Manual of Standard Operating Procedures for Hydrometric Surveys in British Columbia

Prepared by
Ministry of Environment, Lands & Parks
Resources Inventory Branch
for the Aquatic Inventory Task Force
Resources Inventory Committee

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Preface

The *Manual of Standard Operation Procedures for Hydrometric Surveys in British Columbia* defines a common set of standards with detailed procedures for the successful acquisition of water quantity data. This will result in measurable quality, the fundamental requirement under the mandate of the Resources Inventory Committee (RIC). This edition is subject to further editorial and technical review during its formal field test period which goes until the end of 1998.

Writing for this manual has been completed and many of the comments of reviewers including an independent consultant have been incorporated. The subject covered in this manual can not be exhaustive, nevertheless, what is included must be clear and precise, therefore further input is invited from all users.

The next version will consider the following:

1. Adoption and implementation of additional recommendations made by the review consultant, M. Miles and Associates,
2. supplementation of graphics, illustrations, tables and bibliography as required to clarify the text and
3. classification and incorporation of suggestions from reviewers and users, received during field trials.

The next formal edit should begin toward the end of the field trial period.

The Resources Inventory Branch, Ministry of Environment, Lands & Parks (MELP) will accept and compile all relevant materials and comments in preparation for the next edition. Please submit such material to the undersigned or to Wilf Dreher, Manager of the Water Inventory Section in Victoria.

R.P. Richards, P.Eng.
Project Manager
October, 1997

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The Resources Inventory Committee consists of representatives from various ministries and agencies of the Canadian and the British Columbia governments as well as from First nations peoples. RIC objectives are to develop a common set of standards and procedures for the provincial resources inventories, as recommended by the Forest Resources Commission in its report "The Future of our Forests".

For further information about the Resources Inventory Committee and its various Task Forces, please contact:

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This **standards manual** is the first attempt to define and publish a widely available reference for the **practice of hydrometric surveying in British Columbia**. The role of the Resources Inventory Committee in this venture is significant, because the manual provides for the first time the means for regulating the standard of quality for provincially based hydrometric programs.

This work parallels the widely respected **National Standards** developed by Environment Canada, which has been utilized extensively along with other sources listed and acknowledged in Appendix VII. Contract services for assembly of materials and information and writing were provided by Gordon Clark of G.McG. Clark and Associates, drawing on the references and his own experience. The data logger section was written by Frank van der Have of Mill Bay, BC. Editorial and organizational services and formatting were provided by Kathi Hagan, a Vancouver Technical Writer and Editor. Formatting assistance to bring the manual to RIC publication standards was provided by Leah Westereng of the Wildlife Inventory Section, Resources Inventory Branch, (MELP).

Standards development as well as technical writing and review were done by Resources Inventory Branch staff, mainly D.B. Letvak and R.P. Richards. M. Miles and Associates of Victoria conducted an extensive and independent review of the contents and their arrangement. A review committee consisting of individuals within the Ministry of Forests and the Ministry of Environment, Lands and Parks provided helpful advice.

Abstract

Manual of Standard Procedures for Hydrometric Surveys in British Columbia

This manual prescribes the procedures for hydrometric surveys, or the measurement and recording of water level and discharge in an open channel. The three basic measurements are discussed: gauge height (stage); and velocity and area of flow, which are required to compute discharge. The manual describes all aspects of hydrometric surveys including stream reconnaissance, site selection, station design and construction, instrumentation, gauge height measurement, discharge calculation, stage-discharge rating and discharge compilation.

Documentation of station operation and data compilation procedures is essential for verifying the quality of data for archiving; standard forms for this documentation are provided. Software for on-site computation and recording of discharge calculation is introduced.

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A. INTRODUCTION TO PROVINCIAL STANDARDS

A.1 Standardization of Hydrometric Surveys

This manual describes the equipment, methods and documentation that must be used to meet the provincial standards for hydrometric surveys in accordance with the directives of the Resources Inventory Committee (RIC). Once data are acquired, calculated and compiled, the data must then be reviewed for certification and the 'standards class' or the level of quality achieved defined by the reviewer. A provincial hydrometric standard is required to affirm the credibility of data for any application, anywhere in the province.

A.1.1 The Need for Provincial Hydrometric Standards

Hydrometric standards described here are a set of information, which when followed will ensure the quality and accuracy of data product in regard to measurement of water level and discharge (streamflow). A provincial standard is needed so that government programs, contractors, and partners have uniform guidelines for the collection of hydrometric data, and to facilitate the development and maintenance of a hydrometric data archive. This archive (or database) is to be established by the Ministry of Environment, Lands and Parks (MELP).

RIC Hydrometric Standards will:

- support the collection of hydrometric inventory data to known standards using equipment with verifiable calibration, by a variety of parties using standard methods and record keeping
- provide for regulation of standards and data quality by review processes and audits
- support archiving of data of known quality, and use of such data for resource management

Hydrometric data collected or used for provincial resource management purposes, including Forest Renewal BC (FRBC), Forest Practices Code, water licensing, and others will now be required to meet RIC standards.

The Provincial Hydrometric Standards are intended to be complementary to the national standards for hydrometric data collection, which have been in use for many years for Environment Canada programs (commonly referred to as Water Survey of Canada). These national standards are comprehensive and rigorous, and result in a high level of accuracy. Provincial standards are intended to cover a range of accuracies, from equivalent to the national standard down to approximate methods, in keeping with the range of hydrometric operations done by and for provincial programs. There are four designated levels of Provincial Hydrometric Standards: Class A, Class B, Class C and Approximate Methods. Class A has a sub-class defined as A/RS, for rated structures such as weirs and flumes.

A.1.2 The Role of RIC

In recent years, there has been an increasing level of data collection under and for provincial government programs, and by industry, project proponents, and their contractors. These data are intended for use in resource management, but their use is often compromised by the uncertainty as to the quality or accuracy. Also, there has been a lack of organized storage and retrieval systems for these data. In response to these concerns, government ministries involved in data collection connected with natural resources have created a group called the Resources Inventory Committee (RIC). One of the functions of this committee is to establish standards for resource inventory data collection and storage.

A standard in this context is defined as a document which has been established by consensus and approved by a recognized body, that provides rules, guidelines, or characteristics for certain activities or their results.

A.1.3 Hydrometric Data - Approval and Storage

The Ministry of Environment, Lands and Parks intends to establish and maintain a database of hydrometric data that meets the RIC hydrometric standards, for use in resource management. To meet the A or B level of the RIC standard (described below) for hydrometric data, the data must be reviewed and certified as having met the RIC standards by a professional or other person who is able to establish his/her credentials to the satisfaction of the Resources Inventory Committee. Professional Engineers (P.Eng.) and Geoscientists (P.Geo.) have the necessary background, which if supplemented by experience qualifies them to certify data (and stamp reviewed documents) from hydrometric surveys. The Resources Inventory Branch (MELP) will review the credentials of data reviewers and if accepted, they will be added to a list of ‘Certified Reviewers’.

The province intends to carry out audits of ‘approved data’ and where applicable, the qualifications (and professional standing) of individuals who have completed the certification. In order for data to meet a RIC standard, comprehensive documentation of station information is required (station description, operations records, etc., as specified in this manual, much of which will be incorporated into the database). It is anticipated that the guidelines and formats presented will interface with the provincial hydrometric database and will be identified as to standards level and source (including approver’s name).

A.1.4 Who Should Use the Manual

The primary users of this manual will be provincial government agencies, firms, or individuals that collect or review and approve hydrometric data to RIC standards. Other users will include provincial agencies that use the data for resource management or fund data collection, other levels of government, resource user groups such as Improvement Districts, and educational users. In general, users of the provincial hydrometric database will refer to the manual to understand the accuracy of the data that falls within the different standards categories.

A.1.5 Disclaimer

The purpose of this manual is to provide information and standards for activities connected with production of hydrometric data. The reader is reminded that field operations for hydrometric surveys can involve some risk. All field operations should be carried out with appropriate safety measures, and in keeping with all relevant regulations including Workers Compensation Board (WCB). None of the material in this annual (including text, photos, and diagrams) is intended to suggest deviation from safe field practice.

Brand names of products and manufacturers are occasionally used in text and illustrations to describe various hydrometric operations. This is for the purpose of explanation and/or illustration only, and is not intended as a recommendation or otherwise of any brand names mentioned.

A.2 Provincial Standards

A.2.1 Introduction

The purpose of these standards is to reduce or eliminate the uncertainties associated with data collected by non-specific methods, resulting in undefined standards and levels of accuracy. This will provide a basis for developing a provincial archive that store data that have been collected to defined standards with essential and verifiable documentation.

By definition, the **'Standard Operating Procedures'** (SOP) or standards, are *the established written procedures of a given organization* (see the Glossary of Terms Used in Aquatic Inventory (Draft)). Water Survey of Canada (Environment Canada) has been the primary operator of hydrometric stations in British Columbia since the early part of the 20th century. Water Survey of Canada has operated under a system of national standards for hydrometric surveys. To a large extent, the hydrometric procedures covered in the provincial standards are an operational subset of the national standard. Operational subset means that the provincial standards do not cover all types of operations included in the national standards, such as ice conditions. At this time, it is recommended that work beyond the scope of the provincial standard be referred to Environment Canada (Water Survey of Canada), or some other group with appropriate expertise. Another important feature of the provincial RIC Standard for hydrometric surveys is the definition of several levels of accuracy, as explained below.

A.2.2 RIC / Provincial Standards

The following table defines the various standard levels and the anticipated tests needed to confirm any data set. This will not be a simple procedure, but through the preliminary period of field trials, such tests will become more obvious as data certifiers become more proficient.

A.2.2.1 Class A

This standard is the highest level of data quality in the hierarchy of provincial standards, as shown in Table A-1. The accuracy of data in the Class A standard is similar to that in the national standards. The procedures described in this manual are oriented to the Class A standard level. Class A/RS is a sub-class of A, and is a method of data collection which can result in a very high level of accuracy and reliability. Class A/RS is discussed in more detail below.

A.2.2.2 Class B

The Class B provincial standard allows for lower accuracy than Class A. The operational techniques are essentially the same, but allowance is made for more difficult operating conditions, or a less rigorous standard by definition. Class B might be achieved if the highest classification is not attainable because of the circumstances encountered in the field.

A.2.2.3 Class C

Discharge data from manual stations (i.e. staff gauge readings of water level) generally can not meet the higher standard levels, and will typically fall into Class C. This class also allows for less rigorous procedures in development of the rating curve, and greater scatter between the individual measurements and the best fit curve. Because some of the operational requirements are lower than Class A or B, the final standard of the data can not exceed Class C.

Table A-1. Standards requirement criteria.

Standard Class	Discharge Rating Accuracy	Number of Verticals	Number of Benchmarks	Water Level	Gauge Accuracy
Class A/RS	<5%	N/A	3	Recorder	2 mm
Class A	<7%	20+	3	Recorder	2 mm
Class B	<15%	20+	3	Recorder	5 mm
Class C	<30%	10+	1	Undefined	1 cm
Approximate Methods	>30%	N/A	N/A	Undefined	2 cm

A.2.2.4 Standardized Approximate Methods

Approximate methods will be described in future editions of this document. These will include a variety of measuring methods generally used for one-time or miscellaneous discharge measurements. An example of this would be velocity estimates by floats combined with roughly measured cross-sectional area to estimate discharge. While such methods are known to have low accuracy or high potential errors, they often fulfill a fundamental data need. Standard techniques will serve to somewhat reduce potential errors and improve the value of such measurements.

A.2.2.5 Class A/RS - Rated Discharge Structures

The accuracy of rated structures is achieved by the precise geometry of the unit and the details of the installation. Stage-discharge relationships have been defined in both laboratory and field tests. With accuracies in the 5% range, the data fit into the Class A category defined in Table A-1. Correct installation of these structures is essential to achieve the hydraulic conditions necessary for their proper function. To achieve the Class A standard, station records must confirm the correct installation, and include all other appropriate data. Where installation of the structure does not meet specifications, leakage is significant and/or documentation is missing, it may be impossible to assign any standard level to the data. It should be noted that with rated structures, certain apparently minor deviations from ideal conditions can have major impacts on accuracy.

In some cases, minor deviations from specified geometry or conditions might exist, or there might be operating problems such as intermittent blockages, ice, etc. If the effect on accuracy can be assessed and suitably documented, it may be possible to classify the resulting data as Class B. Discharge measurements to check the rating may be required to determine that the deviation from ideal rating is within the Class B acceptable levels.

Stations with rated structures will be designated with the code RS added to the standard class, e.g., Class A/RS (Table A-1).

In some cases, rated structures can not be installed or maintained to the required hydraulic conditions to achieve the specified rating. An example of this would be a weir where the pond fills up with sediment. In these cases, the structure is essentially an improved streambed control, and the station should be rated with discharge measurements.

A.3 Data Certification and Audit

A.3.1 Review and Approval

Hydrometric standards are for the purpose of acquiring data of known quality, and are achieved by following certain set procedures, including detailed documentation. It is necessary to undertake an independent review and approval process to confirm station operating information and final data. Using this process to define a standard is a common feature of a quality controlled system of hydrometric data collection.

The British Columbia hydrometric standards system recognizes that stations will be operated by a large variety of agencies, firms, or individuals. To maintain overall quality, data from all sources must be reviewed, approved and an appropriate standard level assigned by a qualified reviewer with a high level of skills and experience.

In future, it is intended to establish a system to test and certify RIC standard hydrometric reviewers. In the interim, Approved Reviewers will be designated on the basis of a review of qualifications (training and experience), to be undertaken by the Resources Inventory Branch of MELP. There is no firm requirement for any particular professional status, but the essential skills (shown below) will tend to favour some individuals with P.Eng./P.Geo. registration. Where professional registration exists, the stamp/seal of the licensing body will be required as part of data review and approval, and this will invoke the professional responsibility according to the Acts and Codes of Ethics governing such associations. The stamp will be required for data to be considered to have achieved any of the standards, and this will invoke the professional responsibility according to the Acts and Codes of Ethics governing such associations.

To be certain that reviewers are fully qualified, university level training in the following subject areas is required:

- open channel hydraulics
- surveying
- statistics and mathematics
- hydrology
- fluvial geomorphology - sediment, streambed dynamics
- applied mechanics (desirable)
- electrical/electronics (desirable)

Work experience in hydrometric operations and quality review will also be relevant.

Many or all of the above fields of knowledge come into play in an integrated manner in the operations review of any given hydrometric station. While field operations may be and frequently are carried out by skilled technicians or other disciplines, the above skill set applied at a professional level is required to certify that a given standard level has indeed been achieved.

A.3.2 Data Audits

It is recognized that the British Columbia government will not have the resources to review and approve data or assign RIC standards level for all hydrometric data that is produced. Initially, data may be reviewed and approved by qualified professionals representing consultants, contractors, government staff, employees of corporations, etc. It is good practice to have the review/approval done by a person who was not personally involved in the operation of the station. **It is expected that the government will undertake and/or fund audits of approved hydrometric data.** Professionals who have improperly approved data may be referred to the licensing body, just as any P.Eng./P.Geo. might be for professional malpractice.

B. Fundamentals of Hydrometric Operations

B.1 Establishing a Gauging Station

B.1.1 Choosing a Station Type

B.1.1.1 Definition of a Hydrometric Gauging Station

An hydrometric gauging station is a natural or constructed location on a watercourse where records of water quantity (and sometimes quality) are systematically obtained. It is referred to as a gauging station, but is also called an hydrometric station.

B.1.1.2 Purpose of the Station

The purpose of any water quantity (or water quality) data collection program must be clearly defined before site selection is considered. In addition, the benefits of archived data to other agencies or individuals should be considered, particularly when public moneys form any part of the funding for establishing and/or operating the station(s).

Some typical reasons for establishing a gauging station include:

- Runoff volume data for storage or water licensing. Peak flow timing and quantity for spillway, culvert, bridge design.
- Determining peak flow - time and quantity. Low flow timing and quantity for fish, water supply.
- Lake or reservoir level for recreation, storage, flooding, septic tanks.
- Determining low flow - periods and quantity.
- Baseline information for water quality.
- Causal relationships between watershed changes and flow regime changes.

B.1.2 Types of Gauging Stations

B.1.2.1 General

This manual focuses on measuring the smaller streams — from 0 to 10 m^3/s (+/-) — without reference to peaks. Gauging stations and methods for measuring greater flows are referred to, but not detailed.

The station variables considered in this manual are:

- Type of Operation
    - Annual - operates January to December.
    - Seasonal - selected period to satisfy the data purpose (open water, or low flow).
    - Miscellaneous - e.g., individual, periodic flow measurement.

- Type of Gauge
  - Manual - Read periodically (e.g., daily, weekly) by a technician.
  - Recording - Continuous record of water level either as an analogue or digital record.
- Type of Station
  - Water level only - Lake or stream where discharge is of no concern.
  - Water level and discharge - Miscellaneous discharge at a specified location, recorded by date and time, may be used to assess the potential of a stream if referenced to an active hydrometric station on an adjacent/nearby watershed.
  - Other parameters - Sediment or other water quality characteristics may affect the configuration of the station.
- Special Equipment Requirements
  - Type of housing required - governed by number and type of sensors, and equipment.
  - Real time equipment and sensors - will govern positioning of signal relays.
  - Automatic sediment and water quality samplers - will determine degree of automation, i.e. multi-channel data loggers.
- Datum
  - Assumed (local) - placed at the zero of the gauge, which should be below low water for lakes or below zero flow for streams (such as for rated structures).
  - GSC Datum - where feasible, can be related to the GSC datum.

Desirable Criteria for a Basic Station

A well-planned, well-constructed gauging station meets the following criteria:

1. It is possible to get an accurate water level reading from the gauge at all stages.
2. The control, whether natural or artificial, is stable.

   a) A stable natural control may be a:

   - bedrock outcrop, or other stable riffle (shoal) for measuring during low flow
   - channel constriction for measuring at high flow
   - falls or cascade that is not submerged at any water level

   b) A stable artificial control may be a:

   - rated structure (flume, weir, etc.)
   - fish barrier (drop structure)
   - streambed sill (log, concrete, etc.)
3. Discharge can be measured accurately at all stages, either through a rated measurement structure or by means of a current meter.
4. The site is accessible during the operational season.
5. The station is structurally sound, e.g., can withstand being overtopped.

B.1.2.3 Comparison of Small Gauging Station Installations

Several types of gauging stations are suitable for use on small-to-medium watercourses. Each has advantages/disadvantages in terms of accuracy/efficiency, installation cost, and operational cost.

- Discharge measurement structure fitted with a digital water level data logger.

  This is the most efficient type of gauging station, as it has the potential to be multi-use. As well as recording water levels, a multi-channel data logger can record values from water and climate data quality sensors as well as water levels from other nearby installations. Several other applications are possible. Data loggers and sensor capabilities are described in detail in Section C, Hydrometric Equipment.

Note: Rated structures built and installed to tested standards require no further rating. Designs for nonstandard or modified structures must be accompanied by a theoretical stage/discharge curve, and then confirmed by taking a series of current meter discharge measurements. See Section G, Discharge Measurement Structures.

- Discharge measurement structure equipped with an analogue continuous automatic water level recorder.

  The processing of data from analogue recorders requires extraction of hourly water levels by means of a digitizer and appropriate software, or by tedious manual methods. Standard analogue recorders are limited to a single parameter and cost more to purchase, house, and maintain than a data logger.

- A continuous water level recording device set in a pool where the water level is sensitive and stable over the full range of stage.

  The control for this type of installation can be a natural or an existing artificial structure. Either could be modified to bring about the required hydraulic characteristics. If necessary, design and construct an artificial control — see Section B.2. This type of station must be rated by a series of current meter measurements over the full range of stage, confirmed by a further two or more measurements per year in subsequent years. See Figures B-1, B-2, and B-3.

- A continuous water level recording device set in a pool where the water level is controlled by a downstream riffle composed of boulders, cobbles, or gravel.

  This type of installation may be subject to shift caused by erosion of the streambed and/or banks, and will be subject to temporary shifts due to the deposition of granular or floating debris. Therefore, an ongoing program of streamflow measurement will be required. The water level record will also require careful examination and interpretation. See Figure B-4.

Note: A manually read gauge, no matter how stable, will not produce an accurate average daily water level reading, particularly on a small stream, because of diurnal fluctuations in the rate of snowmelt, or short storm events. Accuracy improves with the number of readings during the day.

- Portable flumes.

  This type of discharge measuring device may be used to produce a series of individual miscellaneous discharge measurements, or it may be used in conjunction with a permanent gauge to produce a stage/discharge relationship. In the latter case, the flume must be located in a position that will not affect the water level at the gauge while the flume is installed, or after removal. Installations of this type are frequently used during low flow measurement programs or for checking ditch flows during irrigation periods.

Because of the requirements for flume operation, these devices are favoured over portable weir installations. This is important in a low gradient stream (Figure B-5).

Figure B-1. Two water level recorders: a data logger and an analogue recorder.

Figure B-2. Pool formed by a modified Crump Weir, where both a digital and an analogue recorder are installed. Judge Creek, Victoria Water Board. The crest has been formed with a shallow vee to increase low flow sensitivity.

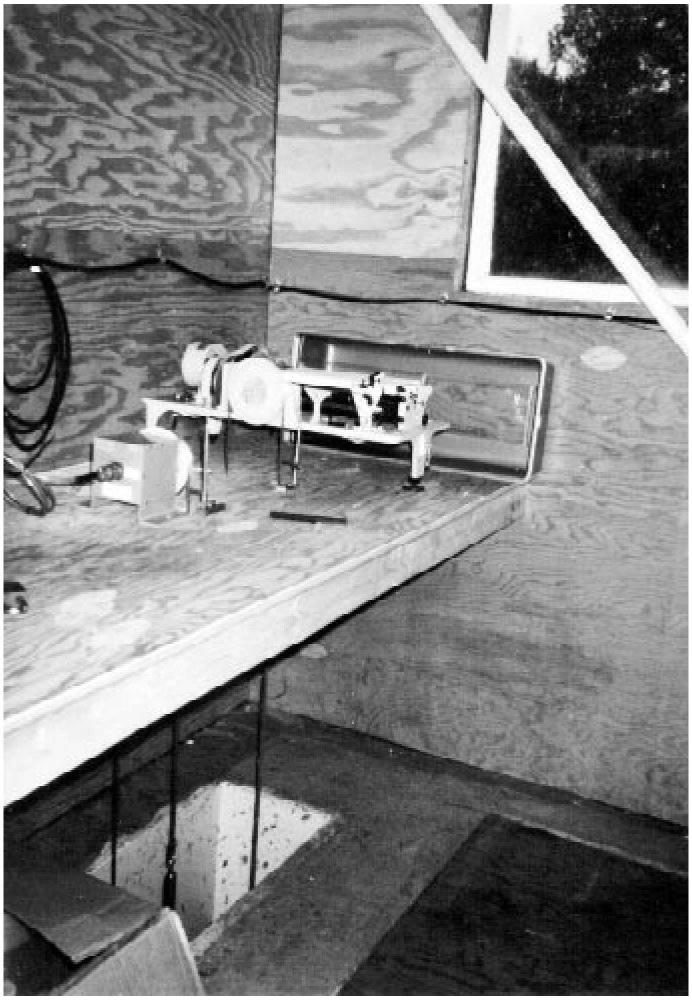


Figure B-3. Data logger and analogue recorder installed in the instrument shelter at the above site. Judge Creek, Victoria Water Board.

Figure B-4. Boulder control (subject to debris build-up) and water level recorder stilling well and shelter. Narcosli Creek, above Ramsay Creek, West Fraser.

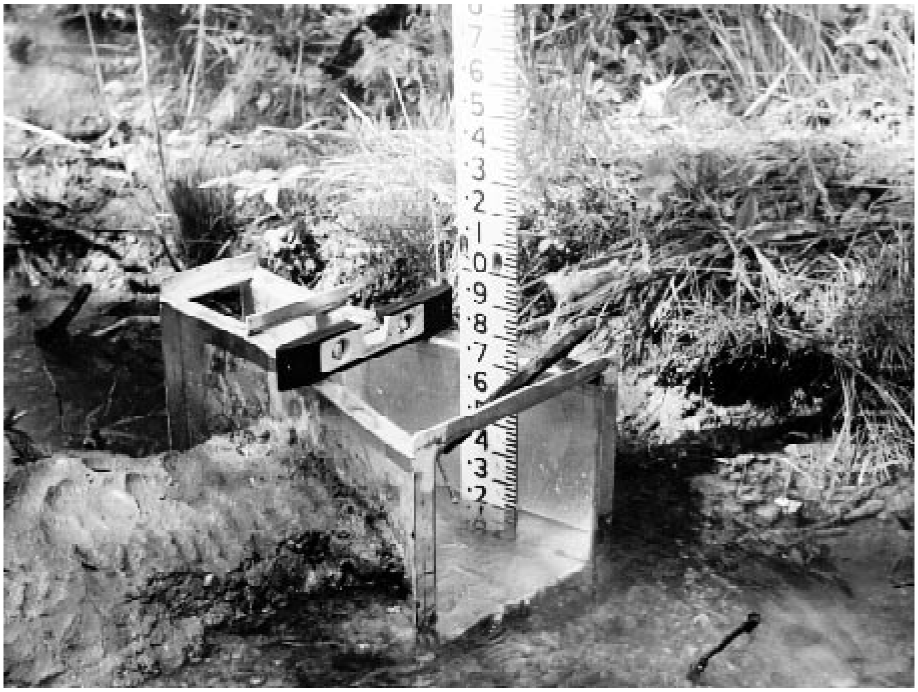


Figure B-5. Three-inch Montana flume set in a mud dam.

- Portable weir plates.

  Sharp-crested weir plates may be installed in locations where the upstream channel banks are high enough and wide enough to contain the elevated water levels and provide the end contractions necessary for fully contracted weir operation. Downstream channel geometry should provide free-flow conditions throughout the range of stage to be measured. Static head (h) is measured at a distance equal to 3.5 h (max. h), upstream of the weir crest (Figure B-6). For example, if the water level in the weirpool can reach 0.6 m above crest, the gauge should be situated 2.1 m upstream of weir.

- Elevated pipes, culverts, and flumes.

  Volumetric measurements may be made at the outlets of elevated pipes, culverts, and flumes. Individual measurements may be related to stage either by a staff gauge reading or by measuring the water level above or below a fixed reference point. Where outlets are too close to the downstream bed, it is sometimes possible to temporarily divert the flow through a flume (Figure B-7).

- High water conditions.

  In locations where higher stage discharge measurement may not be possible due to the unavailability of suitable measuring facilities or equipment, the channel reaches lying within the designated station limits should be reconnoitered to find a suitable site for measurements using indirect methods. Selected sites should be surveyed, permanently marked and the required values recorded. One of the most commonly used methods of indirect measurement is the slope area method. Other, less well known methods are described in U.S. Geological Survey (USGS) Publication *Measurement of Peak Discharge by the Slope-Area Method* (see Chapter A2 of Book 3).

Figure B-6. V-notch weir, portable installation.

Figure B-7. Culvert with low outlet and flow led into flume for volumetric measurement.

B.1.3 Selecting a Site for the Gauging Station

B.1.3.1 Pre-Reconnaissance Work

To select an appropriate site for establishing a gauging station, the objectives and the purpose of the station must first be clearly identified (Section B.1.1). Also, to some degree, the site is determined by the type of station.

The watercourse and basin should be studied in some detail prior to making any field trips. Obtain available maps—topographical, geological, and water licence—and recent air photos. If possible, talk to people who are familiar with the watercourse and region, e.g. residents, water users, loggers, First Nations, other technical specialists, etc. Ask about the characteristics of the watercourse, including flood history, and find out if any activities are under way in the area that might affect the watercourse, e.g. logging, bridge construction, reservoirs, diversions.

Ideally, sites for a gauging station should be uniform, and have the following characteristics:

- Straight, aligned banks.
- Good current meter measuring sites, e.g. single channel, no undercut banks, minimal obstructions, no turbulence, no slow-moving pools (deadwater), no eddies.
- Reasonable means of access.
- No tributaries between gauge and metering sites.
- No swamps downstream or in vicinity of gauge.

Study the maps and air photos. Look for the characteristics of a suitable site, realizing that no site will be perfect. Select two or three potential locations and prioritize them.

Prepare a plan to reconnoitre the site identified as having the most potential, but be prepared to move on to other potential sites if the first one does not work out.

Before setting out on a field trip, be sure to check if written or verbal permission is needed from the land owner or manager to access the property.

B.1.3.2 Field Reconnaissance and Site Selections

To complete the selection of a site for the gauging station, take a field trip to the potential site. The field trip is an opportunity to make a detailed evaluation of the site in terms of the objectives and the characteristics listed above (Section B.1.2.2).

Reconnaissance should include careful observation of the following:

- ***Low Flow Conditions.***

  Look for a stable well-defined low water control. A raised culvert invert at a road crossing can be an ideal site for a gauging station, particularly in areas with flat gradients.

  If a stable control is not available, consider the feasibility of building an artificial low water control. Investigate the options, and gather and record preliminary survey data.

  If a site with a movable streambed must be accepted, i.e. one with a mobile granular channel, it is best to locate the gauge in as uniform a reach as possible, avoiding any channel obstruction that may intensify scour and fill.

  Where the watercourse emerges from an area of steeper gradients onto an alluvial fan, the reconnaissance must include streamflow measurements to determine where the seepage of water into the alluvium becomes significant. The station should be located upstream of the area of water seepage if the maximum yield of the watercourse is required.

- ***High Flow Conditions.***

  To determine the magnitude of maximum discharge, look for evidence of past flooding, e.g. trash lines. Consider how easy it would be to access the gauge at all stages, and if it will be possible to position the recorder stilling well so as to avoid damage from high water levels or velocities and floating debris.

- ***Flow Measurement Conditions.***

  Ensure that the site has a suitable location for measuring discharge, either with a current meter or by other means. Although the station will be designed to accommodate discharge measurement, it is usually best to make observations that will cover all the options for obtaining a stage discharge record. Make enough observations, including making photographs, to prepare reasonable alternative conceptual designs and cost estimates.

Ideally, the metering section should have the following characteristics:

1. Fairly uniform depth and velocity with parallel flow lines across the section.
2. One or more locations at which the full range of flows can be measured with available equipment. For flows that can not be waded, it is more economical to use an existing bridge or culvert for high flow measurements. In the absence of a suitable structure, a site for a metering bridge or other alternative method should be available. See section B.2, Constructing a Gauging Station and Figure B-8, Trout Creek metering bridge.
3. Reasonable proximity to the gauge. This is particularly important in manual gauge installations where rapid changes in stage may occur during the course of a measurement and several gauge readings would be required.
4. No inflows or outflows between the gauging point and the measurement section. If this is unavoidable, an auxiliary station will be required to gauge these flows.
5. No aquatic growth or vegetation. Both the low flow and high flow measurement sections should be clear of aquatic growth. The portions of the bank subject to inundation during high flows should be cleared of any vegetation that could affect the measurement.
6. Backwater effect. Where the site is affected by a variable backwater, care must be exercised to remain above the instrument's threshold velocity.

Record the results of the reconnaissance in a report, with supporting survey data. The report will be a key reference in making decisions regarding the design, costing, construction, and operation of the gauging station.

Figure B-8. Trout Creek metering bridge.

B.2 Constructing a Gauging Station

B.2.1 Design Costing

The reconnaissance report and survey data should provide the information necessary for preparing preliminary conceptual designs and costs.

The factors to consider when producing a cost estimate are:

- Planned period of record.
- Requirements for artificial control in the absence of channel stability.
- Discharge measurement structure vs. ongoing metering in an unstable channel.
- The cost of transporting personnel, equipment, and materials to the construction site.
- The availability of suitable native material at or near the site.
- Construction methods.
- Selected instrumentation.
- Scheduling constraints based on flow magnitude and fishery regulations for in-stream construction.
- Future operational resources.

B.2.2 Permissions

1. Be sure to obtain written permission from the land owner or manager before you enter private land to carry out any proposed construction work. The scope of the permission should include access for construction as well as for the future operational period.
2. Any individual or agency carrying out any type of construction in any watercourse in British Columbia must obtain approval from the Regional Water Manager, MELP. In most cases this means completing *Notification for Proposed Works and Changes In and About a Stream* (Appendix IV). The approval process includes a review by the Ministry of Fisheries, who will, in most cases, limit the periods during which construction may take place. The Ministry of Fisheries will consult with the Federal Department of Fisheries and Oceans where federal regulations are involved.

B.2.3 Reference Gauge Installation

All gauging stations require some form of water level reference gauge in addition to any water level recording device that may also be installed. The chart pen or sensor voltage reading must be referenced to this gauge which in turn is referenced to station datum with bench marks.

The choice of gauge mount will depend on the type of forces that may be exerted at the gauging position during periods of high flow, ice movement, or by human or animal activities in the general area (e.g. lakes or reservoirs with flat bank form, providing access for recreational use, and subject to drawdown and wind-driven ice movement during break-up).

B.2.3.1 Standard Vertical Staff Gauge

The most commonly used manual or non-recording gauge is the vertical staff gauge (Figure B-9). It consists of one or more 1-m sections of enameled steel plate accurately graduated to either 0.01 or 0.002 of a meter. Each decimetre is numbered and intermediate 5-cm graduation marks are wedge shaped. The 0.01-m graduated type of plate is preferred for its less cluttered appearance; the third decimal value is estimated by reading the bottom of the meniscus.

Install staff gauges so that they are protected from damage by moving ice or other floating debris and are not affected by local drawdown or pileup of water. Reduce small local effects by mounting the gauge so that the face is parallel to the current; attach a length of half roundwood moulding to streamline the upstream edge of the backing board (2"x 6"). When the gauge is to be used as a reference for a recording device, position the gauge as close as practicable to the stilling well intake. In most cases it is necessary, and even preferable, to install the gauge near the bank below low water.

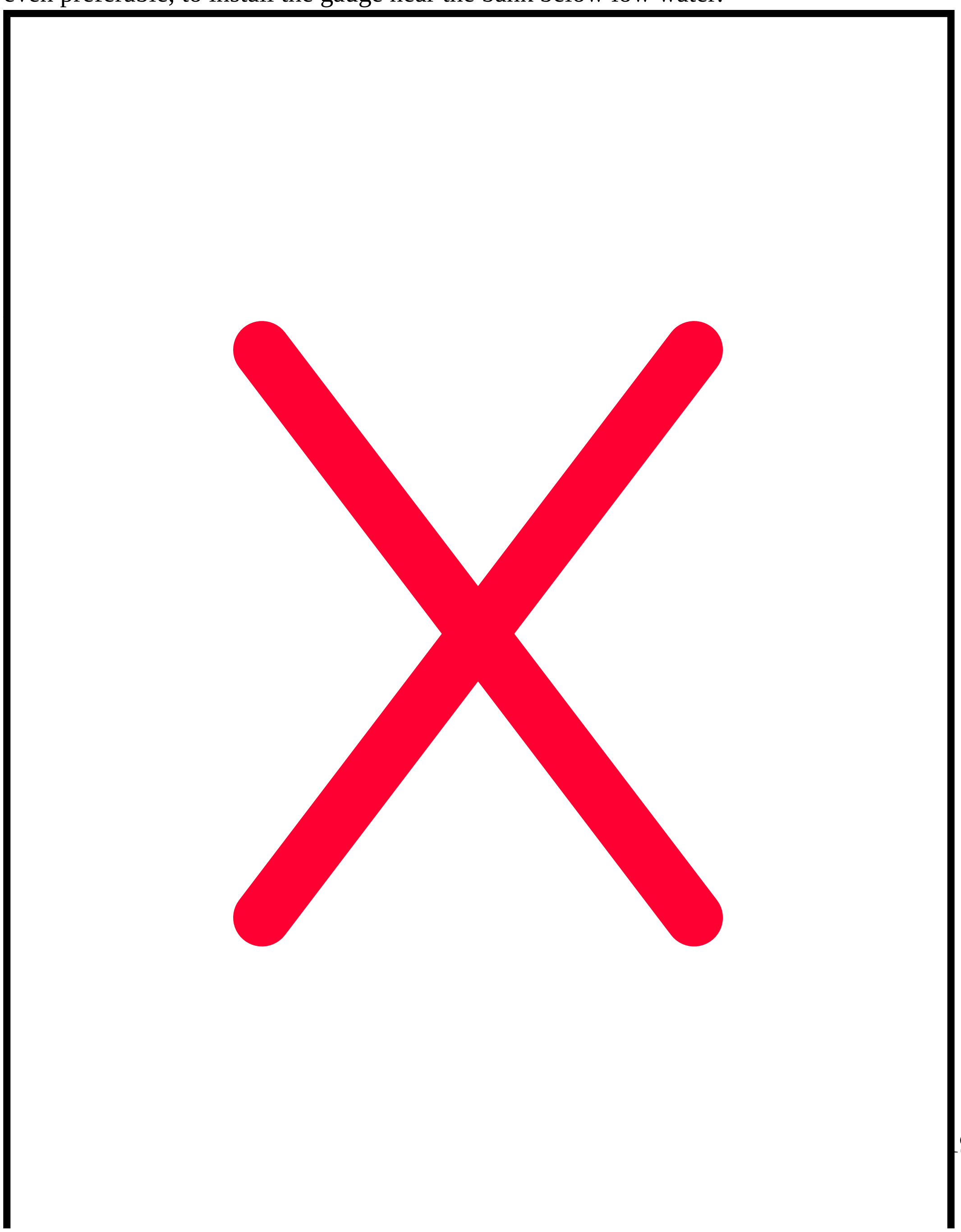


Figure B-9. Illustration of a staff gauge.

B.2.3.2 Non-Standard Reference Gauges

In some locations a standard staff gauge may be subject to damage or destruction due to ice or debris. Or, if a staff gauge is exposed to high velocities it may be difficult or impossible to make an accurate reading. In these cases, another form of reference gauge should be installed. The following types may be installed as either the reference gauge or as the primary gauge.

Reference Mark

This is a stable, well-defined position that is above the water surface at all stages. It may be a spike or lag screw in a tree overhanging the gauging pool from which the observer may measure down to the water surface. The mark could also be some existing object such as a bridge rail bolt. In all cases, the location, related bench marks, and the relationships to any other gauges must be carefully included in the station description (which follows as AQU-01, Figures B-10 and B-11) in the field data book (Section D.1.1). This type of gauge may be a primary gauge for short-term stations, or it may be installed as a back-up or auxiliary gauge. A suitable measuring device, such as a metric fiberglass tape and weight, is needed. If a weight is added, a correction is required - the distance from tape zero to bottom of weight.

If it is necessary to locate the reference mark above a position that dries out during low water periods, or if the station is a short-term low flow measuring section, an underwater reference mark (Bench Mark) may be identified or installed in the watercourse. In the former case, determine the difference in the elevation of the two reference marks.

A series of reference marks linked to a common datum, together with a regular observation program, are often employed to provide the hydraulic grade lines necessary for engineering design, e.g. dike and bank protection, crest elevations.

BRITISH COLUMBIA — RESOURCES INVENTORY COMMITTEE

Description of Hydrometric Station

☐ Original ☒ Revised

Station Operating Agency/Firm: BC ENV/RIB

Stn. No.: 08MC045 Stn. Name: SHERIDAN CREEK ABOVE MCLEESE LAKE

Latitude: 52 ° 25 ' 35 " Longitude: 122 ° 17 ' 34 "

Action (Established, Relocated, Closed)	Date (yy/mm/dd)	By Whom
ESTABLISHED	86/11/05	G. CLARK
DESTROYED	90/05/28	
RE-ESTABLISHED & RE-LOCATED	92/03/30	G. CLARK
700 M D/S		

Describe all station gauges, and locations. For chain gauge or wire weight, give length from end of weight to first marker:
2 METER STAFF GAUGE ON LEFT BANK AT UPSTREAM END OF FIELD

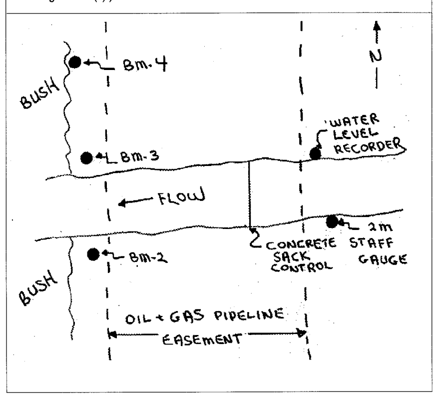
Describe equipment, and location(s) for flow measurements at all stages:
HIGH FLOW MEASUREMENT SITES ARE 200 M & 300 M D/S OF S.G. ALL OTHER MEASUREMENTS ARE DONE 5 M D/S OF S.G.

Describe channel or other conditions affecting control or discharge measurement (variable, backwater, turbulence, vegetation, etc.):
DIVERSION FOR LICENSED DOMESTIC WATER USE (1.5 KM U/S, APPROX. 2200 LITRES/DAY)

Coefficient for 2/10 method: Zero flow at GH:

RIC AQU-01 97/10

Site Sketch: (Show physical features, hydraulic control point, station components, metering section(s).)



Benchmarks: Describe fully. Give year established, elevation above station datum (zero of the gauge when first established). May be linked to other GSC datum.
BM 2 (1992) 1.393 M LAG BOLT IN 0.6 M COTTONWOOD LB 40 M D/S OF S.G.
BM 3 (1992) 1.513 M LAG BOLT IN 0.35 M COTTONWOOD RB AT BUSH LINE 40 M D/S OF S.G.
BM 4 (1992) 2.622 M LAG BOLT IN 0.22 M COTTONWOOD RB AT BUSH LINE 55 M D/S AND 20 M N ALONG BUSH LINE.

