WATER QUALITY PROGRAMS DIVISION

Standard Operating Procedure for Surveying Gaging Stations

Adopted January 2004

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STANDARD OPERATING PROCEDURE FOR SURVEYING GAGING STATIONS
DRAFT
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1.0 Introduction

This SOP describes the use of leveling to set a reference point in order to establish a gage height. The gage height is a critical component for establishing the stage to discharge relationship and can be measured through a variety of accepted means. It is used to establish the river gage, or height of water to a known fixed point. This known fixed point is referenced or leveled to a Reference mark or Benchmark. These marks are assigned either an arbitrary elevation or known elevation that is tied to a national elevation network. Thus over time, with periodic leveling, the reference points can be measured for movement. Because any movement of these points will affect the stage-discharge rating, it is critical that periodic measurements be conducted so that the gage heights remain leveled with the stage datum.

This document is meant to be a guide only. An FTE will demonstrate and explain fully how to operate all equipment and complete all notes. Different types of equipment have different installation requirements, and an SOP will be provided for more detailed guidance. Furthermore, each station will have unique requirements that cannot be covered in a generic SOP. To facilitate the installation and surveying process, a station project plan should be completed prior to work beginning.

2.0 Definitions/Terms

1) Backsight (BS) The reading on a leveling rod held on a point of known elevation. Used to establish Height of Instrument.
2) Benchmark (BM) A permanent marker whose description and elevation are referenced and tied to the National Geodetic Vertical Datum or a state wide equivalent.
3) Collimation Agreement of a level's line of site with its horizontal axis.
4) Collimation Error Factor (c) The inclination of a level's line of sight in ft/100ft.
5) Differential Leveling The determination of difference of elevation of two points by use of an engineers level and a leveling rod.
6) Elevation A measurement established for each station in the survey circuit. Established by subtracting the foresight from the last known height of instrument.
7) Error of Closure The difference between the starting and ending elevation of the starting point of the circuit.
8) Foresight (FS) The reading on a level rod held on a point to whose elevation is to be determined. Used to establish new elevations.
9) Gage Datum The datum whose surface is at the zero elevation of all the gages at a gaging station

10) Height of Instrument The elevation of the horizontal line of sight from the engineer's level. Established by adding the backsight to the last established elevation.
11) Leveling Rod A slender bar with graduated marks on one face starting from the bottom. Used to measure the height of a line of sight above a point on the ground.
12) Parallax The relative movement of the image of the leveling rod with respect to the crosshairs as the surveyor's eye moves. Is caused by improper focusing of the objective lens.
13) Peg Test A test to ensure that the level's line of sight is truly horizontal.
14) Reference Mark (RM) A semi-permanent marker established at the time of survey. Mark is used to consistently tie updated surveys together so that an established datum is not lost. Should be established in an area of little change (e.g., a bridge abutment).
15) Reference Point (RP) A marker established at the time of survey. Mark is tied into the datum and is used to provide a consistent point from which to measure stage.
16) Turning Point (TP) A temporary point of reference used in the leveling process. Always used at the midpoint of basic level circuits.

3.0 Safety

Leveling is carried out around and in water and from bridges. Ensure that all applicable safety procedures outlined in the OWRB Safety manual are followed. Any bridges that have vehicular traffic should be scouted initially to determine traffic control and conditions and personnel required. Each station should have a Station Plan on file that outlines any particular hazards and concerns. **Never survey in electrical storms. Be aware of all power lines when handling the rod. If digging is required, ensure that local utilities are properly marked**. Any questions or situations that involve safety or hazardous conditions, notify your supervisory FTE immediately.

4.0 Quality of the Measurement

The quality of the leveling measurement can be affected by a multitude of factors. The majority of these factors are associated either with equipment malfunction/ calibration issues or improper survey techniques.

4.1 Precision

Leveling precision is mostly affected by the quality of the instrument used but can be affected by measurement decisions. The automatic level has a precision of 0.001 foot up to 125 feet. This precision can also be affected by the quality of the rod being used. Furthermore, precision may be affected by personnel decisions. It is always important to read at distances within the maximum and minimum shot length that the instrument allows. It is also important to read at the same point on the crosshairs when completing a measurement.

