

CHAPTER 3. 2002 FLOW MONITORING GAUGE INSTALLATION AND MEASUREMENT METHODS

SITE SELECTION

Gauging station locations were selected based on the following criteria:

- **Proximity to the Regulatory Control Point**—To the extent possible, gauging stations were located at or near the WAC regulatory control points. The latter are defined by river mile location and section, township and range. The intent was to provide a firm basis of comparison between the 2002 flow data and the regulatory minimum flows while accounting for all tributary and groundwater inflow.
- **Site Access**—Public rights-of-way (bridge crossings, e.g.) were used wherever possible. Access to several such sites was granted by state and county road departments. In cases where site access required crossing private property, permission was obtained from land owners or their representatives.
- **Adequate Hydraulic Conditions**—Stream gauges equipped with water level recorders require that a unique stage-discharge relationship be established. Sites must also include a suitable transect for taking current meter measurements. Ideal sites had consistent flow velocities through relatively prismatic cross-sections. Sites at some of the regulatory control points had low flow velocities or irregular cross-section geometry, were subject to tidal effects, had numerous in-channel flow obstructions (logs and other debris), or were unwadable. Gauges for these control points were placed at locations with better flow conditions or were measured only periodically.

GAUGE INSTALLATION

Figure 3-1 shows a typical stream gauge used in this study. At each site, a staff gauge was attached to a 2-by-6-inch board secured to an angle-iron post. A section of 2-inch PVC pipe was used to house a Global Logger WL15 data water level recorder (shown in Figure 3-2). The housing was secured to the post with hose clamps. The 25-foot sensor cable was shortened by wrapping it around a smaller diameter PVC pipe, which was then inserted into the larger-diameter PVC housing. To reduce the risk of theft or vandalism, the PVC housing was secured with a 2-inch cap and locked with a headless hexagonal screw, and the hose clamps were screwed into the 2-by-6-inch board.

Local reference marks were established at all sites. Staff gauge elevations were surveyed relative to the reference marks so that stage data collected in future studies can be referenced to a common datum.