Figure B-10. Example of completed RIC Form AQU-01, Description of Hydrometric Station (front).

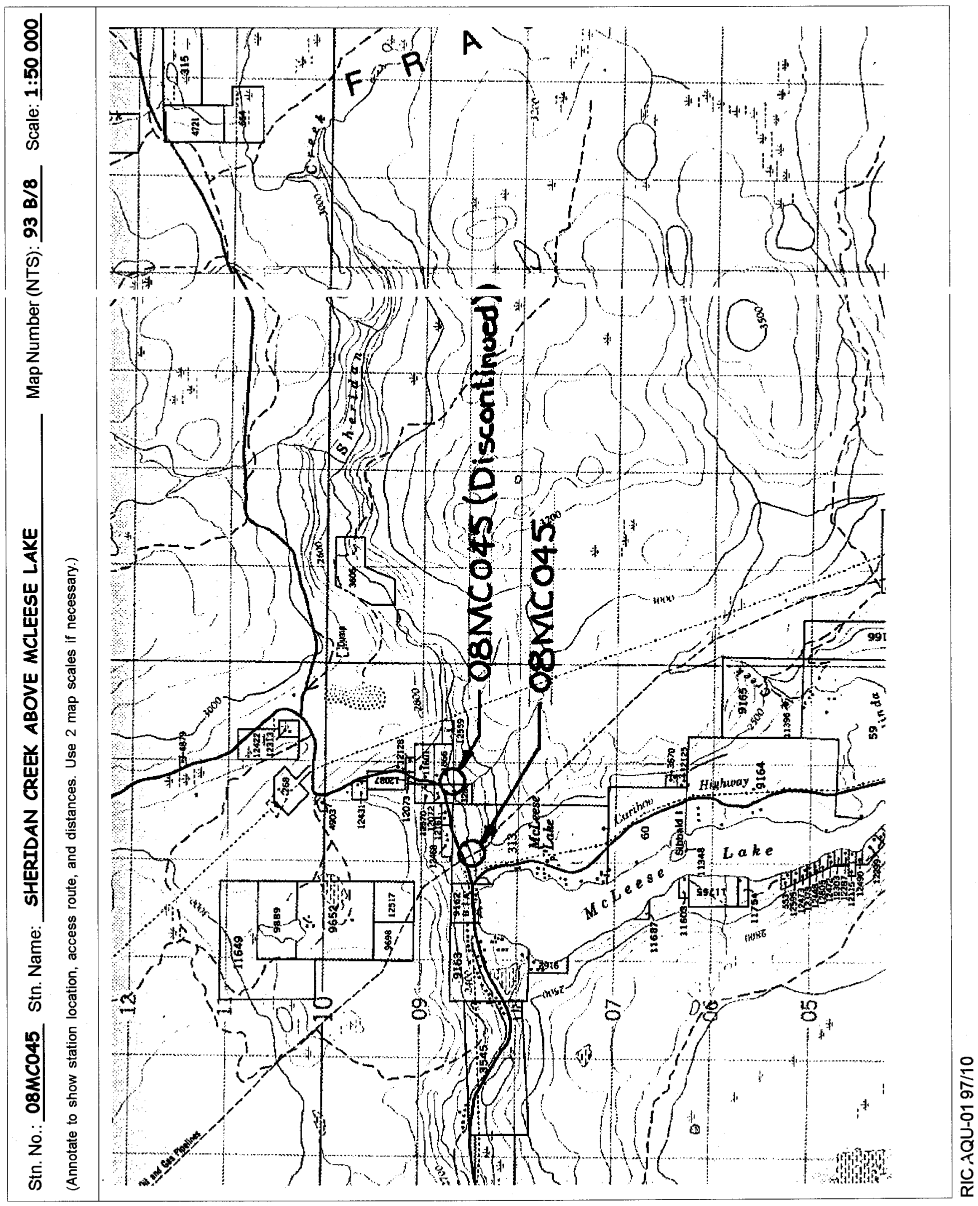


Figure B-11. Example of completed RIC Form AQU-01, Description of Hydrometric Station (back).

Chain Gauge

A chain gauge consists of brass or galvanised stove chain with a weight attached to the outer end, and passing along a horizontally mounted scale (usually a standard gauge plate). The horizontal section can be a fixed bridge component, a cantilever (Figure B-12), or a boom (Figure B-13), to place the chain over open water.

The gauge plate is attached to the top of the horizontal support arm and the tagged chain is read against this plate. If the range of stage exceeds 1 m, two or more tags are required and these should be spaced precisely 1 m apart and colour coded with pairs of metre numerals. Alternatively, several gauge plates may be used with one tagged position pointer.

Link spacing is not always conducive to the precise spacing of multiple tags. The tags are usually small diameter machine bolts and nuts secured through the chain links. A weight attached at the outer end of the chain is lowered to the water surface to make the gauge reading. This type of suspension material is subject to stretching, therefore the weight should be limited to 0.5 kg (8 or 16 oz. fishing weight).

A more suitable material is non-corrosive heavy-duty braided picture wire. This can be tagged by piercing the wire with a sharp point, threading through a few short strands of wire, and twisting the ends together. Mark each tag with a spot of enamel, marking associated metre numeral plates with the same colour.

At the outer end of the arm, the wire or chain should pass over a small diameter sheaf bracket, with wire retention loops, or through an eyebolt fitted with a grommet. The weight is normally raised to the underside of the arm when not in use, and the wire or chain is belayed around a pair of spikes.

Initial and subsequent level checks on wire/weight or chain gauges is accomplished by setting up the level so that you can sight the bottom of the weight on the instrument cross-hairs. Lower the weight until it coincides with the height of instrument, and read the position of the pointer on the gauge. (This is the equivalent of a direct reading on a staff gauge.) Establishing at least one bench mark that can be sighted from this setup will greatly facilitate the operation of the station.A variation of the cantilever gauge is the boom gauge (Figure B-13). in which the outer end of the beam is supported by a cable. The cable passes over a bolt further up the tree with a tension-adjusting turnbuckle at the inner end of the gauge. This tends to prevent a timber arm from warping, lessening the probability of subsequent gauge corrections.

Wire-Weight Gauge

The wire-weight gauge consists of a length of steel wire cable attached to a spooling device. A weight attached to the free end and the assembly is enclosed in a lockable weatherproof box. This gauge may be mounted on a bridge member over the water surface or it can form part of a cantilever or boom gauge assembly installed on a streambank. The weight is lowered to the water surface to obtain the water level reading, taking care not to kink the cable. See Figures B-14, B-15, and B-16.

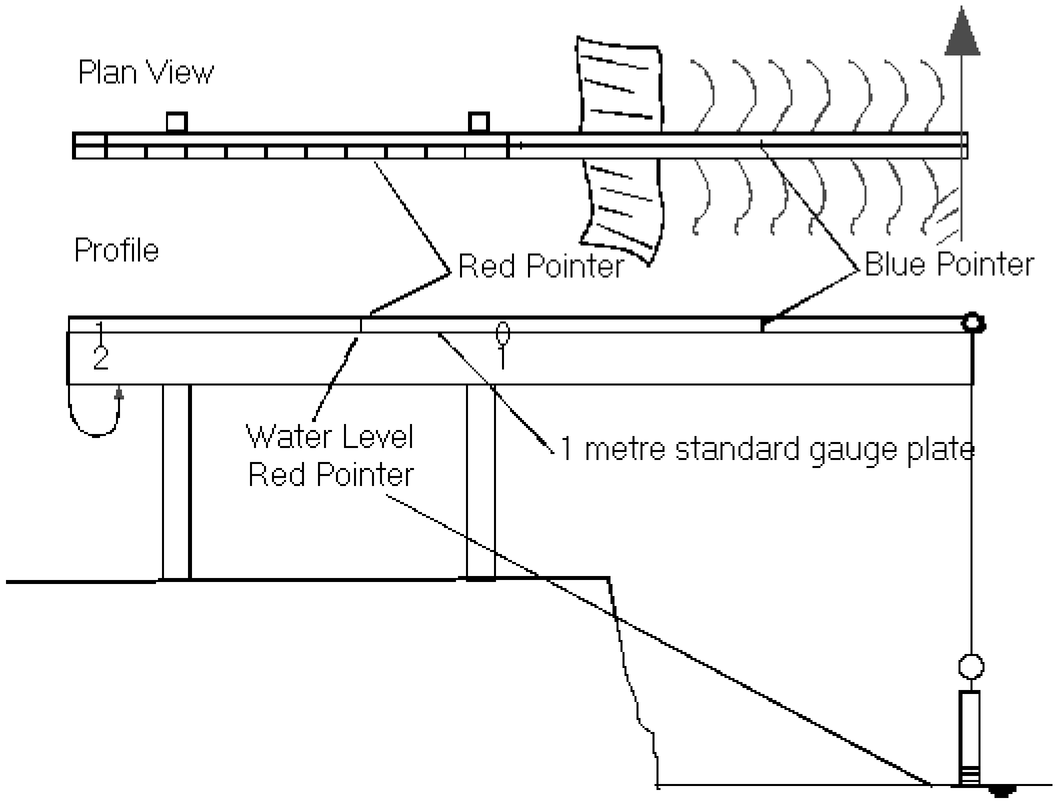


Figure B-12. Each meter, or part of meter, requires colour-coded tags and numeral plates. The spacing between the tag points must be exactly 1.000 m.

Figure B-13. Boom wire weight gauge.

Figure B-14. Wire-weight gauge.

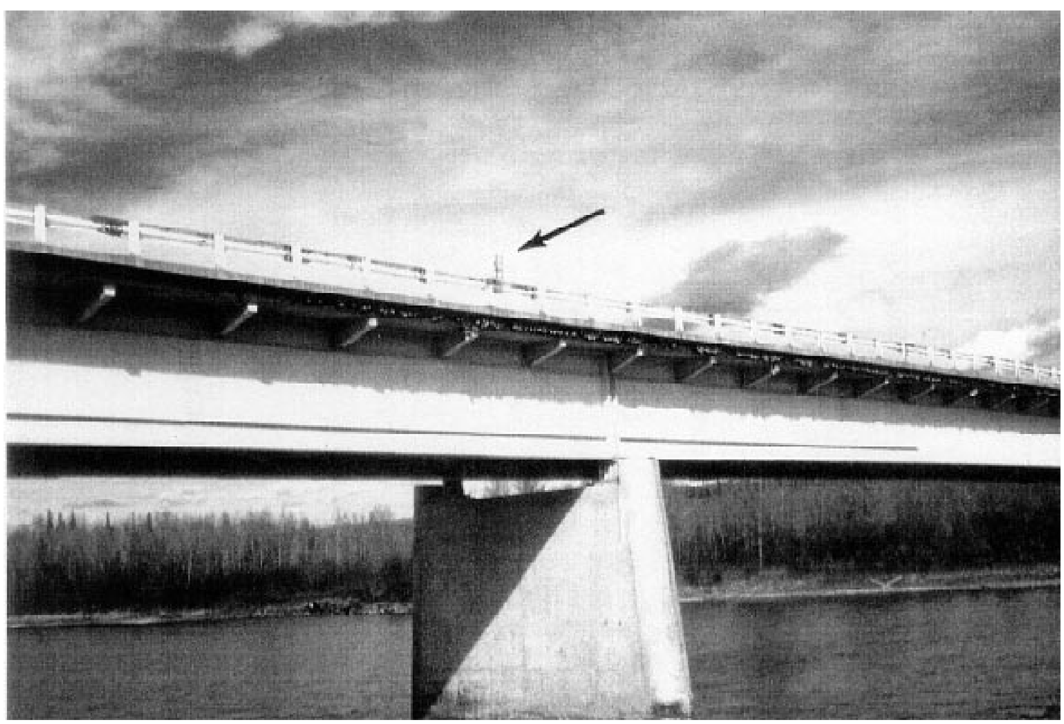


Figure B-15. Wire-weight gauge mounted to a bridge rail. Bear River, near Stewart.

Figure B-16. Wire-weight gauge and mounting brackets. Athabasca River, near Windfall.

The point on the water surface at which the wire-weight gauge reading is taken should have minimal local disturbance. To reduce the effect of surface tension, read the gauge when the weight first touches the water surface. After contact has been made with the water surface, the weight can be raised by as much as 6 mm without breaking the contact. <u>To obtain a good gauge reading it may be necessary to take several observations and then average the results.</u> During periods of high wind, the wind drag on the wire and the roughness of the water surface will reduce the accuracy of the reading.

The wire-weight gauge is used as an outside gauge when conditions at a gauging station make it difficult to read or to maintain a staff gauge. At stations where there is no recording equipment, the wire-weight gauge is the primary gauge. It is usually read by a gauge observer. The wire-weight gauge can also be used as an auxiliary gauge.

Wire-weight gauges require very little maintenance other than removal of dust from the gauge; in some cases, lubrication of the drumshaft may be required.

To help level this type of gauge without a rodperson (assistant), cut 2-mm grooves in the bottom portion of the weight. If these grooves are visible in the eyepiece of the surveyor's level, the elevation of the weight can be determined. The weighted cable can also be suspended from the end of a rigid beam cantilevered out over the water surface. In this latter case, the gauge box is attached to the cantilever base on shore, and the gauge is usually referred to as a cantilever gauge.

Tagged and Non-Tagged Wire-Weight Gauges

Wire-weight gauges are either "tagged" or "non-tagged".

- ***Tagged Wire-Weight Gauges***

Several variations are available, but the general operating principle is similar for each type. Each has a wire that is marked with numbered tags at intervals for the required range of stage. Each gauge also has a graduated brass plate equal in length to the tagging interval.

When the weight on the end of the wire is lowered to the water surface, the tagged wire passes along the face of the gauge plate. The number is read from the tag, and the fraction of the metre is read from the plate. The wire is marked in increments of 0.100 m; the brass plate is marked in increments of 0.001 m or 0.002 m.

In one style of tagged wire gauge, the graduated plate folds out below the storage reel (Figure B-17); a second variation has the graduated plate located alongside the storage reel (Figure B-18). These two wire-weight gauges are designed to be mounted vertically. Figure B-16 illustrates an example of a tagged wire-weight gauge that is designed to be mounted horizontally. To set this type of gauge to zero, the technician must adjust the weight on the wire to within 0.010 m. The graduated brass plate can then be positioned for final adjustment. These types of wire-weight gauges are designed to operate under all weather conditions. Their construction is sturdy and simple. There are very few moving parts, and the tagged wire or counter-type gauge seldom needs adjustment or repair.

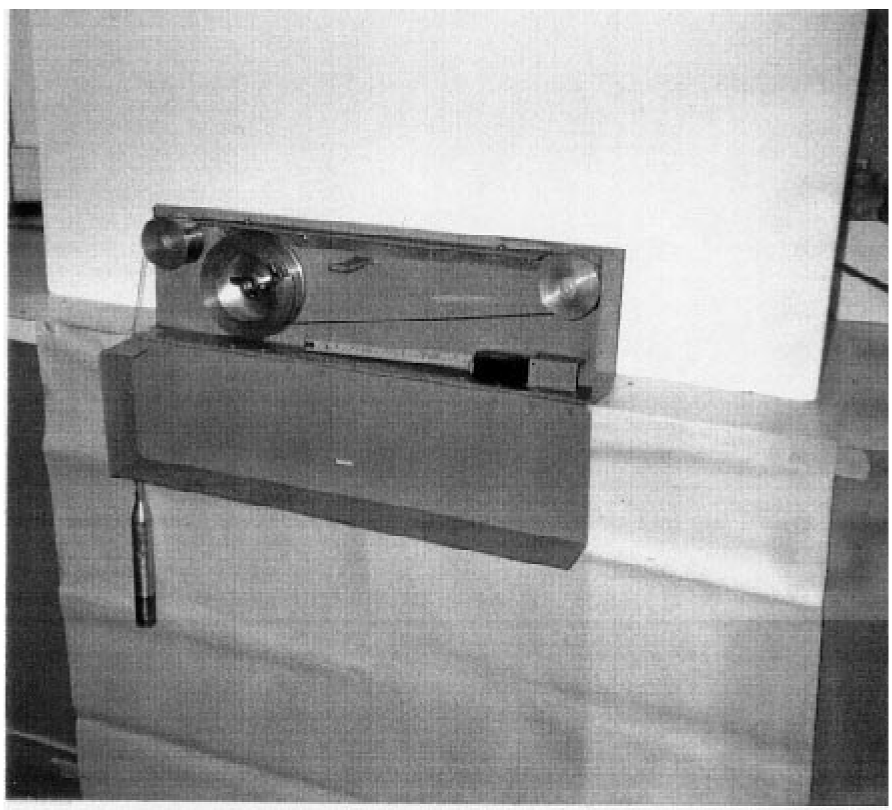


Figure B-17. Horizontally mounted wire-weight gauge.

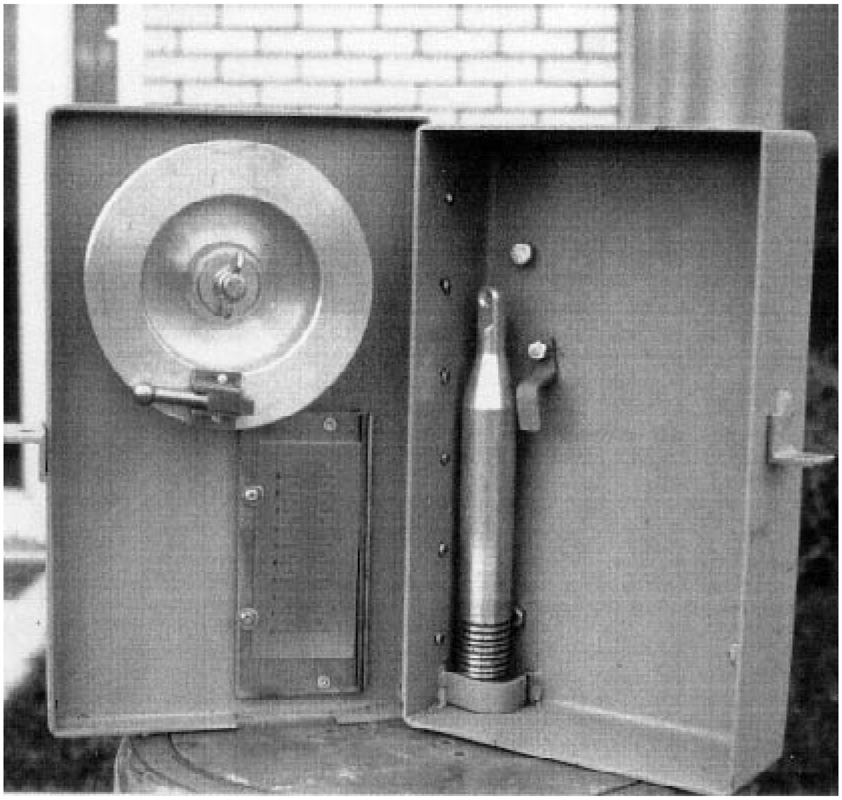


Figure B-18. Wire-weight gauge with decimetre plate.

- ***Non-Tagged Wire-Weight Gauge***

  This uses a precision drum wound with one layer of cable. A weight is attached to the free end of the cable. When the drum makes one complete revolution, the weight is raised or lowered 0.3 m. A revolution counter attached to the drum measures the cable length in metres and centimetres (Figure B-19). Graduations on the flange of the drum adjacent to the counter are in centimetres and millimetres.

  Some counter-type wire-weight gauges are equipped with a check bar. To ensure that it has not changed, verify the gauge reading on this check bar during each visit. If the reading has changed, this is an indication that slippage has occurred between the drum and the counter.

  To set this type of wire-weight gauge to zero, set the counter to the nearest centimetre. Then set millimetres and centimetres on the flange of the drum adjacent to the counter. The centimetre position of the counter can not be set exactly unless the actual elevation is a multiple of 10 mm. This type of wire-weight gauge may not be as reliable as the tagged version because it has a counter and more moving parts. It is also more expensive.

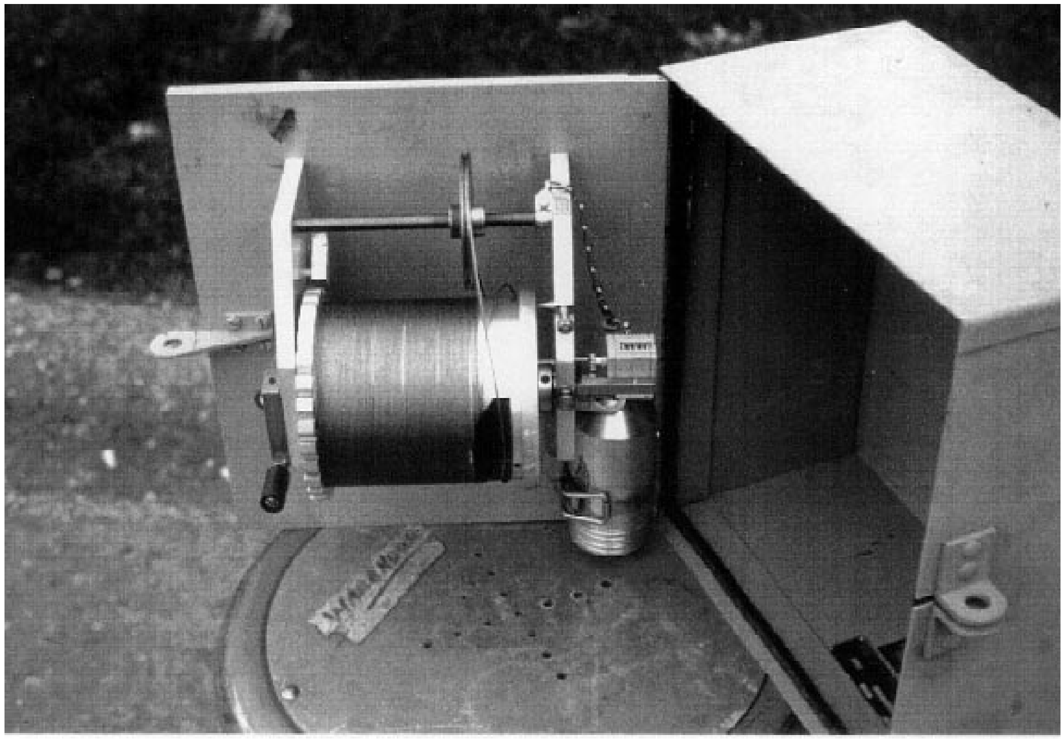


Figure B-19. Non-Tagged wire-weight gauge.

Inclined Gauges

In most cases, inclined staff gauges are attached to existing structural components, such as wing walls or gate shaft support footing for the control shaft of a sliding gate or along the edge of a boat launch ramp, and they are usually installed at or near the ground. If the site has silting problems, the gauge should be raised.

Inclined gauges are used primarily where the bank slope is very low and water level range high, and where it is impractical to use a series of staff gauges or a cantilever gauge (Section B.2.3.2). Because the slope distance can be 30 m or greater, this type of gauge is very suitable for use on lakes, or reservoirs and for use as an auxiliary gauge.

- ***Direct Reading Inclined Gauge***

  A level is used with a direct reading inclined gauge to mark the exact elevation along the incline, so that the vertical gauge height can be read directly.

  Figure B-20 shows an inclined gauge with metal tags between the metre marks. Water level readings can be obtained directly from the gauge.

- ***Indirect Reading Inclined Gauge***

  Standard gauge plates are installed along the inclined surface. Correction tables are then developed to interpret the exact elevation. The slope is not necessarily constant, but can be incorporated in the correction table. Figure B-20 shows an inclined gauge that has various slopes in different segments. This gauge was installed using H-beams dug into the ground below the frost level to overcome differential frost upheaval.

Note: An inclined gauge is seldom used because it is difficult to prevent the gauge from moving during frost action. Also, gauges mounted directly on the ground are subject to siltation problems, while gauges mounted above the ground are subject to damage by ice or floating debris.

Figure B-20. Inclined gauge with metal tags between the metre markers.

B.2.4 Selecting the Metering Section

The location of the metering section may vary with changes in stage. The best location for measuring high and medium flows from a cableway, boat, or bridge may not be acceptable for low water wading. Ideally, once the metering sections for low, medium, and high flow measurements have been selected, they should not be changed.

1. The metering section should be perpendicular to the general direction of flow. (A procedure for determining angle of flow corrections is described in Special Techniques, “Correcting for Angular (Oblique) Flow”.)
2. The metering section should be located where the bed and banks of the watercourse are straight and uniform:
   - Upstream - for a distance of approximately five times the width of the metering section.
   - Downstream - for a distance of approximately twice the width of the metering section.
3. The channel bed at the metering section should be as uniform as possible. It should be free from vegetation, immovable rocks, and obstructions such as bridge piers.
4. The metering section normally must accommodate 20 subsections of uniform discharge. This factor should be considered during site selection.
5. The spacing of verticals along the metering section is not usually uniform. Where the water is shallow and/or slow moving, the spacing will be greater than where the water is deep and swift. Spacing depends largely on the following factors:
   - Overall width of the watercourse.
   - Unevenness of the channel bed.
   - Variation in velocity across the channel.

6. If the verticals are properly spaced, then the discharge in any one of the subsections should be about 5% of the total discharge, and *may* not exceed 10% for the Provincial Class A Standard.
7. The spacing of each vertical may be referenced to a permanent initial point on the shore. The initial point should be well defined, usually by an iron pin driven into the ground above the high water mark. And, the initial point in turn should be referenced to another permanent feature near the metering section or gauging station. (These data are often required for detailed studies long after the gauging station has been established or discontinued.) This is particularly important where it is desirable to define channel erosion or deposition. As changes are usually determined by creating a series of cross-section plots, an iron pin is usually set above the high water mark at the far end of the cross section. The distance between the two points is used to maintain the horizontal vertical ratio in successive computer-generated plots.

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C. Hydrometric Survey Equipment

This section describes the basic equipment required to measure water level or stage and velocity, as well as several other equipment items that make measurement systems more efficient and versatile.

C.1 Water Level Recorders

C.1.1 Introduction

This section describes the instrumentation used to collect automatically continuous water level records, and methods of installation. There are two distinctive recording systems common to hydrometric surveys: analogue, or graphic; and digital. The analogue recorder has been in continuous use since early in the 20th century and is still widely used in Canada. The digital system, on the other hand, came into common use for water level recording only in recent years.

The digital recording system has replaced the analogue recorder for many applications, although neither system is foolproof. For particularly sensitive or important sites, it is common to use both; the digital system as the primary and the analogue as a back-up.

All automatic water level recorders require some form of manual reference to the water level at the time of installation, and again at all subsequent visits to the station by the technician. The reference gauge should be installed in close proximity to the recording device. Manual reference gauges are described in Section B.2.3.

C.1.2 Graphic Recorders

A graphic water level recorder is an instrument that provides a permanent and continuous long-term record of water level variation. A clock movement controls the rate at which a strip chart advances. At the same time, a float in contact with the water surface activates a marking stylus or pen which reproduces the float's vertical movement on the strip chart.

Graphic recorders can record a virtually unlimited range of stage. They provide a low cost record of stage when installed at lakes or reservoirs, and they may be used to provide a record of flow rates, for licensing purposes, below diversion structures in rated channels designed to transport water at a near constant rate.

Two types of graphic recorders, Type F and Type A, are manufactured by the Leupold Stevens Company of Beaverton, Oregon. Similar models are manufactured by Sherlock Instruments in Australia and by Ott in Germany.

Graphic or Analogue Recorders are described in Appendix-III which also includes instructions on their installation, operation and maintenance.

C.1.3 Digital Recorders

C.1.3.1 General

The advent of electronic sensors and data loggers, with their ability to record and store information in database ready digital format, made the importing and compilation of recorded values much easier and faster. While there was the benefit of collecting data faster there were problems to overcome. The first devices were usually more expensive than their mechanical counterpart and were not easy to program.

Extreme environmental operating conditions, (i.e. temperature) revealed problems in getting electronics to operate reliability and accurately. However, as the use of these electronic automated systems increased during the 1980's, advancements in both sensor and data logger design overcame these problems.

Today there are a variety of sensors and data loggers on the market. In addition to recording water level, one can now include water quality and meteorological parameters as well. What used to require a separate recorder for each parameter now can be collected in one data-logging device. To determine what automated system best suits the need of the end user will depend upon their present and future monitoring plans.

C.1.3.2 Sensor Types

There are a variety of different methods for measuring the change in water level. Some of the products currently used include:

- Ultrasonic Level Sensors
- Submersible Pressure Sensors
- Pressure Measurement Sensors (Bubbler Gauges)
- Shaft Encoders with Float Assemblies

Ultrasonic Sensors

Ultrasonic Sensors send out a series of sound waves, which travel through the air and strike a target (water surface). An echo is returned back to the sensor and the transit time taken to send the wave and return is related to the distance traveled. The advantage of this sensor is that it is non-invasive, having no physical contact with the media being measured. In areas where periodic flooding may carrying away a conventional gauge station, a ultrasonic sensor could be safely mounted above the high water. The main disadvantage of the ultrasonic sensor is that the sound wave can travel at different speeds depending upon the prevalent environmental conditions (temperature, pressure, and humidity), thus affecting accuracy.

Submersible Pressure Sensors

Submersible Pressure Sensors represent the largest segment of the sensors market. As the name implies the system consists of a pressure transducer immersed in the water at a fixed depth. The sensor transmits an analogue or digital signal via underwater conductors back to the data logger. In addition to the signal wires there in normally a vent tube as well. The vent tube allows the sensor to equilibrate itself to changes in barometric pressure. If the sensor did not do this then an increase or decrease in barometric pressure would be reflected in the recorded readings, creating another source of error. Submersible analogue sensors can have an accuracy as good as 0.1% of Full Scale Output (FSO), while digital sensors are available with accuracy's of 0.02% FSO or better. The main advantage of the submersible sensor is that it is relatively inexpensive and easy to install. Some of the disadvantages include variances in accuracy (depending upon make and model). A pressure transducer inaccuracy is usually based on the following characteristics:

- Non-linearity - the deviation of the sensor's signal curve from that of a straight line.
- Repeatability - the ability of the sensor to reproduce an output reading when subjected to identical pressures.
- Hysteresis - the difference in value for the same measured point when pressure is first increased, then decreased past the point.

In addition there are errors caused by sensor drift (especially analogue sensors), and the realization that, should the sensor leak, in most cases the electronics are damaged beyond repair and the sensor must be replaced. Digital submersible sensors offer high accuracy and excellent long-term stability, but usually at a substantial cost over their analogue counterparts.

Pressure Measurement (Bubbler) Sensor

The Pressure Measurement (Bubbler) Sensor is an extremely accurate digital sensor which is used to measure the gas pressure required to generate a bubble at the end of a submerged orifice line. The pressure required to create the bubble is proportional to the water head above the orifice. These "bubbler" gauges are similar to the submersible digital sensors, with the exception that they are typically mounted in a walk in shelter along with the pressure source (nitrogen tank or battery compressor) and pressure regulator. The main advantages of this type of sensor is its lower cost compared to its submersible counterpart, and that the only component in the water itself is the low cost orifice line. The main disadvantage is the requirement of a bulky pressure tank or external pressure source.

Shaft Encoders

The use of Shaft Encoders was a natural progression from the mechanical chart recorders. The existing float and pulley arrangement mounted could be removed from the mechanical recorder and mounted directly to the shaft of the encoder. The encoder would typically provide a pulse corresponding to the smallest measured increment (1 mm). As the float raised and lowered the encoder would provide a positive or negative count depending upon the direction of movement. The main advantages of the shaft encoder are the ease to which it can be retrofitted to stations already using a float and pulley set-up, and the excellent linearity and accuracy provided. The main disadvantage would arise from the installation costs as float sensors do require a stilling well to operate.

C.1.3.3 Water Quality Sensors

In addition to measuring and recording the physical aspects of the water, the simultaneous collection of the water's biochemical data is desired. Water quality sensors are available in single parameter and multi-parameter styles. Some of the more common parameters measured include Temperature, Dissolved Oxygen, Specific Conductance, pH, Turbidity, and Redox. Coming onto the market now are: ammonium, nitrates, chlorides, total dissolved gas and fluorescence, to name but a few, and the list keeps on growing. Not unlike the submersible pressure sensors the signal outputs from these sensors can either be analogue or digital. Most single parameter sensor utilize an analogue output, while the multi-parameter sensors use a digital format known as SDI - 12 (Serial Digital Interface, 1200 Baud), which allows the data from the various sensors to be sent over the same set of signal wires.

Having decided on what parameters will be monitored, and subsequently selected the appropriate sensors, one needs to look at the various data loggers available.

Data Loggers, also known as Data Collection Platforms or Data Acquisition Systems, store readings electronically taken from the sensors mentioned previously. Most loggers are programmed through a computer or keyboard. The signal can be from a variety of sensors whose output corresponds to a specific engineering value, whether it be water temperature or turbidity. The recorded information is then stored in the data logger's memory, where it remains until its downloaded by the end user into his/her computer.

Software

Programming the Data Logger can often be a trying experience, as with any new product, which uses software. It is good practice to first review the manuals which come with the data logger and become familiar with the various menus and commands. A lot of valuable time will be saved should you have to explain your problems to the equipment supplier if can navigate your way through the software. Most data logger manufacturers utilize a menu driven format with "pull down" sub-menus to access specific functions (Figure C-1).

Software is installed by placing the manufacturer's disk into the appropriate disk drive of the computer (i.e. Drive A). If you are using a windows based operating system use the "Run" command to access that drive (Drive A) then using the "Browse" command select the software installation program and press the Enter [( ] key to begin the process. If you are using a DOS based operating system, change your drive directory to that containing the software (i.e. cd\A Drive):, then select the installation program and press Enter [( ].

The transfer of information between the data logger and your computer is accomplished using the computers RS-232 serial port. The port can be either a 25 pin, or more commonly, a 9-pin connection. Always ensure that you have selected the correct communications port under the setting sections of the logger manufacturer's software and at the same time check the baud rate (speed at which data is exchanged between the data logger and the computer), (Figure C-2).

Having set up the computer to enable it to communicate with the data logger, the next step is to create your sensor's characteristics. While each logger has its own menu structure, the steps required to create a logging program tend to follow the same basic steps. Typically this will included putting information on Sensor Type (i.e. Temperature, Level…), Signal output, Excitation, Warm-up time, Conversion into Engineering Units etc.

Once the sensors types have been established, the next step is to specify the sampling and reporting intervals for the parameters being recorded. Simple data loggers may only allow a single sampling and recording rate, which would apply to all sensors. More sophisticated data loggers can be programmed to sample individual sensors at various intervals and then calculate and record averages, and maximum and minimum values. Once the program is created, it is saved for uploading into the data logger.

Remember, if you require technical assistance, do not hesitate to contact the data logger supplier. Nothing is worse then getting frustrated over a problem which can be solved relatively quickly using the data logger supplier's expertise. Inquire about training courses as many suppliers can provide training suited to your specific monitoring program.

Prior to connecting the data logger to the computer, make sure that all the connections to the power source and sensors are secure. The data logger can then be connected to the computer, and communications established (Figure C-3). The data logger's time clock should be synchronized with that of the computer or a suitable standard (i.e. Greenwich Mean Time) and then the program can be uploaded into the data logger. Before disconnecting the data logger from the computer, make one last check to ensure that the program is operating properly. Use the software's real-time display capabilities to ensure that the sensors and the data logger are functioning properly. Make sure that your battery is fully charged and able to provide power until you make your next service trip.

Stored data can be retrieved by a number of means. The most common method is by directly connecting the data logger to the computer. However, there are applications where the site is so remote that access is limited. In these cases the data can be sent from the remote location by phone modem, radio transmission, or satellite telemetry. If you plan to use the direct hook-up protocol ALWAYS ensure that you download any recorded values BEFORE proceeding to make any physical adjustments to the logger or the sensors.

Figure C-1. Typical menu-driven software package.

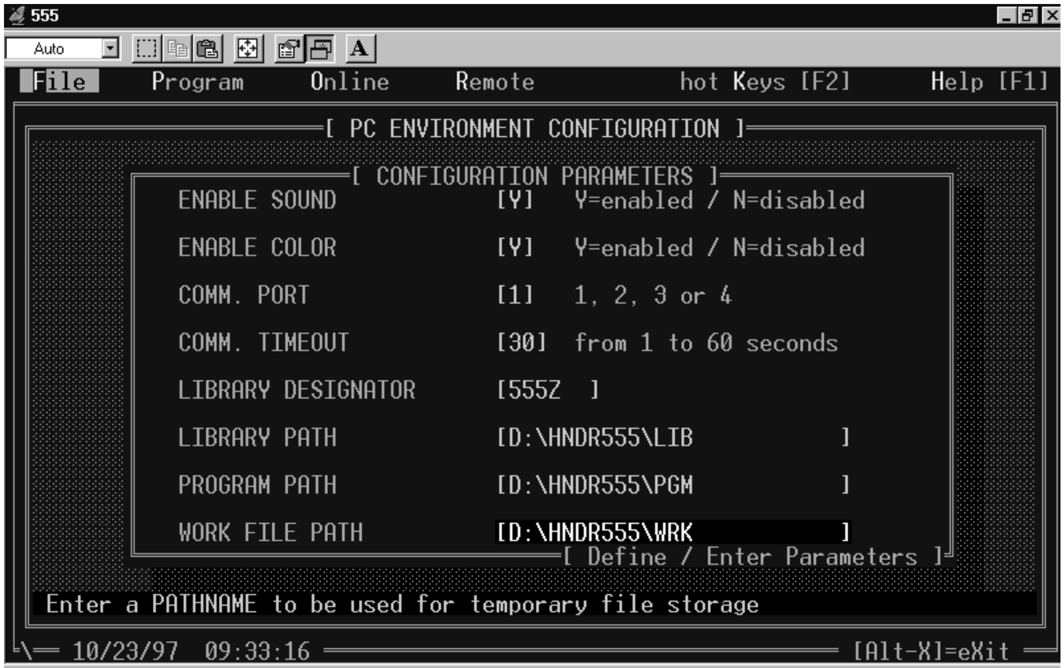


Figure C-2. Check that the correct communication port is selected.

Figure C-3. Programming screen showing types and allocation of sensors being used.

Analogue to Digital Converter (A/D)

As mentioned previously, sensors will either provide an Analogue or Digital output signal. The data logger stores all the readings in a digital format. Therefore, an analogue signal must first be converted before it can be stored. The data logger uses an Analogue to Digital Converter to perform this process.

The important aspect when choosing the appropriate data logger is to look at the number of "bits" used convert the analogue signal to a digital. Suffice to say the larger the "bit" number (i.e. 14 bits vs. 8 bits) the higher the accuracy. A detailed explanation on Analogue to Digital conversion can be found in the Ministry of Environment, Land and Parks "Interim Data Logging Standards for Water Quality Monitoring" manual.

Memory

Recorded data is typically stored in RAM (Random Access Memory). The size of available RAM will dictate how long your data logger can remain in the field before your memory is filled and you have to download the collected readings. Check with the data logger supplier on how their machines records and stores readings and confirm whether the logger will have sufficient capacity for the application it was intended. As you usually only get one try at collecting your data, the safe storage of that data is very important. Most logger manufacturers use a lithium battery to maintain the logger's internal time clock and ensure the integrity of the data. Recently, data logger manufacturers have been using the computer industry PCMCIA type RAM cards as a way of providing additional storage space for readings. In most cases, the card with the stored readings can be replaced in the field with a new one, thus avoiding the problems of taking a computer into a potentially hostile environment.

Signal Inputs

Sensors put out analogue and digital signals, which are in turn recorded by the data logger. However, not every data logger can accept the variety of output signals provided. Here are some of the most common types.

Two of most commonly used Analogue signals employed by sensor manufacturers are voltages (0-1 V, 0-2.5 V, 0-5 V) and current (0-20 mA, 4-20 mA). In each case the measurement range of the sensor is equal to its full-scale output. For example, a sensor with a 15 psi pressure range, and a 4-20 mA signal will output 4 mA at zero pressure and 20 mA at 15 psi. In most cases, adjustments to correct for minor changes in zero and slope values have can be done via the data loggers' software, but most sensors require shipment back to the manufacturer for proper calibration.

In addition to the two different analogue signals, there are three main types of wiring connections used when connecting a sensor to a data logger. Table C-1 illustrates the various signal types and their respective wiring conventions.

Digital signals are most commonly seen in a format called SDI-12 (Serial Digital Interface, 1200 Baud). SDI-12 sensors have their own A/D converter, allowing them to make corrections for changes in the ambient environment before sending the reading to the data logger. In addition, conversions to the engineering units and adjustments to zero and slope and can be directly inputted into the sensor. The result, is a "smart" sensor, which has a greater accuracy then those of an analogue nature. SDI sensors have an address number, which differentiates one sensor from another and each SDI sensor can have multiple fields (i.e. water level & temperature). SDI-12 sensors use 3 connections when connecting to a data logger.

Table C-1. Signal types and wiring conventions.

