Environment Canada   Environnement Canada

HYDROMETRIC FIELD MANUAL

LEVELLING

Second Edition

Water Survey of Canada
Meteorological Service of Canada
Environment Canada
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Canada

Revision History

Revision	Date	Source	Description/Rational for Change
0.0	1973	R.A. Terzi	First Edition
1.0	1984		2nd Edit. - Change from imperial to metric system
1.1	2005	F. Rainville	Reformating

CONTENT

ILLUSTRATIONS

Foreword

The Hydrometric Field Manual was prepared to assist Water Survey of Canada personnel in the collection of hydrometric data that meet national standards. During use of the manual, the need for revisions or additions will become apparent. Suggestions for changes are welcome and will be given careful consideration.

This section of the manual was compiled and edited by R.A. Terzi. The contributions of many individuals and organizations are gratefully acknowledged.

Abstract

The main purpose of this publication is to document the levelling procedures that should be used at Water Survey of Canada gauging stations. The only deviation from current practise is the implementation of a uniform bench mark numbering system so that each Water Survey of Canada bench mark will have a unique number.

Procedures to be used in levelling at tide gauging stations are not covered in this publication. For those procedures the reader should refer to the Hydrographic Tidal Manual, 1970, prepared by Tides, Currents and Water Levels, Ottawa.

Résumé

Le but essentiel de cette publication est d'expliquer les méthodes de nivellement á utiliser dans les stations de la Division des relevés hydrologiques du Canada. Le seul écart á la pratique normale est la mise en oeuvre d'un systéme de numérotation uniforme visant á affecter chaque repére de nivellement de la Division des relevés hydrologiques du Canada d'un numéro unique.

Cette publication ne traite pas des méthodes de nivellement á utiliser dans les stations marégraphiques. Pour ces méthodes, le lecteur doit se reporter a Hydrographic Tidal, Manual, 1970, des Marées, courants et niveaux de l'eau, Ottawa.

Definitions and Abbreviations

Backsight (B.S.) – a sight taken with a level to a benchmark or point of known elevation.

Bench Mark (B. M.) – a permanent, fixed reference point for which the elevation is known. Bench marks can be used as turning points.

Foresight (F.S.) – a sight taken with a level to a bench mark or point for which an elevation is to be determined.

Gauge correction – any correction that must be applied to the gauge observation or gauge reading to obtain the correct gauge height.

Gauge datum – the permanent horizontal plane to which gauge heights are referred. This plane may in turn be referred to a standard datum, such as a Geodetic Survey of Canada bench mark, or to a bench mark with an assumed elevation.

Gauge height – the height of the water surface above the "Gauge datum"; it is used interchangeably with the terms "stage" and "water level".

Gauge observation or Gauge reading – an actual notation of the height of the water surface as indicated by a gauge, it is the same as a "Gauge height" only when the 0.000 m mark of the gauge is set at the "Gauge datum".

Gauging station – a location where systematic records of stage, or stage and discharge are obtained. This is also referred to as a "Hydrometric station".

Height of Instrument (H.I.) – the elevation of the line of sight through the telescope when the instrument has been leveled.

Level Check – the procedure followed to determine the movement of a gauge with respect to the gauge datum.

Turning Point (T.P.) – a fixed point, on which firstly a foresight rod reading and then a backsight rod reading is taken. Turning points are generally temporary in nature.

Field Manual – Levelling Section

INTRODUCTION

The function of a gauge on a river, stream or lake is to provide a means by which reliable and accurate water level data can be obtained for all stages and conditions. Instability of a gauge, lack of a permanent datum or unstable bench marks all contribute to unreliable or inaccurate records. Although some of these problems can be overcome by careful and proper location of gauges bench marks, a program of periodic level checks must be carried out at each gauging station to ensure that gauge installations and bench marks remain reliable.

GAUGE DATUM AND ZERO FLOW

To obtain accurate and reliable stage data, the station gauge and bench marks must be referred to a fixed datum, which is normally an arbitrarily selected plane. This plane to which all stage records are referred is called the gauge datum (Fig. 1). It should be chosen so as to be lower than the elevation at which zero flow is ever likely to occur and yet allow for the convenience of recording relatively low gauge heights. By ensuring that the gauge datum is located at a point sufficiently below the elevation at which zero flow occurs, the awkward and often confusing situation of recording negative stage data is avoided. It must also be kept in mind that the gauge should be low enough to allow for positive stage data to be recorded in the event of unusual occurrences, such as extreme low flows or flow in scoured channels.

It is recognized that there will be the occasional occurrence where, after a station has been in operation for some time, the channel configuration is altered to the extent that the point of zero flow is well below that of the existing datum of the gauge. When this happens, it will be necessary to lower the datum to accommodate the new channel configuration. The elevation of the bench mark must be expressed in metres above the gauge datum, the gauge datum in all cases must be at 0.000 m assumed, and the gauge set to read directly in metres above gauge datum (Fig. 1).

In most locations, it will not be practical, nor indeed possible, to install a staff gauge with the zero of the gauge at gauge datum. In cases such as this, the usable portion of the gauge must be numbered in such a way that if it becomes necessary to extend the gauge downward, the zero of the gauge will be at the gauge datum. This is illustrated in Figure 2.