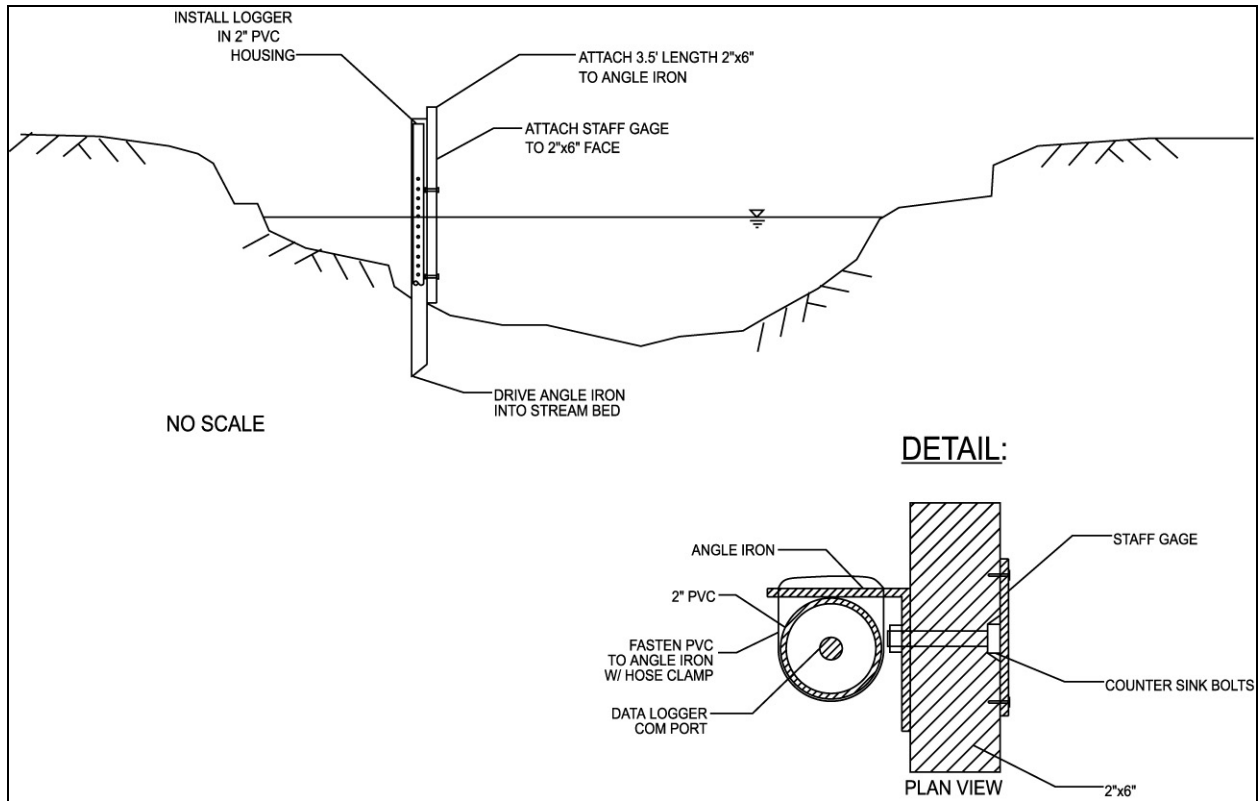


Figure 3-1. Typical Stream Gauge for In-Stream Flow Study

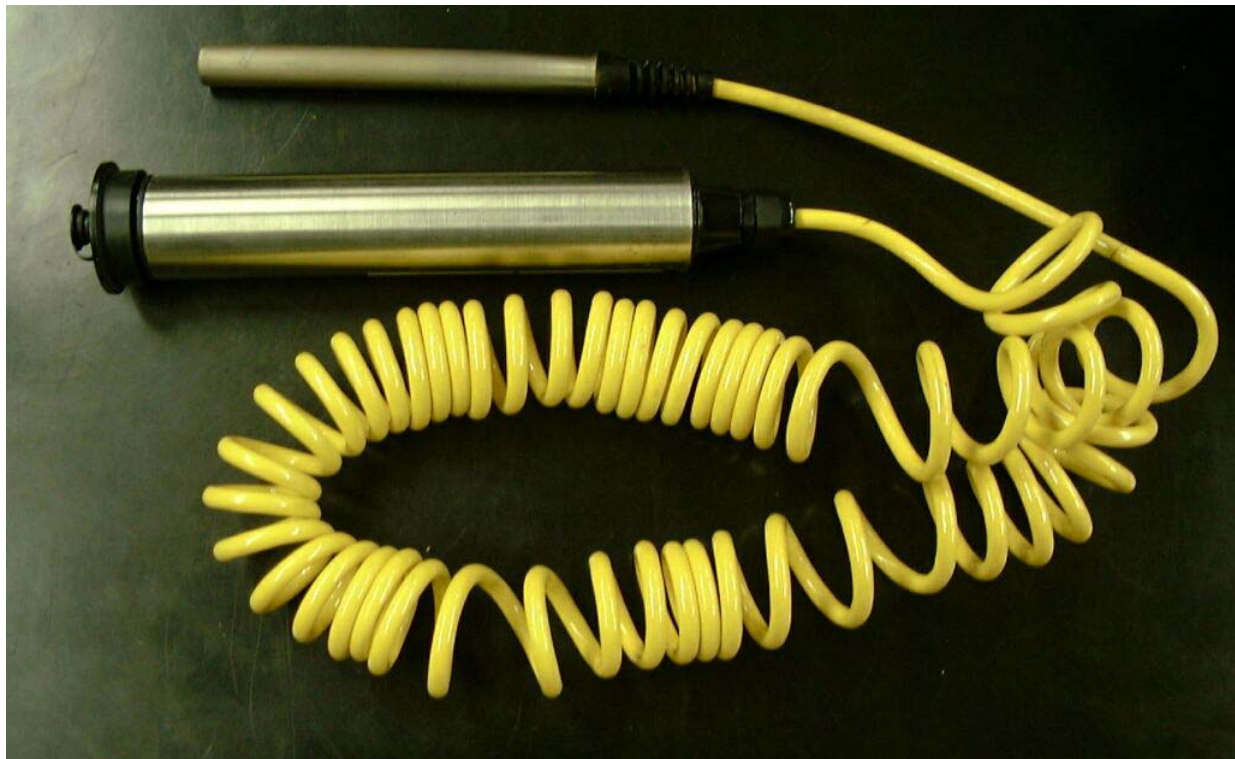


Figure 3-2 – Water Level Recorder

MEASUREMENT METHODS

Several discharge measurements were taken over the course of the study period to obtain paired stage-discharge data. At most sites, discharge was measured using conventional current-meter methods developed by the U.S. Geological Survey (USGS, 1982). Depth and velocity were measured at several points (verticals) along a transect using a tag line, a 4-foot wading rod, and a Swoffer propeller meter. For verticals shallower than 2.5 feet, flow velocity was measured at a point in the water column six-tenths of the total depth relative to the water surface. For verticals deeper than 2.5 feet, velocity measurements were taken at two-tenths and eight-tenths of the total depth, and the average was used in the flow calculations. The total discharge at the transect was then computed as the sum of the discharges of all verticals. To minimize the potential for error, the discharge was measured at a sufficient number of verticals such that no more than 10 percent of the total stream discharge passed through any one vertical. However, at a small number of sites, poor field conditions prevented measurement of sufficient verticals to meet the 10-percent criterion.

