atmospheric conditions caused high intensity rain clouds to form directly over the bottom of the watershed (Figure D 19). The basin outlet rain gauge recorded 14 mm of rain in 45 minutes. The flow produced was short-lived; only one bedload sample was collected before river stage fell below sampling level.

Data Analysis

Bedload samples were generally finer grained than expected (Figure D 20). Review of recent channel surface Wolman counts and subsurface sampling suggest that up to 1/3 of bedload mass is larger than 8 mm in diameter, 1/3 of bedload mass is between 2 – 8 mm diameter, and 1/3 is less than 2 mm. Only one bedload sample collected from the 2017 monsoon season showed this distribution. Oversampling and the source of sediment are possible reasons for the difference from the expected grain size distribution. Some samples (2017_0722_BL2 and 2017_0722_BL4 in particular) suffered from reduced sample efficiency where the sample container exceeded its maximum capacity, clogging the sample. This biases the sample towards finer grained sediment.

In addition, some rain storms formed over the lower part of the basin (e.g. the July 13th storm) which is dominated by finer grained Plio-Pleistocene alluvial basin fill sediment.

Continuous flood stage data was recorded at the basin outlet (Figure 1). Some events caused the stilling well to fill with sediment which caused a negative pressure signal. This signal is clearly seen after the July 9th, 13th, 15th, and 22nd flow events. Once sediment is removed from the stilling well and the transducer cleaned, the barometric pressure signal returns. This presents some potential data quality issues once the stilling well fills with sediment. In particular, comparison of the July 22nd transducer data to the manually recorded stage data

revealed that the latter half of the hydrograph was not recorded by the pressure transducer. To prevent this data loss in future events, the stilling wells were filled with loose gravel. This should prevent finer sediment from obstructing the pressure transducer while allowing the pressure signal from the flow to be recorded. The July 15th event caused significant changes to the channel. The thalweg on the north side of the channel aggraded more than 0.15 meters and covered the stilling well.

The well was moved to a newly created thalweg on the south side of the channel on July 18th.

Flow was only recorded by the up-basin transducer during the July 9th and 22nd flow events (Figure 2). This agrees with the rain gauge data where the up-basin gauge recorded 10 mm and 22 mm of rain respectively. All other storms produced a total of 20 mm up-basin. The up-basin transducer did not suffer the same filling issues that the site transducer did; the dataset is therefore more complete. One peculiar drop in recorded stage occurs on July 31st. This is due to a data offload. Once the transducer equilibrates to the local barometric pressure it returns to a typical baseline.

Sixty-Four direct measurements of stage and velocity were collected during each storm event (Appendix 1). The measurements of stage fit generally well with stage measurements from the site pressure transducer until the stilling well fills with sediment and the transducer signal is lost. During the July 15th event, many of the direct measurements were collected from the river bank due to the height of the flow. These velocity measurements are almost certainly biased low.

These data will be added to the total complement of direct measurements to produce a stage- discharge rating curve once sufficient data has been collected.

A Nanometrics Trillium compact TC120-SV1 seismometer has continuously recorded seismic data at the Arroyo de los Piños site at a sample rate 500 Hz. To date, spectrograms of the July 13th and 15th have been produced (Figure D 21). There is a clear increase in signal strength during

the events. This is one of many planned methods for indirectly measuring bedload; seismic data will continue to be collected to assess its ability to accurately estimate bedload flux.

A wide variety of events occurred along the Arroyo de los Piños during the 2017 monsoon season. Many of the storms were localized towards the bottom of the watershed, producing flows that carried finer grained material. Large events, such as the July 15th event, are not necessarily the highest precipitation events; antecedent conditions are extremely important in climates such as the one found in the semi-arid southwest. Understanding the effect of these conditions is a long-term process and requires many seasons of observations. As the site installation is completed, these data will inform researchers of the types of flow to be expected along the Arroyo de los Piños.

Measuring the Transport of Sediment in an Ephemeral Stream

Table D 4 Sample collection summary.

