CHAPTER 7

Gauge Operation and Sounding Reduction

7.1 Introduction

This chapter treats the general procedures that should be followed in operating a temporary water level gauge, and in applying the information from that gauge to the accurate reduction of soundings taken in the vicinity. Detailed operating instructions for a particular model of gauge (paper loading, pen filling, etc.) may be obtained from the instruction manual accompanying the instrument. Although several methods by which to determine a satisfactory sounding datum are described, situations will almost certainly arise for which no single method is exactly suitable. In such a situation, it is hoped that the principles explained here may be combined with a little common sense to suggest a solution. It is highly desirable that the sounding datum chosen be as close as possible to the final chart datum, but it is recognized that there will be occasions when sounding must be started before sufficient water level information is availabe to permit an elegant choice of sounding datum. The sounding datum should not be altered during the survey, since this would be more likely to give rise to error in the final reduction to chart datum than would consistent use of a poorly chosen sounding datum. Cotidal charts for the reduction of soundings in tidal waters not in the immediate vicinity of a gauge are treated here from the standpoint of the user in the field, not from that of the tidal officer who must prepare them. It is important, however, that the field hydrographer advise the tidal officer of his requirements for cotidal charts well in advance of the survey, and discuss them with him, to obtain the most suitable presentation of the cotidal information.

7.2 Sounding datum from existing BMs

Usually when an area is being re-surveyed, it is possible to recover BMs from the previous survey, whose elevations have been determined with respect to chart datum. When this is the case, the gauge zeros are set to chart datum as described in section 6.23, and sounding datum at the gauge site is gauge zero. Presumably sounding datum and chart datum would be identical in such a case, but until confirmed by the Regional Tidal Officer, sounding datum remains just that. If there are Geodetic or IGLD BMs in the immediate vicinity of the gauge, and if the local relation between chart datum and these datums is known approximately, then the gauge zeros and the sounding datums may be set by reference to these BMs, as in section 6.23. Sounding datum and gauge zero should then be close, but not identical, to chart datum.

7.3 Sounding datum by water transfer — tidal waters

When sounding datum cannot be determined from existing BMs, it may be obtained by water transfer from a site nearby where a gauge has been or is in operation, and for which chart datum has been established. The method described here for datum transfer in tidal waters requires three or four days of high and low water heights measured with respect to gauge zero at the new gauge site, and a corresponding set of high and low water heights (observed or predicted) with respect to chart datum at the reference gauge site. The method is more accurate if the sets of heights can be obtained when the range of tide is large, usually around the spring tide. The assumptions are made that the mean water levels at the two sites over this short period are the same as they would be over the long-term average, and that the tide curves at the two places have the same shape, although they may differ in range and arrival time. Since the distance of chart datum below mean water level is determined by the range at large tide, it follows from the assumptions that the ratio of these distances at the two sites should be the same as the ratio of the ranges of the tide at the two places. If the tide at the two sites is semidiurnal or mixed-semidiurnal, all of the HWs and LWs are averaged to give a mean HW and a mean LW for each site. The mean water level (MWL) is taken to be the same as the mean tide level (MTL), i.e. half way between MHW and MLW. The average range over the short interval being treated is the mean HW minus the mean LW. The distance of sounding datum below the observed mean level at the new site is then taken as the distance of chart datum below the mean level at the reference site times the range ratio (new/reference). Substracting the observed height of the mean level from this value gives the distance of the sounding datum below the gauge zero at the new site. These calculations and entries are all to be entered on the Temporary Gauge Data form. The gauge zero should not be changed to agree with sounding datum, since there is less chance of error if all water levels are recorded on the same gauge zero throughout the survey.

The method is less accurate, and the assumptions less easy to justify, when the character of the tide is mixed-diurnal or diurnal. The calculation is nevertheless carried out in much the same way as described above for the semidiurnal case, with the major exception that only the HHWs and LLWs in

TABLE 5. Datum transfer in tidal waters with small diurnal inequality.

	New gauge site (metres, rel. to gauge zero)			Reference gauge site (metres, rel. to chart datum)	
	HW	LW		HW	LW
	1.40	0.46		2.19	0.70
	1.58	0.70		2.07	0.43
	1.40	0.46		2.23	0.70
	1.58	0.70		2.10	0.40
	1.40	0.43		2.23	0.70
	1.58	0.67		2.10	0.43
Sum	8.94	3.42	Sum	12.92	3.36
Mean	1.49	0.57	Mean	2.15	0.56

$m = (1.49 + 0.57)/2 = 1.03$ $\quad M = (2.15 + 0.56)/2 = 1.36$

$r = (1.49 - 0.57) = 0.92$ $\quad R = (2.15 - 0.56) = 1.59$

$m' = Mr/R = 0.79$; $d = (m' - m) = -0.24$

TABLE 6. Datum transfer in tidal waters with large diurnal inequality.