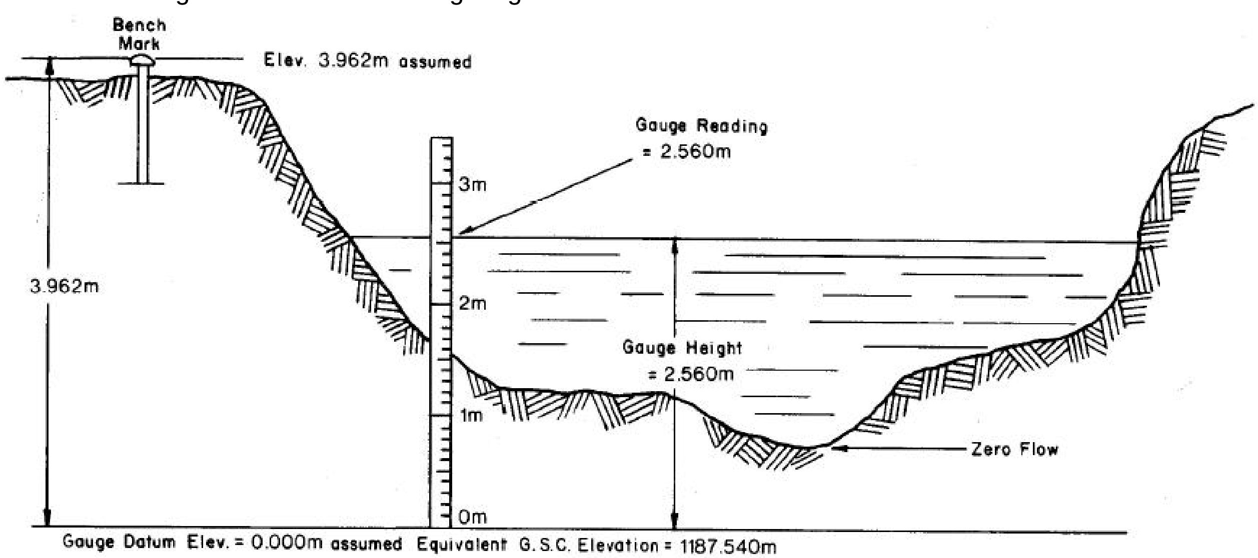


Figure 1. A sketch illustrating definitions of gauge datum, zero flow, gauge height and gauge reading.

<u>LEVEL CHECKS</u> to determine the elevation of zero flow are important for streams which may run dry or where an artificial or well defined natural control exists. By this method it is possible to accurately define the lower end of a stage-discharge curve. This is often difficult to

obtain by discharge measurement alone, especially with a natural control where aquatic weed growth is prevalent during conditions of low flow.

Gauges are subjected to many extreme conditions and are often displaced or even destroyed by the action of frost and ice. Stream bank instability, stream bed erosion and in some cases vandalism have all at one time or other been reasons for lost stage data. To help ensure that stage records remain reliable, the datum of a gauge must occasionally be checked against the bench marks to which it was originally referred. The frequency of this operation is largely determined by the conditions to which the gauge is subjected, and under normal conditions may require checking only two or three times during a season or as otherwise directed. However, for a gauge with a history of instability, a level check during each visit to the station is quite in order.

CONTINUITY OF GAUGE DATUM at a gauging station is a very important part of data collection and every reasonable effort should be made to maintain it throughout the entire period of record. This has been pointed out most often when reviewing and evaluating past and present discharge data for a reactivated gauging station. Since stage data form the basis of the relationship of stage to discharge, perpetuity of

gauge datum greatly enhances the value of hydrometric data for numerous hydrologic and engineering studies. To ensure its continuity, a selected gauge datum must be referred to at least two and preferably three stable bench marks which are associated with the gauging station but which are independent of each other and independent of the gauge or gauging structure. It is also desirable that all bench marks be referred to a datum common to the locality, and if possible, to a datum common to all the other gangues in a drainage basin. For example, where P.F.R.A. datum is used extensively throughout a region, it would be very useful to have stage data referred to this datum. Among other things, this provinces users of hydrometric data with the average slope of the water surface between successive gauging stations in a watershed.

The following is an alphabetical listing of datum planes used by the Water Survey:

Alberta Department of Highways Assumed
Canada Land and Irrigation Co.
Canadian National Railways
Canadian Pacific Railway
Geodetic Survey of Canada
Geodetic Survey of Canada (old)
International Great Lakes
Lake of the Woods
LNID East
Prairie Farm Rehabilitation Administration
Reclamation Service of Canada
Sand Heads
Saskatchewan Conservation & Development Branch
Topographic Survey
United States and Canada Boundary Service
United States Reclamation Service