	Sensor wiring	Data logger connection
Single-ended voltage [1] (0-1 V DC, 0-5 V DC)	Excitation voltage (+)	Positive (+) leg from the power source
	Excitation ground (-)	Negative or Return (-) leg to the power source or data logger ground
	Analogue signal (+)	Signal (+) transmitted by the sensor to the analogue input of the data logger
	Analogue ground (-)	Negative or Return (-) from the sensor to the ground terminal of the data logger
Single-ended current [2] (4-20 mA)	Excitation voltage (+)	Positive (+) leg from the power source
	Excitation ground (-)	Negative or Return (-) leg to the power source or data logger ground
	Analogue signal (+)	Signal (+) transmitted by the sensor to the analogue input of the data logger
Differential voltage [3] (0-1 V DC, 0-5 V DC)	Excitation voltage (+)	Positive (+) leg from the power source
	Excitation ground (-)	Negative or Return (-) leg to the power source or data logger ground
	Analogue signal (+)	Signal (+) transmitted by the sensor to the analogue input of the data logger
	Analogue signal (-)	Negative or Return (-) leg from the sensor to the differential analogue input of the data logger
SDI-12 sensor connections	Excitation voltage (+)	Positive (+) leg from the power source
	Excitation ground (-)	Negative or Return (-) leg to the power source or data logger ground
	Digital signal (+)	Signal (+) transmitted by the sensor to the SDI data input of the data logger

[1] The voltage signal is measured with respect to the analogue ground signal. In most cases, the excitation and analogue grounds are commonly connected on the data logger.
[2] Most data loggers need to convert the milli-amp signal into a voltage format. This is commonly done by placing a know resistance across the excitation ground and the analogue signal wires. In cases where there are only two wires, the (-) ground is usually provided through the cable shielding.
[3] Used in cases where obtaining a proper "earth" ground is a problem. The data logger

	Sensor wiring	Data logger connection
must be equipped to perform differential measurements. The voltage differential is now measured between the two analogue inputs.		

Warm-up Time - Each sensor requires a period of time prior to the reading being recorded in which power is applied allowing the sensor to “wake-up” and the readings to stabilize. For most analogue sensors a warm-up time of one second is sufficient, while SDI-12 sensors may vary from 10 to 30 s. Check the sensor manufacturer’s specifications for the correct time period.

Power Source - Most sensors and data loggers are designed to operate off a nominal 12 volt DC power source. In most cases the power supply will be a external battery. It is very important that one uses a deep discharge battery and not a shallow-cycle battery, such as those used in automobiles. The automotive batteries are not designed to withstand repeated heavy discharge/recharge cycles without damage. When hooking up your external battery, it is recommended that at least one lead, usually the positive (+) is fused to prevent shock damage to the data logger should a short circuit occur.

Wiring - When deploying sensors with long signal lines ensure that the wire gauge is large enough to minimize any voltage loss. Using too small a wire size can result in voltage drops, which may in turn manifest itself in inaccurate readings or damage to the sensor.

Operating Temperature – Most data logger and sensor specifications list an operating and storage temperature specification. As electronics are influenced by extremes in temperature, make sure that your selected equipment will operate reliably under the field conditions expected. Most data loggers used in Canada need to be able to operate down to –40°C.

Not unlike the first desktop computers, the first field data loggers were large, cumbersome, limited in capabilities and not very user friendly. Today’s data loggers are smaller, faster, and easier to program. With the introduction of Windows 95, many data logger manufacturers are developing compatible software thus making programming much more intuitive.

C.1.4 Documentation of Station Water Level

C.1.4.1 General

Accurate documentation of the record is extremely important. It establishes the identity of the location and the base values for future evaluation, and it ensures accurate transfer of the information from the field to the office. The information is gathered for various reasons: to route the original data in a different direction, to cross-reference the accuracy of the documentation, or to provide convenient access to the information on the original record.

Documentation must be complete and legible. Always do the documentation immediately following the observations. Do not depend on memory; never wait for a more convenient time or location.

In most cases, specially designed forms are provided for systematically recording information and readings. Extra information can always be listed on these forms if necessary. Forms can also be completed electronically on a hand-held computer.

Sometimes, information that appears to be insignificant or redundant must be recorded. For example, if a question on one form arises, it can be resolved quickly by comparing that form with others containing a record of the same observations. If two segments of a record requiring the same support data become separated, each segment, when properly documented, can be understood independent of the other.

C.1.4.2 Station Log Form

The station log (Form AQU-06, The Water Stage Recorder - Station Record for the Year, see Appendix II), posted within the instrument shelter, provides a ready reference to the operating history of the station. The "Remarks" column shows the method used for past measurements, and indicates a safe limit of stage for stream wading. Level checks of the gauges are noted, along with any necessary gauge correction. Update the Form on AQU-06 before leaving the site.

C.1.4.3 Discharge Measurement Note

Make all field data entries on the discharge measurement note front sheet (Form AQU-03, Discharge Measurement, see Appendix II) at the time of observation; before leaving the site, complete the form properly. The time, gauge heights, and general information recorded on this form establish the baseline data.

C.2 Instrument Shelters for Stilling Wells

Protecting instruments against varied and severe climate and operating conditions is very important. In addition to shielding the recording equipment, an instrument shelter protects the contents of the stilling well. Shelters are built of metal, wood, concrete, or reinforced plastics. Some locations may require certain design standards and construction materials to conform with site surroundings.

Shelters should be built as securely as practicable and designed to discourage unauthorised entry. In extreme circumstances, shelters must be lined with steel or heavy wood, or be fenced for added protection from vandals or marauding animals. Posting a sign on the entry door that identifies the instrumentation, its owner, and its role in a water management program may help deter some visitors from trying to enter the shelter.

Safety of operators must also be considered. With some look-in shelters, one side can be levered up to provide a canopy and it must be well supported or blocked. Shelters that are elevated above ground level must have safe stairs and/or walkways to the entry door.

C.2.1 Types of Shelters

Shelters are generally classified by size and utility as look-in or walk-in. Which type to construct depends on expected station life, instrumentation, importance, and security concerns.

If the gauging station will be operated in winter, the shelter should be winterized to help control heat and condensation, and to protect the equipment.

Insulation may be needed; non-absorbent formaldehyde-free insulation is best. A properly insulated shelter also prevents the intrusion of troublesome insects.

Heating may also be needed, and is practical in insulated shelters. If a stilling well is heated the shelter must also be heated otherwise excessive frost accumulates inside the shelter and on its contents. Recorders tend to perform better in heated shelters.

Any shelter floor opening, below the float line pulley of the recorder, should have a bar installed across the opening in line with the axis of the pulley. This will prevent the float lines disappearing down the well after being lifted off the pulley.

All shelters must be watertight.

C.2.1.1 Look-in Shelters

The look-in shelter (Figure C-4) is the most common, especially for smaller streams; it is mounted on top of a small-diameter stilling well. Although it can vary in size and shape, usually it measures about 0.8 x 0.8 x 0.6 m high, with a hinged front, and lid for entry. The lid is sloped to shed rain and snow.

The base, fastened flush with the well top, has a removable section, or a semi-circular opening to accommodate the float lines, which permits visual access into the well and access to the fasteners connecting the shelter to the stilling well pipe. Shelters, while secure in the closed position, must be easily removable in order to clear ice or install frost tubes.

Many shelters of this type utilize commercially available electrical junction box covers adapted to fit on the stilling well, or are of custom-made welded aluminium construction. These shelters must be ventilated near the top. The vent opening should be fitted with an insect barrier.

Figure C-4. Look-in shelter.

C.2.1.2 Walk-in Shelters

Walk-in shelters (Figure C-5) are the most convenient to work with. The average size is 1.6 x 1.6 x 2.2 m high with a standard-size entry door. A portion of the floor is removable for access to the stilling well. This trap door should be inspected for safety on each visit. Never leave it open, nor the well unprotected under any circumstances.

Walk-in shelters should be solidly positioned over top of the stilling well so that the floor forms a secure cover for the stilling well. Inside the shelter, a solid, level bench for mounting the recorder is positioned about 1.0 m above the stilling well. Positioning the recorder at this level makes it possible to access the well without interfering with the free movement of the float and float wire. Holes are drilled through the bench top and floor where necessary to accommodate the float wire. A trap door in the shelter floor provides safe, convenient access to the ladder within the stilling well. The flushing tank or portable pump connectors with connecting riser pipes and shut-off valve control rods are usually located above floor level and opposite the recorder mounting bench. Adequate ventilation is important. Plans are available.

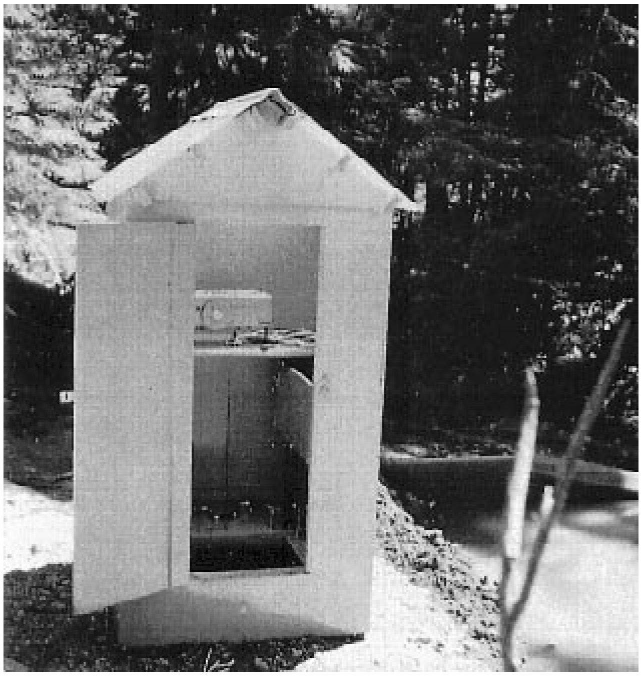


Figure C-5. Walk-in shelter.

C.3 Stilling Wells

A stilling well is a vertical pipe-shaped enclosure placed vertically in or near the streambank. It is watertight, except for restricted access to the outside body of water. The purpose of the stilling well is to dampen water level fluctuation and protect the float sensor components. Figures C-4 and C-6 show various stilling wells and shelters.

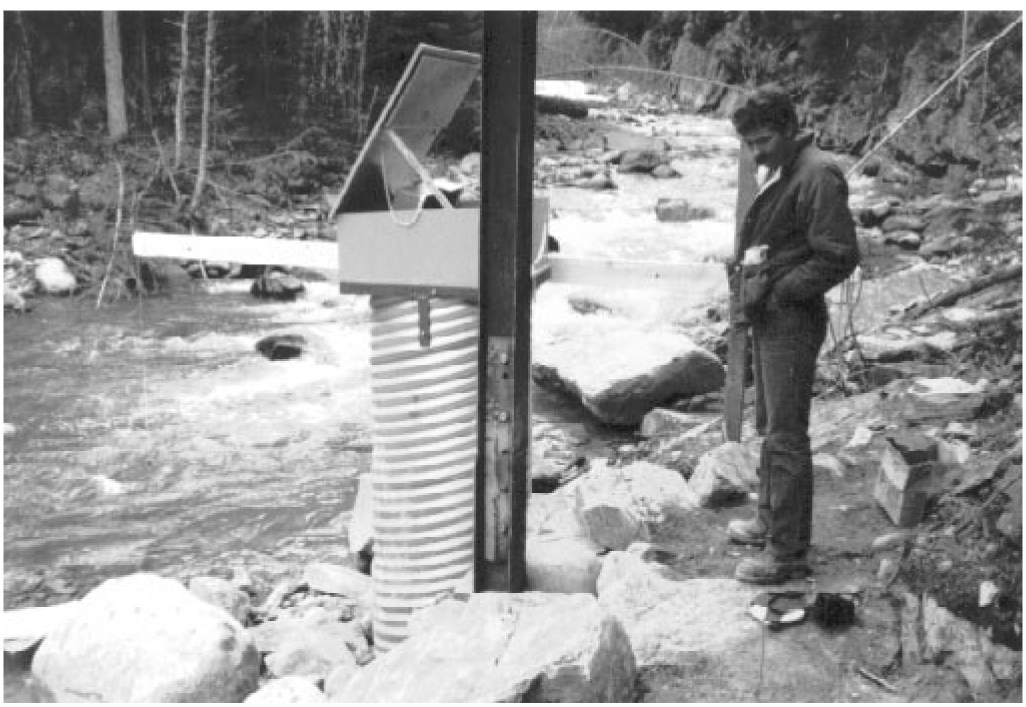


Figure C-6. In-bank stilling well.

C.3.1 Construction and Placement

Site conditions and related equipment dictate the stilling well's construction materials and positioning. Proper design is required to meet the site's physical and climatic conditions, and to ensure constant passage of water flow. Refer to Section B.1.3 on site selection.

The size, shape, and materials for constructing a stilling well vary, but the well must be large enough to allow free and unobstructed movement of floats and counterweights. Space must be allowed for other components and equipment, such as flushing lines.

The well is connected with the body of water by intake pipes made of steel or thick-walled plastic (in-bank installation), or simply by hole(s) drilled directly into the well. All stilling wells require screen-covered vent holes near the top to allow humidity to escape.

Intake pipes used for transferring the water level of the stream must be positioned level and at right angles to the direction of flow. The direction of the flow past the intake pipe may vary at different stream levels. If so, the effect of the flow velocity past the end of the intake pipe may cause drawdown or pileup of the water level in the stilling well. Drawdown causes the water level in the stilling well to be lower than that of the stream; pileup has the opposite effect.

The drawdown or pileup of water in a stilling well can be reduced by attaching a static tube (Figure C-7) to the stream end of the intake pipe. A static tube is a short length of perforated pipe attached to an elbow on the end of the intake pipe and extended horizontally downstream. The end of the static tube is capped. Water enters or leaves through the perforations.

The general arrangements of stilling wells and intake pipes are shown in Figures C-8 and C-9.

Figure C-7. Static tube for intakes.

A stilling well must be positioned vertically and secured sufficiently to eliminate vertical and horizontal movement. The bottom of the stilling well must be placed at least 0.3 m below the minimum expected water level. The top must be above the maximum expected water level.

Where stilling wells are installed to record continuous flow at measuring structures, a wet stilling well is attached to the wall of a dry well and the intake pipes are fitted with rodding eyes, shut-off valves, and an open-end upstand pipe. The top of the upstand pipe is set at precisely the same elevation as the invert of the measuring structure control. This arrangement permits setting zero flow on the recorder. A second, clear acrylic upstand pipe is bracketed to the dry well wall in front of standard gauge plate(s). This is the inside gauge; it extends to the top of the flume side wall. Figure C-10 shows the viewing pipe at the Jamieson Creek Flume.

C.3.1.1 In-Stream Stilling Well

If holes are drilled directly in the tube, the well is positioned against a vertical streambank and anchored at the base by means of angle irons driven into the streambed, or it is secured to a wharf, bridge pier, abutment, or dike wall. Holes are drilled through the wall of the pipe at proper locations to permit water passage sufficient to maintain a continuous balance of the inside and outside water level. The bottom of the pipe must be made watertight by using caps or welded plates. A watertight door near the bottom of the well provides access at low water level for removing silt or ice.

A simple installation of an in-stream stilling well accommodates only the float and counterweight for the water level recorder and consists of an adequate length of 0.3 to 0.5 diameter plastic or metal pipe, properly secured to a solid bridge pier or similar structure.

Figures C-11 and C-12 show examples of in-stream stilling wells.

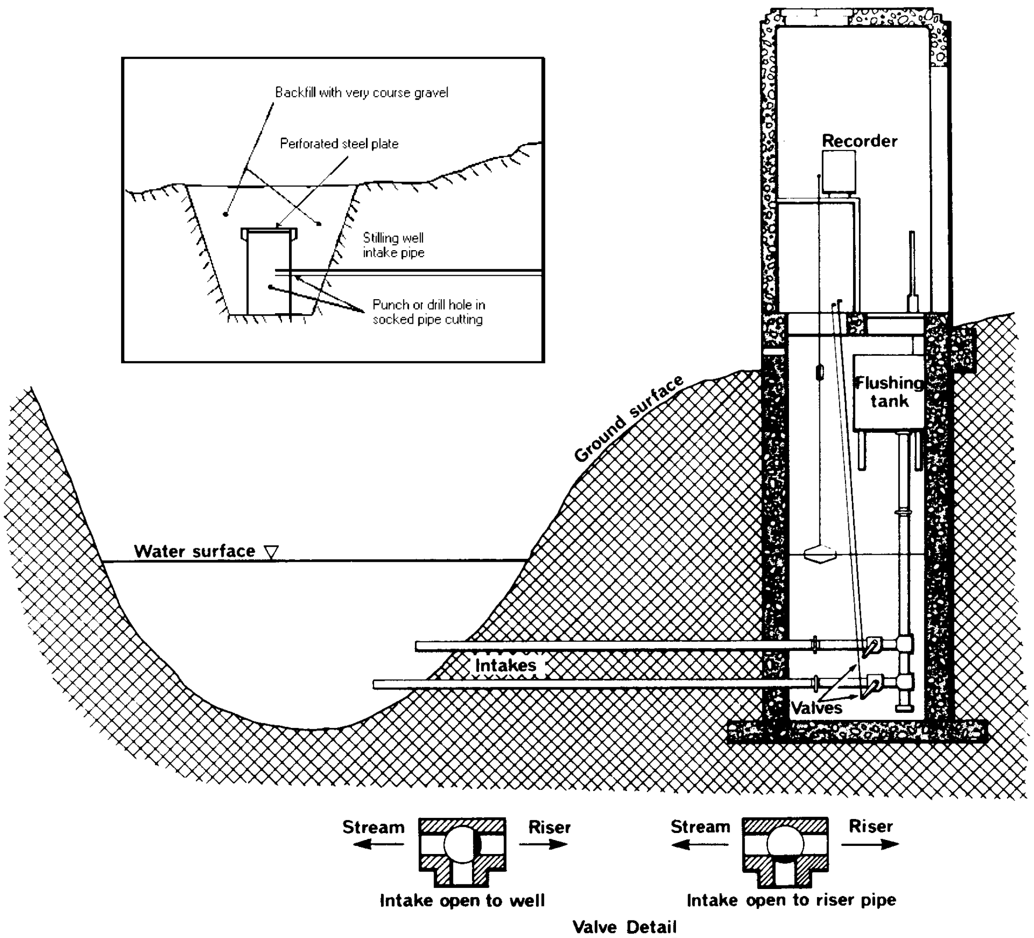


Figure C-8. Diagram of a walk in shelter, stilling well, intakes.

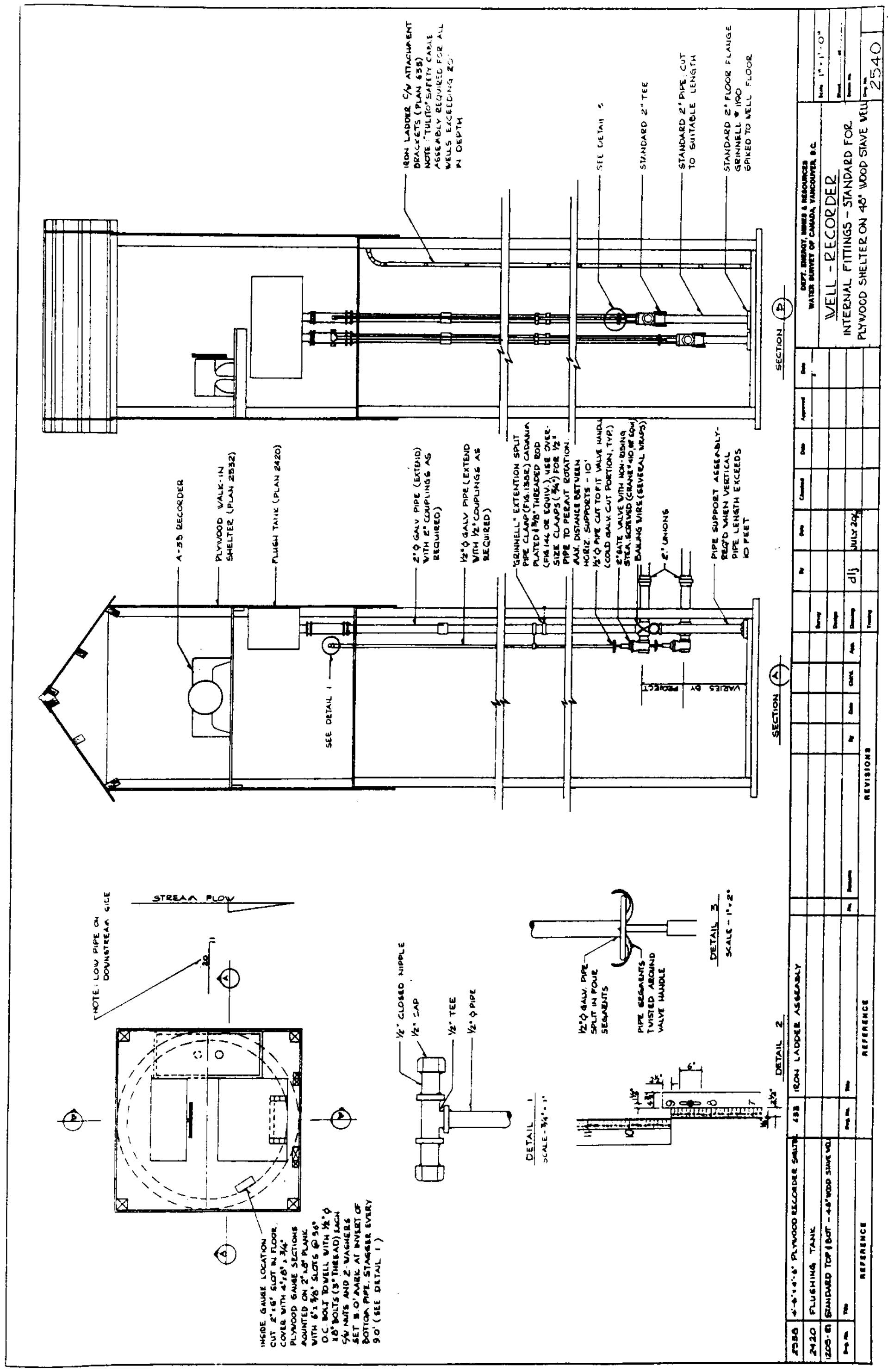


Figure C-9. Diagram of typical stilling well intakes of flushing system.

Note: the shelter for this type of installation requires a minimum floor area of 7.5 m^2 (dry well floor area, assuming a 0.31 m diameter wet well, must be at least 1.5 x 2.0 m). The dry well must be fitted with a ladder bolted to the wall, a 37.5 mm floor drain and covered with a trap door or removable floor plates.

Figure C-10. Jamieson Creek dry well.

C.3.1.2 In-Bank Placement

A stilling well with in-take pipes is placed a few metres inshore, in the bank, where conditions are favourable and where long-term operation is possible. The design and installation of an in-bank well is more complex than that of an in-stream well.

The well is usually constructed of concrete, steel pipe, or wood staves. Connecting pipes transfer water between the well and the outside body of water. Earth is backfilled to the outside perimeter of the well casing. The connecting pipes are buried, leaving exposed the portion of the pipe protruding into the body of water. Provision must be made for cleaning out silt from both the bottom of the well and the intake system.

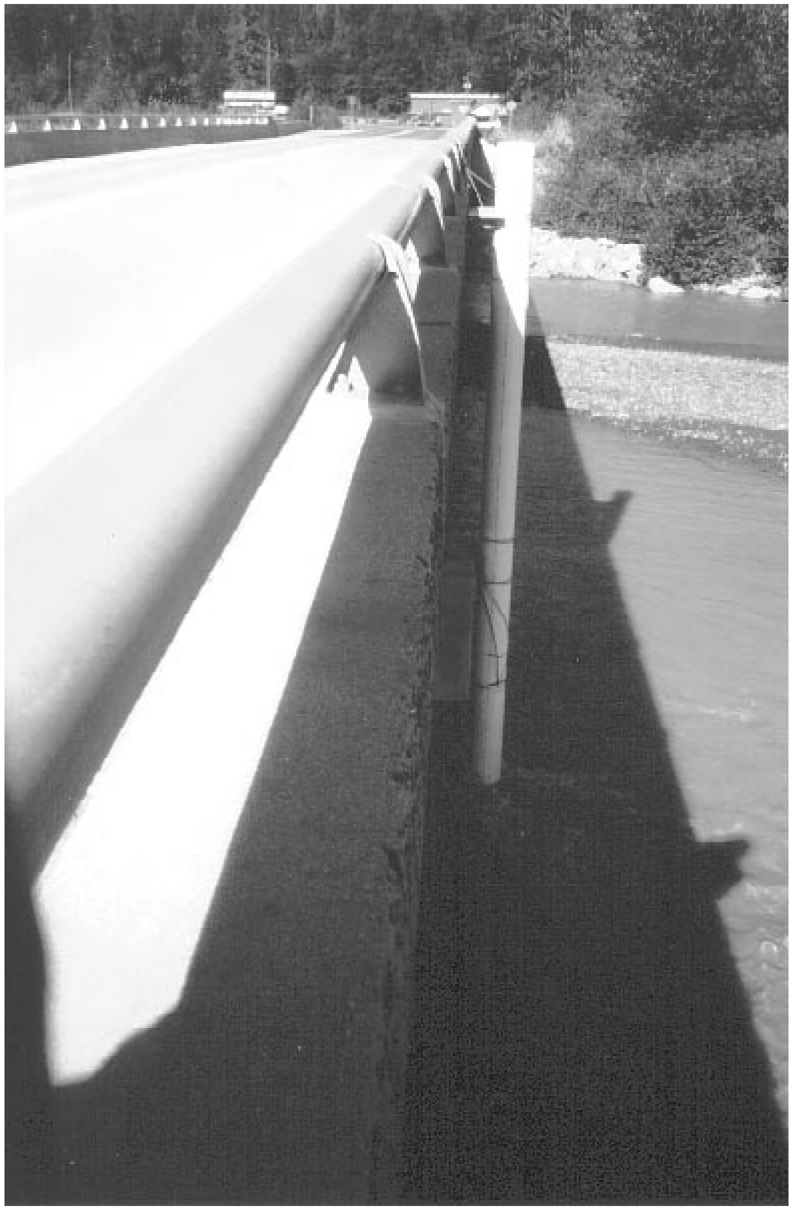


Figure C-11. Instream stilling well, Bear River near Stewart.

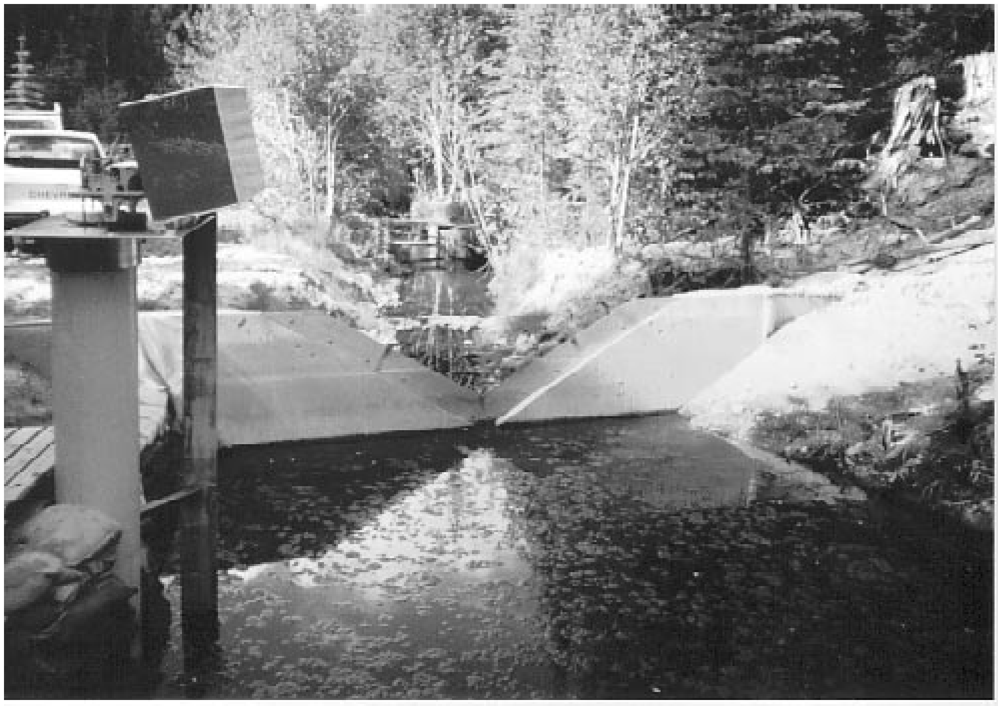


Figure C-12. Instream stilling well, Whitehead Creek near Summerland.

C.3.2 Intake Pipe Design and Placement

Water from the outside the well in the water body is transferred to and from the stilling well through intakes. Depending on the type of stilling well**,** the intakes can be a series of holes in the wall of the well, a single hole in the well bottom, or connecting pipes. The intakes must be large enough to maintain the water level within the well at the same depth as the outside water at all times. At the same time, the intakes must be sufficiently constricted to dampen unwanted oscillation of the water level.

> **Note:** Rule of thumb for sizing the intake--the total area of the intake(s) or the holes in the well should equal one thousandth the area of the stilling well.

To prevent plugging by deposited silt, the intakes should be positioned at least 0.2 m lower than the lowest expected water level, but at least 0.15 m above the well bottom.

Pipe intakes should be positioned horizontally, below the frost line. The open ends of the intakes should protrude into the outside body of water to a point clear of obstruction. Two or more pipe intakes are normally installed at elevations throughout the range of water level variation. During high water, if silt deposits obstruct the lower intake the upper intakes will continue to operate. Record the elevation of the intakes in the field data book on the Description of Hydrometric Station Form (Form AQU-01).

The intake pipes must be positioned at right angles to the direction of flow. The direction of the flow past the intake pipe may vary at different stream levels. If so, the effect of the flow velocity past the end of the intake pipe may cause drawdown or pile-up of the water level in the stilling well. Drawdown causes the water level in the stilling well to be lower than that of the stream; pile-up has the opposite effect.

C.3.2.1 Static Pipe

The drawdown or pile-up of water in a stilling well can be reduced by attaching a static tube to the stream end of the intake pipe. A static tube is a short length of perforated pipe that is attach to an elbow on the end of the intake pipe and extended horizontally downstream. The end of the static tube is capped. Water enters or leaves through the perforations. A properly designed static tube eliminates the pressure due to the stream velocity, but it still reacts to water pressure according to the depth of water over the intake.

C.3.2.2 Intake Chamber

To provide low water levels, the outer end of an intake pipe may have to be located some distance from the stilling well and may be subject to damage due to bedload movement. In such circumstances, the intake pipe should be buried in a trench leading out to a perforated chamber embedded in the streambed.

The most suitable form of chamber is a length of concrete or plastic pipe one metre long and 0.3 m in diameter placed vertically with the top at least 0.2 m below the stream bed. The end of the intake pipe enters the chamber through a hole punched or drilled through the wall of the pipe at least 0.3 m below the top. If a socket pipe cutting is used, a circular piece of steel plate drilled with a number of 10-mm holes can be fitted to rest in the bellmouth opening. The bottom of the chamber is left open, while the cover plate, fitted with a lifting handle, is covered with gravel level with the stream bed.

C.3.2.3 Intake Chamber Position

The position of the intake chamber should be carefully referenced to two or more points on shore so that the chamber may be located easily for cleaning. The reference data should be entered on the Description of Hydrometric Station Form (AQU-01) and on the Water Stage Recorder - Station Record Form (AQU-06).

When seepage or channeled rainfall gets into the stilling well, or when water leaks out of the stilling well through the wall or bottom, the accuracy of water level trace decreases. These problems should be rectified.

C.3.3 Operation and Maintenance

The operation of stilling wells is affected by seasonal changes, runoff patterns, and weather. Work performed on or around stilling wells is subject to safe working conditions. Operating staff should be aware of safety requirements and look for and correct any unsafe conditions before beginning hydrometric work.

C.3.3.1 Open Water Season

Open water season is that part of the year when no ice is present on the watercourse. Each time the technician visits the station, the shelter and site must be inspected for any potential problems such as damaged flooring, broken or bent intake pipes, inoperative shutoff valves, and insecure ladders. Any observed faults should be repaired immediately if possible, or scheduled for repair at the earliest opportunity. Check for obstructions in the well that may impede the float, float line, or clock weight travel.

Check the well for sit deposition by sounding with a weighted tape; compare this measurement to the original clean depth of the well.

> **Note:** Remember, the lower intake pipe may be only 0.15 m above the well bottom.

Promptly remove excessive silt deposits by using a pump and discharge hose to place the accumulated silt into a suspension and to build the water head inside the well. Discharge the water head out through the intake pipes to remove the suspended silt. Continue flushing until the plume of silt being discharged through the intakes is no longer visible. Stilling well system accuracy and reliability depend upon the free flow of water through the intakes.

Flush all intakes immediately before, during and immediately following seasonal high stage. For the rest of the season, flush the intakes during each station visit, or as required. Frequent flushing may be necessary where silting is an obvious problem.

Flush all intakes prior to obtaining a discharge measurement. Make sure the intake valves are open after flushing and before you leave the site. Check to verify that the float, float lines and clock-weight line are not tangled together and see that they are free from obstructions. Also ensure that the float tape or line has not been knocked out of position on the float pulley.

C.3.3.2 Seasonal Operation

The open water season described above excludes ice conditions normally associated with spring start-up and fall shut-down.

The operational 'open water' period for many hydrometric stations is April 1st to October 31st, whether ice is present on the watercourse or not. However, before and after this period the technician must undertake both pre-season and post-season activities.

Pre-season Operations

Pre-season activities involve clearing ice from the stilling well, repairing winter damage, and activating recorders.

Many stilling wells are constructed with 12-inch-diameter (305-mm) ABS water pipe, sealed at the bottom with a glued-on pipe cap. Ice removal from these relatively small diameter wells can prove quite a challenge even when the ice is no longer attached to the wall of the pipe. Preparations for ice removal must take place before freeze-up in the fall (see below).

If ice is frozen to the pipe wall, start-up can be delayed, or water added to the top to speed melting. The judicious application of heat to warm the pipe sufficiently to detach the ice block is suggested, if the stream ice is beginning to break up.

If the ice block is freed from the sides of the stilling well, it may be removed by lifting, although it may weigh up to 40 kg. The shelter must be removed from the stilling well first.

Post-season Operations

In all location subject to winter freeze-up, ice may present problems if it occurs before the end of the operating season. Regardless of the operational period, all recording stations require some degree of winterization if they are to be easily reactivated on time in the spring. Some preventive measures taken at the end of the season will make the following season start-up, much easier. The usual problem found on arrival at station start-up is a large block of ice remaining in the stilling well. If the float has been left activated, it will almost certainly be stuck in the ice and will have to be freed before the ice can be removed. The following shut-down procedures are recommended at the end of the season.

Remove the float, counterweight and float lines (carefully coil and secure lines to avoid kinking) from the well.

Through a 15-25 cm diameter metal or thick plastic disc with a 12 mm hole drilled in the center, pass a 10 mm polypropylene rope through the center of the disc, tie a figure of eight knot, and lower disc to the bottom of the well. Align the rope to hang down the center of the well and tie it off at the top.

> **Note:** Painting the shelter and exposed well exterior black, will promote earlier ice detachment from the well wall. Also, if the recorder is to be left on site over the winter, detach the chart roll from the take up roller, rewind on supply tube and tape. Wind negator spring and leave the clock running.

Winter Operation

Water which freezes in the stilling well and/or intakes during the winter period, presents serious problems. Continuous operations in cases where there is no ice free zone in the stream are extremely difficult.

***Ice Formation*:** If the intake pipes are below frost level and the end of the lowest intake does not become encased in ice, the stilling well can continue to operate. Formation of ice within the stilling well can be prevented or controlled with an insulated frost floor, heaters or an oil cylinder.

Fully exposed metal wells present the greatest problem. At freezing temperatures, ice forms quickly around the inside wall of the well and on the inside water surface which traps the float. Further freezing produces a cylindrical plug of ice.

Ice Effects on Floats: Warming temperatures may free the ice plug, but if the float is trapped within it, records of the response to water level changes will be inaccurate. For an accurate record, the technician must free the float and remove the ice from the well.

Severe damage to the water level recorder can occur if both the float and counterweight become trapped in an ice plug. If the water level below the ice plug recedes, the weight of the ice will place extreme stress on the float pulley shaft and float wire above.

Frost Floor: A frost floor is an insulated sub-floor within the stifling well positioned below the frost line of the surrounding ground. The cold air spilling into the well is partially confined to the area above the frost floor, while the warmer air from below can not escape easily. This warmth retards the formation of ice within the well. Holes cut in the frost floor allow the float and counterweight line to pass through.

Wells in the stream bank are normally encased with back-filled earth, which provides some insulation. However, ice plugs can still form in the well if cold air spills into it. A frost floor may be enough to stop ice from forming as long as the water level remains below the frost level of the surrounding soil.

***Frost Tubes*:** Frost tubes have proven quite effective in overcoming ice in both exposed metal and earth-protected stilling wells. A frost tube is an open-ended cylinder, usually 25 cm in diameter, fastened vertically inside the stilling well. The bottom end is elevated slightly above the well bottom; the top end extends to the well top, or to an elevation above the maximum expected winter water level.

At stations where 305 mm ABS stilling wells have been installed, the well becomes the frost tube and a quantity of oil sufficient to extend below the frost line or ice thickness is poured into it. A 0.1-m column of oil in this diameter of pipe will require 7.3 litres of oil.

To prepare a frost tube, a non-toxic oil is poured into the top of the cylinder. The column of oil that forms above the water forces the water surface in the cylinder below the surrounding water level in the stilling well. The recorder float is then positioned in the cylinder where it will respond to the variation in the oil surface level.

Since the oil surface level stands higher than the true water level, a compensating correction must be made to the record. The degree of correction will be proportional to the amount and specific gravity of the added oil.

To quantify this initial correction, reinstall the float assembly and circle the position of the pen. Read the graduated float tape or mark the beaded wire opposite the recorder base, and read the outside gauge. Remove the float from the tube before pouring the oil. Reinstall the float, circle pen and repeat readings as above. Differences in the relationship between pen/floatline and outside gauge is the correction for the quantity of oil and its specific gravity. Set the recorder pen to the outside gauge for this and subsequent station visits.

Oil Specification: An acceptable oil is ‘Esso Bayol 35M’ with a specific gravity of 0.815. This oil is tasteless, colourless, odourless, and is used in food processing. Do not let the oil spill from the frost tube into the stilling well, because it causes bacteria to grow on the water surface within the well. Non-toxic oil must be used. Kerosene and other petroleum oils must <u>not</u> be used for environmental reasons.

Discontinue using the frost tube at spring break-up time. If the cylinder is not designed and installed as a permanent fixture, the oil and cylinder must be removed from the stilling well before the rising water level forces the oil over top of the tube. Frost tubes do not produce heat nor do they require any heat to be effective.

Spring Operations

Prior to spring break-up, stilling wells must be cleared of winter operations fixtures and any ice remaining in the well. Where the intakes are blocked with ice, the use of a steam generator may be needed to remove ice from the intakes and the well.

Inspect the well for possible structural damage that may have occurred during the winter season. Check especially for vertical movement caused by frost heave. If signs of frost heave are evident, give special attention to the intake pipes, as they may be damaged at the point of entry to the well. Inspect the outer ends of the intakes and remove any attached ice from them.

Clean deposited silt from the stilling well bottom. Remember, in the next few months water will carry most of the annual silt deposit to the well. Flush all intake pipes and make sure they are free and clear of obstruction. When flushing the intakes, observe the discharge from the upper intakes. Finally be sure the intake valves are open before leaving the site.

In general, it is essential that the stilling well and the intakes are in good working order if the well is to provide accurate records through the upcoming spring runoff season. Corrective action for potential problems is far more difficult during spring when the well is full and the intakes are all under water. Under these conditions, repairs or maintenance work may not be possible. Many water level records are lost as a result of improper preparations prior to spring.

Ensure that the float and the suspension lines move freely and that they are clear of any possible obstruction.

Spring Runoff

During high flows the water surface in the well appears to be excessively turbulent. To dampen the oscillation, close one of the upper intake valves and look for improvement. Slowly open the valve until you achieve a tolerable level of disturbance. For in-stream installations, when the water level exceeds the elevation of the top vent holes, block the holes to avoid further velocity turbulence. Note these actions on the station record or log.

If the water level should exceed the upper limit of float travel in the well, cut a hole in the floor to allow passage of the float. This measure will provide additional distance for float travel which will in turn add to record collection. Manually pull the float through the hole in the floor to its upper limit of travel. Check to see if the counterweight hits the well bottom. If it does, shorten the float line proportionately. Remove all buoyant material from the floor to prevent it from obstructing the float line or restricting the float’s return passage through the hole when the water level recedes.

Inspect the streambank for possible cave-in or excessive erosion. If the stilling well is endangered, arrange for emergency corrective action. Until proper corrective actions can be taken, the stilling well should be secured with a strong cable which can be anchored to inshore trees or other stable objects. This will prevent tilting or loss of the well.

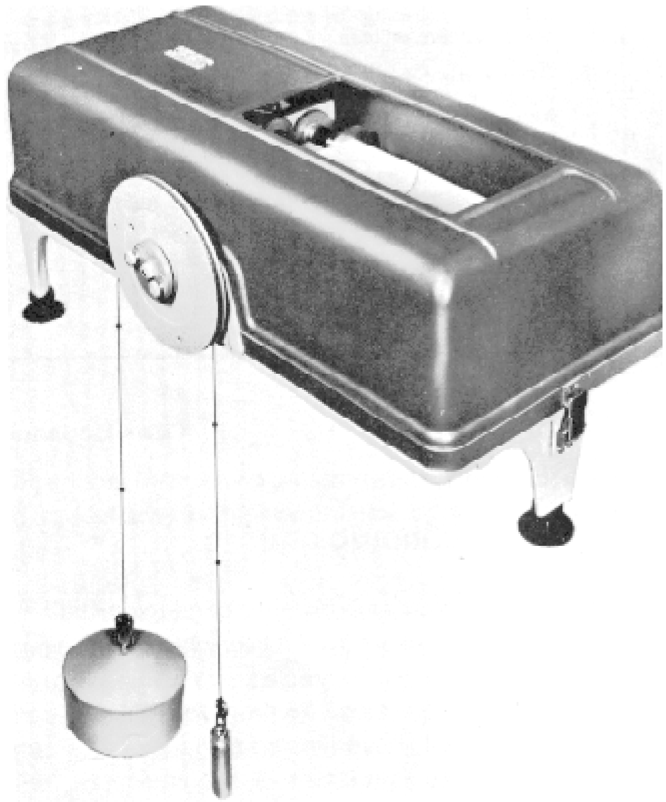


Figure C-13. Stevens A-71 recorder with beaded float wire.