	New gauge site (metres, rel. to gauge zero)			Reference gauge site (metres, rel to chart datum)	
	HW	LW		HW	LW
	2.59*	0.30*		2.87*	0.43*
	2.44	2.23		2.35	2.13
	2.47*	0.49*		2.71*	0.58*
	2.26	2.10		2.44	2.04
	2.50*	0.73*		2.53*	0.82*
	2.26	1.89		2.53	1.92
Sum	7.56*	1.52*	Sum	8.11*	1.83*
Mean	2.52*	0.51*	Mean	2.70*	0.61*

$m = (2.52 + 0.51)/2 = 1.51$ $\quad M = (2.70 + 0.61)/2 = 1.66$

$r = (2.52 - 0.51) = 2.01$ $\quad R = (2.70 - 0.61) = 2.09$

$m' = Mr/R = 1.60$; $d = (m' - m) = +0.09$

NOTE: Only values marked with (*) used in calculation.

each set are included in the averages. It is important that there be a one-to-one correspondence between the HHWs at the new site and those at the reference site (and for the LLWs as well). Recognition of matching pairs at the two sites is not always easy, particulary if the reference site is far away. A little care in making the selection and carrying out the calculations should, however, produce a satisfactory sounding datum, although a further adjustment to chart datum will probably be required later when the complete water level record is available. When there is a choice of acceptable reference sites, it is best to choose the one with the greater tidal range.

Tables 5 and 6 show examples of the determination of sounding datum by water transfer in tidal regimes with small and large diurnal inequalities, respectively. R and r are the ranges at the reference and new sites, respectively; M is the MWL at the reference site, above its chart datum; m is the MWL at the new site, above its gauge zero; and $m' = Mr/R$ is the calculated distance of sounding datum at the new site below its MWL. The height of the gauge zero above the sounding datum at the new site is thus $d = m' - m = (Mr/R) - m$. Provision is made on the Temporary Gauge Data form for the entries and calculations shown in the tables to be made directly on the form. There is also provision for the calculation of the high water datum to which elevations are referred. This datum at the reference site is HHWLT, and its height above chart datum, which we will call H, should be available either from the Tide Tables or from the Regional Tidal Officer. The height of the datum for elevations at the new site is calculated as $h = Hr/R$, above sounding datum, and therefore is $h - d$ above the gauge zero. Just as sounding datum is provisional, pending final determination of chart datum, the datum for elevations is also provisional, pending a final determination when all data is available.

7.4 Sounding datum by water transfer — lakes

Chart datum on lakes is usually chosen as a level surface, whose elevation above one of the survey datums (e.g. Geodetic or IGLD) is known. Only when sounding datum cannot be found by levelling from one of these BMs or from a previously established Hydrographic BM would the water transfer method be used. To transfer datum by water transfer on a lake requires that there be a reference gauge in actual operation at a location on the lake where chart datum has been established: there is no equivalent to the predicted values that may be used in tidal waters. The data input required is a set of hourly (or more frequent) water levels above chart datum for a period of two or three days at the reference gauge, and a simultaneous set of water levels above gauge zero at the new gauge. The data should be gathered on days when the wind is light and the seiche action is small. The wind is usually the more important factor, since averaging over 2 or 3 days will filter out most seiche effect, whereas it will not remove the effect of a steady wind set-up. The assumption is made that the mean surface of the lake over the sampled period is a level surface, and so is the same distance above chart datum at all locations. If M is the mean water level at the reference gauge above chart datum, and m is the mean water level at the new gauge above gauge zero, then the distance of sounding datum below the gauge zero at the new site is $d = M - m$. If a high water datum for elevations has been established at the reference site, then the datum for elevations at the new site should be set the same distance above sounding datum as that at the reference site is above chart datum.

7.5 Sounding datum by water transfer — rivers

Once again, if chart datum is known precisely or even approximately with respect to local BMs, sounding datum should be established by levelling from a BM. If this cannot be done, datum may be established by water transfer from an operating reference gauge, much as described for lakes in section 7.4. The reference gauge must not only be on the same river, but must be on the same stretch of the river, with no locks, dams, or major changes in cross-section between it and the new gauge. This is because the assumption will be made that the water level is the same distance above chart datum at both gauges, for any given river discharge (i.e. that the "stage-discharge relation" of the river is the same at both locations). Because of this assumption, the mechanics of the determination of sounding datum on a river by transfer from a single reference gauge are the same as on a lake, and, in the terminology of section 7.4, $d = M - m$. Unfortunately, the surface slope of a river is unlikely to be the same at all high and low stages, and so cannot legitimately be expected to be exactly the same as the slope of chart datum, except when the river is at the low water stage chosen to define chart datum. For this reason it is desirable to have two reference gauges, one above and one below the new gauge, and to interpolate the datum transfer between them. Let L_u and L_d be the distances of the upstream and downstream reference sites from the new site, M_u and M_d be the mean water levels above their respective chart datums for the period of interest, and m be the mean water level above gauge zero for the same period at the new site. If m' is the distance of sounding datum below the mean water level at the new gauge site, we have

$$m' = \frac{L_u M_d + L_d M_u}{L_u + L_d}$$

This follows simply from weighting the contributions from the two reference gauges in inverse proportion to their distances from the new gauge. The distance of sounding datum below the gauge zero is therefore $d = m' - m$.