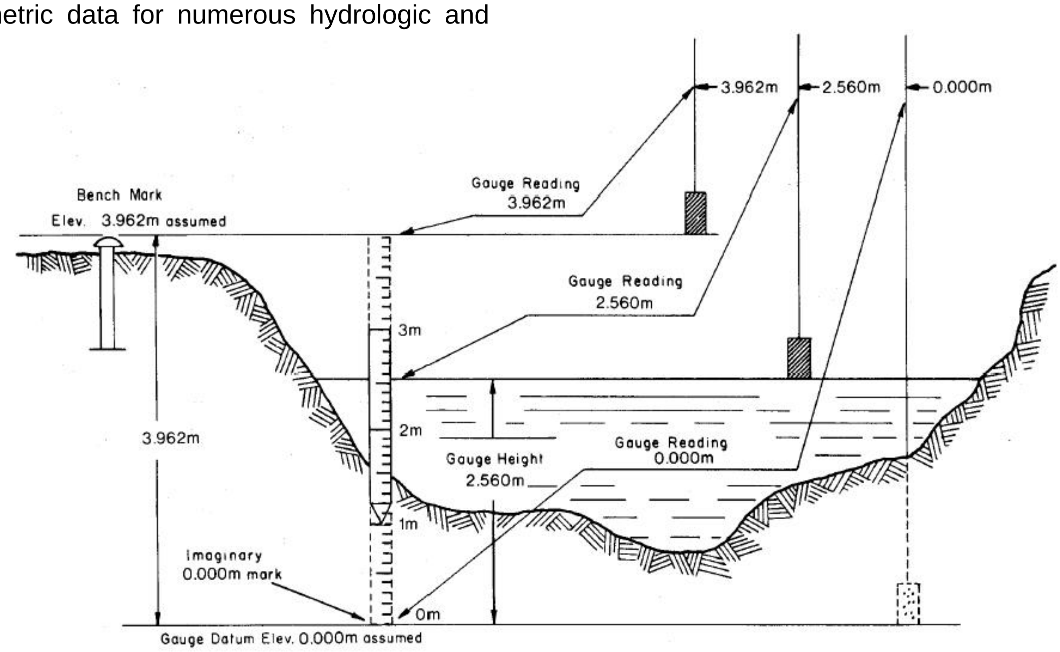


Figure 2. A sketch showing a comparison between a staff gauge and a wire –weight or tape gauge. Gauge reading or gauge observation is the same as gauge height only when the correction to the gauge is 0.000 m.)

BENCH MARKS

As previously mentioned, each new gauging station should normally have three independent bench marks associated with it. This is preliminary to ensure the continuity. local datum in the event that one or two of the bench marks are disturbed or destroyed. It should be further pointed out that for good control the bench marks must be spread apart, preferably above the flood plane, and well away from the river bank. The gauges should not be located in a cluster in the immediate vicinity of the gauge. The establishment of three bench marks does not necessarily mean that levelling must be carried out between all of them during every level check of the gauge. They should however, be checked at least twice a year to confirm their relative stability. If a change in elevation between the gauge and one bench mark is found, it is most important that the gauge be checked against at least one of the other bench marks to ensure that the error is indeed with the gauge and not with the bench mark. Corrugated steel bars driven into the ground to the point of refusal or iron pipes with base plates have both been found to be fairly stable types of bench marks.

DESCRIPTION In the past, the importance of each bench mark having a positive and unique description has not been stressed enough. An identification number controlled and recorded by each Regional Office must be assigned to every bench mark established by the Water Survey. This number is to be placed on the crowned surface of the bench mark top beneath the longer limb of the cross (Fig. 3). The identifier, which is stamped using a set of letter and number dies, provides a means of easy identification so that pertinent information can be made readily available when required.

The SERIAL NUMBER indicates, by the first one or two letters, the province or territory in which the bench mark is located, the following two digits the year in which it was established, and the remaining number denotes the numerical sequence in which the identification is assigned in a particular calendar year.

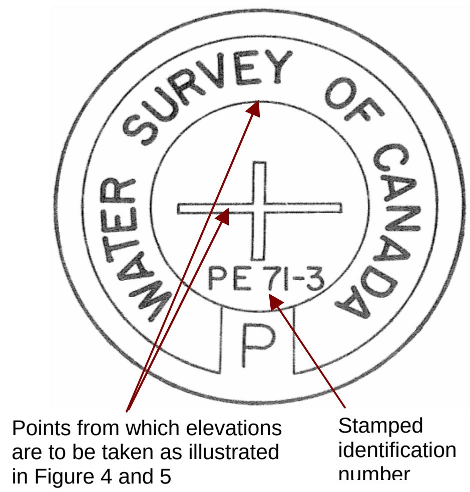


Figure 3. A sketch of a standard WSC benchmark illustrating the style and location of benchmark identifiers.

The assigning and control of bench mark serial numbers are the responsibility of Regional Office staff. The abbreviations to be used for the provinces and territories are as follows:

A: Alberta	NU: Nunavut
BC: British Columbia	O: Ontario
M: Manitoba	PE: Prince Edward Island
N: Newfoundland	Q: Quebec
NS: Nova Scotia	S: Saskatchewan
NT: Northwest Territory	YT: Yukon Territory

TYPES OF BENCH MARK The two styles of bench mark presently used by the Water Survey have identical top surfaces and differ only in the manner in which they are mounted. On is a plug which can be mounted vertically or horizontally in a rock or concrete surface; the other is a cap which is meant to be attached either to a pipe or an iron bar sunk into the ground. The letter P or C (for plug or cap) is stamped into the flat surface of the flange to differentiate between the two. The centre section of the top is raised 6 mm above the surrounding flange and has a slightly crowned surface. Two grooves which form the short vertical and longer horizontal limb are cut into the surface (Fig. 3). When a plug style top is mounted on a vertical surface, the raised centre section protrudes far enough to allow a level rod to be placed on the edge of the crown as shown in Figure 4.

Should the top be mounted under a ledge so that the edge of the crown is not accessible, it can be used with a bench mark chisel placed in the groove of the horizontal limb and the level rod held on the bench mark chisel or a knife blade as in Figure 5. If it is intended that the first approach be used, neither cross limb should be in the horizontal position (Fig. 4). In either case, it is most essential that an arrow be stamped on the crowned surface to indicate the point to which the elevation applies.

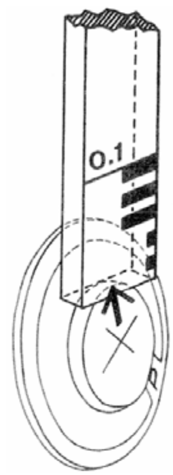


Figure 4. Shows the use of a benchmark mounted in a vertical plane. An arrow cut into the surface with an ordinary cold chisel, shows that the levelling rod must be placed on the edge of the raised centre section.