C.4 Current Meters

C.4.1 Introduction

C.4.1.1 Purpose and Background

The purpose of this section is to review several commonly used current meter types and models available in Canada and to describe the care, maintenance and testing of the current meter.

All mechanical-current meters measure velocity by translating linear motion into angular motion.

An ideal current meter should respond instantly and consistently to any changes in water velocity, and should accurately register the desired velocity component. Also, the meter should be durable, easily maintained, and simple to use under a variety of environmental conditions. Due to the fundamental difference in their axial alignment, vertical- and horizontal-axis meters differ in their maintenance and performance. Meter performance depends on the inertia of the rotor, water movement, and friction in the bearings.

Two common types of current meters are used by the various agencies engaged in the quantification of streamflow in British Columbia: the vertical axis meter and the horizontal axis meter. With either meter, the rate of rotation of the rotor or propeller is used to determine the velocity of the water at the point where the current meter is set.

Before the current meter is placed in service, the relationship between the rate of rotation and the velocity of the water is established in a towing tank. The rating procedure is explained later in this section. In its streamflow measurement program, Water Survey of Canada uses the Price current meter almost exclusively.

A third type, an electromagnetic current meter measures velocity using Faraday's Law, which states that a conductor (water) moving in a magnetic field (generated by the current meter probe) produces a voltage that varies linearly with the flow velocity. Electrodes in the probe detect the voltages generated by the flowing water. As these meters have no moving parts they are not subject to many of the operational and maintenance problems associated with mechanical current meters. However the earlier models were equipped with a counter that displayed an instant velocity value and failed to produce the time averaged velocities required for the measurement of discharge. Generally their use has been confined to fish habitat and water quality studies.

C.4.1.2 Comparison of Vertical Axis and Horizontal Axis Current Meters

Table C-2 lists the current meters have been used for the collection of streamflow data by BC government survey staff. All current meters are periodically calibrated by the National Calibration Service at the National Water Research Institute, Burlington, Ontario.

Hydrologists of the U.S. Geological Survey have studied both the laboratory and field results for meter precision, linearity, and response to oblique flow angles. The current meter types tested included most of the meters shown below and compare the performance of vertical and horizontal axis mechanical meters. The electromagnetic meter was also tested.

Percent standard error for all meters tested was less than 2% with the vertical axis meters providing the most consistent response.

Both horizontal and vertical-axis meters tested had good precision (percent standard errors < 0.75 % for velocities >24.4 cm/s) and a similar linearity of response (Root Mean Square < 2.01 cm/s).

Table C-2. Commonly used current meters.

Vertical Axis Current Meters	Horizontal Axis Current Meters
Price 622AA	Valprot BFN 002 (Braystoke)
Price 622AA Magnetic	OTT 5 (Arkansas), 2 impellers (replaced by C31)
Price 622AA Photo-Fibre Optic (Swoffer retrofit #2200)	OTT, C31, 3 impellers
Price Winter Model AA	OSS, B1, 2 impellers (identical to C31)
Price Pygmy	OTT, C1, 3 impellers (replaced by C2 & OSS, PC1)
Price Pygmy Photo-Fibre-Optic (Swoffer retrofit #2200)	OSS, PC1, 2 impellers (identical to C2)
	Swoffer 2100, 1 impeller

C.4.1.3 Oblique Flow Tests

The magnitude of error for horizontal-axis meters is usually smaller than those for vertical-axis meters in oblique flows Two horizontal-axis meters, the Ott C-31 meter with A and R impellers had the smallest error in oblique flows. At angles between $\pm 10^0$, errors ranged from -7.87% to 8.92% for the vertical-axis meters and from 2.02% to 3.77% for the horizontal-axis meters.

Unfortunately neither the Ott C2 nor the OSS PC1 were included in the above study. (The Ott and OSS meters are identical - components are interchangeable). However, the impellers supplied with these meters accurately compensate for angular flow to the limits specified by the manufacturers (Table C-5). These meters have, together with the earlier model Ott C1, served as the preferred meter for the measurement of flow in watercourses less than 0.3 m deep.

The Swoffer retrofitted Price type AA and the Price Pygmy do not have relatively large chambers on the upper section of yoke and therefore present a more symmetrical shape to the current. The presence of the contact chamber is one of the factors listed as a possible cause of the rather large errors encountered in the oblique flow tests on standard Price meters It is therefore likely that the absence of these chambers on the retrofit models will produce more accurate results in oblique flows.

The electromagnetic current meter has smaller errors than the vertical axis meters for most angles tested.

C.4.2 Vertical Axis Current Meters

C.4.2.2 General

Three models of vertical axis meters are in general use in Canada: the Price 622AA meter, the WSC winter meter, and the Pygmy meter. This section describes these meters.

C.4.2.3 Price 622AA

The Price 622AA meter (Figures C-14 and C-15) is the most common vertical shaft meter and is often considered the “standard” for discharge measurement. It has been subjected to extensive research and experimentation and shown to be well suited to a wide variety of field conditions. The Price 622AA is the principal meter used by the WSC and many other agencies to determine discharge.

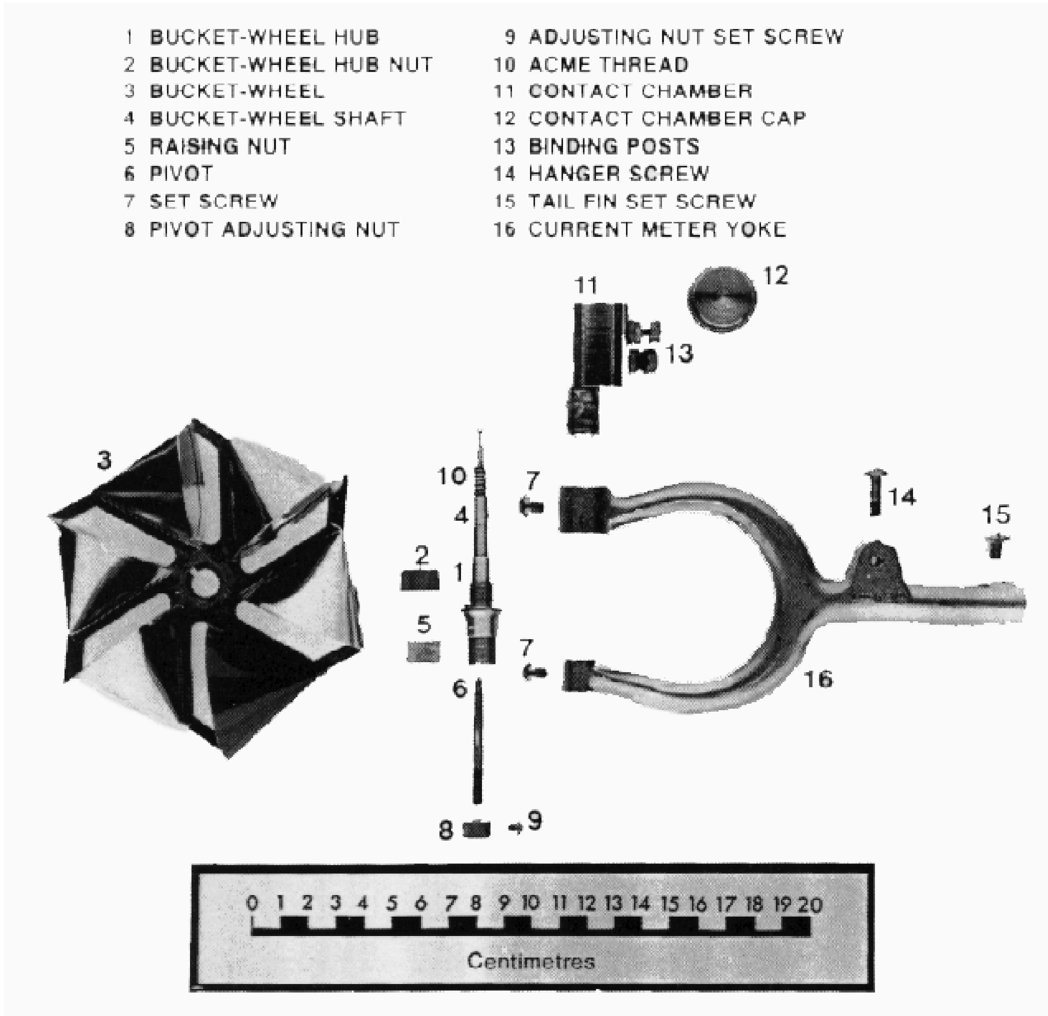


Figure C-14. Components of the Price 622AA current meter.

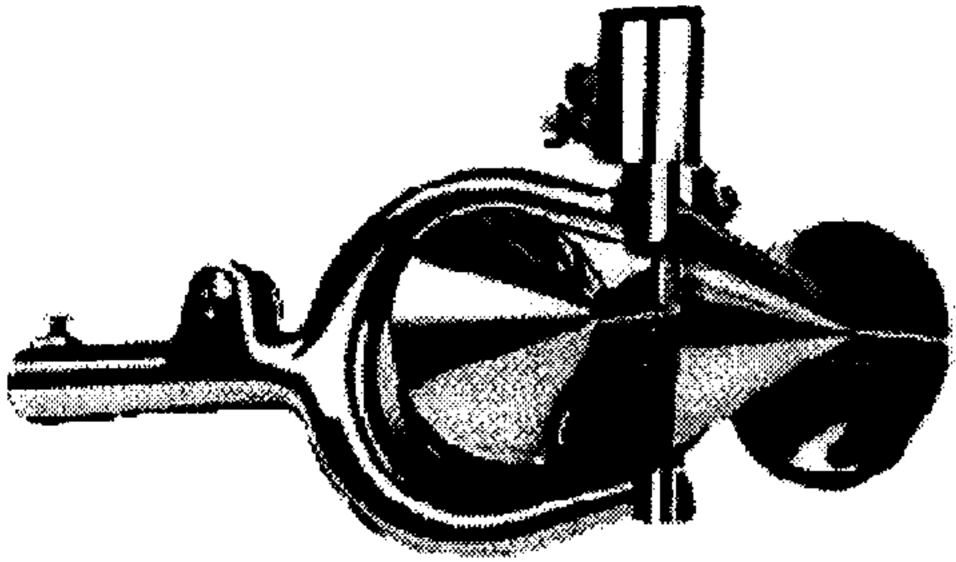


Figure C-15. Price 622AA meter.

Only one bucket wheel assembly is required for the entire range of velocities encountered during normal stream gauging operations. Providing that it is properly maintained, the meter responds accurately to velocities ranging from 2.0 to 300 cm/s. Although the Price 622AA has been in use for 80 years and has an established record of dependability and durability, this meter must be treated with the same care and attention given to any scientific instrument. Damaged components can cause erroneous measurements, which can go undetected for long periods of time.

The main components of the current meter are the pivot and rotor, the contact chamber, and the yoke and tail assembly. The rotor has six cone-shaped elements and is 125 mm in diameter. The letter “T” stamped on the inner portion of the frame indicates the top side of the bucket wheel. When in use, the rotor moves in a counterclockwise direction.

The key feature of the Price meter is the location of both the upper and lower bearing surfaces in fairly deep, inverted cavities which trap air when the meter is submerged. This effectively excludes water-borne silt from the bearing surfaces, which eliminates undue wear. Worn bearings or any other damage to the cup wheel will result in change in the meter rating. This meter may be attached to the standard USGS top-setting rod or the Columbus weight hanger. Mounting adapters, with or without the relocating device (Section D.2), are available from the manufacturers of the 20-mm bridge rods.

On the upper extension of the rotor is a chamber where cup rotation produces an electrical pulse for conversion of angular motion to stream velocity. This contact chamber is fitted with a bearing, a penta gear, and two insulated binding posts. Each post has a fine contact wire.

The top of the rotor shaft is rounded to provide a smooth surface where it comes in contact with the bottom of the chamber cap. Immediately below the rounded end, an eccentric is cut in the shaft. This is the means by which the shaft makes contact with the upper contact wire once during each revolution of the rotor. The next section of the shaft fits into the contact chamber bearing lug. A short section of acme thread is cut into the shaft below the bearing section. This meshes smoothly with the penta gear fitted in the bottom of the contact chamber. The penta gear has two tabs, each of which brushes the lower contact wire once during every five revolutions of the rotor.

Generally, the standard Price 622AA meter does not provide a signal suitable for use with an electric pulse counter in lower velocity regimes. When an eccentric makes a single contact with the “ cat’s whisker”, several pulses may be generated and registered on the counter. The usual method of operation is to time the revolutions of the rotor either visually, or by means of an electrically generated audio signal. The Price meter can, however, be modified for use with a counter; see the next section.

The design and use of current meter vanes in cable suspension assemblies may be a problem in certain forms of turbulent flow. The problem lies with the suspension point (hanger bar) being equidistant between the rotor axis (of a vertical axis meter) and the hydrodynamic centre of the directional vanes, as is the case for the standard Price meter. This meter is inherently sensitive to lateral turbulent fluctuations due to low degree of directional stability, and can introduce an error to the measurement of velocity. The effect the hanger, rotor and vane relationship can only be assessed during field tests in streams over a complete range of turbulent length scales, these conditions can not be duplicated during tow tank calibrations.

C.4.2.3 Modified Price 622AA Meter

The standard Price 622AA meter can be modified in two ways, using retro-fit kits, to compensate for the low-velocity limitations.

1. *Magnetic Switch Contact Chamber.* This accessory produces a “clean” signal for triggering an automatic electric pulse counter.

   A 13-mm long permanent magnet is embedded in the top portion of the rotor shaft. This shaft fits into the centre of a special contact chamber (Figure C-16). A magnetic reed switch, which is accessible from the top of the assembly, is located in a chamber adjacent to the rotor chamber. The binding post and the insulating bushing seal this chamber. During each revolution of the rotor shaft, the magnet passes the chamber and closes the reed switch for a moment. Price 622AA current meters supplied with magnetic reed switches are usually referred to as low velocity models. However, in this case the maximum measurable velocity depends on the pulse rating (pulse/s) of the counter unit employed. The electronic revolution counters manufactured by OTT, Sherlock, and Braystoke, for example, have a maximum counting frequency of 20 pulses/s while some earlier electro-mechanical units were limited to 10 pulses/s In either case the maximum velocity measurable exceeds 5 miles/s while low velocity measurement accuracy is increased due to the absence of friction caused by contact wires.

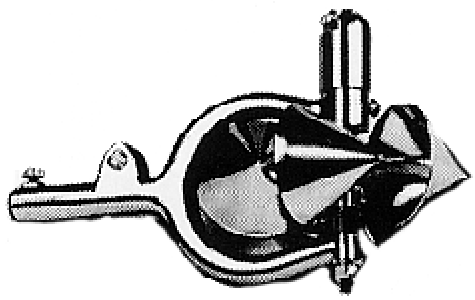


Figure C-16. Price 622AA meter with retro-fit kit containing magnetic reed switch contact chamber.

2. Photo-Fibre-Optic Contact Chamber (Figure C-17). A retrofit kit, consisting of a photo-fibre-optic sensor electrically connected to a digital readout indicator replaces the contact chamber, bucket-wheel shaft, earphones, and stopwatch on both Price 622AA and Pygmy meters. The model 2200 indicator, and other supplied parts, are designed and manufactured by Swoffer Instruments, Seattle, Washington.

   The counter may be set to read direct velocity (display averaging 10 s for the 622AA, and 5 s for the Pygmy), or seconds vs. revolutions. Also, a calibration mode allows the continued use of a damaged meter for a limited time period, by electronically compensating for a meter that does not rotate according to its original specifications.

   Note: This feature does not absolve an organization, working to Provincial Standards, of the requirement of regular calibration of current meters by the National Water Research Institute.

   One of the most important features of this retrofit is its ability to measure accurate low velocities while using both the 622AA or Pygmy current meters which, in their standard contact chamber design, have poor low velocity response. Because the fibre-optic sensor does not require that physical contact be made and broken to produce a signal, as in the "cat's whisker" type, nearly all friction has been eliminated. This means that velocities lower than 3 cm/s can be accurately determined while the counter is in the seconds/revolutions mode. The maximum velocity range of a retrofitted current meter is 4.5 m/s.

   Note: The fibre optic sensor should not be used with reel or handline suspension systems using the suspension cable as the sensor signal wire. Problems have been encountered in connecting to, and signal strength through, the Ellsworth type two conductor cable used by these systems. The fibre optic sensor, which attaches to the replacement meter head, is housed at the end of a two conductor cable. The sensor to counter cable connection is supplied in a standard length of 3 m for use with a wading rod but may be ordered in lengths up to 300 m. Ordering a factory 7-m or 10-m sensor cable for use with a bridge rod will also expand the capabilities of the retrofit for use with a handline or reel.

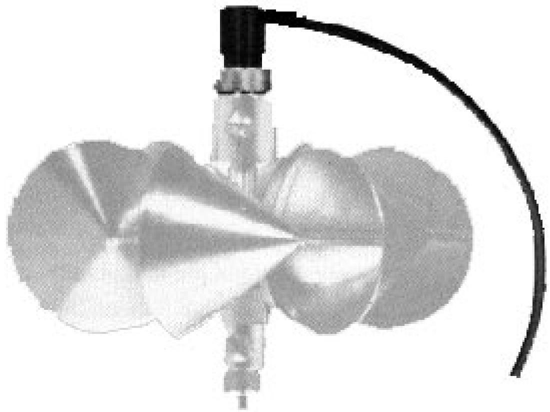


Figure C-17. Fibre optic retrofitted Price 622AA.

C.4.2.4 WSC Winter Meter

Except for the yoke design, the WSC winter current meter is identical to the Price 622AA meter. Its design allows for making discharge measurements in winter because the meter moves easily through holes drilled in the ice. The distance from the front of the bucket wheel to the back of the yoke is 151 mm. Therefore, the meter requires a minimum 200-mm diameter hole through the ice, which can be drilled using the standard ice auger cutter head. The meter is used primarily with the winter rod set. The threaded boss on the upper limb of the yoke permits it to be attached to the bottom rod of the set. See Figure C-18.

> **Note:** When using this or any other meter in ambient temperatures below zero degrees Celsius, the meter must be kept warm and dry prior to its immersion at the first vertical. Subsequent periods of exposure to the air must be kept to a minimum to avoid the formation of ice crystals in the bearings. If a meter becomes frozen, do not attempt to free the rotor by force as this will bend the rotor shaft. The meter must be thoroughly dried prior to further use.

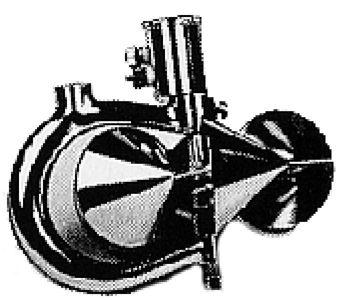


Figure C-18. Price 62AA winter (ice) meter.

C.4.2.5 Pygmy Meter

The Pygmy meter is approximately two-fifths the size of the Price 622AA meter illustrated in Figure C-19. It is designed for measuring streams that are too shallow to use the Price meter.

> **Note:** This meter is not recommended for measuring velocities under 0.3 m/s because the leverage exerted by the small-diameter rotor is insufficient to

consistently overcome the variable frictional component in the contact chamber; the result is in poor accuracy at low velocity. The photo-fibre-optic sensor retrofit kit, described earlier, converts the Pygmy meter to an instrument capable of accurately measuring velocities as low as 0.03 m/s.

As with all other current meters, individual calibrations are maintained for the Pygmy meters. The major difference is that the Pygmy meters are towed at lower velocities, from 2.5 to 140 cm/s.

The two meters differ in other significant ways. The Pygmy meter contact chamber and yoke are one unit. The chamber has only one contact wire that signals each revolution of the bucket wheel shaft. The meter is meant to be mounted on a wading rod. Because it is used in very shallow depths, it has no tailpiece nor can it be suspended from a cable.

The bucket wheel is only 50.8 mm in diameter, and it revolves 23 times faster than the larger Price meter. Unless an automatic pulse counting device is used, the rapidly revolving bucket wheel limits the meter to measuring velocities that are 1 m/s or less. When not in use, the steel meter pivot must be replaced with the special brass shipping pivot. The bucket wheel is not equipped with a raising nut, and the pivot and bearing can be damaged if the steel pivot is not replaced when the meter is not being used.

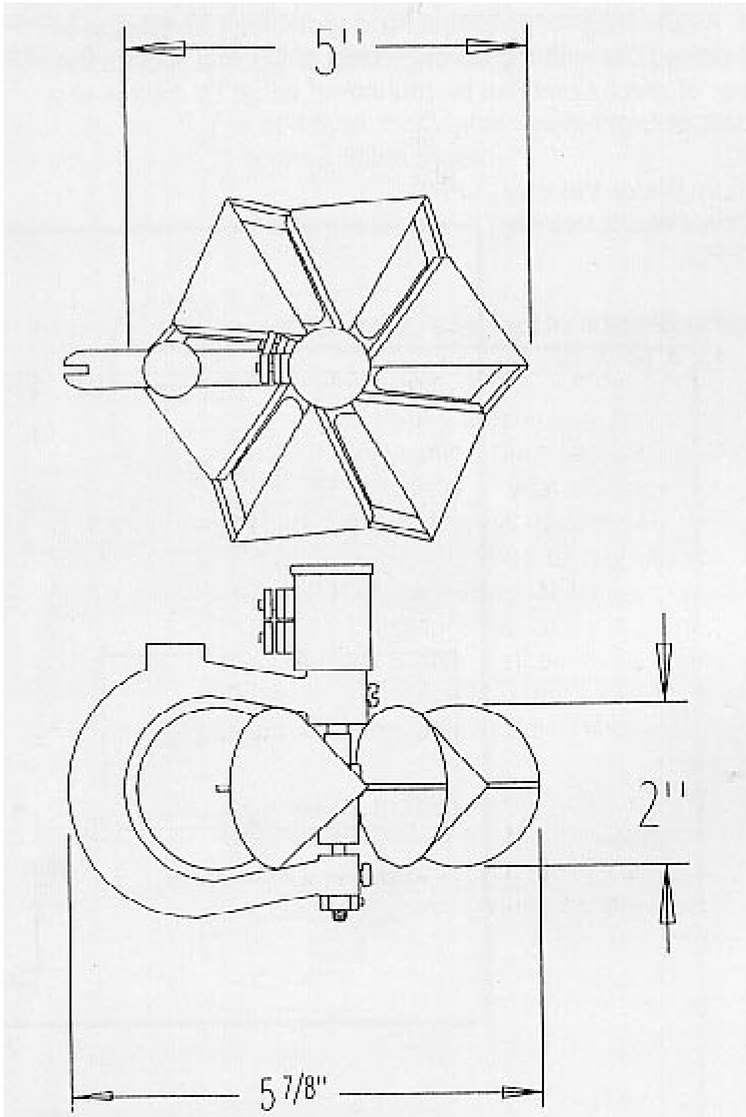


Figure C-19. Price 622AA meter.

C.4.2.6 Maintaining the Meter

The life expectancy and daily efficiency of a current meter depend largely on the thoroughness with which the operator cleans and lubricates the moving parts of the instrument.

Cleaning and lubricating the Price type current meters is simple. It takes only a few minutes and should not be postponed or neglected. During this process, all parts must be carefully examined to ensure that they are working. It is normal practice to clean and lubricate at the end of each day. However, if the meter has been used in a stream that is heavily laden with suspended sediment, clean the meter immediately after the measurement. This helps to prevent abrasive particles from causing premature and unnecessary wear to the bearing surfaces.

> **Note:** If water is already trapped in the head, and in the pivot bearing on the underside of the bucket wheel, applying oil to the pivot may increase the wear.

Adding oil keeps the water in contact with the finely machined surfaces, and carries grit and silt to the bearings. This causes wear and corrosion.

C.4.3 Horizontal Axis Current Meters

C.4.3.1 General

Horizontal axis meters are capable of very accurate flow measurement in areas of local turbulence. The component effect of the rotors compensates for angular flow in both the horizontal and vertical planes, and the orientation of the rotor provides for a balanced translation of the linear motion when measuring near the vertical faces at either edge of a channel. All models use the magnetic reed switch to generate the rotational pulse count, thus avoiding the variable frictional component inherent in 'make and break' systems.

A small horizontal axis current meter continues to be the principle instrument used by Provincial agencies in British Columbia to measure small shallow streams, while the larger models are the preferred for use with bank-controlled cableways and bridge rods.

Note: The criteria for surface and bottom observations using horizontal axis meters is that the axis of the current meter should not be situated at a distance less than 1½ times the rotor height from the water surface, nor should it be situated at a distance less than 3 times the rotor height from the streambed. The rotor height (diameter) of the meters vary from a minimum of 30 mm to a maximum of 125 mm.

C.4.3.2 Braystoke BFN 002 Meter

This miniature current flow meter is supplied in kit form, the accessories include a sturdy 1.5-m, 2 section wading rod graduated in 1-cm divisions, a control unit and 3-m connecting cable with quick release connectors. An optional cable suspension kit includes a 30-m suspension/signal cable, suspension bar and current meter tailfin. Longer sectional rods can be supplied as an option.

The Braystoke current meter, manufactured by Valeport Developments Ltd. UK, is designed for the measurement of flow velocities in fresh water or salt water, and is not affected by water quality. The meter will operate in shallow streams of only 6 cm or suspended to any depth and covers the entire range of velocities from 0.03 to 5.0 m/s with the 50-mm-diameter x 0.10-pitch impeller. The manufacturer does not specify the extent of oblique flow up to which the propeller measures the true velocity value; however, field and laboratory tests conducted by others, indicate the impeller follows the rule of cosine in oblique flows of up to 10° with an accuracy of ±2%.

The impeller shaft and bearings are protected by the design of the impeller hub; when the chamber between the shaft and the impeller fill with water, no silt or weeds will enter the bearings. The neutrally buoyant impeller, fixed on a stainless steel shaft by a washer and two nuts, is fitted with plastic bearings lubricated by the water in which the meter operates. The reed switch contacts housed in the quick release adapter fitted to the end of the cable are energized on each revolution of the impeller by two magnets mounted in the impeller hub. Revolution pulses are registered in the upper LCD display; see Section C.4. for a description.

C.4.3.3 OTT C2 and OSS PC1 Meters

The OTT C2 is identical to the OSS PC1; the former is manufactured in Germany and the latter in Australia. These models are designed to measure water velocity in small natural watercourses, ditches, flumes, small pipes, and laboratory river models. The meter can be mounted on a standard 9-mm wading rod. Adapters are available for use with the 20-mm bridge rod and the U.S. Geological Survey (USGS) top setting rod (Table C-3, and Figures C-20, C-21, and C-22).

> **Note:** Both models require a special oil for operation. The use of any other type of oil will effect the calibration rating of the meter. This oil, Shell Telus 5, is not sold in North America and must be ordered from Europe or Australia.

The OTT C2 provides the choice of six 50-mm and two 30-mm propellers, while the OSS PC1 has a choice of three 50-mm and one 30-mm (Table C-4).

Table C-3. Specifications of the OTT C2 and OSS PC1 meters.

Switch	Propeller	Mounting
• Encapsulated reed, with permanent magnet set into rotating shaft • Single contact/revolution. • 9-V DC. • Max. power 1.6 watts (if spark suppression in counter).	• Slip-on type. • Anodized aluminium alloy. • Supported on bearings within the oil-filled hub of the propeller assembly.	• 9-mm diam. wading rod. • 20-mm diam. bridge rod with clamp (which can also be attached to bottom section of the locating device). • USGS top setting rod with adapter.

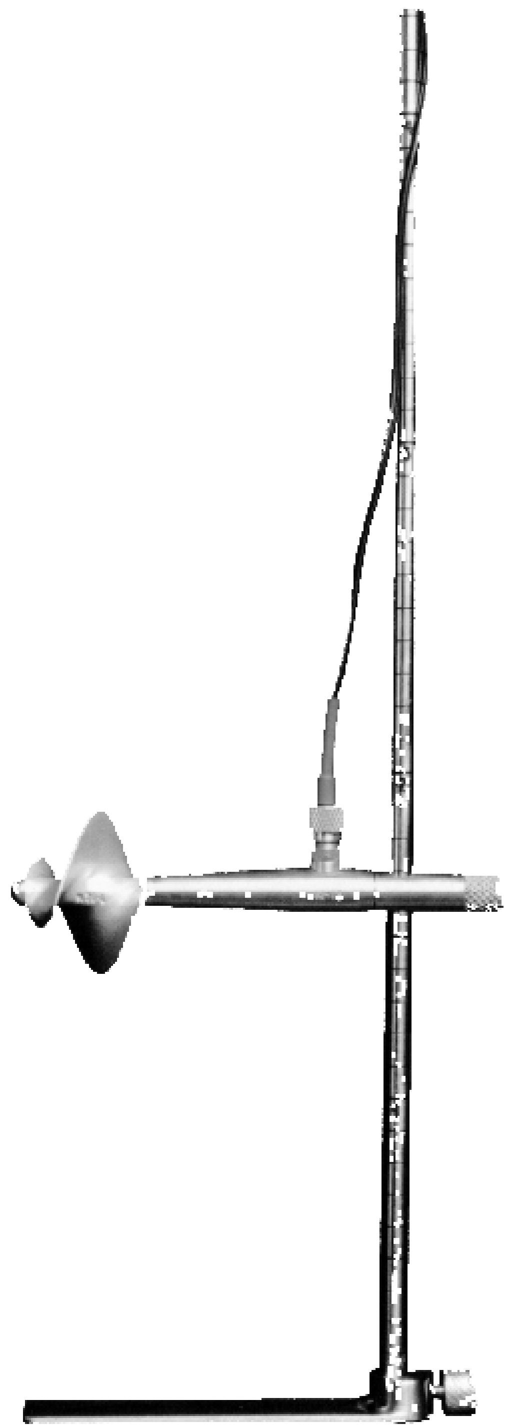


Figure C-20. OTT C2 current meter, mounted on a 9-mm rod.

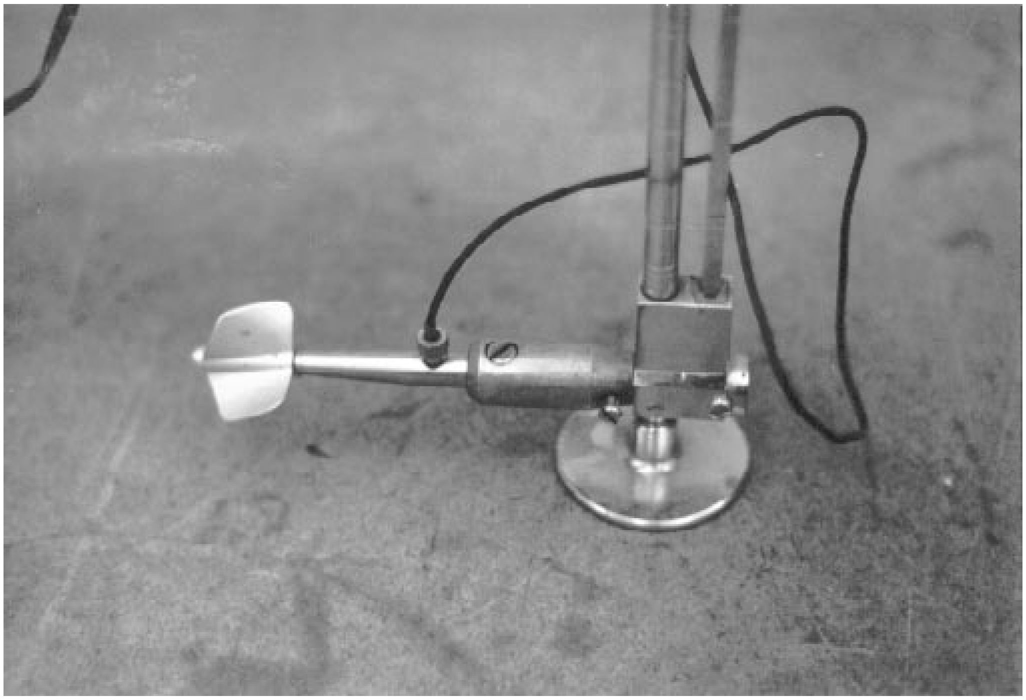


Figure C-21. OSS PC1 with adapter for use on a USGS top setting rod.

Table C-4. Description of propellers for the OTT C2 and OSS PC1 meters.

Propeller number (engraved)	Diam. & pitch (mm & m)	Max. water velocity (m/s)	Starting speed (m/s)	Range of component of effect (degrees)
1 [a]	50 0.05	2.0 (1.0) [b]	0.025	30
2	50 0.10	4.0 (2.0)	0.030	20
3 [a]	50 0.60	6.0 (4.0)	0.035	10
4	50 0.60	7.5 (5.0)	0.060	5
5 [a]	30 0.05	2.0 (1.0)	0.050	20
6	30 0.10	4.0 (2.0)	0.055	10

[a] Propellers supplied by OTT are also available with the OSS PC1. All propellers can be used with either meter.
[b] Maximum water velocities, shown in brackets, are when the meters are used with electro-mechanical type counters such as the OTT-Z21 (10 pulses/s). Electronic counters such as the Z210, CMC 20, or 200 accept 20 pulses/s.

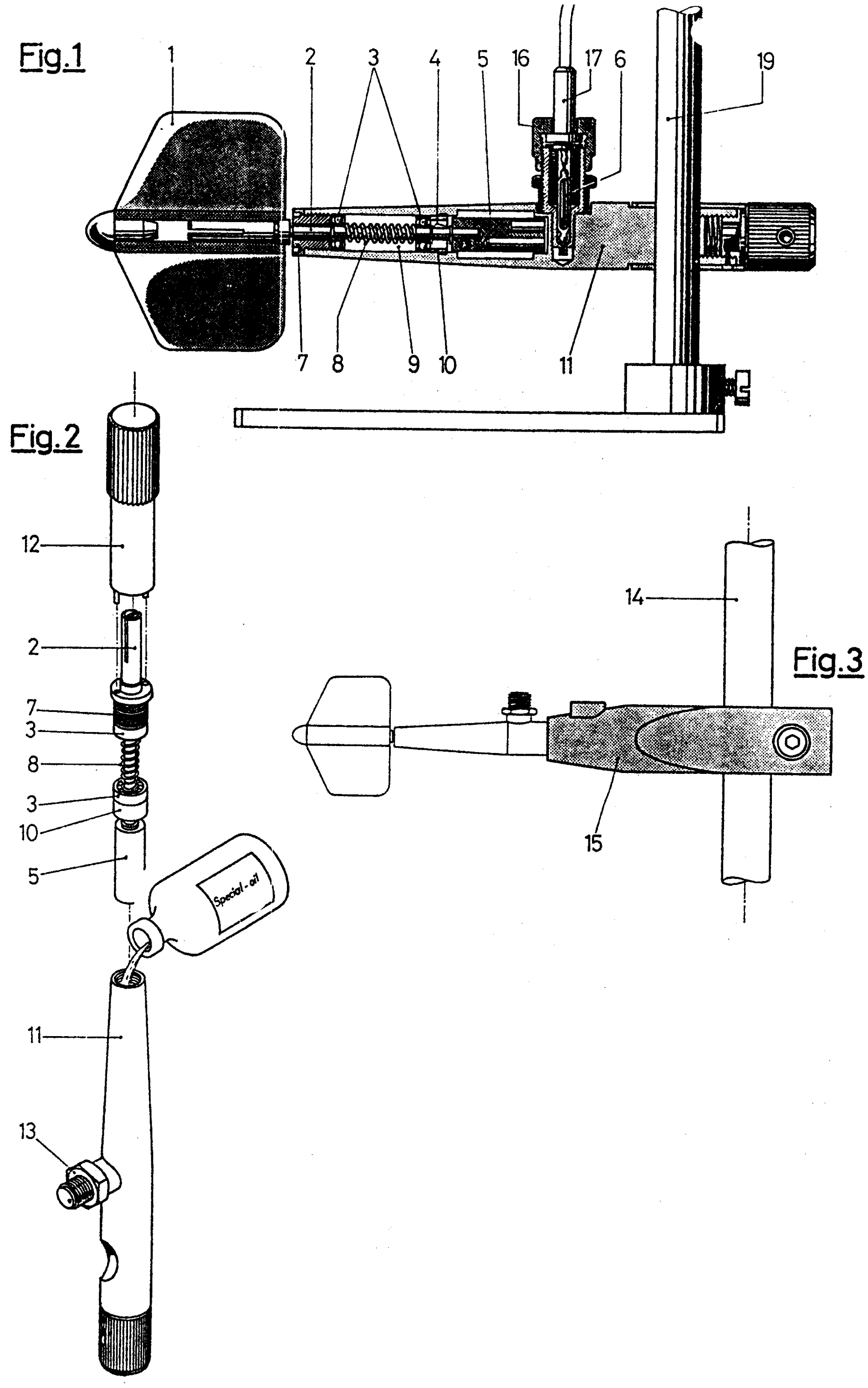


Figure C-22. Components of the OTT C2 and OSS PC1 meters.

C.4.3.4 Universal OTT C31 and OSS B1 Meters

The OTT C31 is identical to the OSS B1; the former is manufactured in Germany and the latter in Australia. These current meters are used to determine the flow velocity of water in open channels and the sea, as well as in pressure pipes. These meters can be used under extreme conditions with the following methods of suspension:

- 20-mm wading or bridge rods with direct connection to the rod or the relocating device casing (Figures C-23 and C-24).
- Two conductor cable and weight assemblies of the following types, available from either manufacturer:
  - Handline and hanger with a choice of 5-kg or 10-kg weights.
  - Portable winch, standard weights, and hanger.
  - Portable winch or double drum (shore-controlled) cableway winch with 25-, 50-, or 100-kg “middle piece” weights equipped with electrical ground feeler (Figure C-25).

Other special options are available for integration measurements, e.g. pressure pipe installations and sliding meter attachments.

Table C-5 lists propellers available from the two manufacturers for the OTT C31 and the OSS B1, together with the velocity range and component effect for each propeller. The maximum water velocities shown can be measured only by means of counters with a counting rate of up to 20 rev/s.

As with the small propeller meters, the components of the OTT and OSS meters are interchangeable.

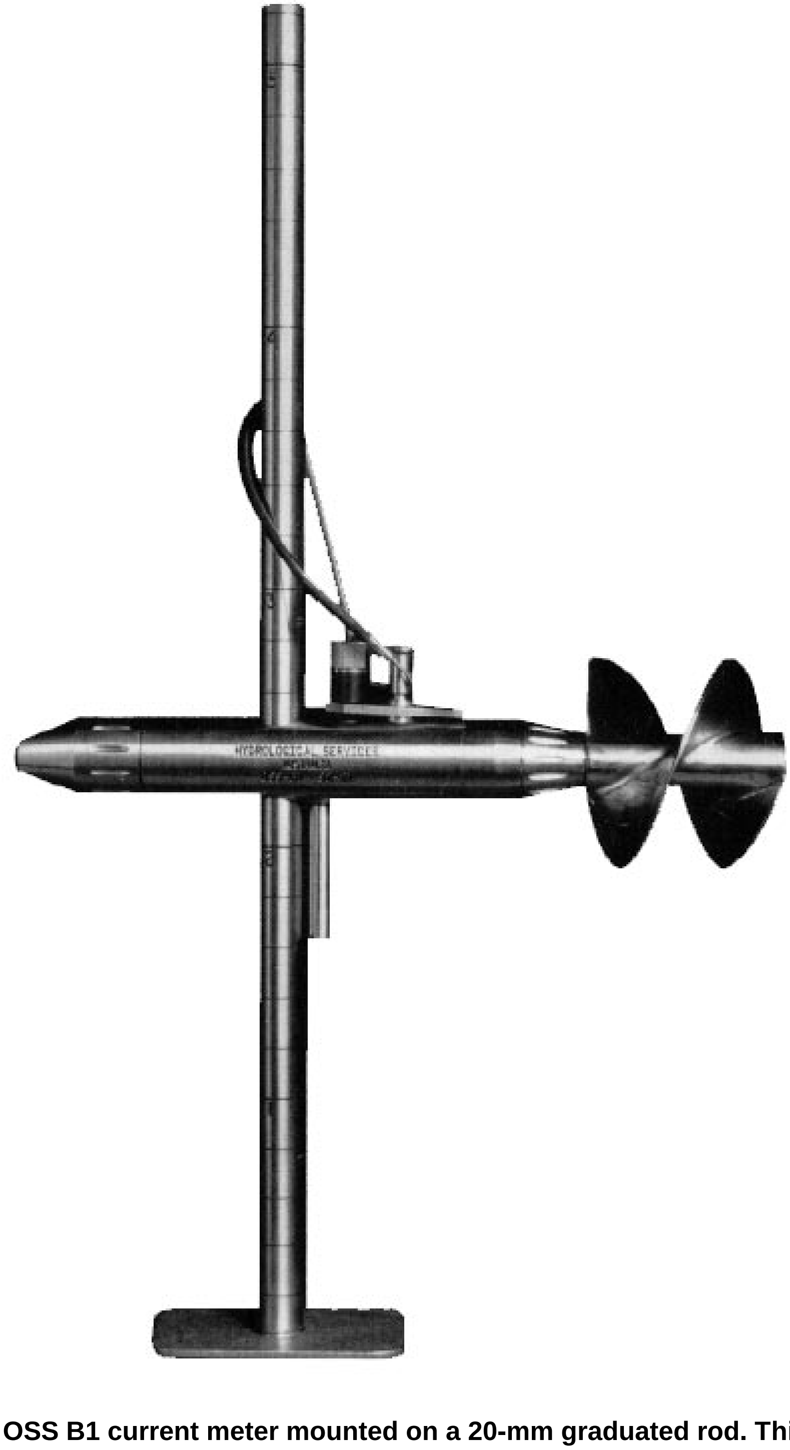


Figure C-23. OSS B1 current meter mounted on a 20-mm graduated rod. This unit may also be attached to a relocating device.