Sample ID	Type	Local Sample DateTime	UTC Sample DateTime	Notes
2016_1107_BL1	Manual Bedload	11/7/16 12:40	11/7/16 19:40	
2017_0713_BL1	Manual Bedload	7/13/17 18:25	7/14/17 0:25	
2017_0713_BL2	Manual Bedload	7/13/17 18:56	7/14/17 0:56	
2017_0715_BL1	Manual Bedload	7/15/17 17:26	7/15/17 23:26	Sampled from bank
2017_0722_BL1	Manual Bedload	7/22/17 18:25	7/23/17 0:25	Efficiency Issues while sampling
2017_0722_BL2	Manual Bedload	7/22/17 19:20	7/23/17 1:20	
2017_0722_BL3	Manual Bedload	7/22/17 19:34	7/23/17 1:34	
2017_0722_BL4	Manual Bedload	7/22/17 20:20	7/23/17 2:20	Efficiency Issues while sampling
2017_0722_BL5	Manual Bedload	7/22/17 20:35	7/23/17 2:35	
2017_0722_BL6	Manual Bedload	7/22/17 21:05	7/23/17 3:05	
2017_0709_SS1	Manual Suspended	7/9/17 22:35	7/10/17 4:35	
2017_0709_SS2	Manual Suspended	7/9/17 22:40	7/10/17 4:40	
2017_0713_SS1	Manual Suspended	7/13/17 18:12	7/14/17 0:12	
2017_0713_SS2	Manual Suspended	7/13/17 18:17	7/14/17 0:17	
2017_0713_SS3	Manual Suspended	7/13/17 18:34	7/14/17 0:34	
2017_0713_SS4	Manual Suspended	7/13/17 18:45	7/14/17 0:45	
2017_0713_SS5	Manual Suspended	7/13/17 19:00	7/14/17 1:00	
2017_0715_SS1	Manual Suspended	7/15/17 17:19	7/15/17 23:19	
2017_0715_SS2	Manual Suspended	7/15/17 17:32	7/15/17 23:32	Sampled from bank
2017_0715_SS3	Manual Suspended	7/15/17 17:41	7/15/17 23:41	Sampled from bank
2017_0715_SS4	Manual Suspended	7/15/17 17:54	7/15/17 23:54	Sampled from bank
2017_0715_SS5	Manual Suspended	7/15/17 18:04	7/16/17 0:04	
2017_0715_SS6	Manual Suspended	7/15/17 18:20	7/16/17 0:20	
2017_0715_SS7	Manual Suspended	7/15/17 18:38	7/16/17 0:38	
2017_0722_SS1	Manual Suspended	7/22/17 19:07	7/23/17 1:07	
2017_0722_SS2	Manual Suspended	7/22/17 19:17	7/23/17 1:17	
2017_0722_SS3	Manual Suspended	7/22/17 19:42	7/23/17 1:42	
2017_0722_SS4	Manual Suspended	7/22/17 20:24	7/23/17 2:24	
2017_0722_SS5	Manual Suspended	7/22/17 20:47	7/23/17 2:47	
2017_0722_SS6	Manual Suspended	7/22/17 21:05	7/23/17 3:05	

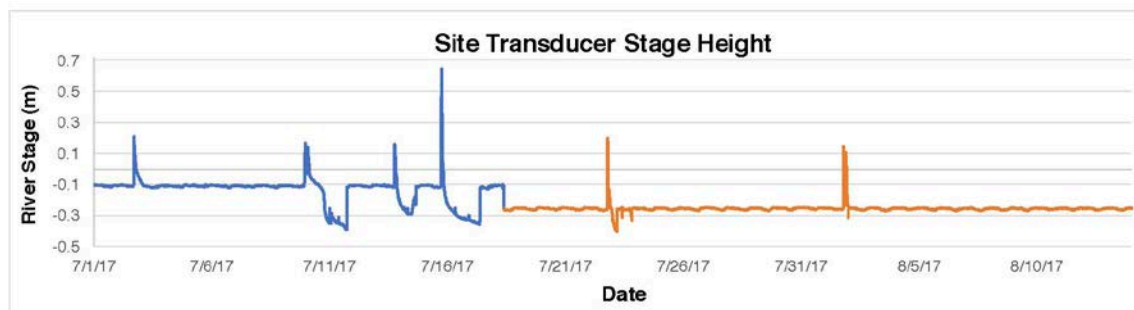


Figure D 11 Site transducer stage height. The negative baseline is the depth that the transducer is below the surface. The blue represents the original location of the transducer on river right. After the July 15th event, the transducer was moved to river left (orange line) due to aggrading around the transducer.