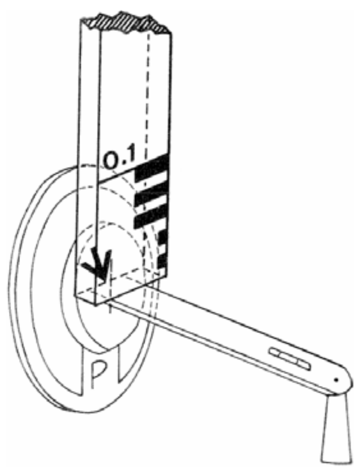
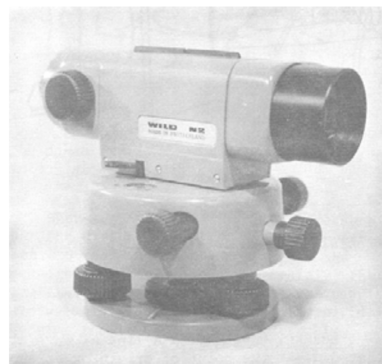


Figure 5. Shows the benchmark top being used with a benchmark chisel. Here the arrow chesselled into the crown points to the long horizontal groove where the benchmark chisel must be placed.

LEVELLING INSTRUMENTS

ACCURACY When levelling, the accuracy of the work depends upon two major factors:

The quality and precision of the instrument used; and the skill and care exercised by the surveyor. For normal hydrometric work, any good quality engineer's level such as the Wild N2 can be used to obtain the required degree of accuracy as long as the instrument is maintained in proper adjustment. It is strongly recommended that a test be carried out by a field man to check the accuracy of any level assigned to him. Repeat tests should be conducted prior to the spring series of level checks, and after any accidental rough usage.. The two-peg test is one which is perhaps most commonly known and used. This procedure, which normally takes about two and one-half hours to complete, is described in Appendix 1.



Wild N2 Level

A particular feature with the Wild N2 level is that it can readily be checked for collimation from one instrument station. First the instrument must be sighted o a fixed point. Then be depressing the telescope locking pin, the telescope and tabular level can be rotated 180 degrees about the longitudinal axis of the instrument. When the level is in adjustment, the reading obtained from the two positions will be the same. If the level is out of adjustment, the mean of the two readings will give the correct horizontal sight. This test is described more fully in the instruction booklet provided with the instrument and, since it is so easy to conduct, it is recommended that it be carried out each time the level is used.

LEVELLING ERRORS The other important factor upon which the accuracy of levelling

is dependent is the skill and care exercised by the field man. Mistakes are not considered in the following list since they are due mainly to miscalculation, carelessness or poor judgment and can be detected and eliminated by checking all work. The field man must, however, be aware of potential problems which will produce errors in levelling and of the steps necessary to limit them. The following is a list to which some levelling errors can be attributed.

1. Improper Adjustment of Instrument – This condition occurs when the line of sight is not parallel to the axis of the level tube. This error can be minimized by careful adjustment of the instrument and by balancing backsight and foresight distances.
2. Parallax – The eyepiece of the telescope must be adjusted until the cross-hairs appear sharp and distinct. The objective lens is then focused on a target. If there is an apparent movement of the cross-hairs on the target with a corresponding slight movement of the observer's eye, the condition of parallax exists. This condition can be reduced to a negligible quantity by careful focusing of both the eyepiece on the objective lens.
3. Inaccurate Reading of Rod – This form of error can be greatly reduced by using shorter sights and by checking each reading before recording it.
4. Rod Not Plumb – A rod level can be used or the rod can be waved to eliminate this sort of error, assuming that when the rod is tipped backward it still rests o the front edge of its base.
5. Improper Turning Points – Turning points which are not both well defined and stable, are a potential source of error. If reasonable care is exercised when selecting turning points so that they are both solid and have rounded tops, this error source can be kept to a minimum.
6. Level Bubble Not Centred – If this condition exists at the time of sighting, the magnitude of the error will vary as the distance between the instrument and the rod. It follows therefore, that the greater the distance to be sighted, the greater the care that should be exercised when levelling the instrument.
7. Settlement of Instrument Tripod – Some settlement of the level tripod is likely to occur when levelling over soft, muddy or thawing ground. At times such as this, backsight and foresight observation should be made in quick succession in order to minimize any effect from the instrument settling.

LEVELLING PRECISION A line of levels that ends at the point of origin or at another previously established bench mark, is referred to as a level circuit. When a long circuit is completed, the elevation computed from the level notes will rarely agree with the initial or given elevation of the point. This difference in elevation is called the error of closure and can be attributed to the conditions previously described.

Experience has shown that these errors will vary as the square root of the number of instrument set-ups. Assuming that the number of set-ups per kilometre is uniform throught the circuit, the error will thus vary as the square root of the circuit distance which is usually expressed in kilometres.

When techniques of levelling are such that the distance of sighting is no greater than 90 metres in length; foresights and backsights are balanced approximately; the levelling rod is waved for large rod readings; turning points are on well-defined, solid objects; the level bubble is carefully centred before each sight; the level tripod is set on firm ground, then the maximum error of closure should in fact be no greater than $\pm 0.010\sqrt{D}$ where D is the distance expressed in kilometres. Normally the error will be substantially less. Except in other than ordinary cases, this same criteria can be used when determining whether or not to apply correction to gauges and bench marks, and the following can be used as a general guide:

Correction Applied When

Length of Run	*Difference in Elevation is*
1 kilometre	0.010 metre or greater
500 metres	0.006 metre or greater
300 metres	0.003 metre or greater

For short levelling circuits involving 3 or less set-ups the maximum closure allowable will be 0.003 m. Should the closure exceed 0.003 m it is wiser to re-do the circuit rather than distribute the error of closure.

Normally, rod readings to 0.002 metre are sufficient. Readings to 0.001 metre imply a degree of accuracy which does not ordinarily exist and is generally inconsistent with the sensitivity of the equipment used to gather stage data.

A correction of 0.002 metre would usually not be applied to a gauge in other than exceptional cases such as where sensitive artificial controls are used and stage data are recorded to greater than 0.002 metre accuracy. However, as a general rule, in cases where numerous consecutive observations have shown the same change of 0.002 metre in elevation, and it can be assumed with some certainty that the elevation of the gauge has changed, the correction can be eliminated by resetting the gauge.