Figure C-24. OTT C31 current meter fitted on a 20-mm rod, with relocating device. Note that the locating device, at top, is aligned with a meter.

Figure C-25. OSS B1 current meter mounted on a 30-kg sounding weight (middle), with a bottom feeler.

Table C-5. Description of propellers for the OTT C31 and OSS B1 meters.

Meter	Type	Diam. & pitch (mm & m)	Max. water velocity (m/s)	Starting speed (m/s)	Range of component effect (^{0}C)
OTT-C31	1 brass	125 0.25	5.0	0.025	5
	1 plastic	125 0.25	5.0	0.035	5
	2 brass	125 0.50	6.0	0.040	5
	2 plastic	125 0.50	6.0	0.060	5
	3 brass	1.25 1.00	10.0	0.055	5
	4 brass	80 0.125	3.0	0.040	5
	A brass	100 0.125	2.5	0.030	45
	R aluminum	100 0.25	5.0	0.035	15

Meter	Type	Diam. & pitch (mm & m)	Max. water velocity (m/s)	Starting speed (m/s)	Range of component effect (^{0}C)
OSS-B1	A stainless steel	100 0.125	4.0	0.030	45
	2 stainless steel	125 0.50	10.0	0.040	5
	4 stainless steel	80 0.125	4.0	0.040	5

C.4.3.5 Maintenance of Horizontal Axis Current Meters

Care and Maintenance

During storage, the propeller should be removed from the meter and the oil drained from the body. If bearings need to be cleaned, they should be flushed with clean white spirits or gasoline. Spare bearings have a protective grease coating which should be removed before they are used.

Before the meter is used, clean oil should be added to the body by holding it upright and half filling as shown in Figure C-22 (Fig. 2). As the axle bush is screwed back onto the carrier, any excess oil will be forced up through the capillary gap around the axle and should be wiped away. Spin the propeller for about a minute to check the condition of the bearings and to ensure proper oil distribution.

Electrical Fault Finding

If an electrical fault has been traced to the current meter, the following conditions should be checked using a multimeter or impulse counter.

Faults will be either closed circuit (Table C-6) or open circuit (Table C-7), and if the CMC-200 counter is sued, set the control switches to “ON” and “INTEGER”. Spin the propeller and if the audible signal sounds continuously, the fault is a “closed circuit”. If no audible signal is heard, the fault is then an “open circuit”.

Adjustment of Reed Switch

The position of the contact assembly determines the angle of closure of the switch, that is with the lock nut loosened (Item 3 in Fig.2 of Figure C-22) the contact assembly (Item 6 in Fig.1 of Figure C-22) may be rotated in the body to achieve the optimum 180-degree switch closure.

Due to the sensitivity of the reed, one quarter turn adjustments are recommended.

An anti-clockwise rotation of the switch increases the angle of closure.

A faulty reed switch is indicated when a continuous contact occurs with the contact assembly adjusted fully clockwise into the meter body.

Closures should be checked with ohm meter, or integrating current meter counter.

Table C-6. Closed circuit fault finding.

Symptom	Possible Cause	Action
Fault occurs only when meter in water.	Water entering contact plug receptacle causing a short in between plug and body.	Replace damaged plug assembly parts 6, 16 and 17 (Fig. 1 in Figure C-22).
Circuit closed in any magnet position, but open when magnet removed.	Reed switch failed.	Replace reed assembly.
Circuit closed without magnet in position.	Reed damaged.	Replace reed.

Table C-7. Open circuit fault finding.

Symptom	Possible Cause	Action
Open circuit between plug (11) and insulated reed contact (6).	Faulty plug contact assembly. Faulty insulated contact assembly (6).	Clean contact in plug-retest. Replace reed.
No closure of reed switch contact when magnet in position.	Damaged reed.	Replace reed.

C.4.4 Current Meter Counters and Timing Devices

C.4.4.1 Counters for Vertical Axis Current Meters

This section describes common methods of obtaining the revolution count from the Price 622AA fitted with a standard penta chamber.

Visual Counting

In situations where the rotor is visible and the rate of rotation is not more than two revolutions per second, a visual count may be timed with a stopwatch. Paint half of one cup with a bright colour. Start and end count as the open face of the cup passes through the yoke.

Audio Counting

Suppliers of current meters usually offer battery powered headset kits as an option. When a low-voltage battery is connected to the meter, an electrical pulse generated by either the single or the penta eccentrics making contact with their respective sensor wires may be used to provide an audio signal or a digital counter input. At low-to-medium velocities, the sensor wires dragging over the eccentrics will usually produce multiple signals during the course of one contact resulting in gross errors in the digital displays of most counter units. A counter for use with a penta head Price meter requires a square wavelength input signal the length of which can be varied to suit the rotor speed.

The direct connection to the Price 622AA or Pygmy meter is accomplished by attaching one spade connector (or bare wire) to the meter/rod mounting screw (or the hanger mounting screw) while the other connector is attached to either terminal on the penta chamber. Connecting to the top terminal should generate 1 click/rev, connecting to the lower terminal produces one click per five revolutions. The Pygmy has one single count terminal.

> **Note:** An audio counter may be easily assembled using the following off-the-shelf-components: mini headphones with mini phone jack, phone jack socket, plastic pocket flashlight, length of lamp cable, and two or more open-ended #10 spade connectors.
>
> Assembly: Remove flashlight bulb socket and replace with mini phone jack socket. Disable flashlight on/off switch. Split one end of the lamp cable and connect it to either pole of the on /off switch. The other end of the cable can be fitted with the spade connectors or any other type of connector to match the meter suspension to be used. Solder all modified connections.
>
> Testing: Plug the headphones into the socket and touch the outer ends of the cable together several times. Matching clicks should be heard in the headphones as the circuit opens and closes.

Price Meter Rotation Sensing

The two following methods of modification result in providing clean signals to digital counters.

The so-called Low Velocity Price Meter is a standard 622AA with the penta chamber sensor replaced by a revolving magnet that activates a reed switch. This alternative sensor unit can be purchased as retrofit or supplied complete with the current meter, i.e. current meter “AA” Magnetic Head Model 1215. This type of current meter may be connected to a variety of revolution counting devices such as powered headphones, digital counters (including the impeller types described below), velocity display calculating units, and field computer interfaces.

> **Note:** All revolution indicators passing current through magnetic reed switches should have a spark suppression diode included with the unit or wired into the positive pole of the connector.
>
> **Note:** Velocity display units must employ time averaging over at least 40 seconds and should be capable of applying <u>changeable</u> current meter calibration equations.

The operational capabilities of the Photo-Fibre-Optic Swoffer 2200 quartz-timed counter/retrofit kit have already been described. This control unit, powered by a standard 9-V transistor battery, provides for input from both the retrofitted Price 622AA and Pygmy meters.

C.4.4.2 Counters for Horizontal Axis Current Meters

There are several types of counters available that are primarily designed to display the faster rate of pulse transmission generated by impeller type meters. The models are described below in ascending order of capability (and price).

> **Note:** The inexpensive and simple counter and stopwatch option is an awkward combination for streamflow measurement because the technician must simultaneously operate the start and stop buttons on both the stopwatch and

counter with one hand while holding the rod or handline steadily in position with the other.

OTT F4 and Z21 Revolution Counters

Every pulse generated by the current meter is counted. The instrument counts a maximum of 10 pulses/s and is thus suited for operation in conjunction with meters generating a signal at every revolution of the propeller. A button is provided for resetting to zero.

The OTT F4 is powered by two 1.5-V flashlight batteries, and the OTT Z21 is powered by four 1.5-V cells. Both instruments are used in conjunction with a stop watch.

CMC 20 and CMC 200 Counters

The CMC 20 and CMC 200 counters (Figure C-26 and Table C-8) are self-contained instruments featuring solid state circuitry, a quartz timebase, and LCD. Both counters are powered by six AA zinc carbon or alkaline cells.

An internal buzzer sounds at each contact closure during the timing period to indicate correct operation. The displays indicate time and count with a resolution of 0.1 seconds and one count respectively, to a maximum of 1000 seconds and 10 000 pulses. See Table C-9 for troubleshooting.

> **Note:** A small variable error is introduced when a counter is operated in the pre-set time mode. While the time count starts when the first pulse from the meter is received, the count stops at the end of the selected time period. If the counter "times out" between pulses, some portion of the pulse cycle will be ignored. This error will not occur in the CMC 200 or OTT Z210 when the pre-set pulse mode is selected.

The simpler of the counters, the CMC 20, displays the accumulated pulse count for a range of pre-set time periods. In addition an "integrate" range is included for use when integrating depth measurements are made with a ground-feeler weight. In the "integrate" mode the buzzer sounds continuously while the contacts are closed and counting continues until interrupted manually by the STOP switch. The use of a supplementary timer is necessary in this mode. The OTT Z210 has similar capabilities.

The CMC 200 counter includes the features of the CMC-20 combined with the choice of counter operation in fixed count mode. Dual displays indicate both time and count. The OTT Z200 has similar capabilities.

The Braystoke (BFN current meters) counter has capabilities similar to the CMC 200, although it is somewhat heavier.

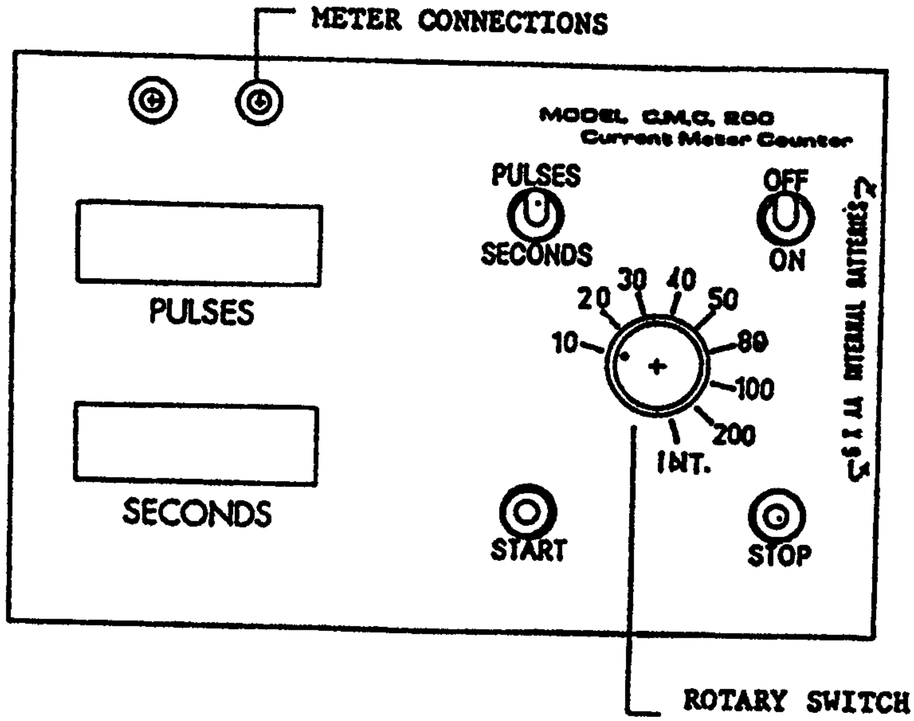
Table C-8. Features of the CMC-20 and CMC-200 counters.

Action	CMC-20	CMC-200
Pulses per second	N/A	Counter allows choice of fixed time or fixed count.
Start	Resets display and commences pre-set time interval.	When PULSES/SECOND switch is set to SECONDS, resets display and

		commences pre-set time interval. When PULSES/SECOND switch is set to PULSES, counting and time commences at the next pulse after operation of the START switch.
Stop	Stops further counting and allows the counter to be resent and restarted by the START switch.	In SECONDS mode, operation of the STOP switch disables the internal counter on the next whole second after STOP switch operation. In PULSES mode, operation of the STOP switch disables both the counter and internal timer on the next pulse after operation of the STOP switch.
Rotary switch	Selects a range of re-set time periods and the integrate mode for use with ground-feeler weights.	Selects a range of pre-set time periods for pre-set counts, depending on the position of the PULSES/SECONDS switch.
Display	Displays pulses on one display.	Displays pulses and time in 1/10 seconds on two displays.
Annual servicing	Replace batteries. Regenerate silica gel by heating contents of capsule at 100^0C for one hour (until blue).	

Table C-9. Troubleshooting faults: CMC-20 and CMC-200 counters.

Symptom	Possible Cause	Action
No count or audible signal while meter propeller turning.	Faulty leads or connections at one terminal.	Check loads for continuity. Check condition of plugs.
All decimal points showing on display.	Low battery voltage.	Check voltage. Low level is 5.5 V.



CMC-200 CONTROLS

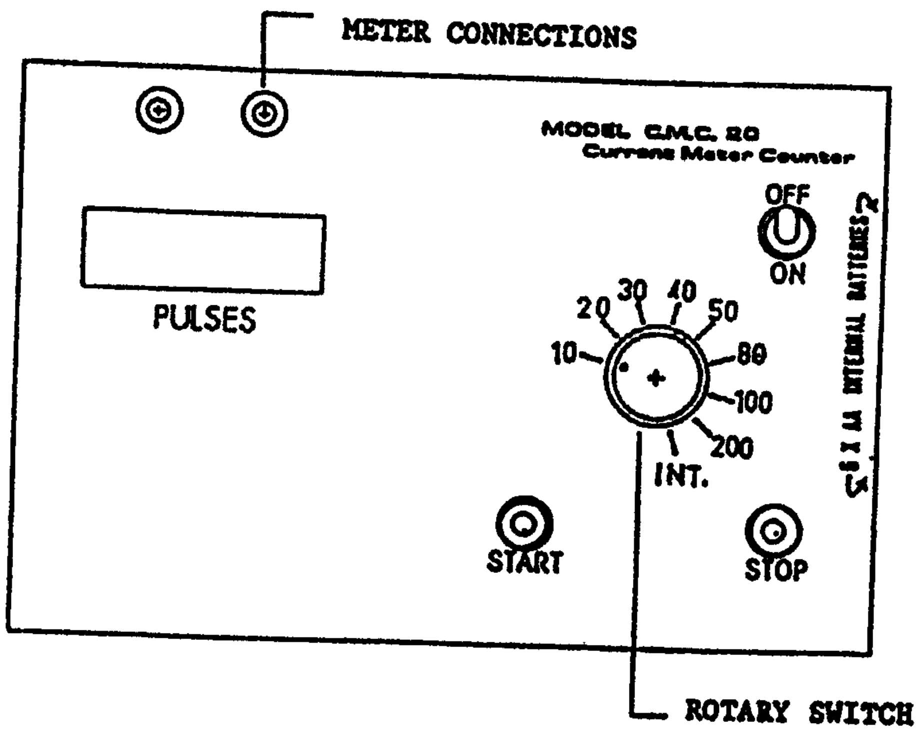


Figure C-26. Panel layout for the CMC-200 (top) and CMC-20 (bottom) counters.

C.5 Other Equipment and Assemblies

This section lists and describes other equipment and portable discharge measuring devices that may be included in the hydrometric operational inventory. Some of these items may form part of the kits supplied by most current meter manufacturers.

C.5.1 Rods

C.5.1.1 Standard (Conventional) Wading Rods

A conventional wading rod is an option supplied with all Price current meters. It usually consists of four ~13-mm diameter graduated rods that assemble to make up a rod 2.44-m long. The length of these rods can be extended by ordering additional sections for use in large culverts or low bridges. An adjustable sliding support attached to the rod holds the meter and meter tailpiece in place. Electrical connections are provided for hook-up to headsets or counters. To adjust of the depth of observation setting, the rod must be raised from the streambed.

European and Australian manufacturers provide three-piece 9-mm-diameter graduated rods with the small current meters. The top section of the rod is drilled to accept the negative plug from the counter. If a shorter length of rod is required, e.g. for placing the meter in a small-diameter culvert, an alligator clip, modified to accept the cable plug, may be used with either of the lower sections.

For the larger model meters such as the OSS B1, and the OTT C31 and C5, a 20-mm diameter conventional rod is provided. The current meter can be clamped directly on this diameter of rod while adapters may be supplied to accept Price AA and small current meters such as the OSS PC1 or the OTT C2. The rod is supplied in 1-m sections, which are graduated in centimetres and numbered decimetres. A suitable length of connector cable(s) to match the meters is needed. A meter relocating device for this rod is described later in this section.

C.5.1.2 Top Setting Wading Rods

Top setting rods (Figure C-27) are designed to securely position Price AA or Pygmy current meter at any desired depth while the technician wades the stream. Adapters for small propeller meters are available from the manufacturer. The design incorporates a graduated stainless steel hexagonal rod and a parallel round aluminum rod (earlier versions are round and square respectively), connected by a cast aluminum handle. The current meter and tailfins are attached to a sliding support on the base of the aluminum rod which is allowed to slide vertically for rapid positioning of the meter. A vernier on the handle permits automatic setting of the meter to any desired depth (Table C-10).

After the wading rod is placed into a stream and the water depth is read from the graduated hexagonal (round) rod, the vernier is used to position the current meter to the desired depth. Most models have an electrical connector mounted on the handle to attach the headset or revolution counter.

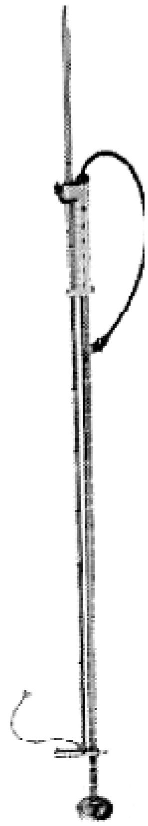


Figure C-27. Top setting wading rod.

Table C-10. Vernier settings for top setting rod.

Vernier setting	Actual current meter position
Exact water depth	0.4 up from streambed
Twice water depth	0.2 up from streambed
Half water depth	0.8 up from streambed

C.5.1.3 Bridge Rods with Relocating Device

The 20-mm rods described in Section C.5.1 can be supplied in 1-m sections to a maximum practical length of 7-m with sequentially number graduations. The OSS B1 and OTT C31 can be directly attached to this rod. Other meters may be attached using a variety of available clamping adapters; however, changing the placement of the meter to obtain the correct depth of observation can be awkward and exposes the meter to damage at sites where a long rod is required. To avoid these problems a relocating device should be employed (Figure C-28).

The manufacturers of the OTT and OSS current meters provide an assembly that gives top setting capability to a 20-mm rod of any length. The assembly consists of two or more 1-m sections of tube with locking connectors that fit over the 20-mm rod, providing an attachment point for the current meters. The use of the relocating device offers the advantage that the current meter can be positioned along the vertical in the measuring point without taking the equipment out of the water. The device, designed primarily for use with the B1, C31, and C5 meters, can also accommodate small current meters such as the PC1 and the C2, as well as Price meters. Adapters are required.

> **Note:** A company in Penticton, BC manufactures (to order) a similar complete assembly with identical capability.

Figure C-28. Relocating device.

C.5.2 Handlines, Hangers, and Weights

The handline (Figure C-29) provides a simple and effective method for suspending a meter and weight assembly and is an alternative to the bridge rod. The handline requires hangers and weights to counteract the effects of moving water.

The handline is lightweight, compact, and easy to operate. These features make it particularly useful for obtaining measurements in winter when roads are impassable by a vehicle and it is necessary to walk a long distance to reach a metering section. The technician normally uses the handline to meter from footbridges and on ice cover. However, the handline is also a useful substitute when regular equipment malfunctions.

The factors that limit its use in some cases are high velocities, excessive depths, and heavy weights.

Most current meter suppliers offer handline kits for use with the type of meter specified. The kits supplied for use with propeller meters usually include a weight of about 5-10 kg with matching hanger and pins. The meter calibration characteristics are usually identical to those of a rod-mounted meter. Price AA current meter kits can be combined with any standard Columbus weight (Figure C-30).

Figure C-29. Handline.

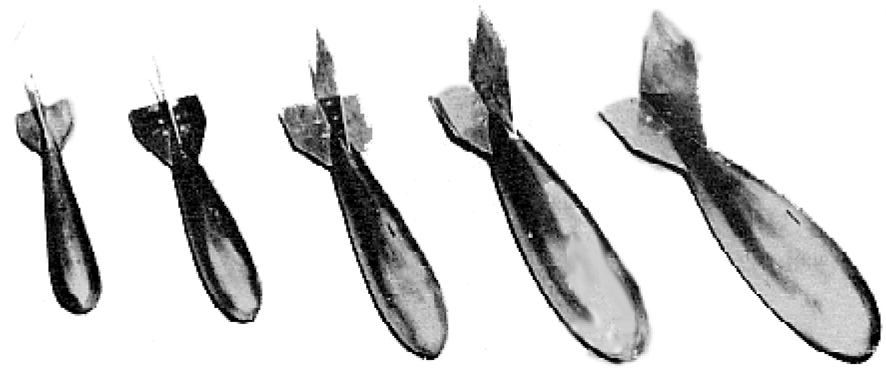


Figure C-30. Columbus weights.

A handline can be made from 15 m or less of 16-gauge cab tire electrical cord. The handline has a Cinch-Jones plug at one end and a cable thimble at the other. A clevis-type connector is fitted to the thimble. The cord is marked at 0.1-m intervals with strips of adhesive tape. The markings can be accomplished in the following manner: one strip for 0.1-m marks, two strips for 0.5-m marks and three strips to denote 1-m intervals.

Another way to make a handline is to spiral wrap a length of 1/16 inch galvanised aircraft cable with 16- or 18-gauge insulated automotive wire. The spiral wrap ensures that the aircraft cable carries the full load of the meter and weight assembly. The entire length of the wire and cable is then double-wrapped with a cloth type friction tape. The aircraft cable is secured to a clevis-type connector and the automotive wire is joined to the meter lead. The weight hanger and galvanised cable function as the return conductor.

A handline can also be made using Kevlar line instead of aircraft cable. However, because Kevlar is a non-conductor, two-conductor automotive wire must be used to transmit the electrical signal.

C.5.3 Reels

The American-made A55 sounding reel and a similar Australian model (Figure C-31) are light-duty sounding reels with a maximum load capacity of 45 kg. The reels are well suited for use in streams of low-to-moderate water velocity where cable length need not exceed 24 m. Reels can be utilized in a variety of situations such as bridge and boat boards, bridge cranes, and cable cars. The meter pulses are transmitted by the two conductor Ellsworth suspension cable through an electrical brush arrangement to the reel terminals. A two-position handle provides sufficient leverage for handling loads up to 45 kg, and the spring ratchet stop provides positive locking of the reel at any desired depth. Digital or analogue depth counters display depth.

Figure C-31. San sounding reel, made in Australia.

Associated Equipment. Three-wheeled bridge cranes, and bridge and boat boards can be purchased from suppliers. A combined bridge/boat board can be fabricated using a 3-m length of 50x150-mm (2x6-inch) fir as the jib on which an alloy plate fitted to accept the reel mounting studs is fixed. The outer end of the jib should be fitted with a 10- to 15-cm v-belt pulley.

C.5.4 Portable Flumes

A properly installed small Montana flume (Figures C-32 and C-33), which is a truncated version of a Parshall flume, can provide a convenient method of making accurate measurements of small streams and ditches. The common sizes (i.e. throat dimensions) for portable use are 76.2 mm (3 inches) and 152 mm (6 inches). Commercially available versions of the Parshall and Montana flumes are typically constructed of fiberglass; they may also be built of plywood or sheet metal) provided the dimensions shown in Table C-11 and Figure C-35 are followed precisely.

Installation. When installing either type of flume, the crest should be used as an index. Careful leveling is necessary in both the longitudinal and transverse directions if standard discharge tables are to be used. In addition, a Montana flume should be used only under free flow conditions, i.e. where the maximum submergence limit (50% for 3 inches, and 60% for 6 inches) will not be exceeded. A submerged flow condition will exist if the tailwater level divided by the flume gauge water level exceeds the percentages shown. Under free flow conditions a phenomenon known as the hydraulic jump forms and is a certain indication of free flow conditions. When a standing wave occurs downstream from the flume, submergence may be indicated.

> **Note:** When portable flumes are used to collect individual discharge measurements, the upstream backwater effect caused by the installation should be allowed to stabilize prior to obtaining the final gauge reading. This may take some time in watercourses with low gradients. In addition, ensure that any temporary changes to channel geometry due to the installation or removal of the flume does not affect the operation of a permanent reference gauge.

Figure C-32. Three-inch Montana flume set in temporary silt “dam”.

Note clamped-on gauge plate.

Figure C-33. Six-inch Montana flume set in permanent concrete sack structure.

Note angled approach at the entrance and attached gauge. This gauge is used when a small V-notch weir plate is inserted across the flume entrance to measure flows <4.5 L/s (h ≤ 0.06 m). See Figure C-34.

Figure C-34. Small V-notch weir plate inserted across flume entrance.

Table C-11. Dimensions for fabricating a Montana flume.

W	**A** mm	**2/3A** mm	**B** mm	**C** mm	**D** mm	**E** mm	**F** mm	**G** mm	**R** mm	**Max. Head** mm	**Max.** **Free flow disch.** L/s	**Min.**
3 in. or 76 mm	467	311	457	609	259	457	152	552	-	0.330	32	0.77
6 in. or 152 mm	621	414	610	915	397	610	305	800	406	0.457	110	1.5
9 in. or 229 mm	879	587	864	1169	575	762	305	952	406	0.610	251	2.5
12 in. or 305 mm	1372	914	1343	1953	845	914	610	1219	508	0.760	455	3.3

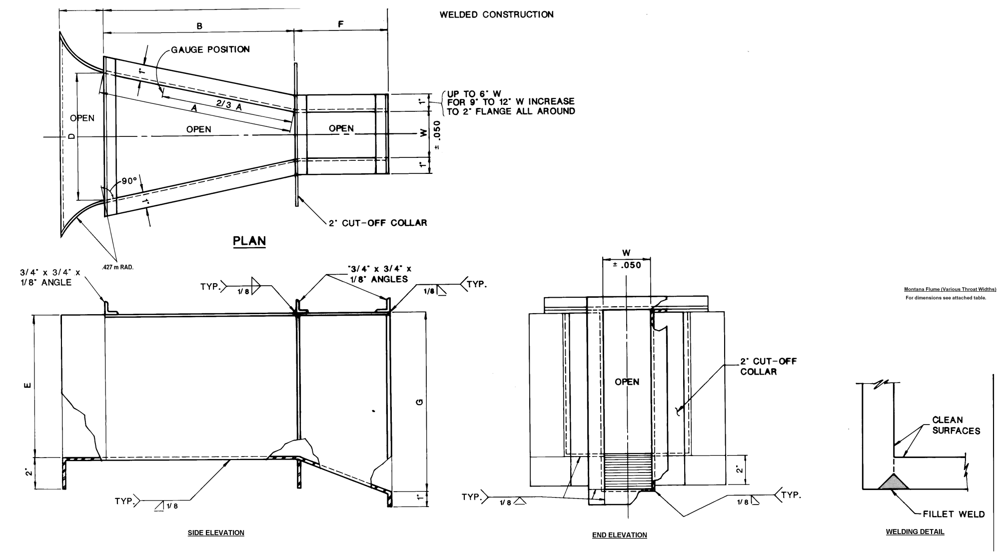


Figure C-35. Various throat widths for the Montana flume.

Improved Designs. The flow characteristics of these flumes can be improved by adding rounded, or angled, entrances in the form of bolt-on additions to the standard design. These improvements will smooth out the turbulence that will otherwise occur in the vicinity of the gauging point when the water level in the flume exceeds 50% of capacity.

C.5.5 Volumetric Measurement Equipment

Volumetric measurement is used to carry out fast, accurate measurement of flow. The sites chosen for such measurements are usually limited to the exits of culverts or below cascades with a clear confined nap.

In many cases culvert exits are too close to the streambed to catch the discharge in a suitably sized container. To convert these awkward sites to measurable ones may be accomplished by installing a 2- or 3-m length of plastic pipe in a sandbag and sheet plastic headwall. Setting the pipe to a level grade will often provide sufficient elevation above the streambed at the downstream end. In the absence of suitable piping, custom-made flumes can be constructed on site using 1x6-inch stock.

Volumetric containers should be calibrated by commercial standard weigh scales, stopwatches should be water resistant and rubber cased.

C.5.6 Metering Bridges

C.5.6.1 General

Metering bridges not only enable the measurement of watercourses that are too deep and swift to wade, but also provide a means of isolating the metering cross section from the effects of the operator's presence in the water. Bridges may be short lengths of plank spanning a ditch, or properly engineered structures for larger streams.

The following information contains suggestions for selecting a portable unit that may be carried between sites on a pick-up truck and placed in position by two people. An example of this type of portable bridge is shown in Figure C-36. It consists of a standard type heavy-duty aluminum ladder modified by the addition of rails mounted on struts to form load-bearing trusses. With a practical clear span length limit of about 5 m, the concentrated midpoint safe working load (S.W.L.) for design purposes should be 200 kg. Decking consisting of 9-mm plywood strips cut to fit between the rails is supported on the ladder rungs. As these units are not fitted with regulation guard rails they may be used only in situations posing no threat of accidents that would result in injury.

The suppliers of this type of equipment (such as Spider Staging Corporation, Richmond, BC) custom engineer and fabricate each unit.

C.5.6.2 Standard Metering Bridge

A cross-sectional view of the standard metering bridge design employed by WSC is shown in Figure C-37 together with a table of the stringer dimensions (Table C-12). Dimensions are shown for both log and sawed lumber stringers. The dimensions shown for lumber are actual rather than nominal sizes. Lumber stringers should be Douglas-fir, spruce, or cedar. Log stringers should be peeled.

Installation. Stringers should be laid level in both directions, resting on sills above well-compacted soil or concrete capped rock. The undersides of the stringers should be at least 1 m above the expected maximum water level. If the elevation on either bank is insufficient, bridge abutments should be constructed to achieve the necessary clearance, and spaced so as not to impinge on the wetted perimeter. Figure C-38 is a typical design sketch of a log crib abutment. Stringer overall length is calculated by using the formula in Note 1 below, i.e. clear span is measured between the inside faces of the bearing sills, overall stringer length shall be 0.3 m longer than the sum of the clear span and the outside dimensions of both sills or cribs. Stairways or ramps should be constructed at the ends of any elevated bridge ends.

Metering Section. All rocks, boulders, and debris must be removed from the streambed within 8 m upstream and downstream of the bridge to provide a smooth laminar flow in the metering section.

> **Note 1:** The overall length of stringer is calculated by taking the sum of the clear span and the total length of the supporting sills or crib structures (the stringers should rest on both the front and rear logs forming a crib) + 0.3 m.
>
> **Note 2:** Only one end of the bridge should be pinned to the supporting member, the other end should be allowed to slide between guide rails when center loading produces deflection.
>
> **Note 3:** Bridge rail posts shall have a maximum spacing of 2.44 m (8 ft).

Figure C-36. Portable metering bridge.

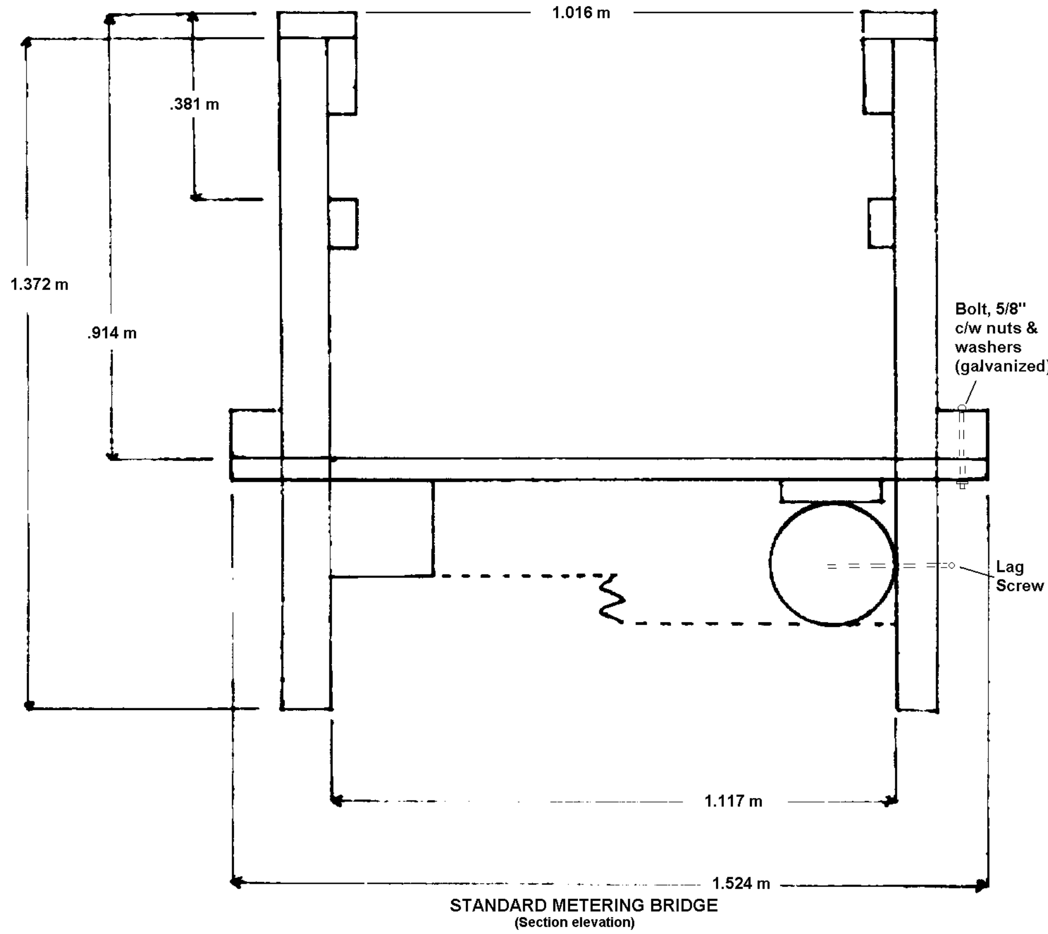


Figure C-37. Section elevation of a standard metering bridge.

Table C-12. Determining Stringer Size for a Clear Span.

Clear span		Lumber size		Stinger size	
M	**ft.**	**mm (w x d)**	**in.**	**m**	**in.**
0 - 4.50	0 - 15	203 x 203	8 x 8	0.230	9
4.75 - 6.10	16 - 20	203 x 254	8 x 10	0.254	10
6.40 - 7.60	21 - 25	254 x 305	10 x 12	0.305	12
4.90 - 9.15	26 - 30	305 x 305	12 x 12	0.356	14
9.50 - 10.70	31 - 35	356 x 356	14 x 14	0.406	16
11.00 - 12.20	36 - 40	406 x 406	16 x 16	0.457	18
12.50 - 13.70	41 - 45	406 x 475	16 x 18	0.457	18
14.00 - 15.25	46 - 50	457 x 457	18 x 18	0.508	20

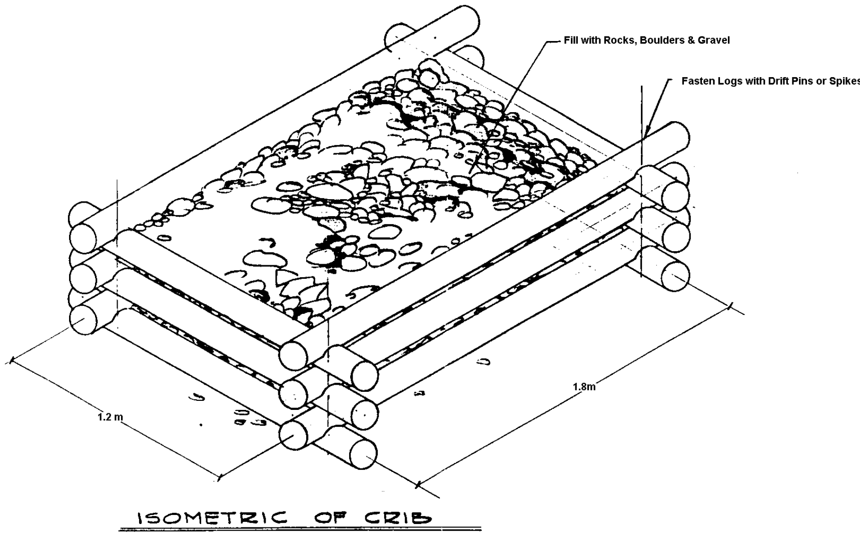


Figure C-38. Abutment for a standard metering bridge.

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D. Streamflow Measurement Procedures

D.1 Pre-Measurement Activities

D.1.1 Field Data Book and Forms

It is very important that the hydrometric field technician establish a record keeping system in the form of a field data book. All pertinent notes and information should be well organized in the field data book to facilitate planning, scheduling, decision making, equipment management, and overall record keeping.

The actual organization of the field data book is up to the individual, but it should be logically organized and kept up to date at all times. If for any reason a field technician can not undertake or complete the field work (e.g. due to illness or re-assignment), the field data book should give colleagues a clear understanding of the design, function, and history of the station.

The field data book should contain the following information for each gauging station:

- Form AQU-01 Description of Hydrometric Station
- Form AQU-02 Gauge Level Notes
- Form AQU-03 Discharge Measurement
- Form AQU-04 History of Gauge Level Check
- Form AQU-05 Summary of Discharge Measurements for the Year
- Form AQU-06 Water Stage Recorder - Station Record for the Year
- Form AQU-07 Station Analysis for the Year
- Form AQU-08 Stage-Discharge Rating Curve
- Special instructions regarding equipment, maintenance, techniques, conditions, etc. as an attachment to Form AQU-01 (see completed example, Figures B-10 and B-11 in Section B.2.3.2).
- Names of field staff, and contact information.

Appendix II at the end of this Manual contains blank forms and examples of completed forms.

D.1.2 Before Departing for the Field

Before departing on a field trip to gauging stations, the field technician should:

- Carefully review the information and notes in the field data book.
- Address all problems that were noted on previous field trips, and be prepared to handle them if they come up again.
- Gather all equipment that might be needed for all potential conditions, i.e. high, medium, or low flow, at all stations.
- Check and test all equipment to ensure that it is functioning correctly.

D.1.3 On Site Preparations

Prior to conducting the discharge measurement, the conditions of the watercourse must be assessed and recorded, and all the equipment must be checked and serviced if necessary.

D.1.3.1 Assessing Channel Conditions of the Watercourse

One purpose of assessing the overall conditions of the watercourse is to be aware of conditions that will affect the measurement, and to note conditions that could have affected the stage-discharge relationship since the last time the station was visited.

Also, assessing the conditions of the watercourse is important in deciding whether or not to go ahead with the measurement. In some conditions it will be unsafe or impractical to do the measurement.

To assess the conditions of the watercourse, look for the following conditions and make notes about them in the field data book:

- Weed growth at the metering section or on the control
- Debris floating or lodged in the proximity of the gauge
- Beaver activity
- Deposition of gravel or development of sand bars in the vicinity of the gauge
- Any obstructions in the vicinity of the gauge
- Erosion of the channel banks
- Overflow channels that are bypassing the metering section (must be measured or estimated)
- High winds
- Ice conditions

D.1.3.2 Gauges and Water-Level Recorder

After noting the conditions of the watercourse, read the gauges and water-level recorder:

1. Note the time and date in the field data book.
2. Record all the gauge readings. Or, obtain a water level by instrument. Note and record any differences (pen setting, gauge height, or water level).
   Note: An accurate determination of the mean gauge height is essential for plotting the results of the discharge measurement. If the stage appears to change while the measurement is in progress, it is necessary to obtain additional readings during the progress of the measurement.
3. Flush the stilling well intakes and make certain they are not obstructed. Observe and record any differences that occur after the flushing.
4. Service the recorder (see Appendix III for details). Remove the stage record that has been accumulating since the last visit to the gauging station.
   Wind the clock drive mechanism of the recorder. Set the pen to the correct time and gauge height.
5. Level check the gauge or gauges if required.
6. Make thorough notes in field data book about observations and procedures.

After taking the discharge measurement, obtain another gauge reading and observe whether the recorder drive system is operating properly and if the pen is tracking correctly. By this time the recorder will have been operating for approximately one hour and any error in setting the pen should be apparent.

This is also the time to check the recorder drive system to make certain that the clock weight spring has not caught on the shelf, or that the ratchet and pawl of a negator spring-driven recorder is disengaged.

D.1.3.3 Current Meter

Before using a Price 622AA current meter, inspect it to be sure the bearing surfaces are in good order. This can be done quite easily:

1. Loosen the bucket wheel raising nut so that the pivot wheel bearing rests on the pivot.
2. Gently rotate the bucket wheel and observe it as it comes to a stop. If the stop is gradual, then the bearing surfaces and the pivot are in satisfactory condition. If the bucket wheel comes to an abrupt halt or the motion is abnormal in any way, the pivot and bearings should be closely inspected.
3. Inspect the pivot and bearings if necessary. If there is evidence of wear, the meter should not be used. Have the meter professionally serviced and re-calibrated.
4. If the pivot and bearings are in good order, then go ahead with the discharge measurement.
5. Horizontal shaft "propeller" meters should be spun to confirm that the bearings and shaft are in satisfactory condition. How to check the propeller meter is described in Section C.4.2.6.