The Global Water recorders used in the study consist of a pressure transducer connected to a data recorder by a sensor cable. The transducer measures hydrostatic pressure (a linear function of depth) at user-defined intervals. During gauge installation, the differences between logger and staff gauge readings were computed, producing "offset" values unique to each gauge. Data loggers were configured to record stage data at 1-hour intervals and data was downloaded at least once a month. During site visits throughout the study period, loggers were checked to ensure proper operation.

DEVELOPMENT OF FLOW EQUATIONS

A record of discharge was developed at each gauged site from continuously recorded values of stage. Flow equations were developed using one of two methods: a semi-analytical approach, or fitting a curve to the observed discharge data using statistical methods.

The range of stage values was expected to be low during the summer months, and relatively few current-meter measurements were anticipated. Thus, it was thought that establishing a stage-discharge relation based solely on a limited set of paired data could produce sizable errors in the predicted discharge.

As an alternative, a semi-analytical approach based on Manning's equation was developed from parameters that could be measured or estimated in the field. Depth, flow area, and hydraulic radius data were obtained from initial discharge measurements at all sites. An initial assumption of constant friction slope and roughness over the range of expected discharges was made, and these parameters were lumped into a single constant. The values of the constants were back-calculated from the measured discharges and are unique to each site. Area and hydraulic radius were defined as functions of depth for cross-sections, and flow equations were developed for all sites.

As more current-meter measurements were conducted and logger data were downloaded, values of field-measured discharge were plotted against the gauge record. The accuracy of the flow equations was evaluated in terms of how well the flow equation curve fit the current-meter data. If the plotted discharge data were within about 10 percent of the curve

(the maximum expected error of current-meter measurements), no modifications were made to the equation.

However, at many sites the discharge measured at lower water levels was consistently lower (by 10 percent or more) than that predicted by the flow equation. In Manning's equation, the difference can be attributed to increasing roughness, decreasing friction slope, an increase proportion of ineffective flow area, or all of these. At several sites, equations were modified to allow roughness to vary as a function of depth over a range of reasonable values. The curves were again plotted against the larger data set and evaluated again.

At sites where unreasonable values of roughness or friction slope were necessary to produce a good fit to the field-measured discharge, an empirical stage-discharge relation was developed and used in lieu of the semi-analytical approach. The empirical functions were developed using regression algorithms in Excel. Stage was regressed against discharge to obtain a prediction equation in the form of a power function. Complete derivations of the flow equations are presented in the technical appendix.

DATA COMPILATION

Logger readings were used to compute a continuous record of discharge. Logger data were transformed into a continuous record of stage (water levels one would observe by reading the staff gauge) by adding the offset value.

One disadvantage of transducer measurements is the tendency for logger readings to "drift," i.e., the offset varies slightly over time, which can lead to errors in computed record of discharge. For this reason, offset values were noted during site visits throughout the study period. To correct for transducer drift, offset values used in the computation of the stage record were assumed to vary linearly between the dates of site visits when offset values were noted. Values of stage were then inserted into the respective flow equations, producing a continuous record of discharge. Methods used for stage and discharge computation are further documented in the appendix.

Discharge data for all sites are summarized in tables included in the appendix. Mean daily flows were calculated as the average of 24 one-hour discharges in a day. Monthly minimum, maximum, and mean values were computed based on the daily means. Discharge hydrographs showing the WAC regulatory minimums and the current-meter measurements are presented in Chapter 4.

CORRELATION WITH HISTORICAL DATA

It is possible to extend the record of a gauging station through statistical correlation to historical data from a nearby gauge, provided both data sets are sufficiently large to capture natural variation in discharge. Establishing a correlation requires a large set of paired measurements and can be accomplished in one of two ways:

- Regression of paired spot measurements
- Regression of median monthly flows measured at the gauges.

The first method would require a large set of simultaneous current-meter measurements taken over the range of low-flow discharges, but could be done in one summer season. Because the measurements are paired in time, annual variation is not important. However, if there are significant sources of inflow or diversion between the gauges, these must be measured or assumed to vary consistently with main stem discharge and time

The second method would require data collection at the sites established for this study during several more low-flow seasons to account for annual variation in discharge. Variation due to inflow or diversions would be implicitly accounted for in the long term record. Because existing records from the summer 2002 gauges are limited to one low-flow season, developing a correlation through regression of mean or median flows is inadvisable as this could produce errors in estimates of historical flows.

Because the data needed for either of these methods is unavailable, relevant data from nearby gauges are discussed in Chapter 2, but no statistical correlations are developed.