Another aspect which has a great bearing on levelling accuracy and is often overlooked is the quality and condition of levelling rods that are used.

Levelling rods must be checked for accuracy upon receipt and it is further recommended that rods used for any major levelling project be calibrated. When not in use, a rod should be sorted in a case, preferably a solid one, so as to prevent accidental scratching of the printed surface or damage to the socket ends. An untreated wooden rod should not continually be placed in water as this will cause the wood to swell and the painted surface will soon become checked and flake off, thereby limiting the useful life of the rod.

<u>LEVEL NOTES</u> During routine level checks of gauges and normal line or differential leveling between between marks,(with backsight and foresights balanced approximately) the format for recording level notes is shown by Figure 6. The level sheet portion of the current meter note 'form R-21A(M)' is divided into columns for recording observations and computing elevations. The lower part of the level sheet or an additional sheet is used for recording the necessary descriptive notes which must accompany the observation data sheet.

When recording notes, the elevation of the bench mark or reference mark is entered on the top line in the column headed "Elevation". The bench mark identification number is entered in the space to the right along with any additional descriptive information required. Should it be necessary, an additional description sheet can be attached to the notes. On the same line in the column headed "Station", (location of rod) the notation BM is entered. In the next space still on the same line, the reading obtained with the levelling rod held on the bench mark or point of known elevation is entered as the backsight (B.S.). The value for the next space under heading H.I. (height of instrument) is computed by adding the B.S. value to the known elevation. The next column under F.S. (foresight), only one line down, the foresight reading or point for which an elevation is to be determined is observed and recorded. This value is then subtracted from the H.I. and the result is the elevation of the foresight point, or first turning point (T.P.1). This is entered in the space to the right, n the Elevation column on the same line as the foresight just observed. The observations and notes are continued in the manner just described until the circuit is closed.

Level notes may be recorded in a note book or on any sheet of paper, as long as the above method is applied. Using this format of note-keeping, the information on each horizontal line pertains to the bench mark or turning point noted in the Station column. A typical set of notes for levelling between two bench marks should be recorded as illustrated in Figure 6.

When completing a long line of levels to refer a Water Survey bench to another datum, it is often an advantage to use the same turning points for the return portion of the circuit at were used for the forward run. Large sources of error can be quite readily detected by this method, thus saving a great deal of time and effort re-levelling the entire circuit.

GAUGE CHECKS

<u>PROCEDURE</u> When running levels to check for movement of a gauge, the circuit must be closed in all cases. Even where the situation involves one set-up between the bench mark and gauge, the instrument must be moved to close the return ron to the bench mark. This procedure however, presents a problem when checking wire-weight gauges without the assistance of a rodman. To completely reposition the instrument tripod after initially sighting on the weight, presents a problem when attempting to resight the level on the graduated portion of the weight when closing the circuit. It is suggested that in this case, <u>and only in this case</u>, that one of the tripod legs be adjusted upward to reposition the level head for the foresight on the graduated weight. Of course this approach is not necessary when assistance is available. The return portion of the circuit is completed by levelling to the bench mark from which the

circuit began. See Figure 8 for a sample of level notes, and Figure 9 for an illustration of corrections to wire-weight gauges.

When levelling staff gauges (both inside and outside gauges), the same general procedure is used. However, in this case repositioning the instrument after sighting on the rod or directly on the staff gauge generally presents no problem, and this step must be taken when closing the circuit. As mentioned in the previous example, the circuit must be closed by returning to the bench mark of origin. A sample of level notes is shown by Figure 10. Staff gauge corrections are illustrated in Figure 11.

In all cases the level circuit must be completed prior to determining the correction which is to be applied to the gauge. It is also strongly advised that a water elevation be obtained at the time the level circuit is run. Among other things, this will readily point out when intake pipes are silted or frozen.

LEVEL NOTES

STATION	B.S.	HT. INST.	F.S.	ELEVATION	
LEVELS BETWEEN WRB BENCH MARKS S70-4 & S70.6					
BM	1.113	7.514		6.401	S70-4 BM 3.60m
TP1	2.408	8.093	1.829	5.685	S.E. of R. abutment
TP2	3.139	10.244	0.988	7.105	
TP3	2.822	12.426	0.640	9.604	
TP4	3.484	14.938	0.972	11.454	
BM	0.686	14.920	0.704	14.234	S70-6 BM est. on R. bank 150m downstr. from bridge
TP5	0.948	12.140	3.728	11.192	
TP6	1.247	11.345	2.042	10.098	
TP7	0.731	9.927	2.149	9.196	
BM			3.520	6.407	S70-4
ΣBS=	16.578	ΣFS =	16.572	6.401	
		Diff. ΣBS –	ΣFS =	0.006	acceptable closing error

SKETCHES

Figure 6. Sample level notes (levelling between benchmarks).