4.2 Accuracy

Accuracy is determined by a comparison of the error of closure (C_E) of the measurement to the allowable closure (C_A) (Table 1). The C_E is the difference between the starting elevation of the circuit and the final foresight (or determination of elevation) to that same point. For example, the starting elevation is 10.000 feet at RM1, and the close of the circuit is 9.997 at RM1, so the C_E is –0.003 feet. The C_A is then determined in one of two ways. In general, the C_A has two components—a factor based on precision multiplied by the square root of a property of the measurement. For long line levels (e.g., levels tying a reference mark or benchmark back to sea level), C_A is determined by multiplying a factor of the level precision (e.g., 0.05 foot based on a precision of 0.01 foot) times the square root of the length of the line (M), which is expressed in miles. For short line levels (e.g., gaging station levels), C_A is determined by multiplying a factor of the level precision (e.g., 0.003 foot based on a precision of 0.001 foot at short distances) times the square root of the number of instrument setups (n). Depending on station conditions, the factor can be changed and can range from 0.003-0.005 foot. For factors above 0.003, proper documentation must accompany the level notes to demonstrate the need for a higher factor of level precision.

Table 1. Illustration of the determination of C_E and C_A.

Station	**B.S.**	**Ht. Inst.**	**F.S.**	**Elev.**
RM-1	**2.678**	**12.678**		**10.000**
RP-1	**2.590**	**12.726**	**2.542**	**10.136**
RP-2	**2.712**	**12.650**	**2.788**	**9.938**
RP-1	**2.602**	**12.74**	**2.512**	**10.138**
RM-1			**2.743**	**9.997**
The C_E is the difference between RM-1 at start and close—CE = 9.997-10.000 = -0.003				
The C_A is the factor of precision (0.003) times the square root of the number of setups (sqrt4)—CA = 0.003(sqrt4) = 0.006				

4.3 Elevation Adjustment

Because acceptable errors may occur throughout a leveling circuit, elevations at the same mark may be inconsistent throughout a circuit. Therefore, the elevation for each mark, other than the starting point, needs to be adjusted to account for the error. This adjustment is relatively simple and is illustrated in Table 2. The table is part of the Survey Notes. Starting with the beginning elevation, the differences between the two elevations calculated at adjacent points is calculated and added throughout the circuit. These are the final elevations and are recorded on the front sheet of the Survey notes.

Table 2. Illustration of elevation adjustments.

ELEVATION ADJUSTMENTS				
MARK	1ST DIFF.	2ND DIFF.	AVE. DIFF.	ELEVATION
RM-1				10.000
	0.136	0.141	0.139	
RP-1				10.139
	0.198	0.200	- 0.199	
RP-2				9.940

5.0 Personnel and equipment

Principle investigators for the OWRB are required to have degrees and/or experience with biological or other applicable sciences. Principle investigators are defined as crew leaders, and this designation may be made upon the leader of a multi- or a one person crew. Training is required for all SOPs dealing with water quality and quantity collections and measurements as well as habitat assessments and biological collections. In-house training will be conducted for the use of all meters and digital titrators used for water quality or quantity measurements. Investigators must be familiar with OWRB SOP document and all training will follow the methods outlined in that document. Extra training will be provided when new SOPs are developed. Training of field crews will be done through dry run exercises in the laboratory to familiarize field crews with sample collection, sample preservation, instrument operation, calibration, and maintenance. In addition, when new personnel are hired or new methods developed, qualified staff will train on sample collection, measurement, and field analysis methods through side-by-side field trips. These trips will familiarize staff with SOP requirements. When training is considered adequate, a qualified staff member will check field staff for adherence to SOPs.