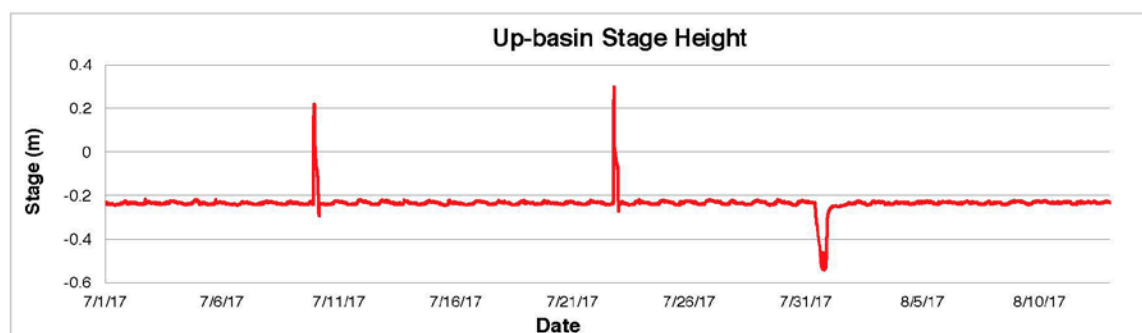


Figure D 12 Up-basin transducer stage height. The negative baseline is the depth that the transducer is below the surface. Flow was only recorded during two events, July 9th and July 22nd.



Figure D 13 Rainfall recorded in the Arroyo de los Piños watershed. Blue is the site rain gauge, near the basin outlet. Orange is the up- basin rain gauge located in the headwaters of the watershed.

Measuring the Transport of Sediment in an Ephemeral Stream

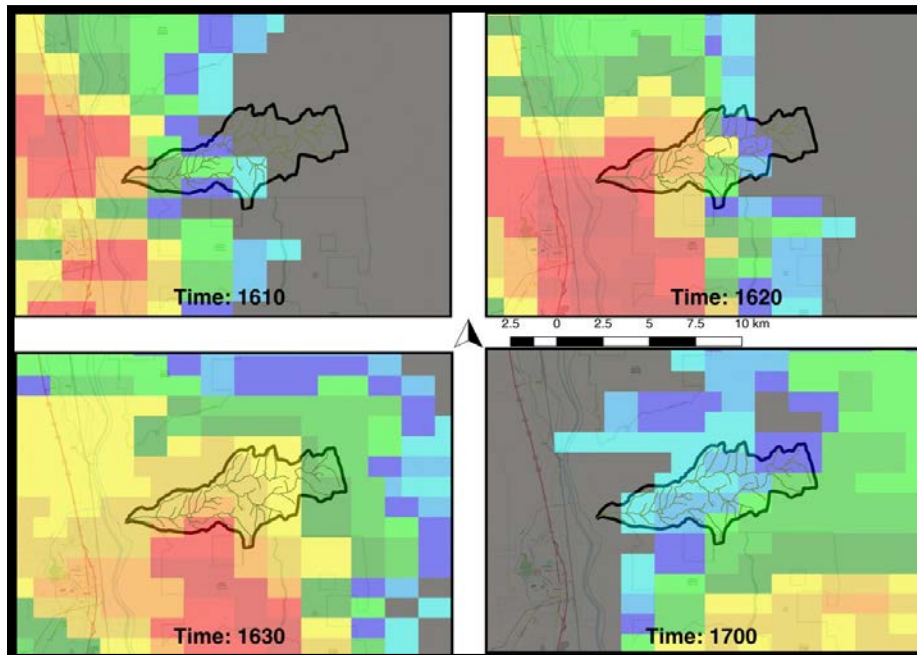


Figure D 14 July 2nd storm progression. Radar colors are correlated with rainfall intensity; red is the highest intensity while blue is the lowest. This storm was concentrated over the bottom of the watershed, producing runoff locally near the basin outlet.