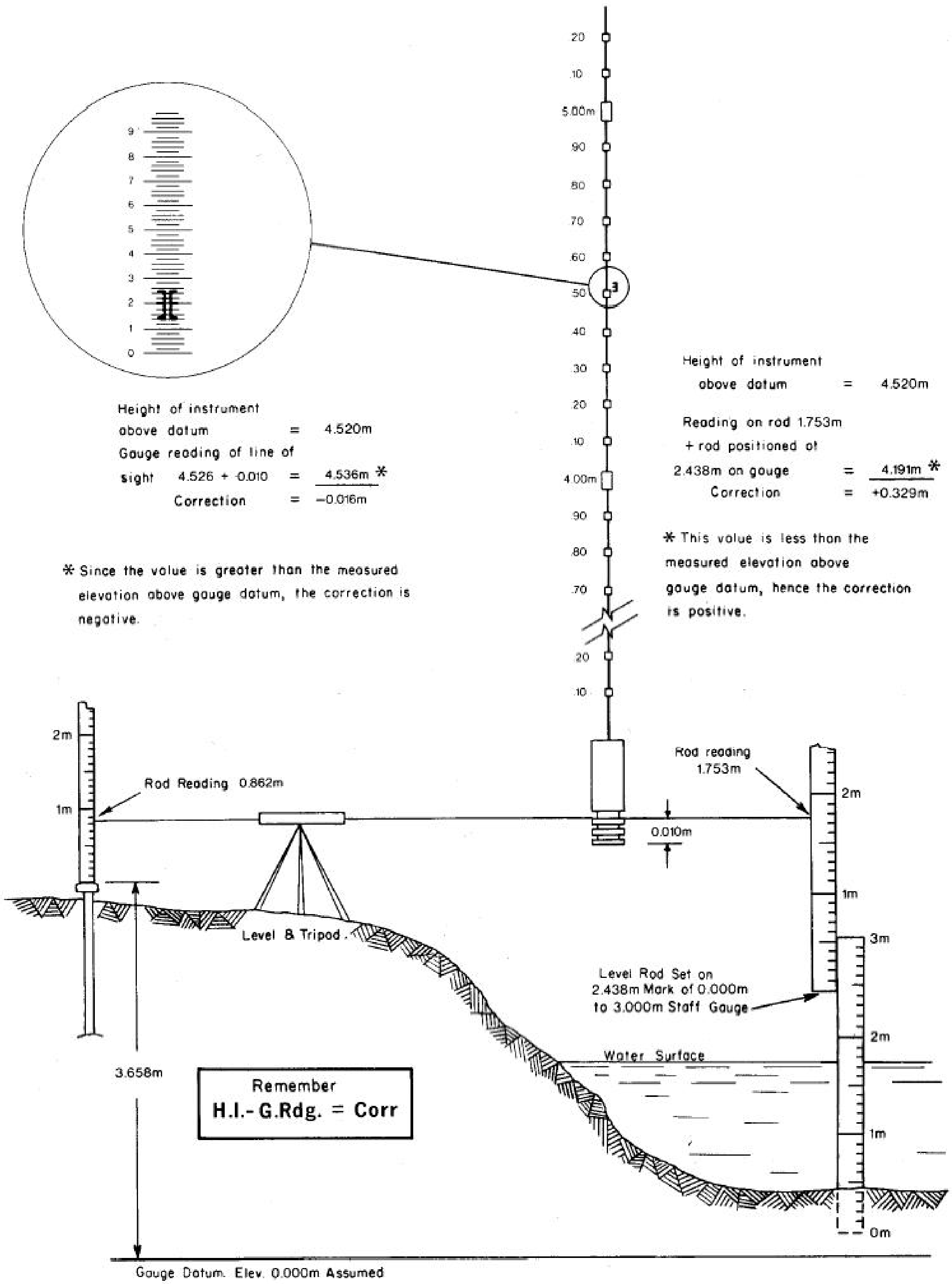


Figure 7. Gauge correcions and how they are derived.

LEVEL NOTES

STATION	B.S.	HT. INST.	F.S.	ELEVATION	
BM	0.152	14.782		14.630	A70-2, BM on R. bank
TP_1	0.305	11.887	3.200	11.582	3m W. of Br. abut.
TP_2	0.152	8.381	3.658	8.229	
W.W.G.			0.012		sight on grooves of weight.
			8.376		W.W.G. reading
			8.388	−0.007	Corr. to W.W.G.
W.W.G.	0.043				sight on weight after changing inst. setup
	8.376				W.W.G. reading
	8.419	8.412			
TP_3	3.810	11.734	0.488	7.924	
TP_4	3.566	14.995	0.305	11.429	
			0.363	14.632	A70-2
Σ	16.404		16.402		
			16.404		

SKETCHES Diff.= 0.002 acceptable closing error

use correction of −0.007m

Figure 8. Sample level notes (level check of wireweight gauge).

