Stage Measurement and Recording Instrumentation
H.J. Andrews Experimental Forest Gaged Watersheds
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25 April 2003, rev. 7 Sep 2005

Introduction:

Nine watersheds within the H.J. Andrews Experimental Forest (HJA) are gaged to measure stream height or stage. The records of stage are converted to stream discharge by applying station specific discharge rating curves. The instrumentation used to measure and record stream stage has changed through the years in response to changes in data collection technology, data management considerations, and end-user needs including the need for real-time distribution of data.

1952 – 1996:

All gaging stations:

- Prior to 1996 streamflow records were derived from stage data collected by Stevens Type A (A-35 or A-71) recorders. The Stevens Type A recorder is a float- operated recorder that provides a permanent and continuous graphic record of stream stage fluctuations. A clock movement controls the rate at which a strip chart is advanced. The rise and fall of the float moves a marking stylus laterally across the chart. The recorder chart stage is initialized to a reference measurement of stream height taken by a hook gage located in a stilling well, or in the case of Mack Creek, WS#6, and WS#7 a tape measurement of water height in the flume.
- The Type A recorder has a precision of .001 feet. Accuracy of the Type A recorders is influenced by small measurement errors due to float lag and line shift. These errors have been minimized by the selection of proper floats and counterweights. The estimated error value over a range of 5 feet for line shift is .001 feet, and the estimated error due to float lag is .004 feet (Error tables provided by Stevens). Accuracy is also influenced by hook gage or tape reference height measurement variations. Rapidly fluctuating water levels or observer bias can cause variations up to +/- .001 feet during repeated measurements.

Mack Cr. and WS #2:

- Prototype digital transmitters were used at Mack and WS#2 beginning in June of 1990. They were float operated recorders which consisted of "Off the shelf" precision potentiometers (A single-turn at WS#2, and a 10-turn at Mack) coupled to Stevens Type A float pulley standards. These were connected to Campbell Scientific CR-10 dataloggers. No documentation could be found to describe the accuracy or precision of these transmitters, but it is likely that it was similar to the Type A recorder due to float lag and line shift errors.
- The records from the prototype transmitters were only used to fill in periods when the Type A recorder record was unusable. There were a variety of problems with the prototypes due to frequent failures of the potentiometer and pulley standard

interface, and frequent occurrences of "electronic noise" which would cause false peaks and valleys in the hydrograph. Alterations were made to the interface coupling which did improve the record, but "electronic noise" continued to be a problem that limited the use of the record.

1996 – Present:

V-Notch: Beginning in 1997, compound weirs are used at our gauging stations in the summer (all except Mack Creek). They are metal v-notch weir plates that are mounted to the existing trapezoidal flumes/weirs to increase measurement sensitivity during the low flow period. We remove the weirs in the winter to allow passage of debris and to measure flows beyond the range of the v-notch weirs.

The v-notch plates were fabricated by a local metal shop. We provided rough drawings of what we wanted and very detailed specifications for the v-notch openings and their position within the existing flumes/weirs. We then worked with the fabricator to design the mounting system. Once the basic v-notch plates were complete, the fabricator then did a custom fit of each one in the field to ensure all specifications were met.

Since we were confined to the existing weir structure, some of the elements of a 'true' v-notch weir could not be met (example: proper pool depth for expected head, and plate not being exactly vertical.). Because our weirs were different we could not use the theoretical discharge formulas, so we had to develop our own discharge curves for each site.