Leveling requires a minimum of two persons. A third person may be required to assist when the conditions and environmental factors require them. The survey party is made up of a level operator and a rod man. The level operator is the individual who will be conducting the survey, with the rod man following instructions. The level operator has the final authority and responsibility for determining needed accuracy as well as the recording and completion of all data. The rod man's responsibility is to ensure that the placement of the rod is plumb and in accordance with the survey plan. This survey plan may include locations of all known benchmarks, reference marks, reference points, turning points, and any equipment that is used to develop and read the gage height. Because it is often difficult to hear on site, the surveyor may develop a unique set of signals to convey instructions to the rod man. These signals should be thoroughly reviewed before the beginning of measurements.

5.1 Automatic Engineer's Level

An automatic, or self-leveling, engineer's level will be used for all surveying. After being manually leveled with the circular, or bull's eye, level before each use, the instrument self compensates as the leveling circuit is run. Each time the instrument is brought out of "bubble", it must be manually leveled again.

Because the level is delicate and can be brought out of calibration easily, each operator must handle with care during use and travel. The level is to be kept in its protective case when not in actual use. The level is to be stored securely in the cab of the vehicle. Eyecups should be placed over the lenses at all times when not in use. The leveling pegs should be screwed or run up into the level housing to protect against damage. When in transport at a survey site, the level should either remain in the case or firmly attached to the tripod. The tripod should be carried with two hands when moving a mounted level. The tripod can be carried over the shoulder only on relatively even surfaces (e.g., blacktop) and in areas with no immediate obstructions (e.g., bridge decks). Ensure that the tripod is anchored to the ground by firmly pushing the feet of the tripod against the ground. Care should be taken when moving the tripod and level through standing brush or narrow confines. If at any time the surveyor is crossing a fence, guardrail or other obstruction, the level is to be placed on the ground and retrieved after crossing. The tripod and level should never be left unattended at a survey site. An FTE will demonstrate appropriate methods to be used during travel and use.

5.1.1 Level Log Book

The logbook provides a means to record all calibration tests, survey operations, maintenance record and general information. This notebook is to be kept with the level in both storage and use. The surveyor has the responsibility to ensure that the logbook is updated when the level is in use, and properly stored when not in use. An FTE will demonstrate how to properly fill out the book.

5.1.2 Parallax

The presence of parallax should be routinely monitored when leveling. Parallax is present if the rod seems to move with movement of the head, while the instrument is in focus and the crosshair is sharpest. If it occurs, the rod is in focus in front of or behind the crosshairs instead of on the crosshairs. Can be tested for by moving head slightly while sighting an in-focus rod. Can be eliminated by adjusting the objective focus or in the worst case finding the best combination of the eyepiece and objective foci. If it persists over time and user, level may need servicing.

5.1.3 Compensator Sticking

Compensator sticking can seriously affect the accuracy of levels and should be tested for routinely. After level is in "bubble" and focused, turn the leveling screw nearest to the eyepiece slightly one way and then the other. If the crosshair return to same reading, the compensator is working, but if the readings are different, the compensator is sticking. If a light tap of the telescope before each reading causes agreement, then surveying can continue as long as the telescope is tapped lightly before each reading of the circuit. If the sticking is occurring, first check the circular level, and if that is “in bubble”, the unit cannot be used until it is serviced.

5.1.4 Level Calibration Using a Peg Test

A peg test is a simple calibration test using elements of a survey. Record your readings in the logbook that accompanies the level. Record the time and date of the last peg test as well as the collimation error factor, “c”, on the Survey notes. A peg test should be run at least once per week during surveying, or when there is reason to believe the level may be out of calibration (e.g., large closure errors, sticking of the compensator, or suspicion based on level handling). To begin a peg test, place two stakes approximately 100-120 ft apart at a reasonably level site. Set up the level and tripod nearer to one stake (A). With the rod man holding the stadia rod plumb on center of stake A, take a backsight reading to the rod. The rod man will now move to the far stake (B), and the surveyor will take a foresight measure to the rod. As the rod man maintains position without moving the rod, the surveyor will break out of the tripod set and move nearer to stake B. The surveyor will then conduct a backsight to the stake B. The rod man will move to stake A and the surveyor will close the circuit by taking a foresight measurement to the rod. Upon completion of the circuit, a peg test closure error (CE) is calculated by taking the difference between both elevations of stake A (calculation of the closure error is included in Section 3.0 of this document).