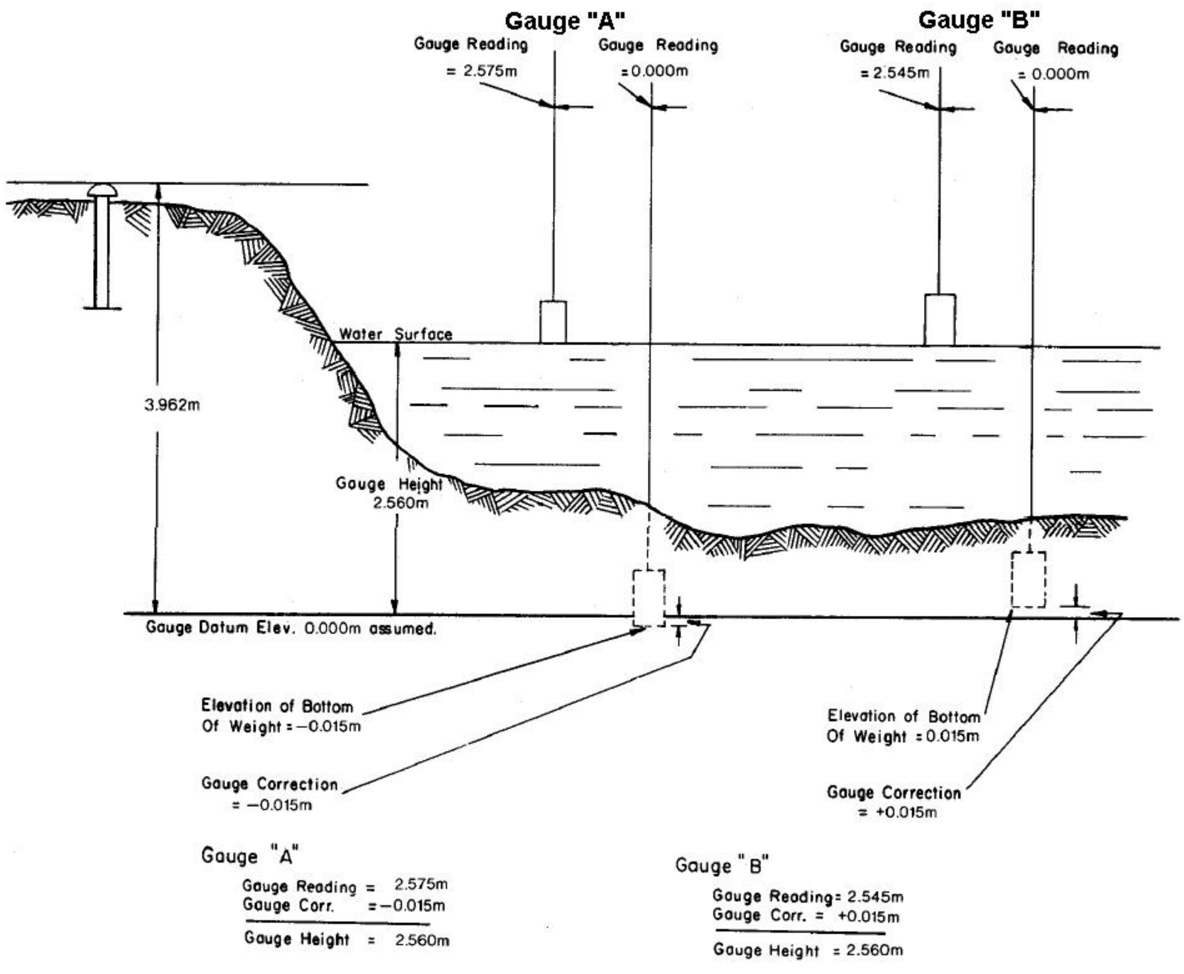


Figure 9. Illustration of corrections to wire-weight gauges.

STATION	B.S.	HT. INST.	F.S.	ELEVATION	
BM	0.914	20.726		19.812	M70–3, BM 18m S.E.
TP_1	0.305	17.483	3.048	17.678	of power pole at shelter
TP_2	0.610	15.240	3.353	14.630	
TP_3	0.305	12.802	2.743	12.497	
TP_4	0.610	9.754	3.658	9.144	
	3.658		3.368		sight on rod
	6.400		6.400		rod held on 6.4m of 0–7.3m I.G. corr. to
GAUGE	10.058	10.044	9.768	−0.014	inside gauge
TP_5	3.353	12.787	0.610	9.434	
TP_6	3.658	16.140	0.305	12.482	
TP_7	2.743	18.578	0.305	15.835	
TP_8	1.829	20.255	0.152	18.426	
B.M.			0.439	19.816	BM M70–3
Σ B.S.=	24.385	Σ F.S.=	24.381	19.812	
		Diff	=0.004	= 0.004	acceptable closing error

SKETCHES

NOTE: This is the 4th consecutive level check to show the inside gauge with a −0.014m correction. The gauge will be reset during summer trip when shelter maintenance is scheduled.

(use correction of −0.014m)

Figure 10. Sample level notes (level check of staff gauge).