Figure 57 attempts to illustrate the principles and implied assumptions involved in the transfer of sounding datum on tidal waters, lakes and rivers. CD denotes chart datum at the reference gauge, and SD denotes sounding datum at the new gauge. Situations will undoubtedly arise where there are no existing BMs and also no suitable reference gauges. The hydrographer must then examine the limited water level data and whatever other information he has been able to gather before soundings are to be commenced, and choose what appears to be a reasonable sounding datum. Conscientious operation of the gauge for as long as possible before, during, and after the sounding survey will greatly assist in the eventual selection of chart datum.

7.6 Daily gauge inspection

Every water level gauge should be inspected at least once each day. In tidal waters an attempt should be made to inspect the gauge near high water and near low water on alternate days. The first aspect of the inspection consists of a superficial visual check to see if any of the installation has been disturbed; e.g. the staff gauge, stilling well, gauge shelter, or pressure sensor mounting shifted, weakened, or damaged in any way. If it appears that the staff gauge may have been shifted, its zero must be checked again by levelling to the BMs. If an electric sight gauge (tape gauge) is in use, the elevation of its gnomon must again be checked against the BMs if it appears the gauge shelter may have been shifted. When any alterations are required, two sets of comparison readings should be made and recorded as described in the following paragraph, one set before and one set after the alteration.

Figure 58 shows a sample of the water level gauge Comparison Form in common use by the Canadian Hydrographic Service for recording daily gauge inspection information. The form is self-explanatory, but the comparison procedure requires some elaboration. Rather than completing the entries in order from column 1 to 15, the sequence below is recommended.

1) Enter the general information requested in columns 1 to 3 and 12 to 15, and ensure that the header on the sheet has been filled in.
2) Read the water level on the staff gauge and enter it in column 9; enter the true time of the reading in column 7. This reading is taken first because the height readings should be as nearly as possible simultaneous, and reading the staff may require a little time to mentally filter out the wave and swell fluctuations to obtain a proper reading.
3) Make a short mark with the recorder pen on the diagram, parallel to the height axis. On a pressure-activated recorder this is done by lightly moving the pen arm; on a float-operated recorder it is done by rotating the float pulley back and forth, taking care not to let the float wire slip on the pulley. The true time of this operation is entered in column 5.
4) If a sight gauge (tape gauge) has been installed, read it and enter the value in column 8. The value may be either the distance of the gnomon above the water or the height of the water above gauge zero, as long as specified by a note on the form.
5) Look back at the mark made with the recorder pen in step (3); read the time from the diagram at the location of the mark, and enter it in column 4; read the water level height from the diagram at the mark, and enter it in column 10. Step (4) is inserted before step (5) to make the height readings on staff, automatic, and tape gauges as