D.1.3.4 Observing Velocity

The guidelines for observing velocity (Figure D-1) are:

- Allow sufficient time for the current meter to adjust to water conditions. The adjustment time will be a very few seconds at high velocities, and significantly longer at low velocities. This adjustment period is very important at low velocities, i.e. <0.3 m/s, and the failure to allow for it could produce errors.
- Observe velocities for 40 to 70 seconds.
- Observe time to the nearest 1/2 second (stopwatch/meter rating table use), or the exact displayed time, when using the meter calibration equation to determine the velocity.
- Where water depth in the vertical is >1.0 m the velocity is measured at both 0.2 and 0.8 depth (from the water surface) with the current meter, and the mean velocity is calculated.
- Where water depth in the vertical is <0.8 m, observations are made at 0.6 depth (from the water surface) only. Using the 0.2 and 0.8 depth method in shallow watercourses places the current meter too close to the water surface and the channel bed to give reliable results.
- Where water depth is between 0.8 m and 1.0 m, the technician can choose the method.

- Usually, depth should be recorded to the nearest 2 cm. However, when wading small or shallow watercourses (<20 cm depth), depths should be recorded to the nearest centimetre. The important concept here is the total cross sectional area.

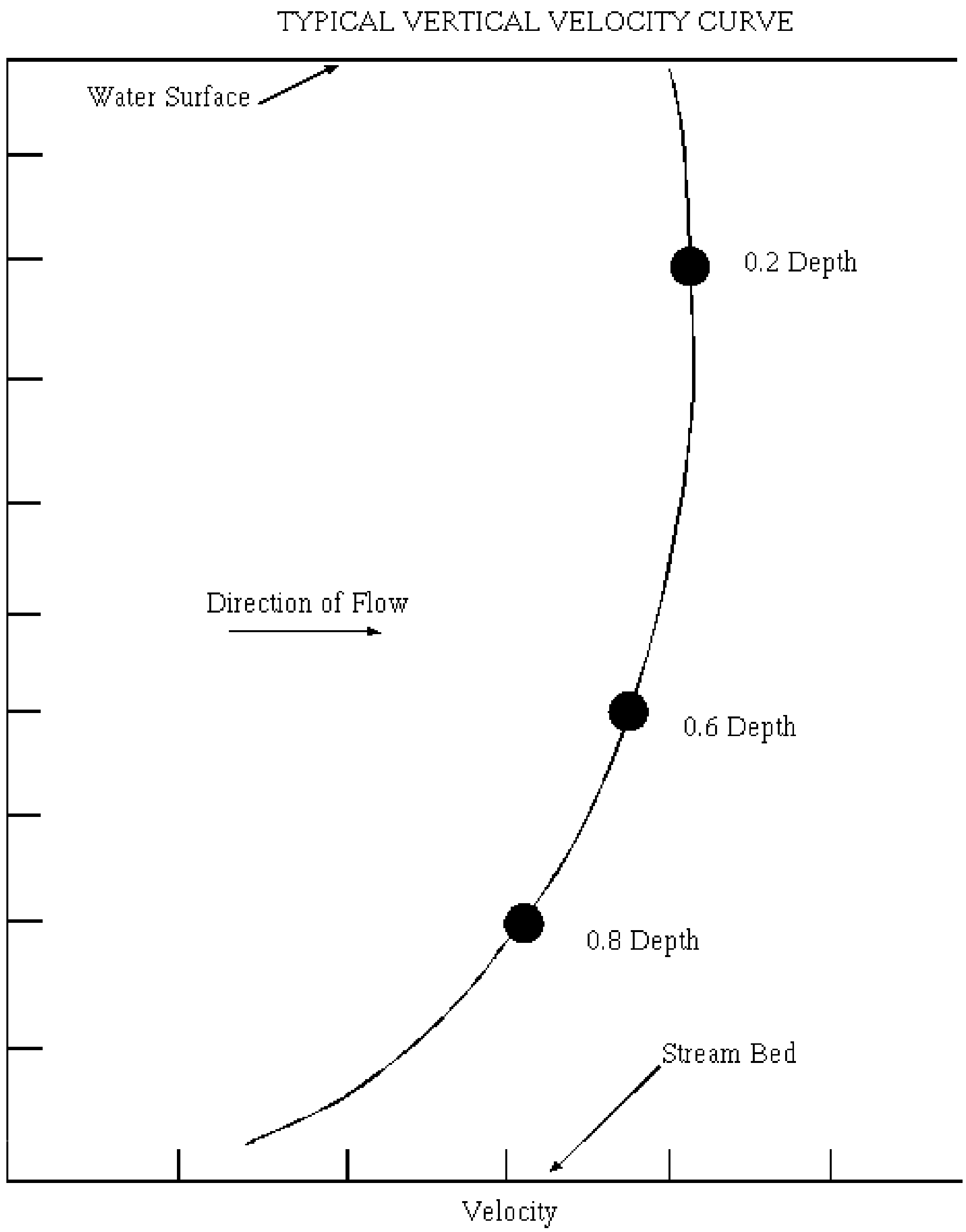


Figure D-1. Example of typical vertical velocity curve.

D.2 Discharge Measurement

This manual presents five basic techniques for making discharge measurements:

1. Measuring by wading (Section D.2.1)
2. Measuring from a bridge with a bridge rod (Section D.2.2.1)
3. Measuring from a bridge with a cable-suspended current meter (Section D.2.2.2)
4. Measuring from a bank-controlled cableway (Section D.2.3)
5. Measuring with small flumes and weirs (Section C.5.4)

Although other techniques exist, such as measuring from a boat, or using dye tracing and salt-dilution methods, they are rather complex for the non-specialist to apply, and are therefore beyond the scope of this manual. The non-specialist technician is advised to locate the gauging station at a spot along the watercourse suitable for conducting discharge measurements by one of the five basic techniques.

D.2.1 Measuring by Wading

D.2.1.1 General

If conditions permit, wading measurements are preferred to those obtained by other means.

Wading measurements are relatively easy to carry out, and computing the discharge can be simpler than for other techniques. However, in very small watercourses, e.g. ditches, the presence of the field technician in the water may significantly affect the flow. In this case, the technician should stand on a plank or log placed across the watercourse (Figure D-2).

D.2.1.2 Checking Safety Conditions

Check the overall conditions at the gauging station to determine if the watercourse can be waded safely.

Providing the channel bed is firm and provides good footing, a general rule of thumb for deciding whether conditions are safe is:

Depth (metres) multiplied by velocity (m/s) does not exceed a value of one.

This rule of thumb may be exceeded if a strong safety line can be installed across the metering section (Figure D-3).

Figure D-2. Ditch flow measurement using planks.

Figure D-3. Measuring by wading, with safety line angled upstream, Granite Creek near Tulameen.

D.2.1.3 Equipment Selection and Testing

If the metering section is very narrow or shallow, or if most of the verticals have depths of <0.15 m, use a small current meter. The Price meter tends to over-register if the buckets are only partially submerged; preferably, use it only where average depths are >0.15 m. Do not use an unmodified Price Pygmy meter in velocities under 0.5 m/s.

Test the current meter's electrical circuit before making the measurement:

1. Attach the meter to the wading rod.
2. Connect the electrical lead on the rod to one of the terminals on the meter contact.
3. Attach the headset, beeper, or counter to the receptacle on the handle of the rod.
4. Rotate the bucket wheel. If a headset or beeper is used, a series of sharp clicks or beeps should be heard. With a counter, the rotor revolutions will register in the viewing window. (Note: See Section C.4.4.)

D.2.1.4 Locating the Wading Section

If the gauging station has been in operation for some time, a wading section for making measurements will already have been established (Figure D-4). Inspect the wading section, and the reach immediately above and below it, to make sure it is still the most suitable.

Figure D-4. Conducting a discharge measurement with tagline across the wading section, Bridge Creek below Deka Creek.

D.2.1.5 Setting Up the Tagline and Establishing Verticals

To begin the discharge measurement, a tagline must first be placed across the watercourse.

1. Make a preliminary crossing before stringing the tagline. Use the wading rod as a support when crossing the watercourse. Turn the rod so that the meter is on the high end, or remove the meter from the rod so that it will not be damaged if a slip or fall occurs.
   Try to obtain an overall impression of the depths and velocities while wading. This is also a good time to look for rocks and debris that might be removed from the channel bed to improve the metering section. Be certain, particularly for very small watercourses, that removing rocks will not affect the control.
2. Anchor the tagline with the zero referenced to the initial point. The initial point is a permanently marked point at the start of a cross section, normally located above the high water mark on the right bank.
3. Wade across the watercourse, stringing the tagline at a right angle to the direction of the current.
4. Secure the tagline on either shore, and determine the overall width of the metering section.
5. Assess the approximate spacing of the verticals, according to the flow pattern. Follow the guidelines in Section B.2.4.
6. Proceed with the measurement.

D.2.1.6 Discharge Measurement Procedure: Mid-Section Method

The mid-section method of discharge measurement is described below, and illustrated in Figure D-5. Refer to Appendix II, Form AQU-03.

1. Record the starting time on Form RIC AQU-03.
2. Record the tagline distance for the edge of the water. If there is a steep drop at the edge of the stream, the first “vertical” depth and velocity observation should be taken close to the edge.
3. Move to the next vertical. Record the distance indicated by the numbered marker on the tagline. Observe and record the depth.
4. Set the current meter to the correct depth to obtain the velocity.
5. To obtain the velocity, count and record the number of revolutions the bucket wheel makes for a duration of time between 40 and 70 seconds.
6. Observe and record the time to the nearest 1/2 second.
   To use the current meter rating table, the number of revolutions counted should be one of the 13 that are listed. Current meter rating tables are designed so that the velocity in meters per second can be obtained directly, for a given number of revolution within the required time frame. The 13 choices of pre-selected revolutions are 5, 10, 15, 20, 30, 40, 50, 80, 100, 150, 200, 250, and 300.
7. If the procedure described above is not used, a double interpolation of both time and count is necessary to use the table to compute velocity.
8. Repeat the above procedure until the watercourse is traversed and the measurement is completed.
9. After completing the measurement, note and record the time and water level.

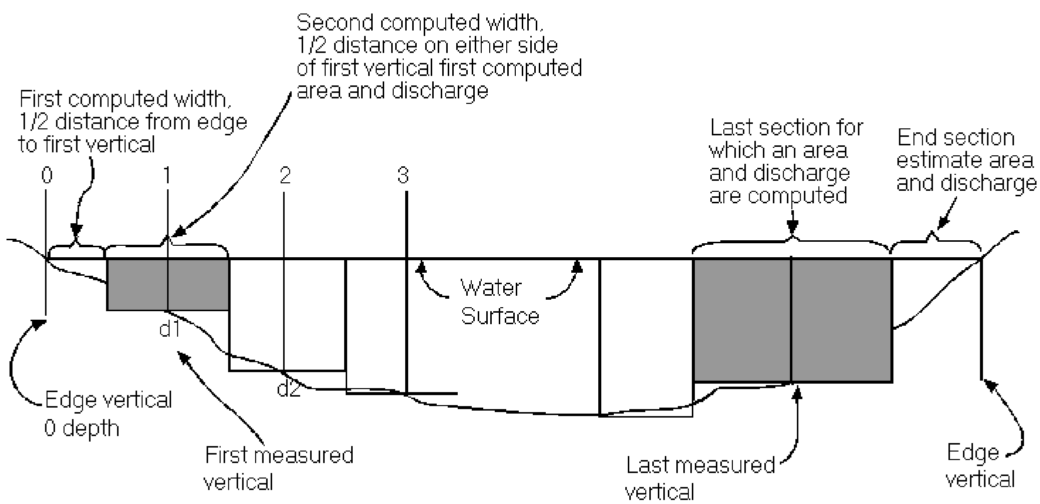


Figure D-5. Mid-section method of discharge measurement.

D.2.1.7 Precautions and Tips

To obtain accurate measurements by wading, the technician must pay attention to detail and technique. If followed carefully, these suggestions will help obtain reliable results:

1. ***Position the tagline correctly.*** Take the time to ensure that the tagline is placed in a position that is perpendicular to the direction of the current.
   Even when this precaution is taken, there will still be instances where angular flow occurs. When this happens, record the cosine of the horizontal angle.

2. ***Improving the metering section.*** Where necessary, take the time to improve the metering section by removing boulders and debris from the metering section and the area immediately above it. Remove weeds for a distance of about three times the depth from the area upstream and downstream from the section. On smaller watercourses it may be possible to construct small dikes to cut off sections of shallow flows and dead water.
   After the modifications are made, be certain to allow sufficient time for conditions to stabilize before proceeding with the measurement. Note if the modifications have an influence on the gauge reading. All improvements to the metering section should be completed before starting the measurement, i.e. do not make changes to the metering section (such as by moving rocks) during the course of the discharge measurement.
3. ***Spacing of Verticals.*** Obtain 20 - 25 observations of both depth and velocity for one complete measurement (Section D.3.1, Errors Affecting Accuracy). If the cross section is narrow, do not space the verticals closer than 0.15 m when using the Price 622AA meter because the distance between verticals must be greater than the diameter of the current meter bucket wheel.
   If the cross section is very narrow, use a small meter and space the verticals more closely. The small propeller meters are usually supplied with 50-mm diameter propellers, and 30-mm interchangeable types are also available.
4. ***Position of the technician.*** The field technician's position with respect to the current meter is very important when making a discharge measurement by wading. The technician should stand to the side and downstream from the meter so as not to influence the velocity (Figure D-6). Studies show that the following position has the least effect on the operation of the current meter: stand in a comfortable and safe place facing either shore, and no less than 0.4-m downstream and to the side of the current meter.
5. ***Position of the current meter.*** Hold the wading rod in a vertical position and the current meter parallel to the direction of flow while making the velocity observation.
   Vertical axis meters - if the axis of the meter is not kept vertical, the meter will tend to under-register.
   Horizontal axis meters - many propellers are designed to compensate for angular flow. Consequently any deviation from the vertical position of the rod will introduce an error in velocity.
6. ***Observing Velocities.*** If depths are sufficient, the 0.2 and 0.8 method should be used for observing velocities. It is quite easy to make the settings on the top setting wading rod.
   To set the 0.2 depth position on the rod, simply double the value of the observed depth. Set the 0.8 depth position as one-half of the observed depth.
   Example: Observed depth = 0.96 m.
   For the 0.2 depth, set 1.92 on rod.
   For the 0.8 depth, set 0.48 on rod.
   Note: The 0.2-0.8 method is not entirely satisfactory if the channel bed is very rough, irregular, or covered with aquatic growth. These conditions will often produce erratic results for the observation at the 0.8 depth. In some situations, more reliable results will be obtained by computing the average velocity on the basis of the 0.2 and 0.8 depths and averaging the computed value with the velocity from the 0.6 depth. This is known as the three-point (3 Pt.) method.

7. ***Uneven Channel Bed.*** Sounding a channel bed that is extremely soft or strewn with boulders requires a great deal of extra care and attention.
   Be careful not to over-sound by allowing the bottom of the wading rod to sink into soft channel bed material. If the channel bed is very rough, take time to adjust the observed depths so that they reflect both the tops of the boulders and the depths between them. Measuring verticals should be equidistant around the vertical line which define the breakpoint on the edge of the submerged obstruction (Figure D-7).

   Sometimes there may be a near-vertical boundary separating zones of different depth or velocity. In this case, position the adjacent measuring verticals equidistant from this boundary, so that the boundary coincides with the common boundary of the partial sections.

Figure D-6. The technician is positioned downstream and to the side of the meter.

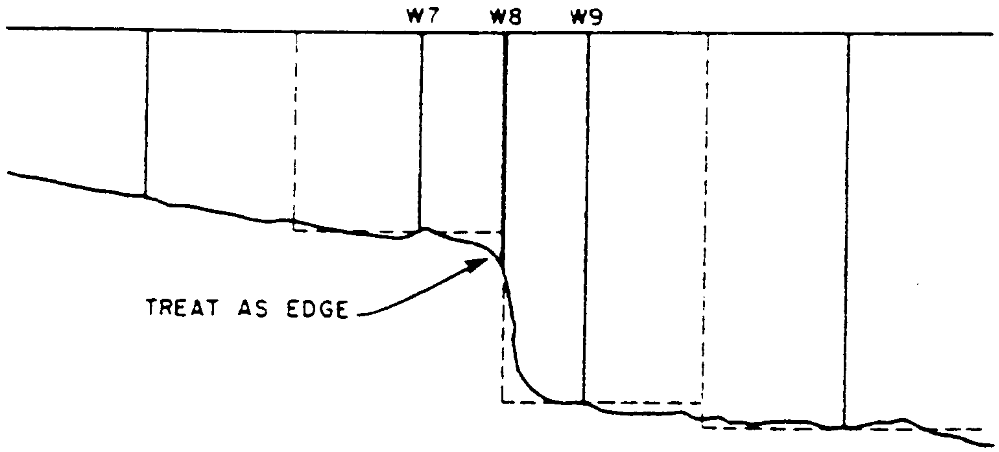


Figure D-7. Defining the breakpoint.

D.2.2 Measuring from a Bridge

If a watercourse can not be waded, discharge measurements can be made from a bridge or cableway (Section D.2.3). Measurement cross sections under bridges are often satisfactory for current meter measurements, but cableway sections are usually superior.

Either a bridge rod (Figure D-8) or a cable/weight suspension system can be used to position the current meter in the watercourse.

Figure D-8. Bridge rod in use on downstream side of bridge.

The cable supporting the sounding weight and current meter may be suspended from a handline (Figures D-9 and D-10) or one of several models of sounding reels. Handlines and sounding reels mounted on bridge boards (Figure D-11) are especially useful when carrying out measurements from logging or farm bridges with no guard rails; however, these assemblies are limited to sounding weights less than 22 kg. Three- or four-wheeled bridge cranes (Figure D-12) can accommodate sounding weights of up to 77 kg, depending on the model of sounding reel, but can be used only on bridges with strong guard rails.

The discharge measurement can be made from either the upstream or downstream side of the bridge. Make this decision independently for each bridge, according to the advantages and disadvantages in each case. Also consider the physical conditions at the bridge, such as location of the walkway, traffic hazards, and accumulation of trash on pilings or piers.

The advantages of measuring from the upstream side of the bridge are:

1. Hydraulic characteristics on the upstream side of bridges are usually more favourable.
2. Drift material can be avoided more easily because it can be seen it coming downstream. With downstream measuring, an assistant may be needed to watch for floating debris.
3. The channel bed at the upstream side of the bridge is not likely to be scoured as badly as the downstream side.

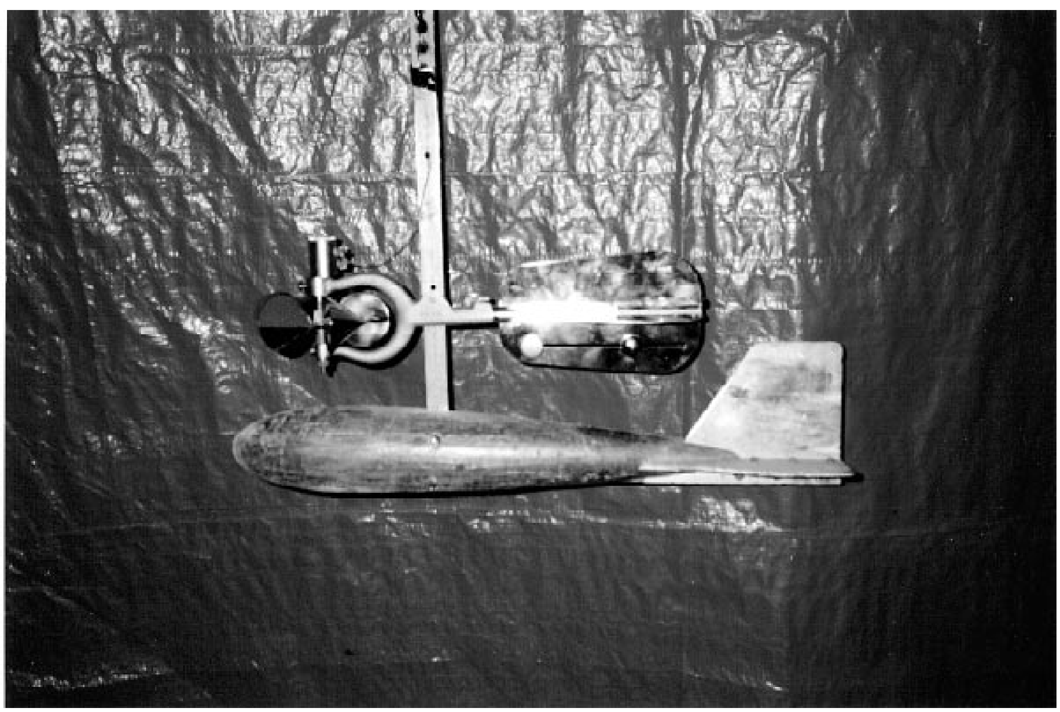


Figure D-9. Price 622AA meter mounted on a 1-ft. hanger, with a 30-lb. Columbus weight.

Figure D-10. Handline-suspended meter and Columbus weight. Just over 1 m of sounding cable unwound from reel. Tags 0.5 m and 1.0 m above centre of meter.

Figure D-11. Sounding reel/bridge board mounted on a boat.

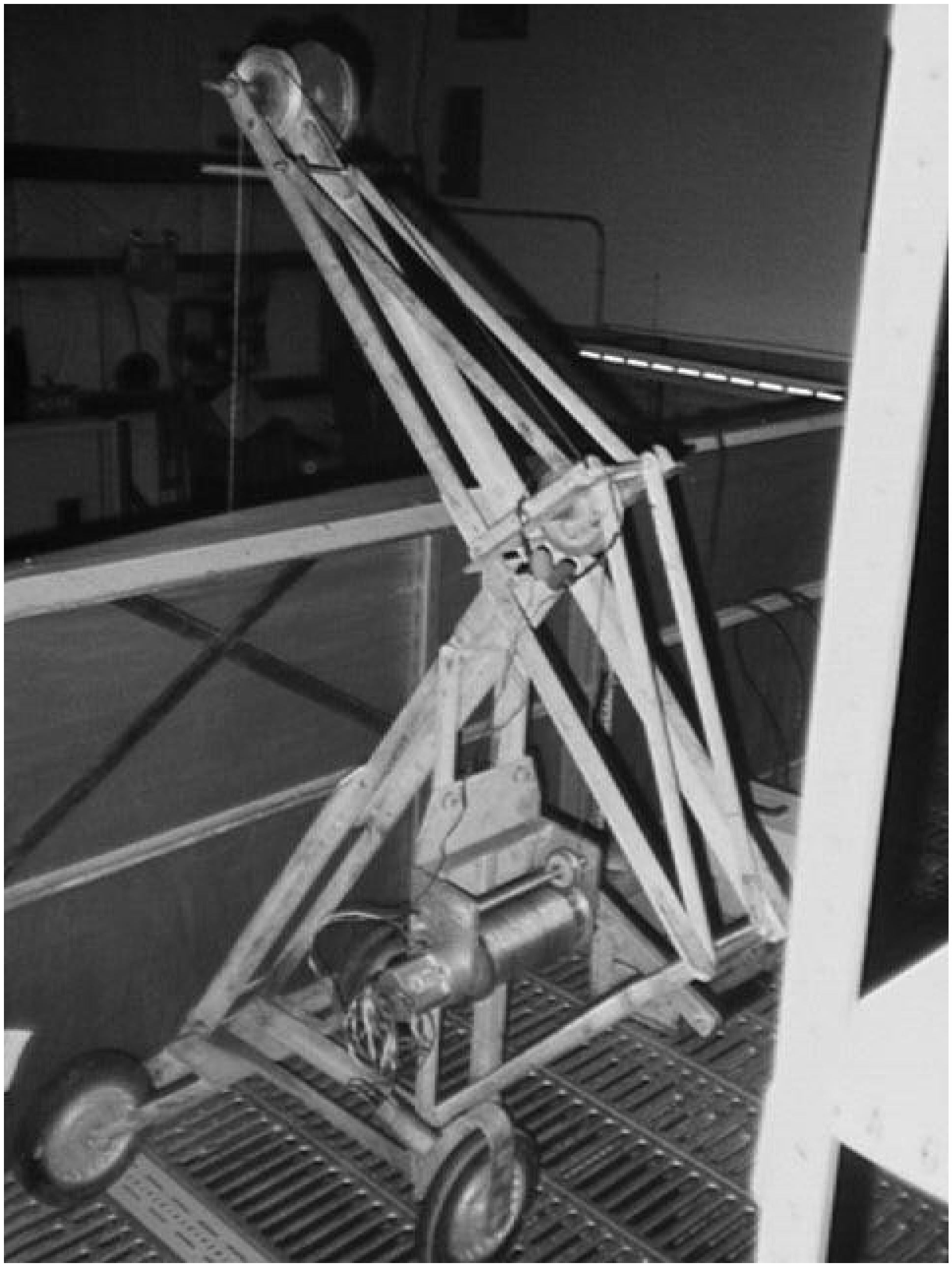


Figure D-12. Three-wheeled bridge crane.

The advantages of using the down stream side of the bridge are:

1. Bridge rods are less likely to suffer damage from bending over the edge of the bridge if caught by the current and/or debris.
2. The vertical angle of a cable-suspended current meter is more easily observed.
3. Bridge abutments and piers can straighten flow lines in some cases.
4. If the bridge is angled across the channel, a single horizontal correction for angular flow can be applied to the measured discharge.

D.2.2.1 Measuring with a Bridge Rod

1. Assemble sufficient sections of rod to reach the deepest point of the channel bed. Probe the channel bed with the rod to determine the range of depths along the metering section. Then determine the number of outer rod sections required, based on the following criteria:

    a) To determine the depth, raise the meter to the surface, and read the graduated inner rod where it emerges at the top of the location device. From this value, subtract the number of outer sections (1 m per section) to obtain the depth.

    b) Multiply the depth by 0.2, and lower the meter to the obtained value. Again this is done by subtracting the number of metric sections of outer rod.

    c) The two values above represent the maximum range of readings to be made from the bridge deck. They also determine the number of inner and outer rod sections required.

2. Complete assembly of bridge rod and current meter. Attach two conductor electrical cables between meter and counter or headphones. Tape the cables to the outer rod sections at several points. Make sure the wires will not touch the propeller or meter cups.

3. Depending on the type of site, stretch the tagline along the top of the bridge rail, the edge of the culvert headwall, or across the face of the culvert barrel.

4. Locate the initial point. It will usually be the bridge abutment, and should be on the right bank.

5. Prepare the discharge measurement field notes. From the initial exploration of depth and velocity distribution, decide on the spacing of the verticals and the mode of measurement required, e.g. a 0.6 depth measurement if none of the depths exceed 1.0 m (Section D.1.3.4, Observing Velocity).

6. Read the gauge. Note the time before starting the measurement.

7. Record the tagline distance from the initial point to the edge of the water. Record the depth at water's edge.

8. Position rod at the 1st vertical. Position the meter at the water surface with the propeller or cups half submerged. Lock the locating device and read the graduated rod at the top of the outer rod. Subtract the number of 1-m sections of outer rod and record distance from the initial point (station) and depth (Figure D-13).

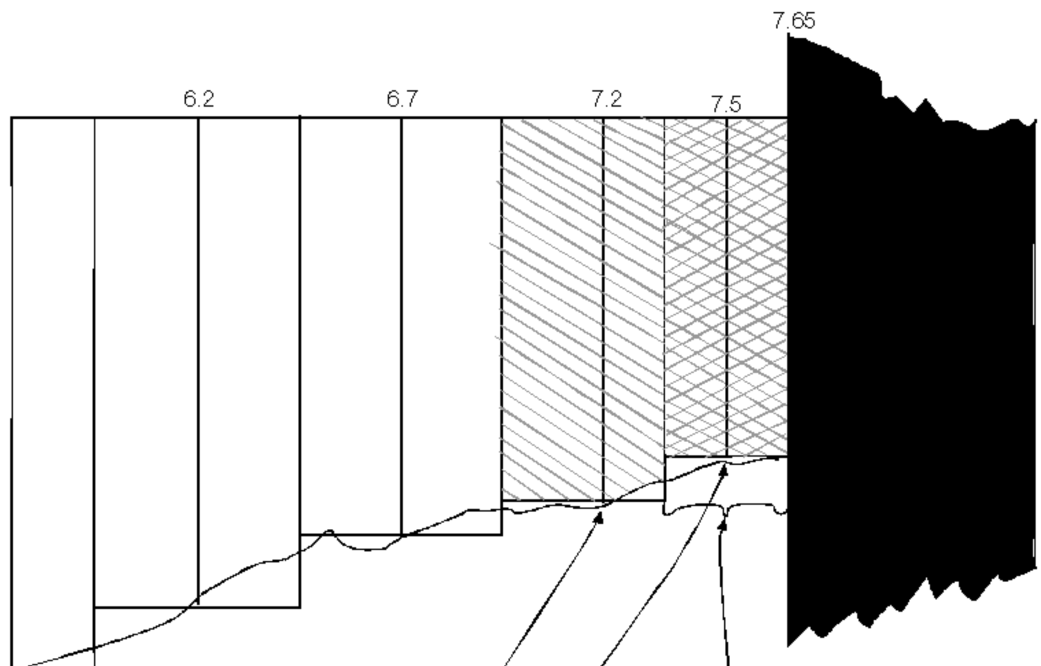
9. Calculate the meter depth setting(s).

    Note: Meter settings are referenced to the water surface. Therefore, when calculating their values on a rod (measuring from the channel bed), use the reciprocal values of the 0.2, 0.6, and 0.8 methods. For example. to position the meter for a 0.6 measurement of velocity, multiply the observed depth by 0.4.

10. Set the meter at the required depth, allow it to stabilize, and start the counter or stopwatch. The number of revolutions divided by the interval in seconds produces the value “n”.

11. Continue measuring distance, depth, and velocity along the cross section.

12. End the measurement at the water’s edge on the left bank. Record distance from initial point (i.e. tagline distance), depth, time, and water level.



OBSERVATIONS									COMPUTATIONS		
Method	Distance from initial Pt.	Depth	Depth of observation	Revolutions	Time in seconds	Cosine of flow angle	Velocity At Point	Velocity Mean in vertical	Width	Area	Discharge
2 pt.	5.7	1.4	0.28						.5	.7	
			1.12								
2 pt.	6.2	1.2	0.24						.5	.6	
			0.96								
2 pt.	6.7	1.02	0.20						.5	.51	
			0.82								
2 pt.	7.2	0.94	0.19	75	50		0.743	0.644	.4	.376	0.242
			0.75	55	50		0.546				
2 pt.	7.5	0.84	0.50	63	50		0.575	0.575	.3	.252	0.145
	7.65	to	8.25	pier							

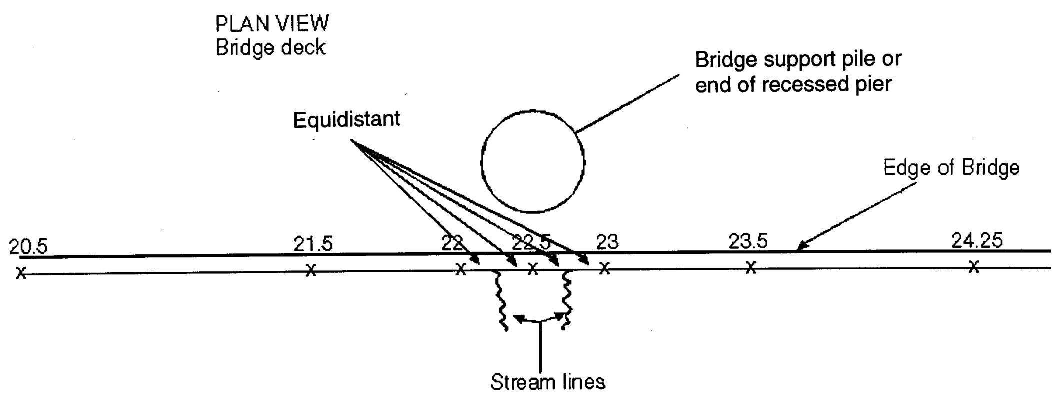
Note: The distance between the face of the structure and nearest vertical should never be less than the diameter of the rotor or propeller of the meter, and then only when the technician can maintain precise control over the lower end of the rod when it is being positioned.

Figure D-13. Measuring around piers and abutments

Precautions and Tips

The following suggestions will help in obtaining reliable measurements with the bridge rod:

1. ***Securing the Stayline.*** The assistant can double as the controller of a stayline secured to the base of the bridge rod. Usually a line may be floated under a bridge or through the barrel of a culvert and hooked up on the downstream side. The stayline will also aid in repositioning the rod, and it will help stabilize the meter during velocity measurement.
2. ***Dealing with Pilings and Piers.*** If bridge pilings or piers are in the cross section, treat the intervening stretches of water as separate channels in order to remove the combined area of piers from the computed total cross sectional area of the watercourse. If the pilings or piers are recessed from the outer edge of the bridge, then ensure a vertical is positioned at the point of convergence of the flow lines downstream of the pier, and that the adjacent verticals are equidistant (Figure D-14).



Note: In the example shown, the locations chosen for the three verticals downstream of the bridge support are designed so that the segment boundaries between verticals upstream piles.

When measuring the velocity downstream of an obstruction by cable-suspended assemblies, i.e. (22.5), the behaviour of the meter must be closely observed both for angled orientation and erratic revolution patterns. The existence of such conditions will indicate a gross over-registered revolution count. Estimating the velocity would be the best choice. Rod-mounted meters fitted with wide-angle compensating propellers will usually produce reasonably accurate velocities under these circumstances.

Figure D-14. Position of meter in cross section downstream of pier/pile.

D.2.2.2 Measuring with a Cable-Suspended Current Meter

General

Another alternative to wading is to make discharge measurements when the current meter is suspended on a cable by a handline suspension (Figure D-15) or a reel suspension (Figure D-16).

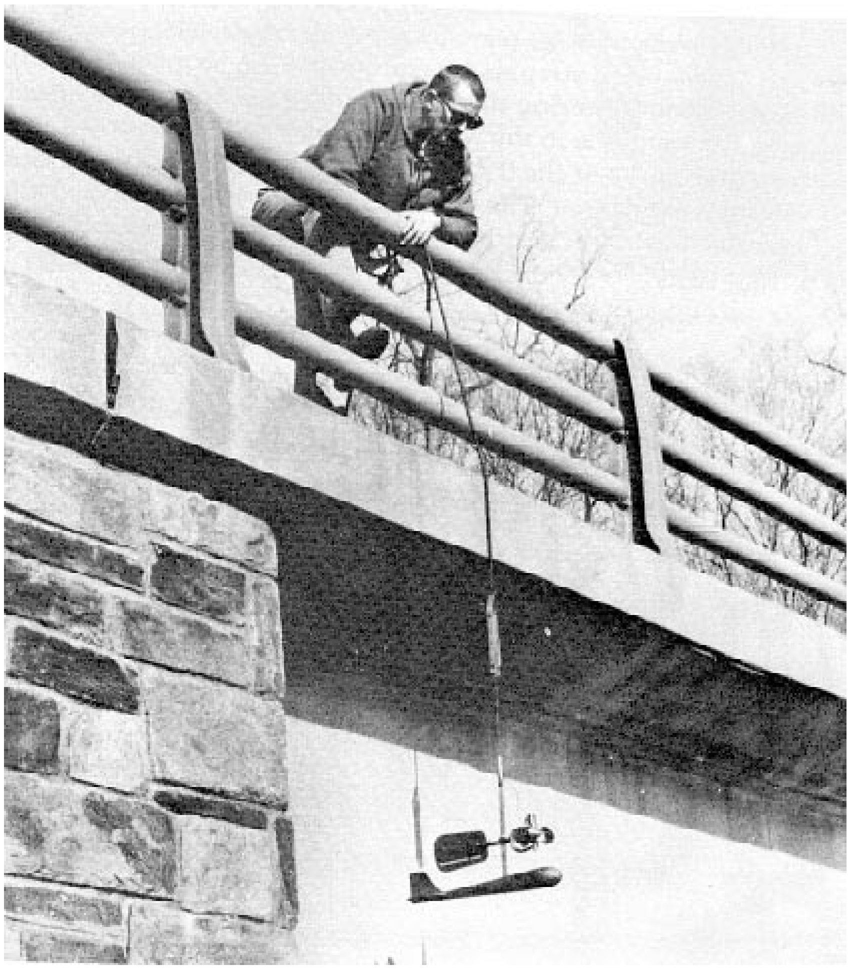


Figure D-15. Handline in operation.

Figure D-16. A55 reel and bridge board mounted in boat (Nechako River).

The previous sections about rod suspension of current meters pointed out that although all settings of the current meter in the vertical plane are referenced to the water surface, reciprocal values are used to position the current meter on the rod relative to the channel bed. Likewise, all cable-suspension measurement values, such as depth of observation, are directly related to the water surface.

Preparations and Procedures Common to All Cable-Suspended Systems

1. Note: to determine the appropriate size (in kg.), multiply the maximum depth (m) and the maximum velocity (m/s) by 5.
2. Depth and velocity observation settings can be accomplished in a number of ways, depending on whether or not floating debris is present, and the type of equipment to be used:

    a) Place tags (usually streamers of survey tape) on the sounding line at known distances above the center of the meter cups or propeller blades. Attach the tags to the cable by carefully threading the tape under a single strand of sounding cable wire, and position the tags at 0.5-m intervals above the center of the meter. The tags are required to determine stream depth and depth of meter for velocity observation. They also allow the meter to remain submerged throughout the discharge measurement, thus avoiding floating debris.
    A 0.5-m measuring stick or steel tape is also required.

b) The Price 622AA current meter is designed to be mounted above Columbus-type weights by means of a hanger bar (known as an M2 hanger) and hanger pin. The M2 hanger (Section C.5.2) provides for the correct spacing between the meter and the various sizes of Columbus weights (Table D-1).

c) Meter calibration varies with weight size and type and position of the meter on hanger; the user must ensure that the correct meter rating is used. A table of various suspensions and minimum operating depths is shown (Table D-1).

3. In cases where current drag deflects the cable in excess of 10 degrees from the vertical, a correction for depth should be applied. Information and tables for this correction can be found in the literature. Generally, this applies only to deep and fast rivers.

Table D-1. Columbus Weights: Suspensions and Operating Depths.

Position of meter above	Minimum operating depth	
Bottom of weight	0.6 method (m)	0.2 & 0.8 method (m)
15 lb @ 0.15 m 30 lb @ 0.15 m	0.37	0.76
50 lb @ 0.17 m	0.43	0.85
50 lb @ 0.27 m	0.67	1.37
100 lb @ 0.30 m 150 lb @ 0.30 m	0.76	1.52

Cable Suspension Control with a Handline

If discharge measurements made from a bridge require light sounding weights (i.e. 15 to 30 lb; 5- to 15-kg Ott weights) the weight and meter are often suspended on a handline.

A handline is the cheapest and most compact assembly for suspending weights. A handline is easy to assemble, and easy to use from certain types of bridges, particularly logging or farm bridges without guard rails, and truss bridges that do not have cantilevered sidewalks. See Section C-5 for a description of handlines.

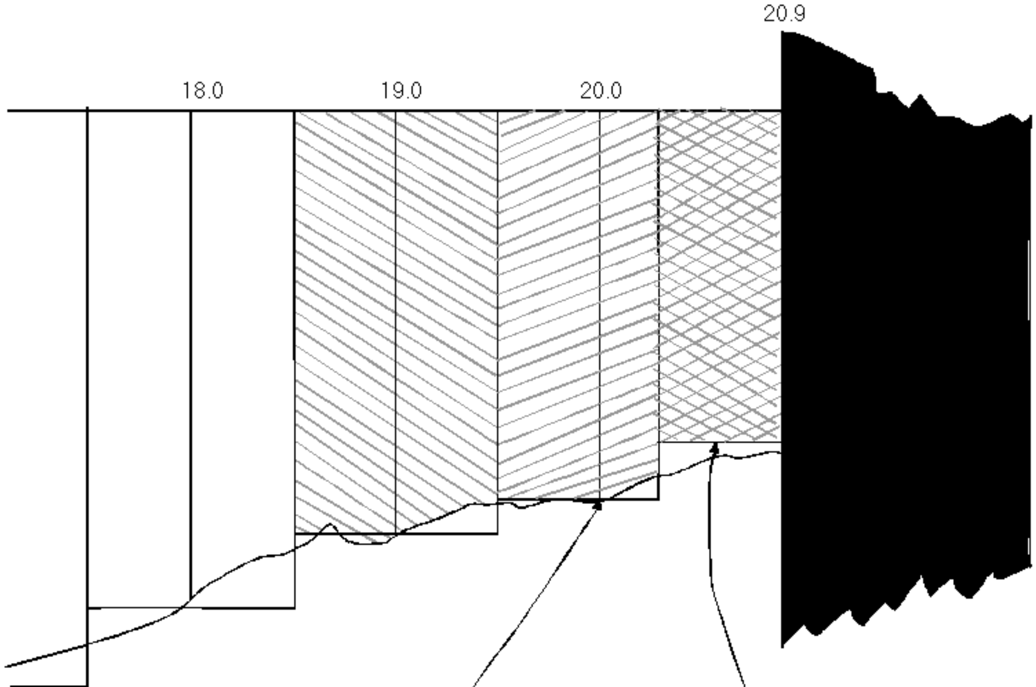
However, the handline does have disadvantages. Its has a lesser degree of accuracy in determining depth of water than a sounding reel, more physical exertion is required, and the velocity/depth combination is limited by the maximum weight the field technician can manipulate.