WS#1:

- In October of 1996 a Model 2 Stevens Instruments Position Analog Transmitter (PAT) and a Campbell Scientific CR-10X datalogger were installed at WS#1 in addition to the Stevens Type A recorder already present. The PAT is float operated and consists of a float pulley shaft coupled through gears to a precision potentiometer. The output of the potentiometer drives a circuit that converts the input shaft position to a 4 to 20 mA signal. The output signal is recorded by the CR-10X and converted to a stage by the datalogger programming instructions. An 18-inch circumference float pulley was mounted on the PAT to produce a measurement range of 0 to 2.5 feet. With this configuration the PAT has a precision of .001 feet, but since it is float operated float lag and line shift errors are present. The estimated error is .005 feet over a range of 5 feet.
- On December 12, 1996 a Campbell Scientific radio telemetry unit was connected to the CR-10X. Data now could be downloaded hourly to the base station located at the HJA headquarters.
- On June 6, 1998 vandals destroyed the hook gage at WS #1. Tape measurements in the flume were used as the reference until a new hook gage was installed on July 1, 1998.

- On July 1, 1998 a new hook gage was installed using the same elevation relationship to the flume intake as the old hook gage.
- During the summer of 1999, a new shelter was constructed at WS#1
- On September 24, 1999 the PAT was replaced with another PAT that had been altered by the removal of the output conditioning circuit (altered PAT). The PAT output now is directly from the precision potentiometer. This was done to reduce the power requirements for the PAT (17.4 VDC to 12.0 VDC). No change in PAT accuracy occurred after the alteration.

WS#2:

- Instrumentation at WS#2 did not change until April 4,1999 when the CR-10 connected to the potentiometer was replaced with a CR-10X, and radio telemetry was installed.
- On October 19, 2000 an altered PAT was installed to replace the old prototype potentiometer transmitter.

WS#3:

- On February 6, 1996 the gaging station at WS#3 was totally destroyed by a large debris avalanche/torrent that occurred during a major flood event. The station site was buried by 11-12 feet of debris, so it was early September before it was excavated down to the original elevation of the site. Fortunately the flume was still in place, but was damaged. The original shelter, stilling wells, and hook gage were never found, so the station would need to be completely rebuilt.
- On September 19, 1996 the flume had been repaired to the point it was usable, and a temporary stilling well was installed. The well could not accommodate a Type A recorder, so a Bendix Corporation FW1 recorder was installed. Tape readings in the flume were used as the stage reference. The FW1 is a float operated chart recorder. A clock movement controls the rate that a cylinder-mounted chart is advanced. The rise and fall of the float moves a pen arm vertically across the chart leaving a continuous graphic record of stream stage. No documentation of FW1 precision could be found, but it is estimated to be .01 feet. It is estimated that the accuracy is similar to the Type A recorder due to float lag and line shift errors.
- On December 11, 1996 another temporary stilling well and shelter was installed. The FW1 was replaced with a Type A recorder that used tape measurements in the flume as the stage reference. The temporary station operated continuously until July 29,1998 when it was removed for construction of a permanent station.
- On September 25, 1998 construction of the station was completed. A Type A chart recorder, altered PAT, and CR10X were installed and started. The new hook gage was not installed yet, so tape readings in the flume were used as the stage reference.
- The new hook gage was installed on September 30, 1998. The new hook gage was installed using the same elevation relationship to the flume intake as the old hook gage. The hook gage measurements are now used as the stage reference at WS#3.

WS#6:

- In the early fall of 1997 the H flume at WS#6 was replaced with a trapezoidal flume.
- On October 30, 1997 a Type A recorder, and a hook gage were installed and started at the remodeled station.
- On December 5, 1997 an altered PAT and a CR-10X datalogger were added. All instrumentation now uses the hook gage measurement as the reference stage.

WS#7:

- The H flume at WS#7 was replaced with a trapezoidal flume during the early fall of 1997. On November 6,1997 a Type A recorder, and a hook gage were installed and started at the remodeled station.
- On November 19,1997 an altered PAT, and a CR-10X datalogger were added. All instrumentation now uses the hook gage measurement as the reference stage.

WS#8:

- Instrumentation at WS#8 did not change until August 18, 1998 when an altered PAT, and a CR10X datalogger were added to the station.
- On July 6, 1999 radio telemetry was added.