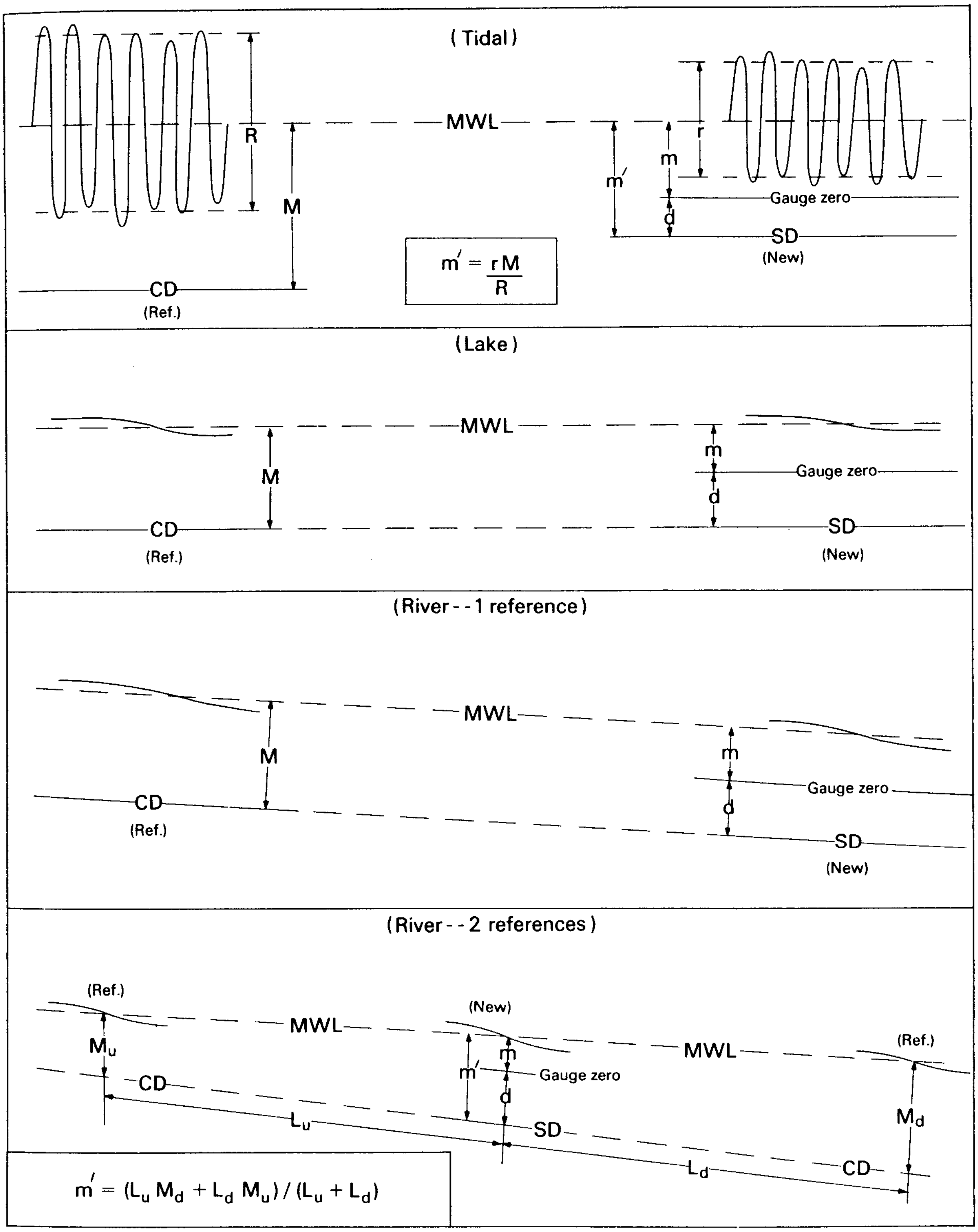
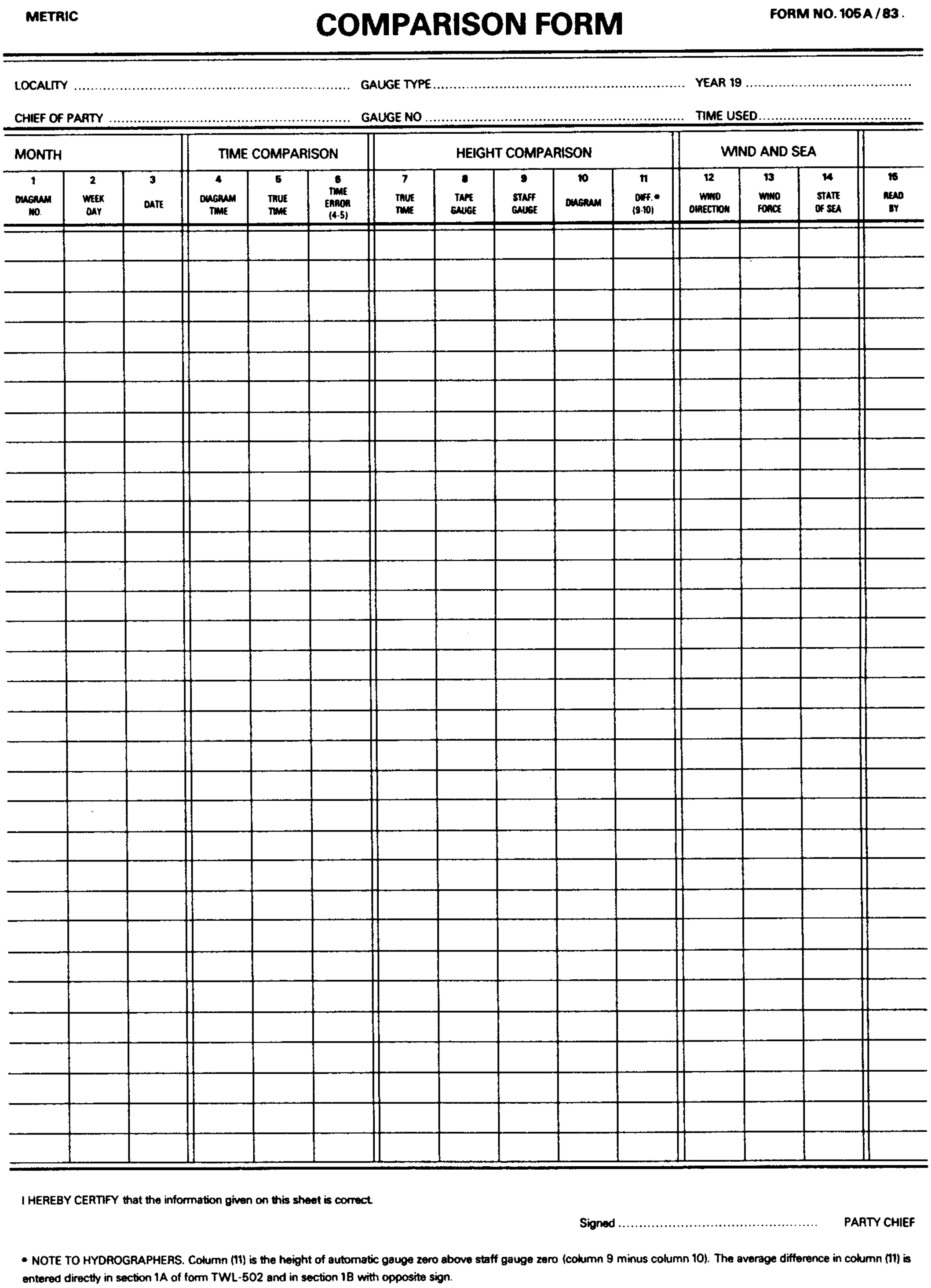


FIG. 57. Transferring sounding datum by water transfer in (a) tidal waters, (b) lakes, (c) rivers with only one reference gauge and (d) rivers with two reference gauges.