The c is calculated by the following equation: $c = 100 \times \frac{(R1+R3) - (R2+R4-CR)}{(d2+d4) - (d1+d3)}$

CR (curvature and refraction) is calculated by (d2+d4)/2 with d2 and d4 being the long shots of the circuit. Compare to the following table to determine the CR to use. If c is greater than CR, adjust level according to manufacturer specifications.:

(d2+d4)/2	CR
0-110	0
110-190	0.001
190-245	0.002
245-290	0.003
290-350	0.004

5.2 Tripod

The engineer’s level is mounted to a metal tripod with adjustable legs and stake-like feet. It is important that the tripod travels in a secure area and is set in a stable area for measurement. It is equally important that the leg tension of the tripod be maintained. To test, set up tripod, place legs about three feet apart, and lift tripod by the head. If tension is appropriate, the legs should fold in slightly. Adjust leg tension according to manufacturer’s specifications.

5.3 Leveling Rod

The leveling rod commonly used is a 3-section fiberglass rod with gradations marked to the nearest tenth. Hundredths are denoted by black hashmarks with each black mark representing an odd number and the intervening white representing an even number. The rod should always travel in a carrying case and should never be left unattended in the field. It should never be carried over the shoulder with any section extended. Always check the booted end for cleanliness during measurements, and never drag the end along any surface. To ensure that the rod is in plumb, the rod man should always use a rod level. It is important that the rod be maintained in "bubble" throughout each measurement. The rod should be checked weekly or when the accuracy of the rod is in question. Use a calibrated steel tape to measure the sections. Record the measurements on the current station survey notes.

6.0 Conducting a Survey

Although all surveys have commonalities, they can be conducted differently depending on what the primary objective is. This section covers certain basics including survey points and pre-survey checks. Furthermore, a discussion of certain types of circuits is included.

Several rules of thumb should be followed when reading all levels:

1. All measurements should be made to the nearest thousandth.
2. Minimum shot distance is set by the manufacturer but should be no less than 15 feet.
3. Maximum shot distance is influenced by several factors including surveying experience, light (too much or too little), precipitation, air quality, traffic, wind, and change in elevation. It is better to establish an intermediate turning point than miss the needed precision on the closeout.
4. Consistently read to the top or the bottom of the crosshair in the viewer. Make a notation on the level sheet to assist in future levelings.
5. Attempt to avoid readings below 1 ft.
6. Attempt to avoid reading upper extensions of the rod during high winds.
7. During high winds, the rod should be rocked slightly forward and back to aid in reading the level.
8. <u>A rod level should always be used</u>.

6.1 Survey point

A benchmark (BM) or reference mark (RM) is used as the starting and end measuring point in the level measure. The difference between a BM and an RM is that BM's have usually been placed by a Federal, State or local organization and tied to a national or state wide geodetic datum. The United States Geological Survey (USGS), National Geodetic Survey (NGS), and the respective State Departments of Transportation have placed the most common BM's. These BM's are often located in a permanent structure or mounting that ensures that the marker has little to no movement in relation to the surrounding structure or area.

An RM is used in the absence of a known benchmark. The RM's will often consist of three types of marks. The first, with the lowest level of accuracy, is a chiseled square into a permanent concrete structure such as a wing wall or bridge abutment. To avoid improper rod placement, the chiseled square should be raised above the surrounding material and outlined with paint. The second is placement of an anchor or bolt into the structure. These pins often are common concrete anchor bolts or hex head steel bolts and are installed following the manufacturer's directions and/or common construction techniques. They should be in areas free of impact hazards to avoid damage and/or loss. They can be cut short and filed to a smooth surface to decrease the chance of damage. The third method involves placing a permanent marker during construction or in a permanent hardened location. The difficulty of placing an RM during construction is the cost, proper placement and scheduling of the placement. Therefore, installation of this type may cause an unnecessary increase in cost, materials, and manpower. The installation of a permanent RM is undertaken usually when a long-term commitment is required with a requirement that the RM be tied to a national or state survey system. All RM's should be labeled with paint.