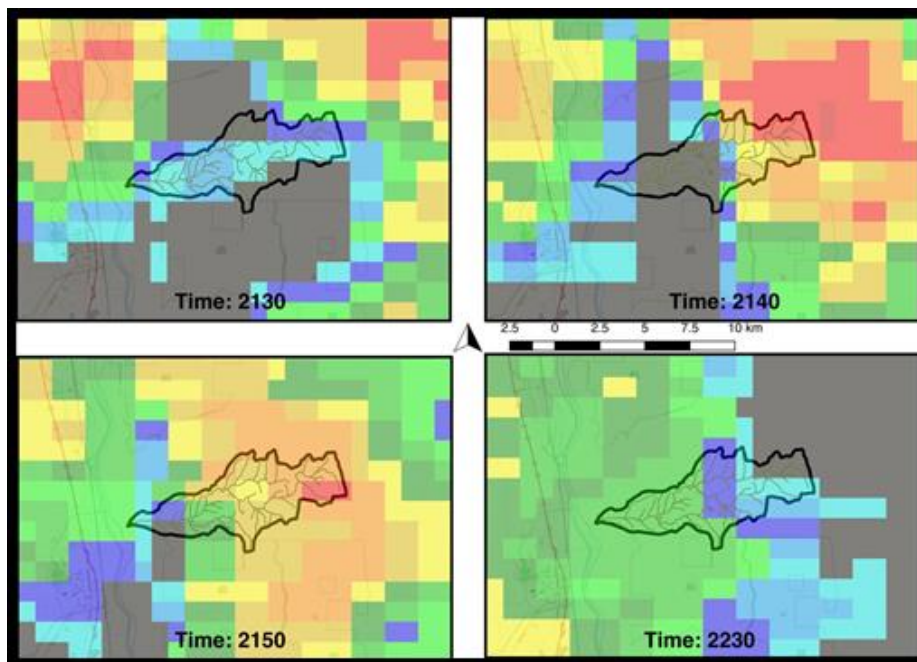


Figure D 15 July 9th storm progression. Radar colors are correlated with rainfall intensity; red is the highest intensity while blue is the lowest. This storm caused even rainfall over the entire basin.

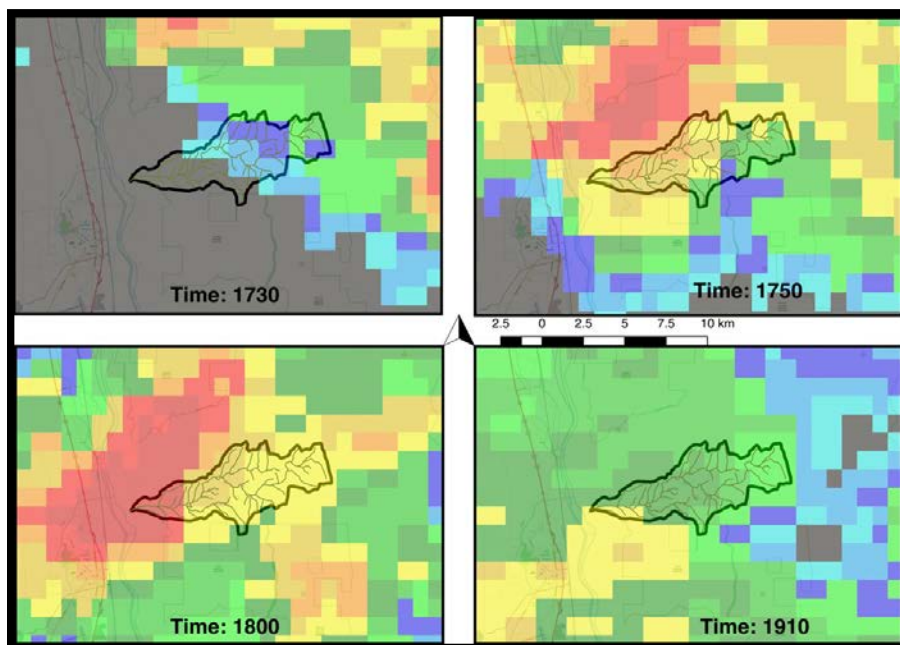


Figure D 16 July 13th storm progression. Radar colors are correlated with rainfall intensity; red is the highest intensity while blue is the lowest. This storm was concentrated over the bottom of the watershed, producing more runoff locally near the basin outlet.