METRIC

COMPARISON FORM

FORM NO. 105A/83.

LOCALITY .... GAUGE TYPE .... YEAR 19 ....

CHIEF OF PARTY .... GAUGE NO .... TIME USED ....

MONTH			TIME COMPARISON			HEIGHT COMPARISON					WIND AND SEA			
1 DIAGRAM NO.	2 WEEK DAY	3 DATE	4 DIAGRAM TIME	5 TRUE TIME	6 TIME ERROR (4-5)	7 TRUE TIME	8 TAPE GAUGE	9 STAFF GAUGE	10 DIAGRAM	11 DIFF.* (9-10)	12 WIND DIRECTION	13 WIND FORCE	14 STATE OF SEA	15 READ BY

I HEREBY CERTIFY that the information given on this sheet is correct.

Signed .... PARTY CHIEF

* NOTE TO HYDROGRAPHERS. Column (11) is the height of automatic gauge zero above staff gauge zero (column 9 minus column 10). The average difference in column (11) is entered directly in section 1A of form TWL-502 and in section 1B with opposite sign.

FIG. 58. Standard Canadian Hydrographic Service Gauge Comparison form.

nearly simultaneous as possible.

6) Enter the time error in column 6; its value is column 4 minus column 5. Enter the height difference in column 11; since the tape gauges are not commonly installed at temporary gauge sites, this is taken as column 9 minus column 10, and so is a measure of the height of the zero of the automatic gauge above that of the staff gauge.
7) If it is convenient to mark on the recorder diagram without disturbing anything, mark the true time (from column 5) and the date on the diagram opposite the mark made with the pen in step (3). A soft-tipped pen should be used to mark lightly.

The inspection is not complete until indications of possible trouble are investigated. If the record trace seems unusually smooth, if the tidal range seems unduly small on the record, or if the automatic gauge and the tape gauge agree with each other, but not with the staff gauge, clogging of the intake by silting or marine growth is indicated. Flat spots in the record may be caused by the stilling well being too short, the float wire being too short, the intake or pressure sensor being exposed at low water, the water around the intake or sensor being impounded near low water, a pressure connection leaking, or by the movement of the diaphragm in a pressure sensor being restricted by silt. Problems peculiar to particular recorders may also arise (clogged pen, paper jammed or off sprockets, etc.), and these, along with the routine recorder maintenance (fill pen, wind clock, etc.), must be attended to as detailed in the particular instruction manual. When any adjustment or alteration is made that could change the time or height readings, a gauge comparison (steps (1) to (7)) must be made immediately before, a note written on the comparison form describing the alteration, and another comparison made and recorded immediately afterwards.

Small discrepancies in height or time that can be tolerated within the accuracy of the sounding reductions should not be removed by adjustment of the gauge or recorder. This is because a record with a small continuous error is easier to treat in the final analysis than is one with frequent adjustments. How large an error should be allowed to become before it is adjusted is left to the discretion of the field hydrographer, within limits that may be suggested by the Regional Tidal Officer.

7.7 Documentation of gauge records

The Temporary Gauge Data form, the Comparison Form, and the levelling sheets and summaries are sufficiently documented and identified when all the pertinent entries have been made in the spaces provided. The first step when starting a fresh form should always be to enter the header information (station name, location, date, etc.). If it is not done at first, it may be overlooked altogether, and the information could become orphaned later on. It is even more important to identify each piece of water level record (sheet or strip-chart) with the station name, date and starting time immediately recording is commenced. The word "Start" should be marked at the beginning of a strip-chart record, and the word "End" marked at the finish; station name, and the end time and date should also be marked at the end of the record, to avoid having to unspool a record to identify it. If pieces of record are cut off for use during the survey, each piece of the record must be identified at each end as described above. When recording is completed, all pieces of record should either be taped or pasted back together consecutively, or each piece should be marked on the outside with its consecutive number and the total number (e.g. #1 of 5), and all of them bundled together. This applies only to temporary gauge records, since records and parts of records may not be removed from permanent gauges by the field hydrographer.

The above advice has been written with strip-chart recorders mainly in mind, since they are in most common use with temporary gauges at the time of writing. The principles, however, remain the same regardless of the method of recording, whether it be punched paper tape, magnetic tape, solid-state memory banks, or whatever: each piece of record and each supporting document must be identified as to station, date, time (including time zone), and any other parameter that seems appropriate.