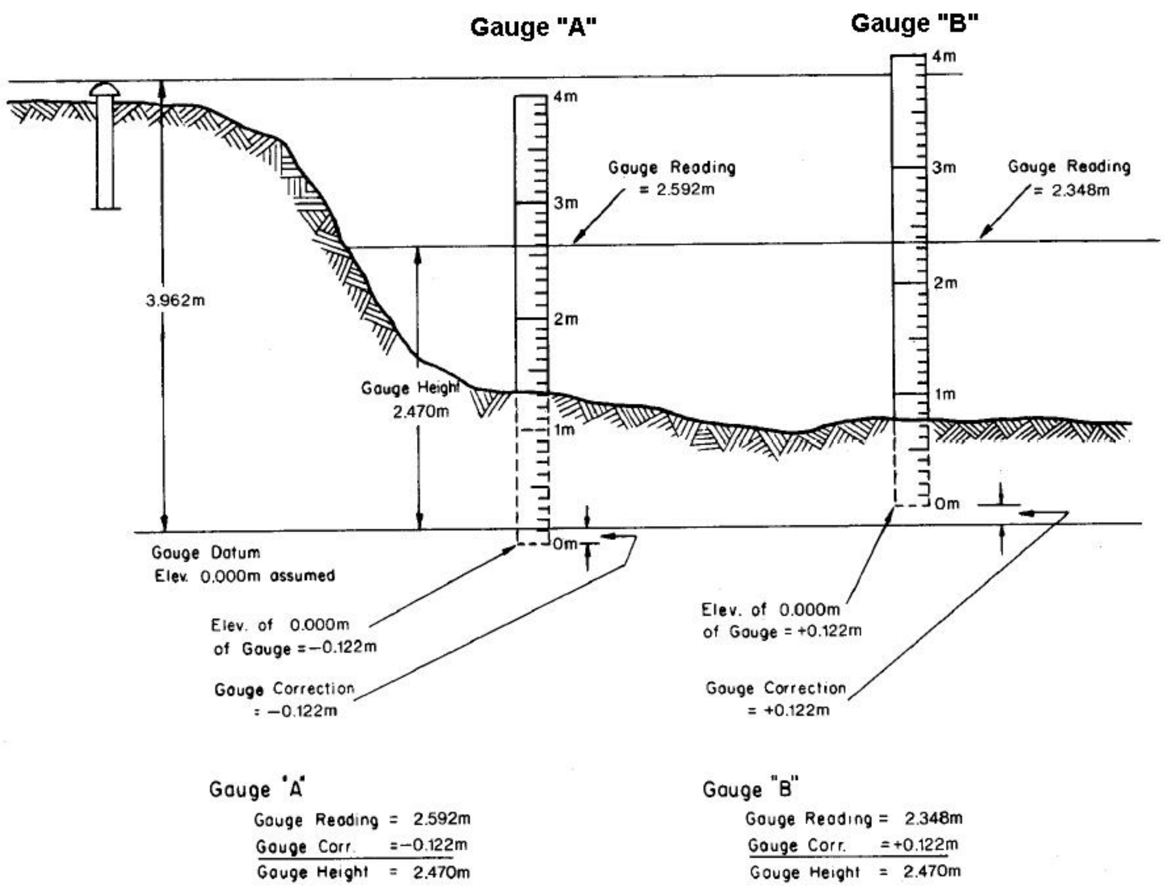


Figure 11. Illustration of corrections to staff gauges.

Bibliography

Breed, Charles B., Hosmer, George L., Bone, Alexander J. Volume I, Elementary Surveying. 10th Ed. New York, Wiley 1966; Volume II, Higher Surveying, 8th Ed. New York, Wiley 1961.

Campbell, P.I. Part 3, Manual of Hydrometric Field Procedures, Department of Energy, Mines and Resources, Inland Waters Branch, Water Survey of Canada. 1967.

Corbett, D.M. Water Supply Paper 888, Stream-Gaging Procedure, A Manual Describing Methods and Practices of the Geological Survey. United States Geological Survey. 1945.

Davis, R.E., Foote, F.S., Kelly, J.W. Surveying Theory and Practice. 5th Ed. New York, McGraw-Fill. 1966.

Survey Monumentation Sub-Committee, Recommendations for Survey Markers in Horizontal and Vertical Control Surveys. Department of Energy, Mines and Resources. 1972.

Wild Heerbrugg Ltd., Wild N2 Engineer's Level Instructions For Use. Wild Heerbrugg Ltd., Heerbrugg Switzerland.

APPENDIX I

TWO PEG TEST This test is used to ensure that the line of sight through the telescope s parallel to the axis of the level tube.

Set two stakes A and B, 60 to 90 metres apart on reasonably level ground (Fig. 12.) Set up and level the instrument at a point midway between the two stakes and take a rod reading a on the first stake and a reading b on the second stake. The difference in the reading, b-a, is the correct difference in elevation between the two stakes, regardless of any error in the instrument, since the observations are made from a point that is equidistant from each stake.

Next, set up and level the instrument at stake A so that the eyepiece will swing within 0.012 metre of the rod. Read c on the rod by observing through the objective lens of the telescope. Although the crosshairs will not be visible, the field of view is so small that its centre may be determined by holding the point of a pencil on the rod. Move the rod to stake B and obtain reading d.

If the instrument is in good adjustment, the difference in elevation of the two stakes as observed from midway between them will be the same as when observed from stake A. Or, d-c will equal b-a, and if b-a is added to the reading c, the result must be the correct reading at e. The difference between this value and the actual reading at d is the error in the adjustment of the line of sight between stakes A and B.

Assume that the following observations are made: a=0.573 m, b=1.350 m, c1.161 m, d=1.923 m. When observed from midway between the stakes, the difference between the readings b-a=0.777 metre, is the true difference in elevation between stakes A and B regardless of the error in the line of sight. This value 0.777 when added to the reading c, 1.161, gives the value for e=1.938 m. This is the true value for the horizontal line of sight and the difference of 0.015 between calculated true line of sight and the reading d=1.923 is the error in the line of sight between the two stakes.

Adjustments are carried out while the instrument is still in position at station A. If the instrument is equipped with an adjustable cross-hair ring or reticule, the correction is made while the level bubble is kept centered. First, one of the adjusting screws is loosened and then the other is tightened the corresponding amount. For the example cited above, the adjustment screws are turned until the cross-hair is set to read 1.938 on the levelling rod when it is held on stake B.

This same test can be used for the Wild N2 level. The adjustment differs however, in that the tubular split bubble is moved to correspond with the correct horizontal line of sight. First, the cross-hair is set to the correct reading on the levelling rod. The outer horizontal screw of the coincidence level is then loosened slightly to permit vertical adjustment of the end of the level tube. Next the vertical screws are adjusted first by loosening one very slightly and tightening the other an equal amount. This is repeated until the coincidence of the bubble ends has been restored.

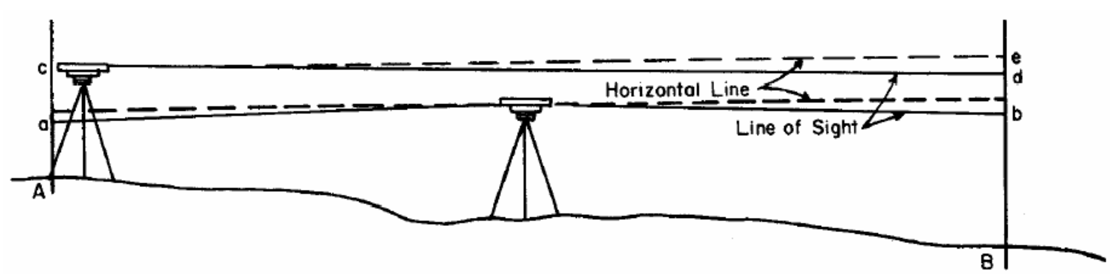


Figure 12. A sketch illustrating the principle of the two peg test.