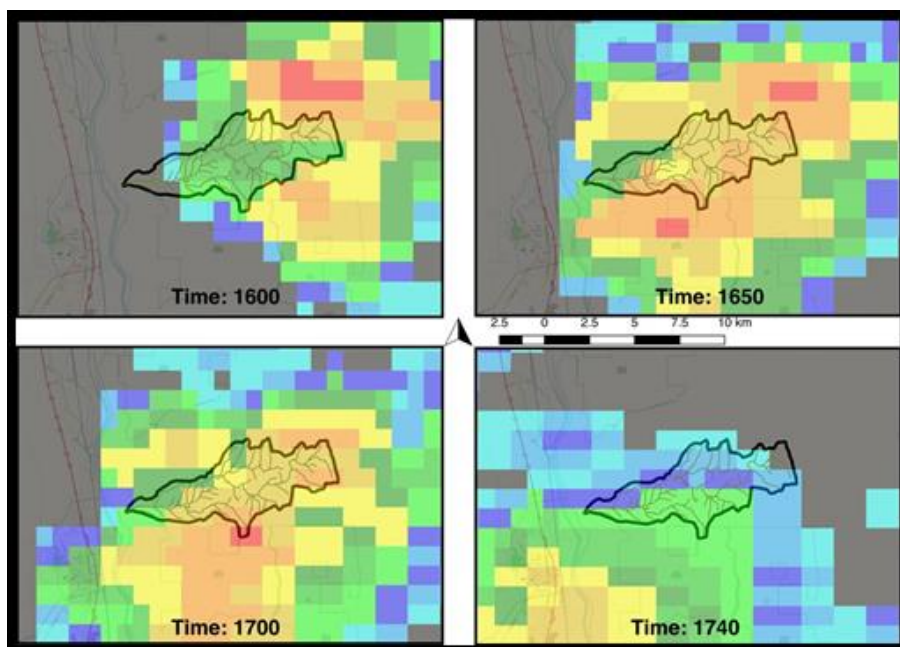


Figure D 17 July 15th storm progression. Radar colors are correlated with rainfall intensity; red is the highest intensity while blue is the lowest. Although a relatively low intensity storm, antecedent conditions within the watershed made this event the largest of the season

Measuring the Transport of Sediment in an Ephemeral Stream

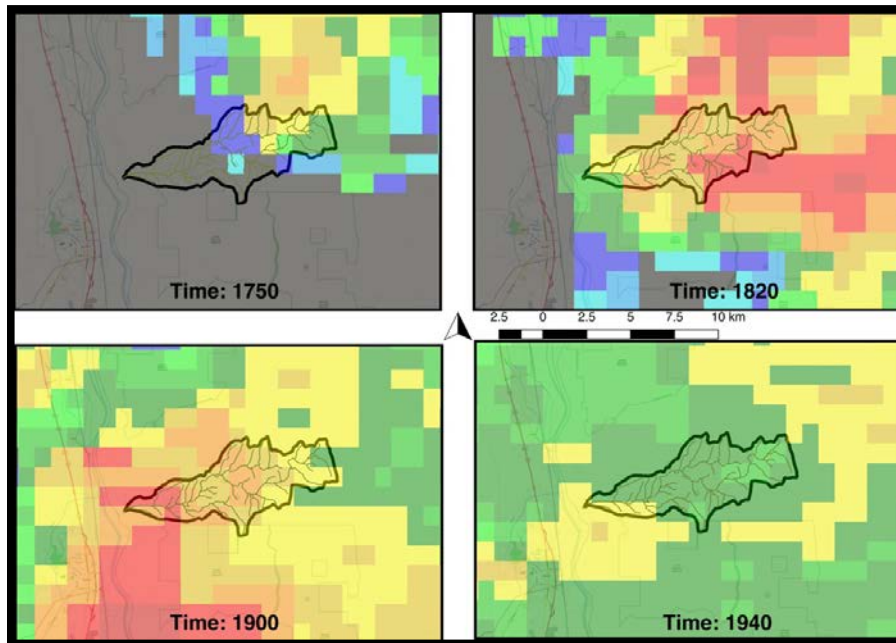


Figure D 18 July 22nd storm progression. Radar colors are correlated with rainfall intensity; red is the highest intensity while blue is the lowest. The largest storm of the season, by precipitation. High intensity rain fell in the upper part of the watershed and then progressed southwest to the basin outlet. Dry antecedent conditions caused much of the precipitation to infiltrate.