7.8 Datum notes on field sheets

Every field sheet on which soundings are marked must have a datum note defining the elevation of the sounding datum used in the reduction of soundings shown on the sheet. On surveys of deep offshore regions it may be that no sounding reduction is considered necessary or practicable, or that a constant amount is subtracted from each sounding just to be on the safe side. In such cases there is no standard format for the datum note, but the note must still be supplied: it might read

"Reduced to a sounding datum which is the surface (or x metres below the surface) of the water at the time of the sounding."

There is a standard format for the sounding note to be used when the sounding reductions have been made with reference to the water level at a particular location. The basic note in this case is to read

"Reduced to a sounding datum which at (name of gauge location) is x metres below BM (name of benchmark)."

A supplement to the basic note should be added, however, stating how the reduction at the sounding site was obtained from the water level at the gauge site (e.g. applied directly or calculated from cotidal chart).

When sounding datum has been determined at the gauge site by levelling from a BM on International Great Lakes Datum (IGLD) or Geodetic Survey of Canada Datum (GD), it is desirable to add the following sentence to the basic sounding note:

"The elevation of BM (name of benchmark) was determined in (year) to be y metres above IGLD (or GD)."

This wording respects the fact that the Canadian Hydrographic Service is not authorized to assign benchmark elevations except with respect to its own chart datums.

7.9 Submission of records and documents

All records, documents, and explanatory information pertaining to the operation of water level gauges, the establishment of benchmarks, and the method of sounding reduction are to be submitted to the Regional Tidal Officer at the first opportunity following completion of that phase of the survey. This is not, of course, an invitation to terminate operation of a gauge before sufficient record is obtained to permit useful tidal analysis (absolute minimum 15 days; desirable minimum of 29 days). The material to be submitted includes the originals of

1) Temporary Gauge Data form, showing sounding datum determination and relation to gauge zeros and BMs, BM descriptions and sketches, and general descriptive information;
2) BM photographs;
3) Water level gauge Comparison Forms;
4) Complete water level gauge records (pen-on-paper traces, punched paper tapes, magnetic tapes, memory bank print-out, or whatever);
5) Levelling notes and summaries;

and a copy of

6) The datum notes from the field sheets.

While it is desirable to submit as much of the above information as possible before the end of the field season, no original records should be sent by mail or other third party carrier unless a usable copy has been retained. It is always wise, in fact, to make copies of records whenever possible, and to store the originals and copies separately.

7.10 Sounding reduction — general

Sounding reduction based on surface elevations recorded at a gauge site is very similar in principle to the determination of sounding datum by water transfer from one gauge to another, as described in sections 7.3, 4 and 5. Sounding datum is, in effect, carried by water transfer from the gauge site to the sounding location. The water transfer in this case, however, is based on only one reading at each end of the line, and does not have the benefit of averaging over several days of record as in the previous case. Because of this, when accurate sounding reductions are required, the region of sounding should not be far from the control gauge. It is not possible to specify a fixed distance from a gauge, beyond which sounding should not be carried. That decision must take into account such factors as the required accuracy of the survey, and the local surface slopes that may be generated by wind, seiche, river discharge, etc.

7.11 Sounding reduction — cotidal charts

Cotidal charts have already been discussed in section 3.10. Their application to sounding reduction is mostly in offshore regions, where it is not feasible to place gauges close enough to the sounding area to justify taking the correction directly from the gauge, and where a lesser accuracy in the reduction can be tolerated. The cotidal charts most commonly used for sounding reduction implicitly assume that the shape of the tidal curve at any point on the chart has exactly the same shape as that at the control gauge, but that it may be shifted in time and magnified or reduced in vertical scale. This assumption may be valid over an extensive region when the tide is mostly semidiurnal, but over only a restricted region when the tide is strongly diurnal. A cotidal chart is prepared and provided by the Regional Tidal Officer, after discussion with the concerned field hydrographer about required accuracy, extent of the survey, proposed gauges, etc. The area covered by the chart is divided into two sets of zones, one set defined according to the time differences, and the other set defined according to the amplification factors (ratios of ranges), relative to the tide at the control gauge.

Figure 59 shows a cotidal chart for a fictitious region. Boundaries between time difference zones are shown as solid lines, and those between amplification zones (range zones) as broken lines. Each time zone is labelled with the average number of minutes by which the occurrence of a tidal event (e.g. HW, LW, etc.) within the zone lags behind the occurrence of the corresponding event at the control gauge. Each range zone is labelled with the average ratio of tidal ranges within the zone to the tidal range at the control gauge. The size of the step between time zones and between range zones must be chosen to accord with the required accuracy of the soundings and the average range of the tide. If, for example, the tide is semidiurnal with a 5-m range, a time shift of 10 minutes produces an average height change of 0.13 m, and a maximum change of 0.21 m; a shift 0.1 in range factor produces for the same tide an average height change of 0.32 m, and a maximum change of 0.50 m. Improved accuracy in the use of cotidal charts may be obtained if values are interpolated, rather than taken as constant over a zone. At the very least, when a sounding location is closer to the boundary than it is to the centre-line of a zone, the value chosen should be the average of those on either side of the boundary. To help illustrate the reduction method, Table 7 contains a hypothetical set of water level data supposed to have been read from the control gauge for the cotidal chart of Fig. 59. The times shown in the table are the times taken directly off the gauge record (or diagram), corrected only for gauge clock error, if any.