Measuring with a Handline

1. Select a weight. Connect it to the hanger using the special connector pin.
2. Mount the current meter in the lower hanger hole.
3. Attach the sounding cable connector to the top hole of the hanger.
4. Measure the distance from the bottom of the weight to the center of the meter and record it on the Discharge Measurement RIC Form AQU-03. Check the

distance of sounding cable streamers (tags) from center of meter (normally 0.5 m intervals)

5. Stretch the tagline over cross section. Prepare the Discharge Measurement notes sheet, noting gauge reading and time.
6. Connect headphones or counter to handline; spin meter, and check circuits.
7. Estimate or measure water depth at the deepest point on the cross section and unwind sufficient sounding cable from the reel (at least one tag marker should be showing above the water).
8. Using the sounding line as a plumb-bob to define the water's edge, record the horizontal (tagline) distance and depth (depth may be zero).
9. Move assembly to the first selected vertical (as close as possible to the bridge abutment), and start the measurement.
   Use the following method to measure depth and meter depth settings (Figure D-17).
10. To determine depth, first lower the sounding weight to the channel bed and then raise the weight until one of the tags is at the water surface.
    Measure the distance that the weight is raised. Using a reference point on the bridge, measure along the rubber-covered cable with a steel tape or graduated rod.
    Total depth of water = distance of the particular tag above the meter cups + distance the meter and weight were raised + distance from the bottom of the weight to the meter center.
11. To set the depth of observation for velocity, multiply the depth by 0.6, or 0.2 and 0.8, and position the meter by means of the tag markers and measuring tape on rod. Weights up to 25 kg can be held in position by standing on the rubber-coated cable inside the bridge rail or guard.



OBSERVATIONS							COMPUTATIONS				
Method	Distance from initial Pt.	Depth	Depth of observation	Revolutions	Time in seconds	Cosine of flow angle	Velocity At Point	Velocity Mean in vertical	Width	Area	Discharge
2 pt.	18.0	2.40									
2 pt.	19.0	2.02									
2 pt.	20.0	1.84		50	44.5		0.757	0.700	0.80	1.472	1.0304
				40	42		0.642				
	20.9	E 1.6	Edge pier	66%	of 20.0			0.462	0.60	0.96	0.4435

Note: To avoid equipment damage, the vertical closest to the face of an abutment or pier must be located a sufficient distance from the edge to allow for the lateral swing of the meter/weight assembly, and estimate the average depth and velocity.

The width of the estimated discharge panel is two-thirds the distance between the face of the structure and the nearest measured vertical.

Figure D-17. Spacing of verticals when measuring around piers.

Measuring with a Sounding Reel

A sounding reel is an alternative to using a handline to suspend the current meter in the watercourse.

The steps for determining depth and position of the current meter in the vertical are the same as described for the handline.

1. Select a weight. Connect it to the meter/weight hanger.
2. Measure and note the distance from the bottom of weight to the center of the current meter. If floating debris is present, attach a streamer tag to the cable 0.5 m above the center of the meter so that the meter can remain submerged.
3. To observe depth, lower the center of the meter to the water surface and set the depth counter to zero. Lower the weight to the channel bed. Read the counter and add to it the distance from bottom of weight to the center of meter. This is the observed depth.
4. To set the depth of observation for velocity, calculate the value for depth below the surface (multiply depth by 0.2, 0.6, or 0.8). Raise the meter until the obtained value is displayed in the counter.
   If debris is present, position the tag at the water surface and set the tag distance above the meter on the reel counter. Lower the weight to the channel bed and read the counter.
   Depth = counter reading + distance from bottom of weight to center of meter + distance from center of meter to tag.
5. To set the depth of observation, raise the assembly until the counter registers the calculated depth below the surface.

D.2.3 Measuring from a Bank-Controlled Cableway

Conducting the measurement with a cableway is generally preferred to doing it from boats or from bridges with piers. The lengthy set up time required for boat measurements is eliminated as are areas of disturbed flow caused by bridge abutments and piers. Safety of personnel, and the possible need to employ a certified boat operator, are other factors that make cableways attractive.

Bank-controlled cableways employ a capstan drive arrangement that moves a traveler across the river and positions the meter vertically and horizontally. They also send a signal from the meter through the suspension cable to the operator on shore, for velocity measurement. Cableways with cable cars for personnel are outside the scope of this manual. See Section C-5 for a description of two kinds of bank-controlled cableways, and photographs.

Measuring with a Cableway

1. Record the size of weight and the position of the meter above the bottom of the weight or bottom feeler plate.
2. Locate the initial point. It will usually be located near the top of bank on the control side of the watercourse.
3. Position the meter over the initial point, and set the horizontal displacement at zero. Move the meter assembly directly over the nearest water edge and note distance from the initial point. **Do not touch the horizontal reset lever during the course of the measurement**.
4. Observe and record soundings to the nearest 2 cm at each vertical. Be careful not to over estimate depth by allowing the cable to extend beyond the point when the sounding weight initially touches bottom. The distribution of verticals must be in accordance with that outlined in Section B.2.4.
5. At each vertical, set meter to appropriate depths for velocity measurement. Observe and record the time and revolutions of the current meter.

6. At the end of the measurement, record the time of completion and make some notes to identify the edge of the channel. Record any pertinent information that may have had an effect on the measurement results.

Precautions and Tips

1. ***Marking the Initial Point.*** The initial point should be marked very clearly because all distances, observations of depth, and velocities must be referenced to this point. This information must be included in the field data book.
2. ***"Zeroing" the Meter.*** Soundings are usually made with the meter at the water surface, that is, with the bottom half of the bucket wheel or propeller submerged and the horizontal section of the tail assembly at the water surface. The distance between the meter and the bottom of the weight must be added to the soundings indicated on the reel counter to obtain the correct depth. The slight amount of drag on the meter and weight when the "meter is zero-ed" has a stabilizing effect that makes the process of sounding quicker and easier than when attempting to "zero" the bottom of the weight. There is also the convenience of not having to apply a correction each time the meter is positioned in the vertical.
3. ***Effects of Vertical Movement of the Meter.*** Some cables may undulate from the pulling motion required to move the traveler block from one vertical to the next, or from vigorous cranking movements when sounding with heavy weights. This motion must be allowed to subside before carrying out the depth and velocity observations. This is of particular importance when measuring velocities below 0.75 m/s, because the effects of vertical movement on the current meter are significant in this range.
4. ***Direction of Flow.*** The direction of flow is often not perpendicular to the metering section. Even worse, the flow may be inconsistent throughout the section, or the flow may change from vertical to vertical with the section, and vary with changes in stage. In these cases, measure the cosine value; make the appropriate correction for angular flow.

D.3 Post-Measurement Activities and Discharge Measurement Computation

D.3.1 Errors Affecting Accuracy

The purpose of this section is to identify some of the common factors that lead to inaccuracies when observing widths, depths, and velocities. Inaccuracies can occur during the measurement of any of these parameters through errors introduced by technique or the type of equipment used. Errors can be categorized as human, systematic, or random.

D.3.1.1 Width Measurement

Measuring overall stream width and defining individual verticals, using a measuring tape or tagged nylon chain, can be done with precision and neither contributes to overall error in a discharge measurement. Human error can be a factor when measuring permanently marked cross sections on bridge rails or other structures if unconventional spacing has been employed. Wind can oscillate the tape and lead to movement of the tape anchorage points and/or mistakes in observing values.

Record keeping errors can occur during boat measurements when the boat is positioned by electronic or survey equipment operated on shore with the rest of the data recorded in the boat. To avoid errors, good communication and post-measurement record comparison are essential.

D.3.1.2 Depth Measurement

Depth observations made by rod are subject to random errors such as the sinking of the rod into a soft streambed, failure to identify obstructions in the cross section between soundings, and incorrect reading of the graduated rod.

The opportunity for error is far greater when cable suspension systems are employed. In addition to the errors listed for rod measurements, certain techniques used in the measurement process can result in errors in the recording of depth. The most obvious and most common error is the failure to add the distance from the bottom of the weight to the center of the meter when the latter point of reference has been used to “zero” the reel or handline at water surface. Other errors peculiar to the handline suspension occur as a result of mistakes in the method of subdividing the distance between cable markers (streamers) and applying to obtain exact depths.

D.3.1.3 Measurement of Velocity

Other sources of significant error in a discharge measurement are those that relate to the measurement of velocity. Among the more readily apparent are those associated with the calibration of current meters, the direction of flow, the duration of the observation time, and the number of observation verticals as well as the number of observation points in each vertical.

Calibration

The Province of British Columbia has maintained a standard, similar to the Water Survey of Canada, that all current meters have individual calibrations. These are obtained by towing the meters through a tank of still water at velocities of between 4.5 to 300 cm/s, and from this individual calibration curves are developed. Although it is generally accepted that this procedure is equivalent to the stream gauging situation where the meter is held in flowing water, there is some question about the validity of this assumption when using the meter (particularly cup-type meters) under turbulent flow conditions.

Direction of Flow

Discharge measurement cross sections are usually chosen so that the flow is perpendicular to the cross section. Even though they are carefully selected, it is not always possible to avoid oblique flows at some of the verticals. At these verticals the velocities must be corrected by applying an appropriate cosine coefficient. Random errors may be introduced when observing the angle of flow if it is assumed that the angle observed at or near the surface remains the same throughout the entire depth.

Other sources of error can be introduced when using rod suspensions and in particular when used in deep fast-flowing water. Although the current meter can be misaligned both vertically and horizontally with the direction of flows, the most significant error will result from vertical misalignment. The current meter will under register if tilted above or below the horizontal, and the magnitude of the error will depend upon both the velocity of the water and the angle of departure.

Duration of Observation Time

Pulsations in velocity are evident in all streams even though flow conditions are essentially steady. Because pulsations are random in nature, the effects of pulsation will be eliminated when velocities are observed for a sufficient length of time. In actual practice during a discharge measurement, velocities are observed for relatively short periods of time. The expectation is that a sufficient number of observations will be made so that pulsation effects will tend to cancel each other during the course of a measurement. Studies have shown that at low velocities, pulsation effects are usually greatest. Studies have also shown that the optimum observation duration is between 40 and 60 seconds and that accuracy decreases significantly if a duration of less than 30 seconds is used; for durations longer than 60 seconds, the increase in accuracy is generally negligible.

Number of Observations

There are two ways in which the accuracy of a discharge measurement can be significantly affected by the number and distribution of observation verticals. First, the observation verticals are used to define the channel cross-sectional area. Appreciable errors will be introduced if the number of observations made to define the cross section are not sufficient. This particular problem can be overcome by obtaining additional depth observations.

Secondly, the velocity observations in the verticals are used to define the mean velocity in the cross section; therefore, the verticals should be spaced so that the velocities observed are more representative of those in the preceding half panel and the following half panel.

The spacing of observation verticals can be accomplished on the basis of either the equal flow method, the equal width method, or a combination. With the equal flow method, the width segment can change frequently, and using the mid-section method for computations the horizontal velocity profile tends to be distorted. That is, if the width segments change frequently, the observed velocities will not occur at the midpoint of the panels.

A good compromise is to use the equal width method and to change the spacing of verticals only a few times during a measurement to accommodate any significant changes in flow distribution.

Studies on measurement accuracy have shown that accuracy tends to be low when fewer than 16 verticals are used but the improvement becomes negligible when more than 35 verticals are used. All else being equal, the use of 20 - 25 verticals is considered optimum.

Number of Observation Points in a Vertical

The mean velocity in a vertical is normally obtained by measuring at one or two points in that vertical. Comparing these observations with those obtained by some detailed method (a mean of observations at every tenth of the depth, plus half the value observed at the surface and half the value at the bottom), indicated that random errors do occur when determining the mean velocity in any given vertical. Furthermore, the one-point method is usually not as accurate as the two-point method. Nevertheless, surface and bottom effects become significant as the stream depths decrease, and when depths are less than 0.8 m, the one-point method should be used.

D.3.1.4 Conclusions

Errors in the measurement of width, depth, and velocity as well as the lack of care in choosing the number of verticals and observations in a vertical, all combine to reduce the overall accuracy of a discharge measurement. To a large extent, human errors can be avoided by careful attention to detail and by adhering to established and proven techniques and routines. Systematic errors can be reduced significantly by proper maintenance and calibration of instruments and equipment, and by adequate training. However, random errors will always occur. A significant reduction in these errors can be achieved if the field technician obtaining the measurement can recognize the potential problem areas and can take the appropriate precautionary measures to avoid or minimize them. One possible indication of measurement accuracy can be obtained by conducting several consecutive or simultaneous measurements, and by using different sets of equipment and different techniques.

D.3.2 Mean Section Method

Prior to 1974 the Water Investigations Branch used another form of computation of discharge. This involved doubling the values of depth and velocity taken at the vertical and adding the value of depths and velocities of the preceding and following verticals. Twenty-five per cent of the sum of both depth and velocity was then used to calculate the mean discharge using a width for this partial section of one half the distance from the preceding vertical to one half the distance to the following vertical.

After a period in which check computations were carried out by computer programs and the results of both mid-section and mean section were produced, it was determined that a comparison of the results using both methods produced differences of less than 1% in most instances. The province adopted the mid-section method for all subsequent discharge calculation.

D.3.3 Mid-Section Method

The mid-section method of computing discharge measurements is carried out as follows:

1. Observed depth at the vertical is considered to be the mean depth for the section or panel.
2. It is assumed that the mean velocity at the observation vertical represents the mean velocity for the section.

3. Width for each section is computed as one-half the distance from the preceding vertical plus one-half the distance to the following vertical.
   In Figure D-18, the discharge for the heavily outlined section at distance b6 from the initial point is computed as:

$$q = V_6 d_6 \times \frac{(b_7 - b_5)}{2}$$

The calculations for the first and last sections of a discharge measurement are handled in much the same manner as just described. The main difference is in the determination of the widths. Because at the beginning and the end of a measuring section there is no preceding or following vertical, the width becomes one-half the distance from the edge to the first vertical or from the last vertical from the edge. Figure D-19 shows typical edge sections. As a result of the computational procedures, in these instances the area and discharge are not derived for the edge sections. Therefore, when making a discharge measurement, the first and last verticals should be taken as close to the edge as possible. The two edge sections will then be very small in proportion to the total measurement and an estimated discharge for these sections will introduce very little if any appreciable error.

An edge section will also occur where there is a vertical drop at the water's edge, such as at a pier, a bridge abutment, or a wingwall. Again, the width calculation is one-half the distance from the previous or to the following vertical as shown in Figure D-19. Here, however, an area and discharge can be computed. Once again, soundings should be arranged so that edge sections are made as small as possible.

Keep in mind that caution must be exercised when observing depths and velocities close to piers and abutments. At times, it may be necessary to estimate these values to avoid the possibility of the meter and weight assembly being damaged against the pier or abutment. In some instances, debris will have lodged on or against the pier and this further complicates matters. Where these situations are encountered, it becomes necessary to estimate the depth from the previous vertical and the velocity which is expressed as a percentage of that observed at the previous vertical.

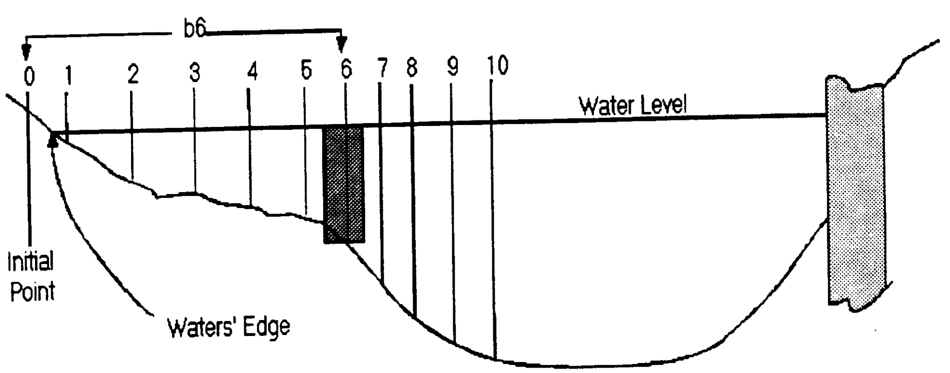


Figure D-18. Typical stream cross-section with numbered verticals, Panel 6 is highlighted.

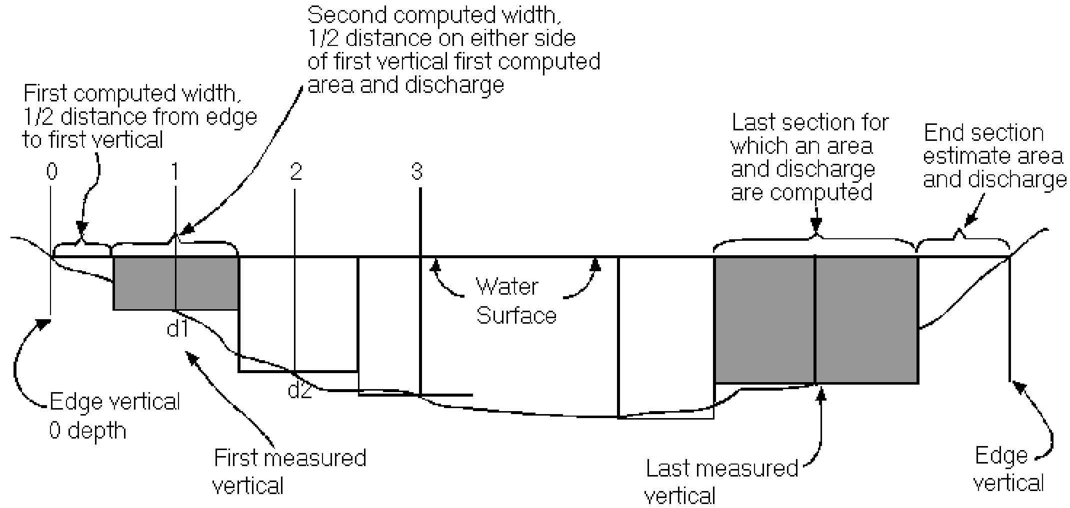


Figure D-19. Method for selection of edge verticals.

D.4 Documentation of Station Water Level

D.4.1 Introduction

Accurate documentation of the record is extremely important. It establishes the identity of the location and the base values for future evaluation. It also ensures accurate transfer of the information from the field to the office.

It is easiest to evaluate a hydrometric record successfully when the supportive values and observations have been well documented. Each segment of the record must contain the necessary identification, support values and information. Documentation must be complete and legible. Always do the documentation immediately following the observations. Do not depend on memory; never wait for a more convenient time or location.

D.4.2 Proper Documentation

In most cases, specially-designed forms are provided to record the necessary information and observed readings systematically. Example RIC Forms are inserted in the text as they are introduced. Blank forms are included as Appendix II. Extra information can always be listed on these forms if it is necessary.

Sometimes information that appears to be insignificant or redundant must be recorded. All this information is gathered for various reasons: to route the original data in a different direction, to cross-reference the accuracy of the documentation, or to provide convenient access to the information on the original record. For example, if a question on one form arises, it can be resolved quickly by comparing that form with others containing a record of the same observations. If two segments of a record requiring the same support data become separated, each segment when properly documented, can be understood independent of the other.

D.4.3 Station Log Form

Form AQU-06 Water Stage Recorder - Station Record for the Year ___ (Figure D-20) posted within the recorder shelter, provides a convenient record of observed data from all past visits to the station. The Remarks column shows the method used for past measurements and indicates a safe limit of stage for stream wading. Level checks of the gauges are noted, along with any necessary gauge correction. Update the form before leaving the site. The station log form, properly documented, provides a ready reference to the station operation history.

D.4.4 Discharge Measurement Note

Make all field data entries on the meter note front sheet at the time of observation and. before leaving the site, complete the form properly. The time, gauge heights, and general information recorded on this form establish the baseline data.

British Columbia
Resources Inventory Committee

Water Stage Recorder - Station Record for the Year 1996

Station Operating Agency/Firm: BC ENVIRONMENT/RIB

Stn. No.: 08MC045 Stn. Name: SHERIDAN CREEK ABOVE MCLEESE LAKE

Manual Gauge: Staff. Chain. Wire Weight. Other. Zero of Trace is 2 cm from left margin.

Recording Gauge: Manufacturer STEVENS Model A-71.

Analogue Digital. Shaft Encoder: Manufacturer ______. Model ______.

Transducer: Manufacturer ______. Model ______.

	Arrival					Departure								
	Time (PST)		Stage (m)			Time (PST)		Stage (m)						
Date (mm dd)	Watch	Recorder	Outside Gauge	Inside Gauge	Recorder	Watch	Recorder	Outside Gauge	Inside Gauge	Recorder	Intakes Flushed (y n)	Initials	Dir. of pen in rising stage → ←	Remarks on Metering. Level Check. etc.
3/28	13:34	16:00	.356	4.564	.500	13:45	13:45	.356	4.563	.356	NO	CH	→	ICE IN STILLING WELL.
4/28	17:00	14:30	.925	4.693	.482	17:40	17:40	.925	5.146	.925	YES	HO	→	INTAKES PLUGGED ON ARRIVAL. NEW FLOAT INSTALLED.
4/10	07:35	07:30	.955	5.026	.828	09:25	09:25	.945	5.018	.942	YES	HO	→	METERED TWICE. POLE MEASUREMENT.
4/14	08:05	08:30	.790	4.859	.798	09:05	09:00	.785	4.854	.788	YES	HO	→	METERED TWICE.
4/16	07:40	07:40	.745	4.814	.756	08:30	08:30	.744	4.813	.749	YES	HO	→	METERED.
4/18	07:20	07:45	.690	4.755	.695	08:10	08:10	.685	4.752	.690	YES	HO	→	METERED.
5/6	13:28	16:30	.301	4.391	.337	13:50	13:50	.301	4.391	.301	NO	HO	→	METERED.
5/22	18:11	00:00	.282	4.378	.322	18:20	18:20	.282	4.378	.282	YES	HO	→	METERED. DEBRIS REMOVED.
5/30	08:51	09:15	.198	4.304	.248	09:05	09:05	.198	4.304	.198	NO	CH	→	
5/26	12:10	19:10	.207	4.275	.219	12:55	12:55	.207	4.272	.216	YES	CH	→	METERED.
7/12	13:56	14:30	.202	4:268	.210	14:05	14:05	.202	4.268	.210	NO	HO	→	
7/31	13:58	16:15	.194	4.259	.204	14:05	14:05	.194	4.259	.204	NO	HO	→	
8/20	12:45	23:00	.190	4.254	.200	12:50	12:50	.190	4.254	.200	YES	HO	→	METERED.
10/30	11:20	22:45	.192	4.260	.209	12:10	12:10	.192	4.260	.202	YES	JM	→	METERED. NEW CHART ON. NO ICE.

RIC AQU-06 97/10

Figure D-20. Example of completed RIC Form AQU-06, Water Stage Recorder - Station Record for the Year _____

E. Hydrometric Levelling Procedures

E.1 Introduction

Before stage/discharge curve can be developed, gauge heights must be confirmed or adjusted. This section sets out the procedures and note-keeping format to be used for leveling in hydrometric operations (measurement of stage and the maintenance of station datum). The methods described must be strictly adhered to so that the data can be properly reviewed at a later date. Many of the methods in the section could be described as basic survey practice; however, procedures and documentation peculiar to hydrometric operations require these basics be carefully reviewed as a part of standard hydrometric operational requirements. In addition, some less frequently employed techniques are described, such as reciprocal leveling, i.e. transferring datum across a lake.

The following section has been prepared from material supplied by Environment Canada staff R.A. Terzi, E. Mayert, and D.G. Goller.

E.2 Procedure for Conducting Two-Peg Test

The two-peg test ensures that the level is accurately calibrated, i.e. that the line of sight through the telescope is parallel to the axis of the level tube (Figure E-1).

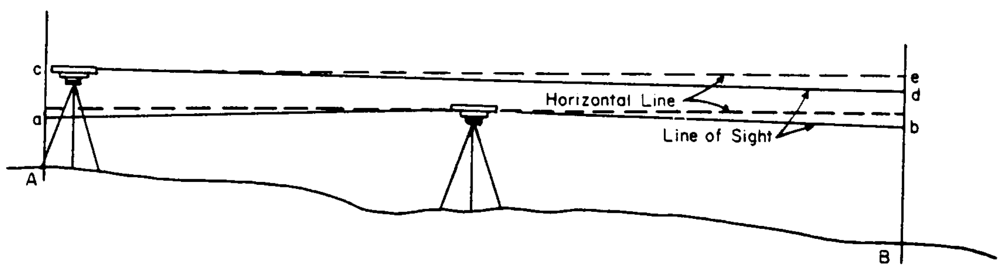


Figure E-1. Principles of the two-peg test.

Establish two firm points, A and B, about 60 m apart. Each point can be marked with a peg or a stake. Set up and level the instrument exactly midway between A and B. Take a rod reading *a* on point A, and a rod reading *b* on point B. The correct difference in elevation between points A and B is *a* - *b*; this is true even if the level is not sighting a true horizontal line, because the instrument is set up exactly midway.

Next, move the level to point A.

Set up and level the instrument so the eyepiece will swing within one centimeter of the rod held on point A.

Looking through the objective lens (looking backward through the telescope) record the rod reading *c* at A. As the crosshairs will not be visible, use a pencil to locate the exact rod reading on the rod. Now take a reading on point B to obtain reading *d*. (The difference between these readings should equal the correct difference established earlier.)

If these ‘Differences in Elevation’ are equal, the instrument is in proper adjustment: i.e., $a - b = c - d$.

If the last reading does not check, the instrument must be adjusted so that the rod reading on point B is $e = b + c - a$. See the following examples.

Example 1: Level in adjustment

a = 1.510
b = 2.230
a - b = -0.720

c = 1.730
d = 2.450
$c - d$ = -0.720

Example 2: Level out of adjustment

a = 1.390
b = 2.110
a - b = 0.720

c = 1.630
d = 2.310
$c - d$ = -0.680

Adjust level so rod *b* reading is $e = b + c - a = 2.350$.

Any adjustments to the instrument must be carried out while the instrument is still in position at point A. The manual supplied with the level instrument will describe the method of adjustment for each type of instrument. If adjustment is required, it is recommended that the entire level check process be repeated.

E.3 Levelling Procedures

E.3.1 Setting Up the Instrument

The person in charge of the leveling instrument should give some thought to where it will be positioned before setting it up. The tripod should be set on firm ground so that the person using it has secure footing and can conduct the level circuit.

The level and tripod are placed in a desired location with the tripod legs spread well apart and firmly pressed into the ground by standing on the feet at the base of the tripod. The tripod head should be nearly level with the telescope and at a convenient height for sighting. On hillsides, place one leg of the tripod uphill and two downhill for better stability. If the tripod has a domed head, the instrument can be shifted so that the circular bubble is near level. Coarse level adjustment can be obtained by using the foot-screws on the base so that the circular bubble can be carefully centered in the middle of its setting circle.

The level must first be adjusted so the crosshairs are in focus for the operator, which requires the following steps. Point the telescope towards a uniformly light-coloured surface, or a sheet of white paper. Turn the telescope eyepiece until the reticule crosshairs appear sharp and absolutely black. Turn the eyepiece slowly until the image starts to go out of focus. A small rotation in the opposite direction will refocus the hairs correctly. This setting corresponds to the technician’s eyesight; it is constant, but individual to each technician.

The telescope can be pointed roughly at the leveling rod, by looking along the open sight and turning the instrument by hand. Set the vertical hair of the reticule cross along the middle of the rod image by turning the horizontal adjustment screw. Turn the focusing knob until the image of the rod graduations are sharp. The observer should move his/her eye up and down and from side to side behind the eyepiece, to ensure parallax does not exist (there should be no movement between the staff image and the reticule cross when viewed in slightly different positions). If such parallax is observed, the instrument must be refocused, as described in the previous paragraph. In the case of self-leveling instruments, the line of sight is now horizontal and the rod is ready to be read.

With a tilting level, the line of sight must be set horizontally using the tubular bubble. Position the fixed reflector for optimum illumination of the tubular bubble as seen through the bubble viewing eyepiece. The split bubble image seen in that eyepiece must be set to coincidence, by turning the tilting knob below the eyepiece. When the bubble ends are far from coincidence. an arrow in the bubble image indicates the proper direction to turn the tilting screw to obtain coincidence. The split bubble should be checked before each reading of the rod.

E.3.2 Positioning and Reading the Rod

The rod is positioned properly by placing it vertically on the point of a stable object. The rod must then be held plumb. The instrument person can tell if the rod is plumb in one direction by observing if the rod is parallel to the vertical cross-hair, but he/she can not tell whether it is tipped forward or backward. Therefore, the rodperson should use a rod level to plumb the rod in this direction. If the rodperson does not have a rod level, plumbing of the rod can be accomplished by balancing the rod between two fingers (if there is no wind). Waving the rod slowly towards and away from the instrument and observing the lowest reading on the rod is another method of ensuring that the rod is vertical, as in Figure E-2.

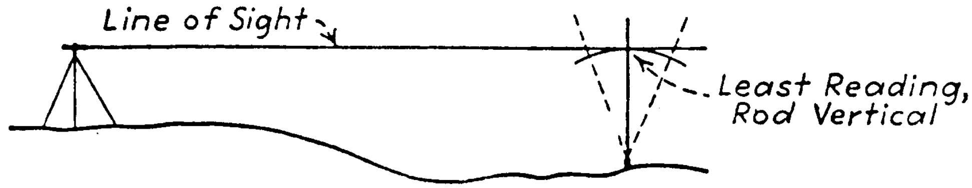


Figure E-2. Positioning the rod.

Errors created by not holding the rod plumb are much greater for readings taken near the top of the rod than for those taken at the bottom.

When the instrument is properly leveled and the rod is in a vertical position, the technician observes and records the reading indicated by the horizontal crosshair on the rod as seen through the telescope. To verify the accuracy of the reading, observe the split bubble and the rod reading again.

The telescope reticule has stadia lines, one above and one below the centre crosshair. The average of the readings of stadia lines on the rod represents the actual horizontal reading. The difference of the two stadia readings multiplied by 100 represents the distance between the instrument and the rod (Figure E-3).

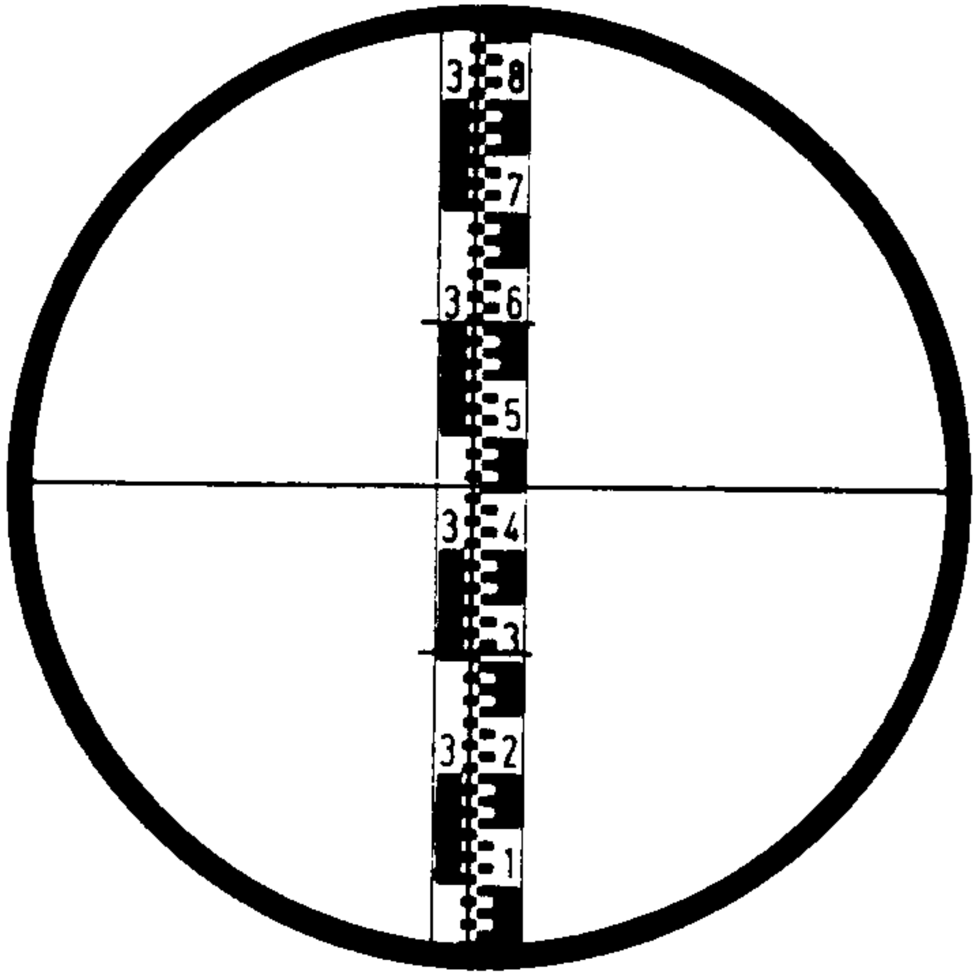


Figure E-3. Reading the rod height 3.456 m, distance 29.2 m, (Source: Automatic Level, Wild NAO, Instructions for Use, Manual G2 106e - IX.80, p.9).

Normally, rod readings to 0.002 m are sufficient. Reading to 0.001 m implies a degree of accuracy that does not exist and is generally inconsistent with the sensitivity of the equipment used to gather other stage data.

E.3.3 Level Notes

Recording accurate and complete field notes is the most important part of the leveling operation. Notes and sketches constitute a permanent record of the survey, and it should be possible for them to be interpreted with ease by anyone having a knowledge of leveling. Non-standard notes that can be interpreted only by the note keeper are unacceptable.

The format for recording level notes during routine level checks of gauges and normal line or differential leveling between bench marks (with backsights and foresights approximately balanced) is shown in Figure E-4.

LEVEL NOTES at MUDDY RIVER AT NEW GAUGING STATION

STATION	B.S.	HT. INST.	F.S.	ELEVATION	
BM S70-4	1.113	7.514		6.401	BM 3.6 m S.E. of R. abutment
TP1	2.408	8.093	1.829	5.685	
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 S70-6	0.686	14.920	0.704	14.234	BM est. on R. bank 150 m downstream fr. 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 S70-4			3.520	6.407	
B.S.=	16.578	F.S.=	16.572	6.401	
	16.572				
	0.006			=-0.006	Acceptable closure error

SKETCHES

Figure E-4. Level notes between two bench marks, Muddy River at new gauging station.

Hydrometric level note forms are 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 that must accompany the observation sheet.

When recording notes, enter the elevation of the bench mark or reference mark on the top line in the column headed Elevation. The bench mark identification number is entered in the column headed Station, with any descriptive information recorded in the space at the right. Should it be necessary, an additional description sheet can be attached to the notes. On the top line, in the column headed BS (backsight), the reading obtained with the leveling rod held on the benchmark or point of known elevation is entered as the backsight. The value for the column height of instrument HT.INST. or HI is computed by adding the backsight value to the known bench mark elevation. One line down, in the next column, headed foresight (FS), the foresight reading for the point for which an elevation is to be determined is observed and recorded. Commonly called a turning point (TP), this value is then subtracted from the HI and the result is the elevation of the foresight point. This is entered in the elevation column and on the same line as the foresight just observed. When the instrument is moved, the new height of instrument is determined by a backsight on the TP. The observation and notes are continued in this manner until the circuit is closed by leveling back to the original bench mark.

Level notes may be recorded in a notebook 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 level notes between two bench marks should be recorded as illustrated in Figure E-4, and for direct water level in Figures E-5 and E-6. Note that Figure E-5 is a special case (no surge in water level during the level run, and the elevation of the turning point rock being identical to the water elevation). It is preferable to use the approach shown in Figure E-3 with the cut on the rod being indicated.

> **Note:** Something solid (e.g., a section of pipe) can be driven into the stream of the river bed for a turning point, if a suitable natural turning point can not be found.
>
> **Note:** When measuring the water level with a rod and level, the rod can be set on a fixed point under the water surface. The water level can be read on the rod like on a staff gauge, using care to observe any water level surging and to read the mean water level correctly.

LEVEL NOTES at CLEAR RIVER AT LITTLE BEND

STATION	B.S.	HT. INST.	F.S.	ELEVATION	
BM M70-3	0.914	20.726		19.812	BM 18 m S.E. of power pole at shelter
TP1	0.305	17.983	3.048	17.678	
TP2	0.610	15.240	3.353	14.630	
TP3	0.305	12.802	2.743	12.497	
TP4	0.610	9.754	3.658	9.144	Rock at water level
W.L.	3.793	10.044	3.503	6.251	@ 10:30 PST.
TP5	3.353	12.787	0.610	9.434	Cut on rod 0.000
TP6	3.658	16.140	0.305	12.482	
TP7	4.267	20.255	0.152	15.988	
BM M70-3			0.439	19.816	
B.S. =	18.120	F.S. =	18.116		
			Diff.	= -0.004	CLOSURE O.K.

SKETCHES

Figure E-5a. Level notes for direct water level, Clear River at Little Bend.

LEVEL NOTES at CLEAR RIVER AT LITTLE BEND

STATION	B.S.	HT. INST.	F.S.	ELEVATION	
BM M70-3	0.914	20.726		19.812	BM 18 m S.E. of power pole @shelter
TP1	0.406	17.984	4.058	17.678	
TP2	4.128	18.019	4.092	13.891	Rock below water CUT on rod 0.134 m @10:30 PST
TP3	3.868	21.743	0.144	17.875	
BM M70-3			1.934	19.809	
B.S =	9.215	F.S.	= 9.218	0.003	
			Diff.	= 0.003	Acceptable closure
					Error
ELEV TP2	=	13.891 m			
Cut on	rod +	0.134			
Water	level	14.025 m			

SKETCHES

NOTE: Due to surge when obtaining a direct water level, discretion is required when reading the water level on the rod. The rod when set on a fixed point, can be read like a staff gauge.

Figure E-5b. Level notes for direct water level (submerged TP), Clear River at Little Bend.

LEVEL NOTES at CLEAR RIVER AT LITTLE BEND

STATION	B.S.	HT. INST.	F.S.	ELEVATION	
BM M70-3	0.914	20.726		19.812	BM 18 m S
TP1	0.305	17.983	3.048	17.678	power pol shelter
TP2	0.610	15.240	3.353	14.630	
TP3	0.305	12.802	2.743	12.497	
TP4	0.610	9.754	3.658	9.144	
	3.658		3.368		@10:30 P. sight on
	6.400		6.400		rod held of 0-7.3m
GAUGE	10.058	10.044	9.768	-0.014	to inside
TP5	3.353	12.787	0.610	9.434	
TP6	3.658	16.140	0.305	12.482	
TP7	2.743	18.578	0.305	15.835	
TP8	1.829	20.255	0.152	18.426	
BM M70-3			0.439	19.816	
B.S =	24.385	F.S =	24.38	19.812	
		Diff =	0.004	=0.004	Closure 0.

SKETCHES

LEVEL NOTES at CLEAR RIVER AT LITTLE BEND

STATION	B.S.	HT. INST.	F.S.	ELEVATION	
BM M70-3	0.914	20.726		19.812	BM 18 m S. power pole
TP1	0.305	17.983	3.048	17.678	shelter
TP2	0.610	15.240	3.353	14.630	
TP3	0.305	12.802	2.743	12.497	
TP4	0.610	9.754	3.658	9.144	
I.G.	3.658	10.044	3.368	6.386	rod held of 0-7.3 m
TP5	3.353	12.787	0.610	9.434	@ 10:30 P.
TP6	3.658	16.140	0.305	12.482	
TP7	2.743	18.578	0.305	15.835	
TP8	1.829	20.255	0.152	18.426	
BM M70-3			0.439	19.816	
B.S =	17.985	F.S=	17.981	19.812	
		Diff. =	0.004	-0.004	Closure 0.
Corr.	to +G	6.386 m -6	.400 m	=-0.014 m	

SKETCHES

Figure E-6a. Example 1: Level notes for staff gauge A, Clear River at Little Bend.

Figure E-6b. Example 2: Level notes for staff gauge B, Clear River at Little Bend.

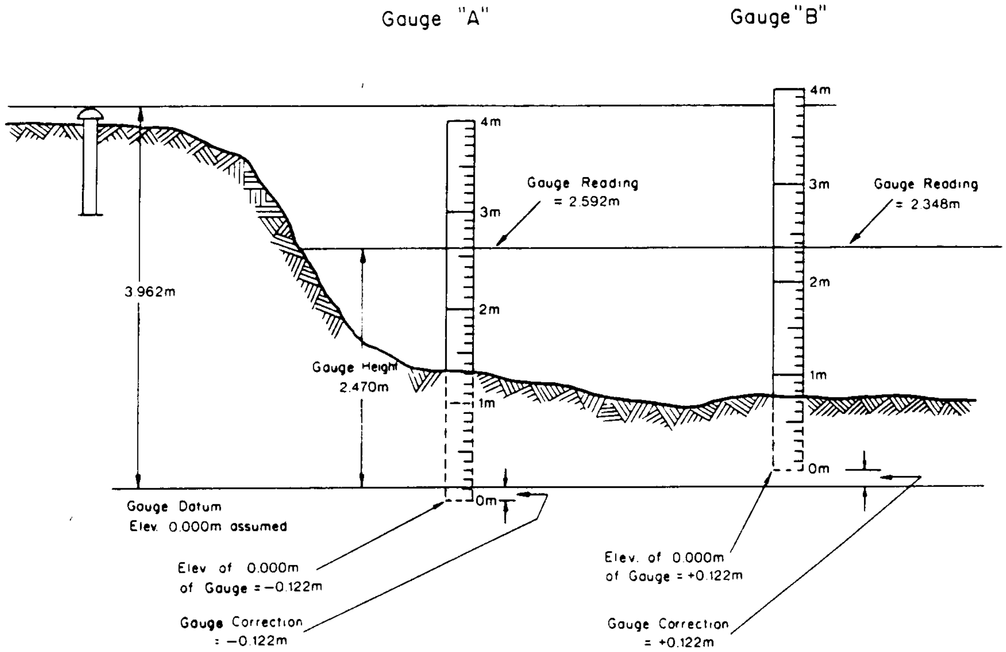


Figure E-6c. Illustration of corrections to staff gauges.