WS#9:

- Instrumentation at WS#9 did not change until June 6, 2000 when an altered PAT, and a CR-10 datalogger were added.

WS#10:

- Instrumentation at WS#10 did not change until November 18, 1999 when an altered PAT, and a CR-10X datalogger were added.

Mack Creek:

- Instrumentation at Mack Creek remained unchanged until January 15, 1996 when radio telemetry was added to the station
- In the spring of 1996 the output from the prototype potentiometer transmitter became very unstable.
- On June 27, 1996 the prototype was replaced with a Stevens Instruments Pulse Generator III (PG3) transmitter. The PG3 consists of an input shaft coupled to a disk with four magnets mounted at 90 degrees around the rim. These magnets are magnetically coupled to three reed switches, which connect to a very low power circuit that keeps track of pulse count and direction of rotation. The circuit has two outputs that provide short up or down pulses that are recorded by the existing

CR-10 datalogger, and converted to a stream stage value by CR-10 programming instructions. The PG3 has internal gears with a 25 to 1 ratio, resulting in 300 up or down counts per revolution of the input shaft. A 12-inch circumference float pulley was mounted on the input shaft to provide a precision of .0033 feet. Since this is a float- operated system, there are float lag and line shift errors. The estimated error is .005 feet over a range of 5 feet.

- On December 7, 2000 the PG3 was replaced with an altered Model 3 PAT to standardize the stage instrumentation used at the HJA. The Model 3 PAT has the same precision and accuracy as the Model 2. An altered PAT was also added at this time to measure the water level in the precipitation collector well at the station.

Mack Creek Fish Passage:

- During the summer of 1995 a fish passage was built around the flume at the Mack Creek station. A compound weir (120 degree v-notch at the bottom of the weir plate with a rectangular area on top.) was installed in the passage to measure the water level. A MTS Level Plus model LT420 magnetostrictive transmitter mounted in a stilling well is used to measure the stage. The transmitter consists of a ferromagnetic waveguide protected by a solid rod, a electronic assembly that determines the water level based on waveguide behavior, and a float containing a set of magnets that "ride" the outside of the waveguide protective rod.
- The water level is determined when the electronic assembly initiates a short, low current pulse that runs through the waveguide, and simultaneously starts a timer. The pulse, along with the magnetic field it generates travels the length of the waveguide. When the pulse reaches the float, the magnetic field from the pulse interacts with the magnetic field from the float and initiates a torsional "twist " in the waveguide material. This "twist" creates a sonic wave that travels in both directions and is detected by the electronic assembly. The timer stops when the "twist" is detected. The distance from the float is determined based on the return time and the signal transmission properties of the waveguide material. The return time interval is converted into a 4-20mA loop powered output. The output from the transmitter is recorded on the existing CR-10 datalogger, and converted to a stage value by the datalogger programming instructions. The transmitter has a precision of .001 feet, and an accuracy of .002 feet over a range of four feet. A tape reading of the water level in the stilling well is used as the stage reference.
- The fish passage stage measurements began on October 5, 1995. Mack Creek streamflow is the sum of the flows from the regular flume and the fish passage compound weir from this time forward.

Addendum: On instrumentation calibration:

- We do not have a system of calibration for the recorders, but do have a regular and frequent system of checks that would indicate any problems. Every week a hookgage measurement is taken and compared to the recorder readings. Significant variations from the hookgage would indicate changes in recorder operation, but factors such as chart spooling, or stilling well response time during

rapidly changing stage levels must also be considered. The hookgage position/elevation in relation to the flume is surveyed every year. Tri-weekly measurements of the water level in the flume also serve as a rough check of hookgage accuracy.

- Accuracy of the chart recorder is controlled by the gearing of the pulley standard; there is really nothing to calibrate. The same holds true for the PAT, but the potentiometer can malfunction resulting in electronic spikes or dead zones in the range of resistance, and we inspect annually to assure full range of resistance. The potentiometer has no adjustments, so it must be replaced if problems occur.