Reference points (RP) are placed as a fixed point from which to measure stage. It is the point to which the datum is tied and from which the gage height is established. The RP is usually established as the check bar of a wire weight gage and/or a pin installed on the outer portion of a bridge. These pins are the same type as those used for RM's and placed and maintained accordingly. The RP's can also be established by placing a painted, chiseled arrow. All RP's should be labeled with paint.

Turning Points (TP) are used when the distance between the various points is too great to be accurately measured or at the midpoint of the basic level circuit. When running a basic level circuit, any firmly placed item can be used as a TP (e.g., a reflector mounted on a bridge or a quarter placed on an even surface). When running a complex level circuit, when possible, a semi-permanent or permanent mark should be placed along the bridge or in the ground. These can be concrete spikes with washers or pins as described above. The material or location should be free of debris and have a uniform thickness or flat surface. When a TP is established, that place should be marked with paint .

6.2 Pre-Survey Checks

Leveling should be scheduled for certain periods. Reliability of results as well as time spent at the station can be influenced by traffic, weather, water level, and time of day. Often traffic cannot be planned around but the other three can. Optimally, surveys should be conducted during periods of low water and favorable weather as well as after the initial light of day and before dusk. If inclement weather is adversely affecting measurements, the survey should be postponed. High winds, excessive cloud cover or haze, and precipitation can drastically alter results.

Before beginning, a series of checks should be conducted at appropriate intervals. These checks are fully described under Section 5 of this document. A consistent routine should always be used and a checklist maintained.

Before surveying begins, all BM's, RM's, RP's, and TP's should be located or established. If measuring from points established in historical surveys, the description of the point should be double checked by the survey leader and reaffirmed by a team member. If points are being established, a thorough description of the point should be made before surveying begins. After survey points have been established or located, a survey circuit should be laid out and reviewed thoroughly. When establishing the circuit, attempt to make all shots comparable in length. Take note of any shots that may be made difficult due to increases in elevation, station conditions, or length of shot, and ensure that conditions will not affect shot by doing informal reads of the level rod.

6.3 Frequency of levels

The frequency of levels should be established in the Station Plan, and this plan should be the ultimate guide for each station. However, there are several rules of thumb that can be followed.

1) New levels should be rerun at least 1 to 2 times in the first 3 years.
2) After the initial 3-year period, all levels should be run at least every 3 years.
3) Levels established at stations with transient channels (e.g., sand) should be run at the end of each rainy season.
4) Levels at stations with stable channels (e.g., bedrock or boulder) can be run every 3 years after the initial 3-year period.
5) Levels at stations with semi-stable channels (e.g., hardpan clay or gravel) should be checked diligently after the initial 3-year period and updated as needed.
6) Levels at stations located on wooden or wooden/steel bridges should be run annually throughout the life of the station.
7) Levels at stations located on new bridges should be checked diligently after the initial 3-year period for up to 10 years. They should be updated as needed.

6.4 Running a Basic Level Circuit

A basic level circuit (Table 3) is used when no permanent or semi-permanent installation (for example, a wire weight gage or a continuous gage) is made at the site. Also, it is used when the lower end of the discharge rating is relatively unimportant or when stage is used only as a screening measurement. A basic level circuit can be divided into seven main steps.

Table 3. Illustration of a basic leveling circuit.

Station	B.S.	Ht. Inst.	F.S.	Elev.
RM-1	**2.678**	**12.678**		**10.000**
RP-1			**2.542**	**10.136**
RP-2	**2.678**	**11.694**	**1.120**	**9.016**
RP-1			**1.556**	**10.138**
RM-1			**1.697**	**9.997**
The C_E is the difference between RM-1 at start and close— CE = 9.997-10.000 = -0.003				
The C_A is the factor of precision (0.003) times the square root of the number of setups (sqrt of 2) — CA = 0.003(sqrt2) = 0.004				

6.4.1 Step 1—Establishing the Initial Elevation

The initial elevation can be set in one of two ways. If a BM is used, the known elevation of the BM is to be used and is the initial elevation of the survey. If an RM is used, an arbitrary elevation of at least 10 feet is set and is adjusted after the datum is established. This initial elevation is set at 10 feet to avoid negative numbers.