TABLE 7. Control gauge readings for sounding reduction

Gauge diagram time (AST)	Water level above sounding datum (metres)
10:40	4:05
11:00	3.70
11:20	3.35
11:40	2.90
12:00	2.50
12:20	2.10
12.40	1.65
13:00	1.30
13:20	0.95

The following two examples demonstrate how to calculate the sounding reduction from the cotidal chart information and the water level data.

Example (a):

At 11:05 AST a sounding of 9.6 m is taken at point A on the cotidal chart. From Fig. 59, the time lag of the tide at A relative to the tide at the control gauge is interpolated approximately as $T = 12$ min. and the range factor as $R = 1.03$. Since the time lag is positive, it must be subtracted from the sounding time to obtain the diagram time at which the corresponding tidal phase occurred at the gauge. Thus, the gauge reading should be taken at 11:05 – 00:12 = 10:53. By interpolation between the first two readings in Table 7, the gauge reading at 10:53 is $4.05 - 0.35 \times (13/20) = 3.82$ m. This times the range factor gives the height of the water level at A as $3.82 \times 1.03 = 3.93$ m above sounding datum. The sounding reduction, to the nearest decimetre, is thus 3.9 m, and the corrected sounding is $9.6 - 3.9 = 5.7$ m below sounding datum at point A.

Example (b):

At 12:45 AST a sounding of 12.3 m is taken at point B on the cotidal chart. From Fig. 59, $T = -7$ min, and $R = 0.95$. Since the time lag is negative, tidal events arrive at B before they arrive at the control gauge, and so T must be added to the sounding time to obtain the appropriate diagram time. The gauge reading is therefore taken at 12:45 + 00:07 = 12:52. By interpolation between the

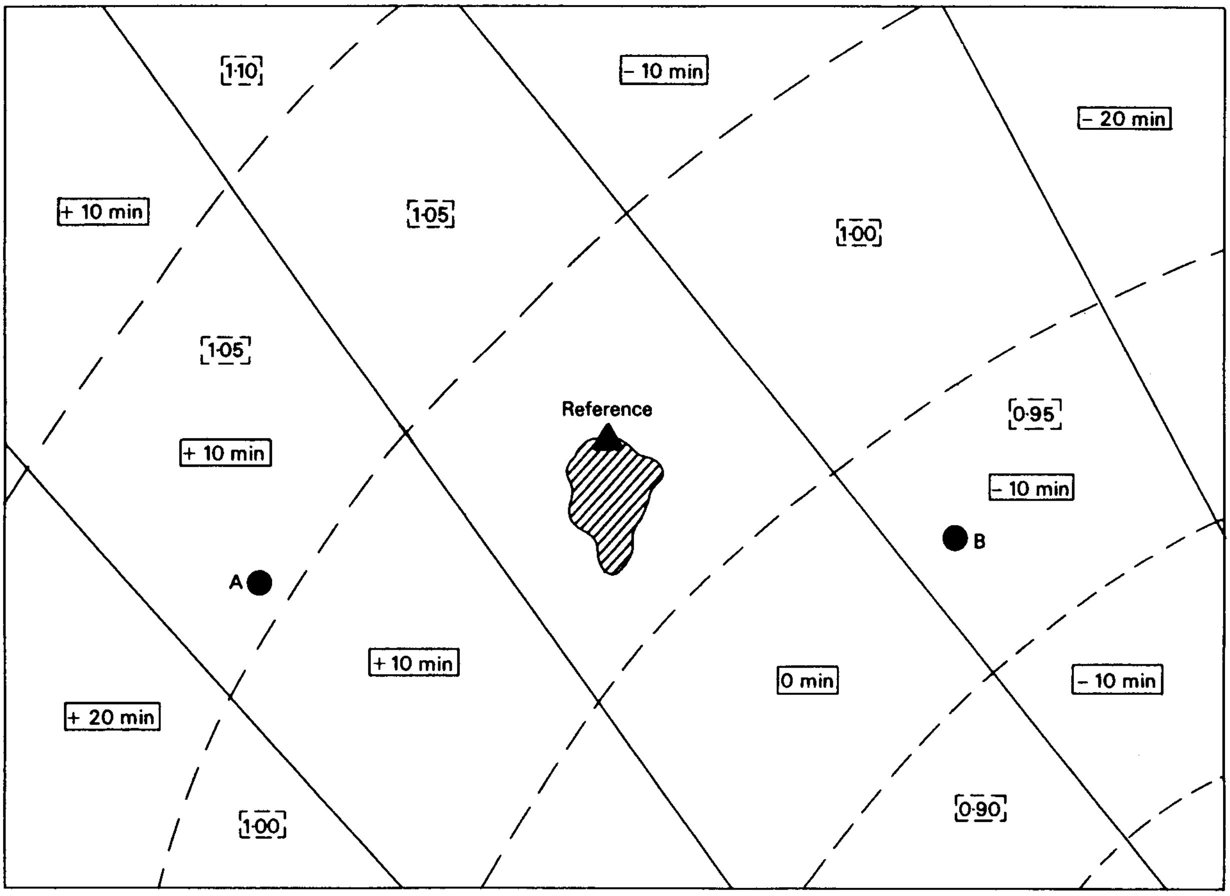


FIG. 59. Specimen cotidal chart of a fictitious region.

seventh and eight readings in Table 7, the gauge reading at 12:52 is $1.65 - 0.35 \times (12/20) = 1.44$ m. This times R gives the water level at B as $1.44 \times 0.95 = 1.37$ m above sounding datum. The sounding reduction, to the nearest decimetre, is thus 1.4 m, and the corrected sounding is 12.3 − 1.4 = 10.9 m below sounding datum at point B.