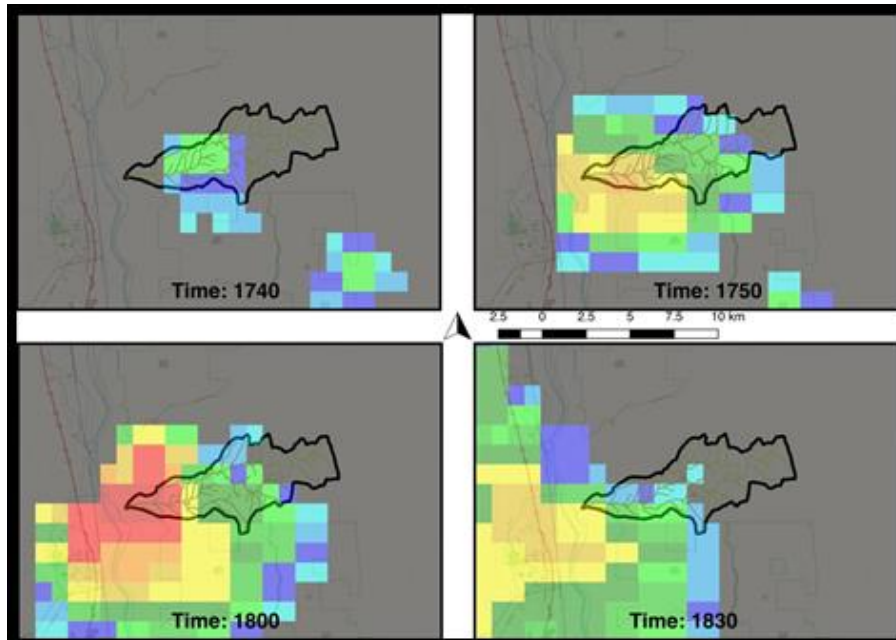


Figure D 19 August 1st storm progression. Radar colors are correlated with rainfall intensity; red is the highest intensity while blue is the lowest. Rainfall fell almost exclusively on the bottom of the basin near the basin outlet. The flow produced was subsequent small and lasted less than an hour.