6.4.2 Step 2—Establishing the Initial Height of Instrument

The initial H.I. is established by adding the initial elevation to the initial backsight, which is the first measurement taken. As long as the instrument remains set, this H.I. will be used to establish elevations at all points.

6.4.3 Step 3—Establishing elevations of all remaining points

As long as the instrument remains stable (does not move due to site conditions or length of shot), sideshots may be used to establish the elevations of all remaining survey points. Station RP-1 in Table 3 is an example of a sideshot. To obtain the elevation, the foresight measured during each sideshot is subtracted from the initial H.I. However, because not all measurements may be taken from the same position, intermediate H.I.'s may need to be determined. The intermediate H.I.'s are determined by establishing the elevation at a set TP, moving and releveling the instrument, and reestablishing the H.I. by taking an intermediate backsight back to the same TP. When intermediate H.I.'s are used, the elevations of the following points are set from the new H.I.

6.4.4 Step 4—Establishing a Closeout H.I. for the Remainder of the Circuit

All basic survey circuits will have at least one TP and a change in the H.I. This change occurs at the beginning of the closeout of the circuit and is also known as the breakup or shakeup. By doing this, the initial placement of the instrument can be eliminated as a factor in biasing elevations. When doing the breakup, the instrument tripod must be completely lifted off of the ground and be taken out of level. The instrument is then releveled and the closeout H.I. is established.

6.4.5 Step 5—Circuit Closeout

After the closeout H.I. has been set, the circuit is closed out by establishing elevations at the same points but in opposite order. The method for setting elevations is the same and all intermediate TP's used in the first half of the circuit should be used again.

6.4.6 Step 6—Elevation Adjustment

As each of the closeout points are measured, the closeout elevation readings should be compared to the elevations calculated during the first half of the circuit. An example of elevation adjustment is in Table 2. Before finalizing the survey, an elevation adjustment sheet must be completed and attached.

6.4.7 Step 7—Surveying the Datum

In a basic level circuit, a rough tapedown, using a weighted steel tape, is made to the streambed directly below RP-1 and sometimes RP-2. Depending on the substrate, a half to 3 feet may be added to the measurement to account for bed shift. This measurement is the datum and should be checked after all major events. Record both the initial and the adjusted measurement on the level notes.

6.5 Running a Complex Level Circuit

A complex circuit (Table 4) is used when a permanent or semi-permanent installation (for example, a wire weight gage or a continuous gage) is present or to be installed at the site. In general, these installations occur when one or more of the following attributes apply: 1) a discharge rating will be established, 2) the station is a long-term monitoring station, 3) data are used for making loading estimates, 4) data are used to determine ground/surface water interactions, or 5) when any mechanical (e.g., a wire weight gage) or continuous (e.g., a radar gage) stage measurement device is installed. For the most part, the same basic concepts used in a basic level circuit apply to complex circuits.

Table 4. Illustration of a complex leveling circuit.

Station	B.S.	Ht. Inst.	F.S.	Elev.
RM-1	2.678	12.678		10.000
RM-2	2.610	12.613	2.675	10.003
TP-1	2.720	12.779	2.554	10.059
RP-1	2.540	13.017	2.302	10.477
CH. BAR	2.993	13.000	3.010	10.007
RP-2	2.568	13.244	2.324	10.676
RM-3	2.115	13.360	1.999	11.245
RM-4	2.355	13.575	2.140	11.220
RM-3	2.256	13.503	2.328	11.247