As an alternative to a cotidal chart drawn out as in Fig. 59, a program might be supplied for use in a mini-computer, to calculate R and T as functions of grid coordinates, and perform the sounding reduction from the sounding times and tabulated gauge readings. Coupling such a system to a telemetering water level gauge can provide real-time automated sounding reduction. When it is not feasible to have an operating gauge to control the sounding reduction, tidal predictions may be used in conjunction with the cotidal chart or computer program. Predicted water levels for the control site admittedly do not include the non-tidal fluctuations that would be detected by an operating gauge, but then, neither do the non-tidal oscillations behave in the manner prescribed by the cotidal chart.

Sounding surveys covering an extensive area in which the tide displays a large diurnal inequality may not be well served by the type of cotidal chart (or computer program) described above, because the assumptions of constant time lags and amplification factors are not justified. In these cases it may be necessary to supply a separate cotidal chart for each of the major tidal harmonic constituents (usually M_2, S_2, O_1, and K_1). From the cotidal charts, the constituent amplitudes and phaselags for the immediate sounding area may be read, and tidal predictions made in the manner described in section 3.8. No control gauge site is directly invoved in this field procedure, but information from several neighbouring gauge sites would be used in preparation of the cotidal charts.

in preference to graphic cotidal charts for the constituents, computer programs might be provided to generate the tidal constants as functions of grid coordinates, calculate sounding datum relative to MWL, predict the water level relative to sounding datum, and so automatically provide corrections for soundings. In the above procedure, the distance of sounding datum below MWL would usually be taken as the simple sum of the major tidal constituent amplitudes.

7.12 Sounding reduction — non-tidal waters

Sounding datum on a lake is chosen as a level surface, whose elevation is defined relative to BMs at the control gauge site. The sounding correction is usually taken directly as the water elevation above sounding datum at the gauge. The correction is thus accurate only insofar as the water surface between the gauge and the sounding is level at the time. Improved accuracy may be obtained by interpolating between values from two control gauges, weighting each value in inverse proportion to the distance of the sounding from the particular gauge. Even this procedure provides no compensation for surface slope in the offshore direction, unless one of the control gauges is itself off shore. Because of this, sounding should not be carried out far from a control gauge on a lake when large wind set-up or seiche activity is suspected; this is particularly true for lakes that are shallow, and of large horizontal extent (see sections 4.3 and 4.6).

Sounding datum on a river should be a surface that approximates closely to the actual water surface when the river is at its lowest stage of the navigation season. If a sounding correction is transferred directly from a single gauge on the river, it is accurate only insofar as the river slope at the time of sounding is parallel to the river slope at low stage. It may be necessary, particularly on shallow rivers, to establish two control gauges and to interpolate sounding corrections between them, except when soundings can be done at or near low stage. The method of interpolation and its justification are the same as those given for the determination of sounding datum by water transfer on rivers (section 7.5).

7.13 Sounding reduction — offshore gauging

In general, offshore sounding does not require as high an accuracy as that near shore, because of the greater depths offshore. There are occasions, however, when sounding must be done in shallow water far from shore, over offshore reefs, shoals, or banks. In such a case, sounding reductions taken from a distant shore gauge, whether by direct transfer or by cotidal chart, may not be sufficiently accurate. Some sort of offshore water level measurement is then necessary to control the soundings. If the water is very shallow, it may be possible to drive a long pole into the bottom and attach a staff gauge to it: it may not be feasible to station a vessel to read the staff every hour, but it could be visited twice or four times a day near high and low waters to observe the maxima and minima, from which an adequate tidal curve could be constructed. If it is not possible to set an offshore staff gauge, a vessel or launch equipped with a sounding device may be moored over a level bottom, to take a series of soundings at the fixed location. The vessel acts as an inverted float gauge, and the series of soundings is the water level record. Alternatively, a bottom-mounted pressure gauge of the type described in section 6.7 may be employed. Records from these gauges require subtraction of a corresponding set of atmospheric pressure measurements before being interpreted as water levels (section 4.4). The pressure record is stored in the gauge, but may also be acoustically telemetered to a surface float or vessel for more immediate use in sounding reduction. While it is not possible to reference the datums from offshore water level measurements to BMs on shore, the records may be very useful in tidal studies and the preparation of future cotidal charts. They must, therefore, be submitted to the Regional Tidal Officer, just as are the other gauging records and documents.