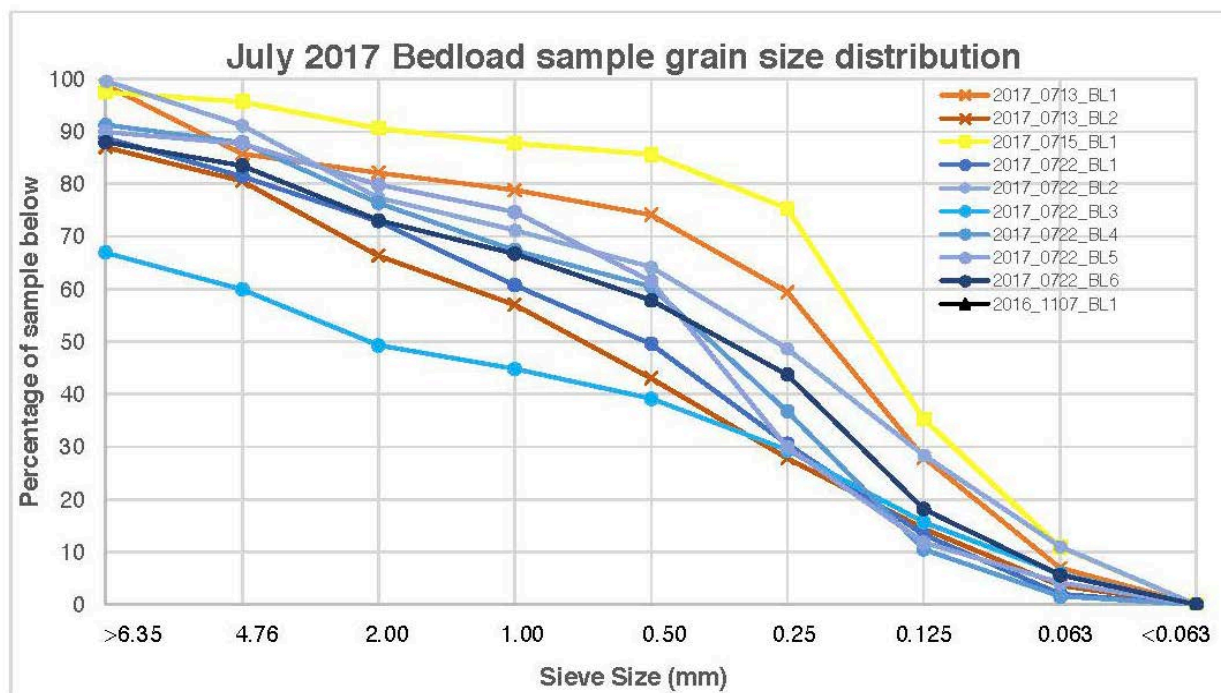


Figure D 20 Bedload sample grain size distribution. Most of the sediment mass fall within the 0.125 mm – 0.5 mm sieves.

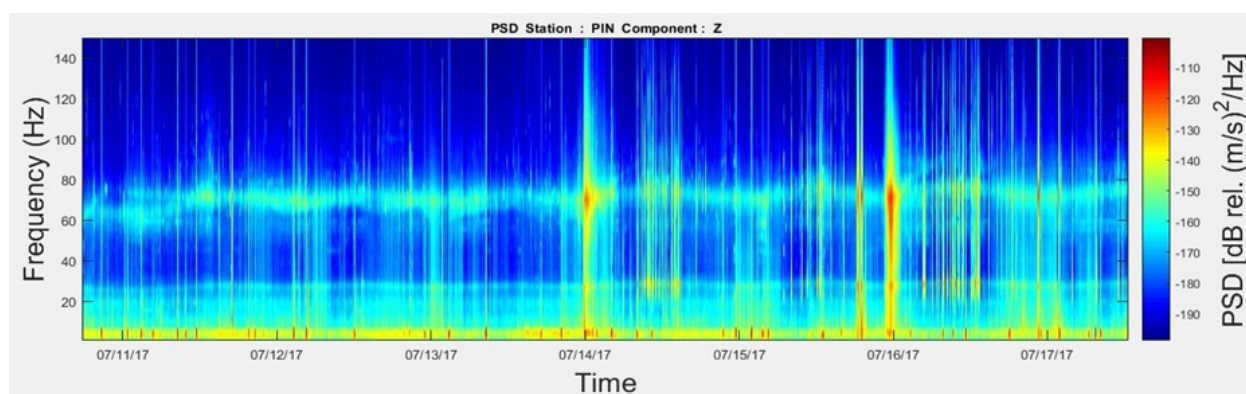


Figure D 21 July 10th – July 17th spectrogram analysis from the Arroyo de los Piños. Seismic frequency is shown on the y-axis, time (in UTC) is the x-axis, and color scales with amplitude of the seismic energy, in dB. Two events occurred during this date range, one on July 13th and one on July 15th. Both are clearly visible within the data.