Station	B.S.	Ht. Inst.	F.S.	Elev.
RP-2	**2.953**	**13.625**	**2.831**	**10.672**
CH. BAR	**3.779**	**13.789**	**3.615**	**10.010**
RP-1	**2.999**	**13.474**	**3.314**	**10.475**
TP-1	**2.895**	**12.959**	**3.410**	**10.064**
RM-2	**2.795**	**12.794**	**2.960**	**9.999**
RM-1			**2.800**	**9.994**
The C_E is the difference between RM-1 at start and close— CE = 9.994-10.000 = -0.006				
The C_A is the factor of precision (0.003) times the square root of the number of setups (sqrt14) — CA = 0.003(sqrt14) = 0.011				

6.5.1 Step 1—Establishing the Initial Elevation

The only difference in this step is the need to use a benchmark when making long-term installations. Most bridge construction requires that a benchmark be established. If these preestablished marks are not readily found, they can usually be obtained by contacting the entity that owns or maintains the bridge. For short-term installations (1 to 3 years), a benchmark is preferred, but because the station may be used in the future, a well-placed reference mark must be used. The RM should be low profile and permanently placed in the bedrock. For example, a concrete bolt with a flat head or a brass cap can be placed along a more stable portion of a bridge pier. If a permanent structure must be formed for RM placement, it should grounded in bedrock.

6.5.2 Step 2—Establishing Elevations of Remaining Points

Sideshots should be avoided when running a complex level circuit. Therefore a new H.I. is established for each station. Turning points can be used when points are at a distance too far to read. The calculations for H.I.'s and elevations are the same as before. Several new points will be established when installing permanent or semi-permanent stage measurement devices. These new points and the survey circuit are fully described in SOP's pertaining to each of the different types of instruments. These SOP's are referenced in Section 7 of this document. Figure 4 illustrates the installation of a wire weight gage. Note that the check bar of the gage is included as a point along the circuit.

6.5.3 Step 3—Circuit Closeout

After the closeout H.I. has been set, the circuit is closed out by establishing elevations at the same points but in opposite order. The method for setting elevations is the same and all TP's used in the first half of the circuit should be used again.

6.5.4 Step 4—Elevation Adjustment

As each of the closeout points are measured, the closeout elevation readings should be compared to the elevations calculated during the first half of the circuit. An example of elevation adjustment is in Table 5. Before finalizing the survey, an elevation adjustment sheet must be completed and attached.

Table 5. Illustration of elevation adjustments for the circuit in Table 4.

Station	1st Difference From Prev. Sta.	2nd Difference From Prev. Sta.	Average Difference	Elev.
RM-1	N/A	N/A	N/A	10.000
RM-2	0.003	0.005	0.004	10.004
TP-1	0.056	0.065	0.061	10.065
RP-2	0.418	0.411	0.415	10.479
CH. BAR	0.470	0.465	-0.468	10.012
RP-3	0.669	0.662	0.666	10.677
RM-3	0.569	0.575	0.572	11.249
RM-4	0.025	0.027	-0.026	11.223

6.5.5 Step 5—Surveying the Datum

In a complex level circuit, a second, and sometimes third, circuit of levels is made to establish the datum. Repeating steps 1-4 runs this circuit. The only exception is for step where the remaining points run to the streambed. If available, an RM should be established on the underside of the bridge or on a bridge pier. The reference point is referenced to the permanent installation at the streambed as part of the circuit. This step is not fully discussed or illustrated in this document but is in the SOP's for the different types of instruments. These SOP's are referenced in Section 9 of this document.

7.0 Survey Notes

Survey notes are documents used to annotate and record information that is gathered at the project site. They are a data sheet and should be treated as such. Therefore, they should be written, legible, and complete. To avoid confusion and loss of data, a new sheet should be used at each new project site. For guidance on proper procedure to complete the survey notes, refer to your supervisor and or FTE. The cited references will also provide examples and details on level notes. Survey notes can be found at S:\Monitoring\STREAMS\technical documents\Survey Notes.doc

8.0 Data Storage

All paper copies of Survey Notes should be maintained with the Station Plan. The data from the Survey Notes should be entered into the Water Quality Database and station levels updated electronically as new surveys are made.

9.0 References

Levels at streamflow gaging stations, by E.J. Kennedy: USGS—TWRI Book 3, Chapter A19. 1990.