Measuring the Transport of Sediment in an Ephemeral Stream

Table D 5 2017 Monsoon Season Stage and Velocity Measurements

Date	Local Time	Location	Stage	Velocity	Flow Width
7/9/2017	10:26	1 m RR	4- 6 cm	3sec/m	1.5
7/9/2017	10:27	1 m RR	4- 6 cm	3sec/m	1.5
7/9/2017	10:28	1 m RR	8-10 cm	2sec/m	2
7/9/2017	10:30	1 m RR	6-8 cm	2sec/m	2
7/9/2017	10:35	1 m RR	5-7 cm	3sec/m	1.5
7/9/2017	10:40	1 m RR	4-6 cm	3sec/m	1
7/13/2017	18:05	1 m RR	0.16	0.63	8 m
7/13/2017	18:13	1 m RR	0.32	1.2	8 m
7/13/2017	18:19	1 m RR	0.26	0.98	7 m
7/13/2017	18:28	1 m RR	0.22	0.88	
7/13/2017	18:33	1 m RR	0.2	0.71	
7/13/2017	18:52	1 m RR	0.1	0.52	5 m
7/13/2017	18:57	1 m RR	0.18		
7/13/2017	19:02	1 m RR	0.1	0.45	3.5 m
7/15/2017	17:17	Transducer	0.22		
7/15/2017	17:18	Transducer	0.3	1.4	Bank Full
7/15/2017	17:19	Transducer	0.42	1.47	Bank Full
7/15/2017	17:25	From bank	0.5		Bank Full
7/15/2017	17:29	Transducer	0.48		Bank Full
7/15/2017	17:31	Transducer	0.48	1.91	Bank Full
7/15/2017	17:36	From bank	0.56		Bank Full
7/15/2017		From bank	0.55		Bank Full
7/15/2017	17:50	From bank	0.44	1.51	Bank Full
7/15/2017	17:53	From bank, 40cm	0.32	1.33	Bank Full
7/15/2017	18:00	Transducer, RL	0.18	1.15	Bank Full
7/15/2017	18:04	center of flow, 5m	0.25		Bank Full
7/15/2017	18:09	3m, RR	0.14	1.09	8 m
7/15/2017	18:10	7m, RR	0.22	1.58	8 m
7/15/2017	18:12	9m, RR (Thalweg)	0.38	2.2	7 m
7/15/2017	18:18	9m, RR (Thalweg)	0.26	1.97	5 m
7/15/2017	18:25	8m RR	0.2	1.15	5 m
7/15/2017	18:27	9m, RR (Thalweg)	0.25	1.63	3.5 m
7/15/2017	18:29	10 m RR (River Left)	0.28	0.91	3 m
7/15/2017	18:34	8m RR	.02 - .04	not measurable	1.5 m
7/15/2017	18:34	9m RR (Thalweg)	0.18	1.33	1.5 m
7/15/2017	18:37	10 m RR (River Left)	0.28	1.04	1.0 m
7/15/2017	18:52	10 m RR (River Left)	0.18	1.3	1.0 m
7/22/2017	19:02	9m, RR (Thalweg)	0.18	0.89	5 m

Date	Local Time	Location	Stage	Velocity	Flow Width
7/22/2017	19:08	9m, RR (Thalweg)	0.24	0.95	6 m
7/22/2017	19:15	9m, RR (Thalweg)	0.28	1.13	6 m
7/22/2017	19:22	9m, RR (Thalweg)	0.28	1.15	6 m
7/22/2017	19:24	5 m RR	0.33	1.22	8 m
7/22/2017	19:26	5 m RR	0.33	1.41	8 m
7/22/2017	19:39	9m, RR (Thalweg)	0.14	1.02	5 m
7/22/2017	19:39	7 m RR	0.06	n/a	5 m
7/22/2017	19:47	9m, RR (Thalweg)	0.14	1.07	6 m
7/22/2017	20:14	9m, RR (Thalweg)	0.22	1.75	8 m
7/22/2017	20:15	7 m RR	0.18	1.51	8 m
7/22/2017	20:17	3 m RR	0.18	1.52	Bank Full
7/22/2017	20:22	5m RR (center of flow)	0.28	1.95	Bank Full
7/22/2017	20:28	5m RR (center of flow)	0.32	2.2	Bank Full
7/22/2017	20:33	5m RR (center of flow)	0.3	1.97	Bank Full
7/22/2017	20:39	5m RR (center of flow)	0.28	2.11	Bank Full
7/22/2017	20:45	5m RR (center of flow)	0.26	1.75	8 m
7/22/2017	20:52	5m RR (center of flow)	0.24	1.32	8 m
7/22/2017	20:56	5m RR (center of flow)	0.22	1.45	7 m
7/22/2017	21:01	5m RR (center of flow)	0.16	1.29	7 m
7/22/2017	21:16	5m RR (center of flow)	0.14	0.77	5 m
7/22/2017	21:18	9m, RR (Thalweg)	0.2	1.25	5 m
7/22/2017	21:31	9m, RR (Thalweg)	0.18	1.05	4 m
7/22/2017	21:44	9m, RR (Thalweg)	0.16	1.02	2 m
8/1/2017	18:36	9m, RR (Thalweg)	0.08	0.46	1.5 m
8/1/2017	18:38	9m, RR (Thalweg)	0.06	n/a	1.5 m
8/1/2017	18:42	9m, RR (Thalweg)	0.06	n/a	1.5 m
8/1/2017	18:46	9m, RR (Thalweg)	0.04	n/a	1.5 m

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