E.3.4 Gauge Checks

Staff gauges are subject 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 vandalism are other reasons for lost data. To help ensure that stage records remain reliable, the datum of the gauge must occasionally be checked against the original reference elevation. How often this is done is largely determined by the conditions. Under normal conditions a gauging station may require checking only two or three times during a season. However, for a gauge with a history of instability, or in an area of fluctuation due to frost, a level check during each visit to the station is required.

When running levels to check for the possible 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 the gauge, the instrument must be moved to close the return run to the bench mark.

The procedure for determining the elevation of a staff gauge in relation to the elevation of a bench mark involves several steps. First, set up the leveling instrument in a convenient location between the staff gauge and the bench mark, so that a clear rod reading is obtainable at both points, but no attempt is made to stay directly on the line between the two. A backsight on the bench mark is then observed and recorded. Next the rodperson goes to the staff gauge and holds the rod on the staff gauge while the instrument person observes and records a foresight reading. Move the instrument and set up again for another backsight reading on the staff gauge. The rodperson then returns to the bench mark where the instrument person observes and records a foresight.

By adding the recorded backsight value to the known elevation of the bench mark, the height of instrument is determined. The foresight is then subtracted from the height of instrument to obtain the elevation of the staff gauge. Also, the difference between the backsight taken on a given point and the foresight taken on the following point is equal to the difference in elevation between the points. In this example, only one bench mark was used, BUT THE ACCEPTABLE PROCEDURE WOULD BE TO TIE IN AT LEAST THREE BENCH MARKS. When a number of turning points are required to obtain the water level reading, it is advisable to run a closed circuit between the bench marks first to minimize the closure error corrections due to the turning points.

> **Note:** Both examples shown (Figures E-7 and E-8) are acceptable, the difference being that Example 1 determines the elevation at the bottom of the gauge; Example 2 determines the elevation of a point on the gauge.

Example 1: Gauge A

Gauge Reading	= 2.592 m
Gauge Correction	= -0.122 m
Gauge Height	= 2.470 m

Example 2: Gauge B

Gauge Reading	= 2.348 m
Gauge Correction	= 0.122 m
Gauge Height	= 2.470 m

This procedure, however, presents a problem when checking wire-weight gauges without the assistance of a rodperson. Completely repositioning the instrument tripod after initially sighting on the weight makes it difficult to resight the level on the graduated portion of the weight when closing the circuit. In this case, and only in this case, the following procedure can be used. Raise the level head very slightly by extending one of the level legs a small amount, and ensure the instrument is leveled. This should allow for a foresight on the graduated weight (Figure E-9).

> **Note:** The graduations on weights are usually in the form of 2-mm grooves with 2-mm spacing.

Of course, this approach is not necessary when assistance is available. The return portion of the circuit is completed by taking level readings back to the original bench mark from which the circuit began. See Figures E-7, E-8, and E-9 for illustrations of corrections to wire-weight and staff gauges and for samples of level notes.

When leveling staff gauges, both inside and outside gauges, the same general procedure is used. However, the instrument must be repositioned when closing the circuit. As mentioned in the previous example, the circuit must be closed by returning to the original bench mark.

When performing level circuits, the technician should turn on all the points on which he/she is determining elevations.

In all cases the level circuit must be completed prior to determining the correction that is to be applied to the gauge. It is strongly recommended that a water elevation be obtained at the time the level circuit is run. Among other things, the water level obtained will indicate if the intake pipes are silted or frozen.

Example 5: Gauge A

Gauge Reading = 2.575 m

Gauge Correction = -0.015 m

Gauge Height = 2.560 m

Example 6: Gauge B

Gauge Reading = 2.545 m

Gauge Correction = +0.015 m

Gauge Height = 2.560 m

Note: The RIC Standard AQU-02 shows a typical example of a level check (Figure E-10).

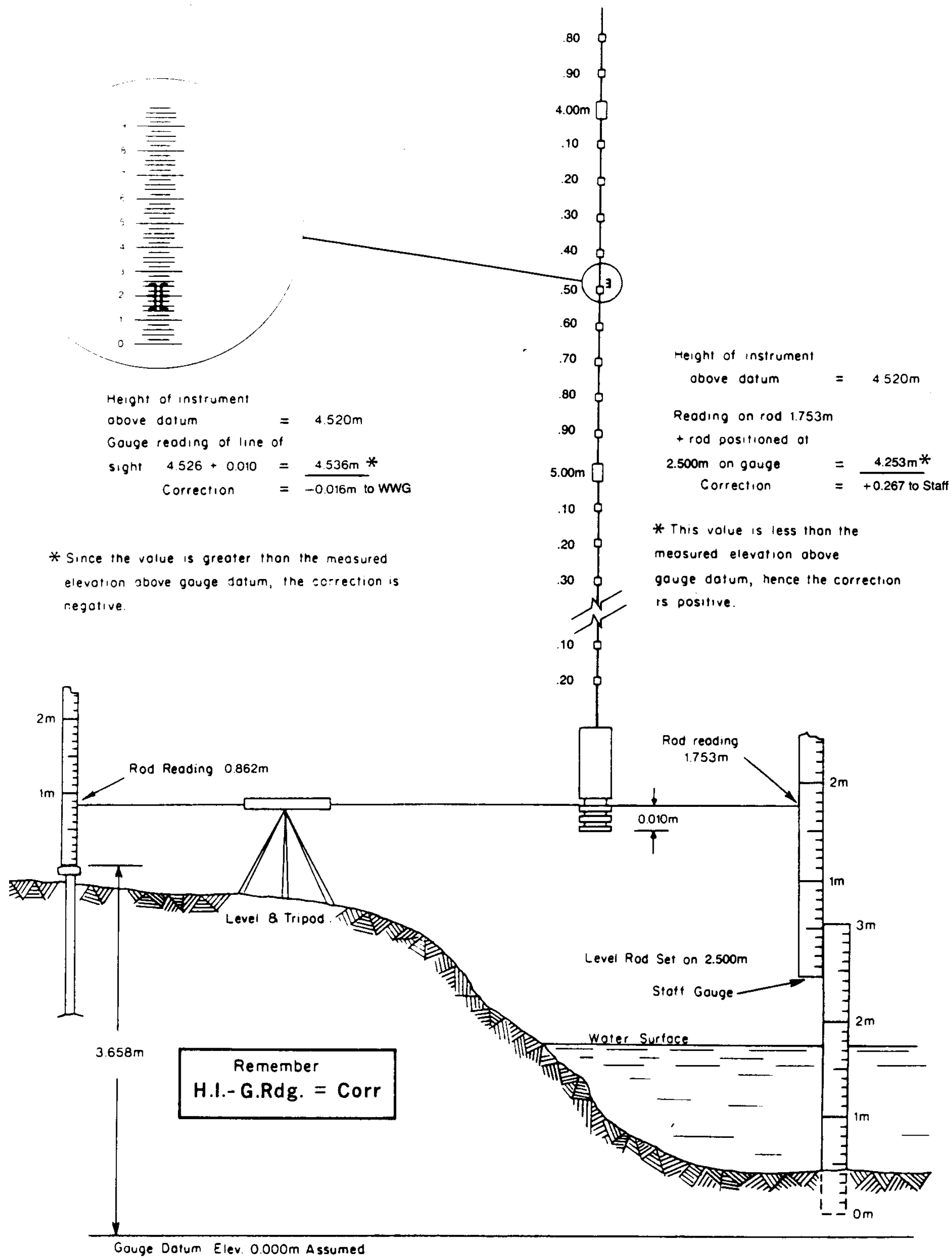


Figure E-7. Gauge corrections and how they are derived.

LEVEL NOTES at BIG RIVER AT LITTLE BEND

STATION	B.S.	HT. INST.	F.S.	ELEVATION	
BM A70-2	0.152	14.782		14.630	BM on R. of Br.
TP1	0.305	11.887	3.200	11.582	
TP2	0.152	8.381	3.658	8.229	
W.W.G.			0.012		Sight on of weight
			8.376		W.W.G. corr. to
W.W.G.	0.043				@10:30
	8.376				
	8.419	8.412			
TP3	3.810	11.734	0.488	7.924	
TP4	3.566	14.995	0.305	11.429	
BM A70-2			0.363	14.632	
	16.404		16.402		
			16.404		
		Diff. =	0.002		Closure

SKETCHES

NOTE: Use correction of -0.007 m

Figure E-8a. Example 3: Sample level notes and illustration of wire-weight gauge corrections, Big River at Little Bend.

LEVEL NOTES at CLEAR RIVER AT LITTLE BEND

STATION	B.S.	HT. INST.	F.S.	ELEVATION	
BM A70-2	0.152	14.782		14.630	BM ON R.B. of BR. abu
TP1	0.305	11.887	3.200	11.582	
TP2	0.152	8.381	3.658	8.229	
W.W.G.	*8.419	8.412	*8.388	-0.007	Sight on of weight @10:30 P.S
TP3	3.810	11.734	0.488	7.924	
TP4	3.566	14.995	0.305	11.429	
BM A70-2			0.363	14.632	
B.S. =	16.404	F.S.	= 16.402	0.002	Closure er acceptable

SKETCHES

NOTE: * is wire weight reading
Use correction of -0.007 m

Figure E-8b. Example 4: Sample level notes and illustrations of wire-weight gauge corrections, Clear River at Little Bend.

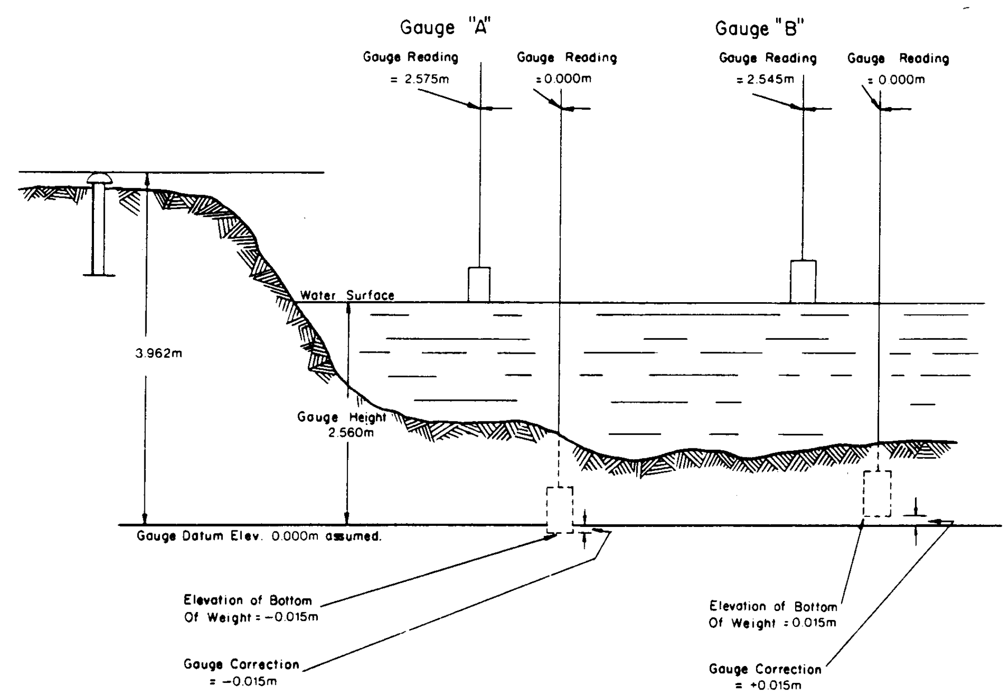


Figure E-9. Wire-weight gauge corrections.

BRITISH COLUMBIA — RESOURCES INVENTORY COMMITTEE

Gauge Level Notes

Station Operating Agency Firm: BC ENV/RIB

Stn. No.: 08MC045 Stn. Name: SHERIDAN CREEK ABOVE MCLEESE LAKE

Date: 96/04/16 (yy/mm/dd) Gauge Ht.: .740 Time: 14:15

Station	BS (m)	Ht. Inst. (m)	FS (m)	Elevation (m)	Elev. as Given (m)	BS or FS, in Feet *
BM-3	1.011	2.516			1.505	
BM-2			1.139	1.377	1.378	
2-M MARK S.G.	.534	2.532	.518	1.998	2.000	
BM-2			1.155	1.377	1.378	
BM-3			1.027	1.505	1.505	

*Check readings for rods that display both scales. Conversion Factor: (1 foot = 0.3048 metres).

Elevation Means:

BM #	Established Elev. (m)	Mean Elev. (this date) (m)	Differences (m)
2	1.378	1.377	-.001
3	1.505	1.505	-.000

Comments on Elevation Changes: BM 1 DESTROYED 1995

Gauge Correction:

Date of Change (if known):

Surveyed by: H. OVIE

Computations by: H. OVIE

Checked by: D. RICHDALE

Additional Notes: REQUIRES 3RD BENCH MARK. INSTALL NEXT VISIT.

RIC AQU-02 97/10

Figure E-10. Example of completed RIC Form AQU-02, Gauge Level Notes in Metres.

E.3.5 Line, or Differential, Levelling

To determine the difference in elevation between two widely separated bench marks, a level circuit is run between the two stations (e.g., Geodetic Survey of Canada bench mark to a hydrometric gauging station). A number of intermediate instrument set-ups are selected, so that sighting distance for backsights and foresights are approximately equal (range 50 to 90 m). At the first instrument set-up, the rod is held vertically on the bench mark of known elevation with its face turned to the instrument. The backsight (BS) reading on the rod is added to the known elevation to obtain the height of instrument (HI). Next, the rodperson carries the rod to the instrument, counting the number of paces from the bench mark to the instrument. He/she then proceeds the same number of paces away from the instrument and finds or establishes a suitable turning point (TP1) (e.g., a hub driven into the ground or a high point on a rock). The HI minus the foresight (FS) rod reading at the turning point is the elevation of the turning point (TP1).

When the turning point has been established, the instrument is carried to the next set-up. The distance to the next set-up is determined in the same manner as the distance to the first turning point. The reason for balancing backsights and foresights is to eliminate instrument and physical errors (see two-peg test). (If it is not possible to balance the backsights and foresights when using the Wild N2 level, the rod should be read in both positions of the telescope [bubble right and bubble left] and the two readings averaged to eliminate the instrument error.) When sighting distance is over 70 m, influences of the earth's curvature and refraction may be noticeable, and they are not eliminated by reading the rod in two positions. The difference in elevation of the two bench marks should equal the difference in the sum of all backsight readings minus the sum of all foresight readings (from the first bench mark to the second bench mark).

Some of the turning points can be temporarily marked and used again when returning from the circuit to the original bench mark. If there is an error in the levels, only a portion of the circuit may have to be re-run. Refer to Figure E-11 for a schematic of the level run, and Figure E-12 for differential level notes.

<u>In all cases the circuit must be closed, even when it involves only one set-up to check gauge movement, to do a bench mark tie, or to obtain a direct water level</u>.

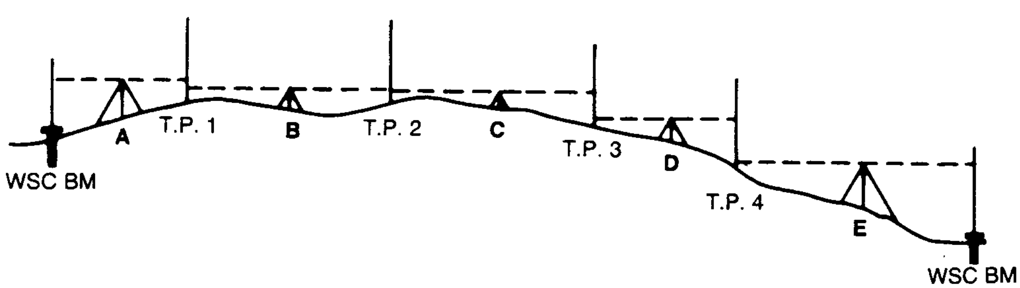


Figure E-11. Differential leveling.

LEVEL NOTES at From GSC EM 785193 to WSC EM'S

STATION	B.S.	HT. INST.	F.S.	ELEVATION	
GSC 785193	1.241	877.767		876.526	Concrete monu. @ station
TP1	0.901	877.095	1.573	876.194	Rock
TP2	0.532	875.222	2.405	874.690	2" X 2" hub
TP3	0.202	873.552	1.872	873.350	tree stump
TP4	0.004	870.454	3.102	870.450	2" X 2" hub
S 87-101	2.754	870.954	2.254	868.200	steel rod 8 m S.
S 87-102	2.370	870.623	2.701	868.253	steel rod 2 m E.
TP4	2.975	873.425	0.173	870.450	2" X 2" hub
TP3	1.962	875.314	0.073	873.352	tree stump
TP2	2.392	877.086	0.620	874.694	2" X 2" hub
TP1	1.527	877.725	0.888	876.198	rock
GSC 785193			1.195	876.530	monument
		Closure =		-0.004 m	Closure O.K.

SKETCHES

NOTE: Geodetic elevation of WSC BM's are

S 87-101 = 868.198 m
S 87-102 = 868.251 m

Figure E-12. Level note for differential leveling.

E.3.6 Reciprocal Levelling

Occasionally it is necessary to transfer a known elevation from one side of a large river channel to the other. This may result from the need to relocate an existing gauging station with a known datum or to carry a line of levels from an established bench mark when installing a new gauging station. The continuation of an existing datum and the transfer of an established elevation for a gauging station site are essential parts of hydrometric work.

The procedure to perform reciprocal leveling is as follows:

1. Set up the instrument near the point of known elevation (point A). Observe and record backsight readings at point A and foresight readings at the point across the channel to which the elevation is to be transferred (point B).
2. Now set up the instrument near point B. Observe and record backsight readings at point A and foresight readings at point B.

3. Often the horizontal distance between points is large, making it necessary to fit a rod target on the distant rod. To obtain precise results, take a series of foresight readings, re-centering the bubble and re-setting the target after each observation.
4. The difference between the mean value of the backsight readings and the mean value of the foresight readings is the difference in elevation of the two points.

This method of reciprocal leveling assumes that the conditions under which observations are taken remain unchanged during the procedure. When leveling points are far apart, two factors may affect the accuracy of readings: unequal expansion of the instrument parts and variations in atmospheric refraction. It is best to carry out this task on a cloudy day when temperature and atmospheric conditions remain constant; otherwise protect the instrument from the sun's rays. Complete the procedure in as short a time period as possible.

E.3.7 Adjustment of Elevation

It can be assumed that the principal errors of leveling are accidental and that most of the level circuits run in hydrometric surveys are relatively short.

When a line of levels makes a complete circuit, almost invariably the final elevation of the initial bench mark as computed from the notes does not agree with the initial elevation. The difference in value between the bench mark's known elevation and its computed elevation according to the level circuit is known as the error of closure. This is the true error value incurred while running the level circuit. It is obvious that the elevation of the intermediate points established while running the circuit will also be in error.

When significant errors of closure are experienced in level circuits over small distances such as the immediate vicinity of a hydrometric station, the survey should be repeated. In the case of a long distance circuit, there are statistical techniques for computing corrections to intermediate points. These can be found in surveying texts.

E.3.8 Levelling Errors

One of the most important factors required to achieve accurate leveling is the skill of the field technician. Field technicians must be aware of potential problems that will produce errors in leveling and the steps necessary to limit them. The following list discusses many of the common errors committed while performing leveling work:

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 crosshairs appear sharp and distinct. If there is an apparent movement of the crosshairs on the target with a corresponding slight movement of the observer's eye (vertically or horizontally), the condition of parallax exists. This condition can be reduced to a negligible quantity by careful focusing of the eyepiece on the objective lens.

   Alternate procedure:

   i. Focus the telescope to the greatest distance.
   ii. Tilt the level to view the sky.
   iii. Adjust eyepiece until crosshairs are as sharp as possible.
   iv. Note the reading on the dioptric refraction scale for further checks.
   v. Proceed to use the instrument.

3. *Inaccurate Reading of Rod.* This 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 type of error. When the rod is tipped backward, ensure that it still rests on the front edge of the base.

5. *Improper Turning Points.* Turning points that are not both well defined and stable are potential sources of error. If reasonable care is exercised when selecting turning points that are both solid and have rounded tops, this error can be kept to a minimum.

6. *Tubular Bubble Not Centered.* The magnitude of this error will vary with the distance between the instrument and the rod. It follows that the greater the distance to be sighted, the greater the care that should be exercised when leveling the instrument.

7. *Settlement of the Instrument Tripod.* Some settlement of the tripod is likely to occur when leveling over soft, muddy, or thawing ground. Under these conditions backsight and foresight observations should be made in quick succession in order to minimize any effect from the instrument settling.

8. *Incorrect Rod Length.* Level rod lengths should be checked periodically with a steel tape. Dirt or snow can become trapped in the sleeve of sectional rods which may prevent sections from fitting together properly. Rods should be assembled and carried so that the upper portion is never in contact with the ground.

9. *Mud, Snow, or Ice Accumulation on Base of Rod.* Mud, snow, or ice accumulations on the rod must be removed before each reading is taken so that level circuits will close. Note that ice accumulation is sometimes unavoidable when obtaining direct water levels in the winter. Uniform wear of the rod base causes no error.

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F. Rating Streams and Computing Discharge

F.1 Introduction

A thorough understanding of the relationship between stage and discharge is the foundation of hydrometric work. This section details the steps involved in converting the field data to actual flow data set to Provincial Standards.

Discharge is the volume of water flowing through a given cross section of a watercourse during a given or implied time period. A measurement of discharge at a given point in time has limited value by itself because it does not allow determination of daily or monthly flows or other flow parameters which are required to understand the streamflow regime. But for any stream location there is a correlation between water level and discharge, that once established, allows one to record the water level, which is relatively easy to do on a continuous basis, and estimate discharge from this correlation (water level, when recorded against a fixed reference is referred to as gauge height or stage).

Daily discharges are rarely measured directly because of the effort required. On occasion, when the effort is justified, it can be approximated by near continuous metering.

This Section will describe the stage-discharge relation and attempt to portray its importance to the practice of hydrometric surveying.

F.2 Stage-Discharge Relationship

Daily or continuous discharge data can not practically be obtained directly. It is however possible to obtain daily or continuous stage data and from that a continuous discharge record can be estimated based on this relationship of water level and flow. The result is a correlation called the stage-discharge relationship.

To develop this relationship, discharge measurements are obtained at the gauging station over the maximum range of gauge heights possible. A history of the relationship evolves over time, as each discharge measurement and corresponding stage is plotted, and a smooth curve is drawn that best represents these points (Figure F-1). This curve is converted to a table of discharge values for incremental gauge heights, which in turn is referred to as a stage-discharge table. Daily or continuous discharge can be derived from this table using a daily or continuous stage record.

F.2.1 Development of a Stage-Discharge Rating Curve

The stage-discharge rating curve has historically been drawn by hand on standard arithmetical forms. This form has been adapted to the RIC Standards Program and is available as Form AQU-09 (Figure F-1).

Rating curve drawing can be performed mathematically by computer using standard graphics software as well as more specific applications. But few hydrometric sites can be well represented by this method and therefore computer fit curves are not acceptable for Provincial Standards. The reasons for the restriction against computer plots include:

Stream geometry changes with depth and requires more than one equation.

The relationship between plotted points is affected by chronological order. In a manual plot, dates are added and must be constantly referenced.

Confidence in data is not constant. Field personnel must give weight to the measurements based on experience.

The difference between an errant measurement and a shift in the stage-discharge curve is a grey area that is best resolved using skilled judgment when drawing the curve manually.

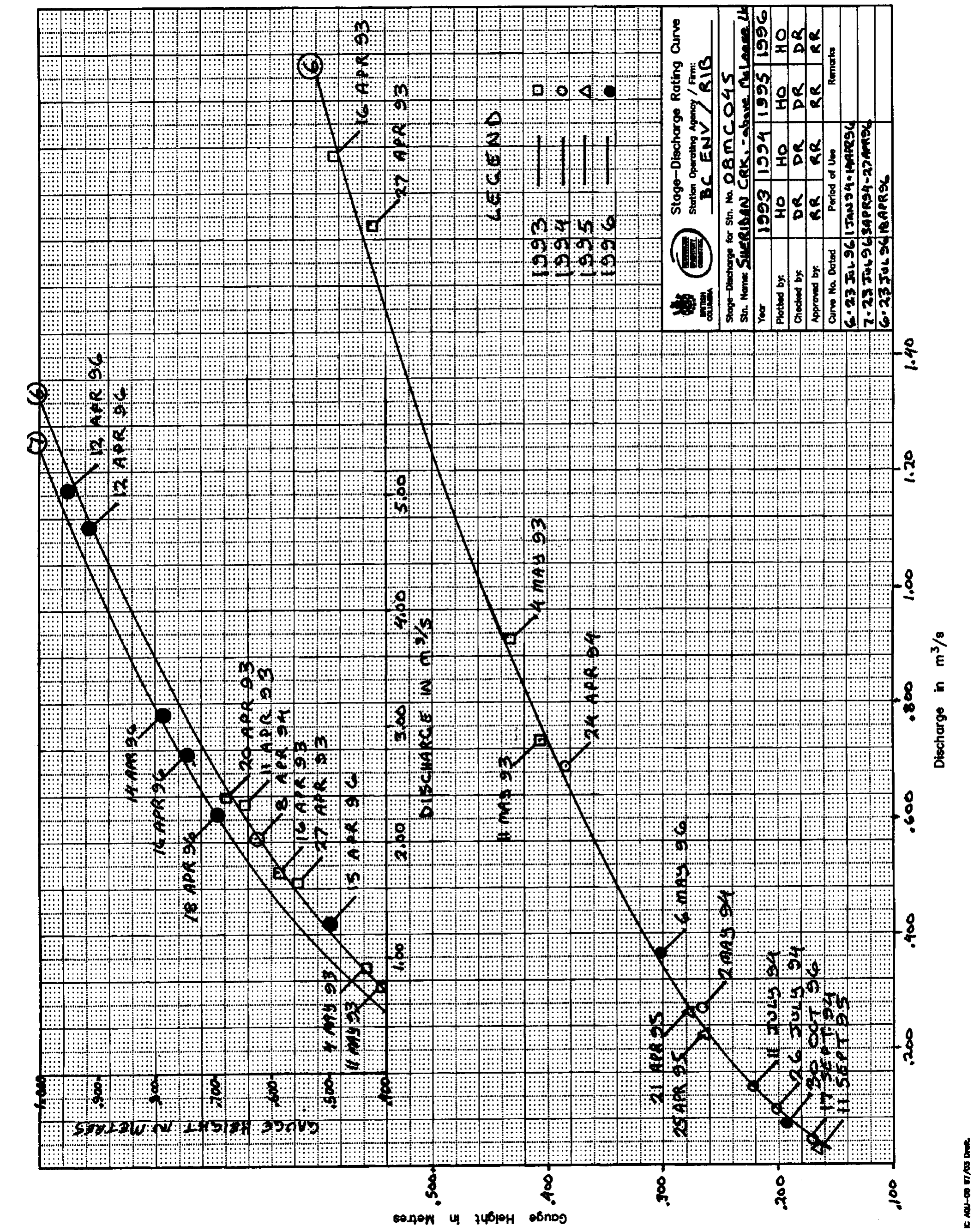

Figure F-1. Example of a Stage-Discharge Rating Curve RIC Form AQU-08, shown half size.

F.2.2 Curve Plotting

To determine the stage-discharge relationship, assemble all stage-discharge information, plot the measurements on Form AQU-09, then determine the best fit curve or curves. This procedure has been extracted and modified from the Manual of Hydrometric Data Computation and Publication Procedures, Inland Waters Directorate, pp. 27-28.

Proceed as follows:

Select scales on the curve sheet so that the significant figures, as required for the stage-discharge table, can be read with reasonable accuracy. Gauge heights are plotted on the vertical scale and the discharges on the horizontal scale. Suggested scales for the gauge height are 1 cm = 0.1, 0.2, 0.5, 1.0, or 2.0 m and for the discharge, 1 cm = 1, 2, 5, 10, 50, 100, 200, or 500 m^3/s. Make adequate provision for the entire range in stage which is known to have occurred during the history of the station. The stage-discharge relationship may have to be shown in one or more curves to obtain the degree of accuracy required for the computation of the stage-discharge table. Designate each curve as “low flow curve,” “high flow curve,” etc.. Where feasible, carry each curve down to or near the “zero flow” stage. Allow for at least 0.3 m of overlap between curves and use more than one sheet, if necessary, to avoid cramping and confusion.

When a new curve sheet becomes desirable, first plot all extreme high or low discharge measurements from former years on the new sheet. Then on this new sheet, plot the latest applicable stage-discharge curve. Finally, plot all new open water measurements and, if necessary, plot a new stage-discharge curve.

Field discharge measurements will have been computed in the field and plotted in the Field Data Book. Any measurement that is considered an outlier should have a supplemental measurement completed before leaving the site. The supplemental measurement will confirm an error in the first or indicate a shift.

Indicate the plotted point for each discharge measurement by a dot surrounded by an open circle about 2 mm in diameter. Circles that indicate measurements for previous years should be color coded to distinguish them from the measurements made during the current year. Designate a discharge measurement by its date (e.g., June 12, 1997) with a diagonal line from the plotted point (use the same angle, say 60°, on each sheet or draw the diagonal line about perpendicular to the curve).

Any set of points which lie within 7% of a selected curve can be defined as Curve 1. Calculate deviations in Form AQU-05. Positive and negative deviations should balance out, and all should be within 7% (of discharge). At the curves extremities, deviations in excess of 7% may be acceptable. An example of this tabulation is shown in Appendix III.

Measurements known to be affected by backwater may be plotted in pencil or by use of a distinctive symbol. To identify measurements made by another organization, use a different symbol (e.g., a triangle, square, or cross) with an explanatory note in the lower right-hand corner of the curve sheet.

F.2.3 Determining Zero Flow Gauge Height

The presence of shallow flow and low gradients, often make it difficult to obtain discharge measurements at very low flows. Extending the low end of the stage-discharge curve to zero flow is desirable, but problematic, because of the lack of accurate measurements. A graphical technique for determining the gauge height for zero flow is explained below (Figure F-2).

(a) Refer to the current stage-discharge curve (example in Figure F-3).

(b) Take three discharges that are in a geometric progression. (For example, 2, 4 and 8 m^3/s).

(c) Plot up from 2 m^3/s and across from 4 m^3/s to obtain point (1).

(d) Plot up from 4 m^3/s and across from 8 m^3/s to obtain a second point (2).

(e) Draw a line through these two points.

(f) Draw a line through the points where 2 m^3/s and 8 m^3/s intersect the stage-discharge curve (points (3) and (4)).

(g) The intersection of these two lines identifies the best estimate of the zero-flow gauge height.

Note: For a stream where flow actually decreases to zero, it is possible to verify the estimate. This is more likely where there is a good control, however, it must be remembered that the water level can and does fall below the actual zero flow level.

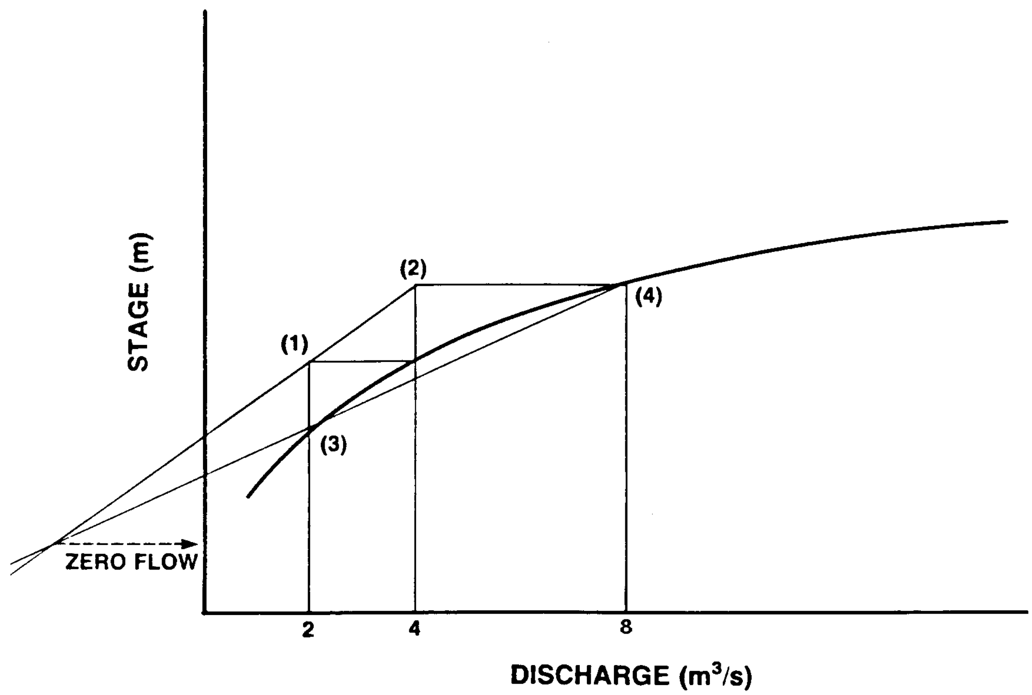

Figure F-2. Graphical method for obtaining zero flow gauge height.

Environment Canada / Environnement Canada
Environmental Management / Gestion de l'environnement

STAGE-DISCHARGE TABLE
TABLE DE RELATION HAUTEUR-DÉBIT

Station Name / Nom de la station: Sample Creek near Sampleburg
Station No / N° de la station: 01AA001
Table no / N° de la table: 1
Computed by / Calculé par:
Checked by / Vérifié par:
Date: Jan. 9, 1981

G.H. Hauteur m	Discharge Débit m³/s	Diff. m³/s	G.H. Hauteur m	Discharge Débit m³/s	Diff. m³/s	G.H. Hauteur m	Discharge Débit m³/s	Diff. m³/s	G.H. Hauteur m	Discharge Débit m³/s	Diff. m³/s	G.H. Hauteur m	Discharge Débit m³/s	Diff. m³/s
1.6 .00	10.50	0.16	.00			.00			.00			.00		
.10	10.66	0.17	.10			.10			.10			.10		
.20	10.83	0.17	.20			.20			.20			.20		
.30	11.00	0.17	.30			.30			.30			.30		
.40	11.17	0.17	.40			.40			.40			.40		
.50	11.34	0.17	.50			.50			.50			.50		
.60	11.51	0.17	.60			.60			.60			.60		
.70	11.68	0.17	.70			.70			.70			.70		
.80	11.85	0.17	.80			.80			.80			.80		
.90	12.02	0.18	.90			.90			.90			.90		
1.7 .00	12.20	0.18	.00			.00			.00			.00		
.10	12.38	0.18	.10			.10			.10			.10		
.20	12.56	0.18	.20			.20			.20			.20		
.30	12.74	0.18	.30			.30			.30			.30		
.40	12.92	0.18	.40			.40			.40			.40		
.50	13.10		.50			.50			.50			.50		
.60			.60			.60			.60			.60		
.70			.70			.70			.70			.70		
.80			.80			.80			.80			.80		
.90			.90			.90			.90			.90		

Allowable Range Table / Table du niveau admissible	Gauge Height / Hauteur d'échelle	Range / Niveau
Below 0.80	0.04m	
0.80 to 1.00	0.06m	
Above 1.00	0.20m	

Period of use / Période de validité: March 17/79 to
Remarks / Remarques:

Page 2 of 2

067-2119-M (05/80) R42 WATER RESOURCES BRANCH/DIRECTION DES RESSOURCES EN EAU

Sheet/Page ______ of/de ______

Figure F-3. Typical stage-discharge table as extracted from the relevant curve.

F.2.4 Extending the Rating Curve

For relatively new stations with few discharge measurements, it is often desirable to extend the stage-discharge curve beyond the highest discharge measurement available. This can be accomplished with the use of double logarithmic plotting paper. Plot the full range of measured discharges against stage.

In most cases, this logarithmic plot of measurements will form a straight line in the high flow range. This makes it a useful tool in extending curves beyond the highest discharge measurement. The "curve" as determined in the log plot is then transferred to the standard stage discharge plot.

Discharges estimated by indirect methods may be used to confirm the high end of the curve extension developed by the log plot. Indirect measurement of discharge is determined after the high water event has passed and involves engineering surveys to determine the geometry of the channel, and the application of hydraulic formulae. The most commonly used procedure is the slope-area method, which is described in various engineering texts.

F.2.5 Curve Labelling

The stage-discharge curve must now be numbered and labelled. Use the following procedure:

(a) The first curve used in the first year of operation will usually be designated "Curve No. l." However, another number, such as 31, may be selected if desired, but always increase curve numbers in chronological order of when the curve was derived.

(b) Use a diagonal line from the curve to the notation.

(c) Label any succeeding curves as "Curve No. 2," "Curve No. 3," etc. (or "Curve No. 32," "Curve No. 33," etc.).

(d) Enter the dates for the period of use of each curve in the space provided within the sheet title block.

F.2.6 Stage-Discharge Tables

Having established a best-fit curve, complete with zero flow stage, the next step is to prepare a stage-discharge table from the curve (Figure F-3). The following procedure is used to compile a stage-discharge table from the stage-discharge curve:

(a) Identify the number of the stage-discharge table as shown in Figure F-3, which must correspond to the stage-discharge curve number. The data processor's initials and the date the table was compiled are recorded as well.
(b) When compiling the stage-discharge table, deviate as little as possible from the exact coordinates, as indicated by the curve. Express discharges to at least the same number of significant figures as required for daily discharges.
(c) When the stage-discharge table is completed, plot the values on the curve sheet to ensure that the original delineation of the curve is consistent with the table.
(d) In some cases, a new stage-discharge curve is exactly the same as a former curve through part of the range in stage. In preparing the new stage-discharge table for these areas, copy the data from the former table through the range of stage in which the new curve and the former curve are identical. Then compile the new table in the range of stage where the two curves diverge. The new table will cover the entire range of stage.

(e) If a stage-discharge curve is extended above or below the original range, the same original number and date identification may be used. However, an explanatory note should be added on Form AQU-07, as well as the date when this extension was made. Note that this applies only if the curve is extended and not if it is revised.
(f) Enter the dates in the space provided for the periods of use of each table.

F.2.7 Expanded Stage Discharge Table

For production of discharge data, it is recommended that the discharge figure be tabulated to at least every 0.002 m of gauge height. Figure F-4 illustrates the expanded stage-discharge table format. This example was produced by digitizing a manually drawn curve.

F.2.8 Daily Discharges

F.2.8.1General

One of the basic objectives of a hydrometric technician's work is to gather data for the determination of daily discharge. A detailed knowledge of the procedures involved in preparation of these data to publishable standards is essential.

While several automated procedures have been developed for the computation of open water discharges, the following sub-sections explain the procedures used in the manual preparation of Daily Discharges. Procedural mistakes could well arise if one is not aware of the functions the computer is performing during automatic computations. To truly understand the basic concepts of discharge computations, the procedures for manual data processing must be understood.

Figure F-5 illustrates the steps involved from data collection through to data archiving. This chart, taken from *Water Survey of Canada* (Hydrometric Technician Career Development Program. 1990. Vol. 1-5), an Environment Canada training manual, demonstrates the complexity and large number of components involved in the process. It can be seen that gauge heights must be compiled. In the simplest case, a daily mean stage (or gauge height) is determined from the stage records. This is then used with the stage-discharge table to determine the daily mean discharge.

F.2.8.2Subdivided Day Method

Computation of Daily Mean Discharge

The daily mean gauge height is often used to compute the daily mean discharge, as described above. However, a daily mean discharge determined directly from the daily mean gauge height may be in error for a number of reasons.

These reasons include:

(a) the rate of change as indicated by the shape of the stage hydrograph for the day and the proportion of time during which the stage is relatively high or low; and
(b) the relative curvature in the stage-discharge curve in the range of stage recorded during the day.

To obtain a more accurate determination of the daily discharge, it may be necessary to subdivide the day into two or more parts, determine the mean gauge height for each part, and determine the discharge for each mean gauge height. From these, compute the weighted mean discharge for the day. If the resultant weighted mean discharge differs from that determined using the mean gauge height by more than the selected allowable limit of 2% for discharge above a predetermined amount, then subdivision is necessary for all similar conditions.

To determine whether it is necessary to subdivide, examine the data and select a few sample days that may be critical because of the conditions listed in (a) to (b). Compute the daily mean discharge for these days: (1) from the daily mean gauge height, and (2) by subdivision. A few tests of this nature will provide the necessary experience for the particular station upon which to base future decisions regarding the necessity of subdivision.

Allowable Range Tables

Allowable range tables may be used to determine if a day for a particular station needs to be subdivided. The following trial and error procedure is used for drawing up allowable range tables. A hypothetical example extracted from the Manual of Hydrometric Data Computation and Publication Procedures, page 27 (Environment Canada 1980), is used to illustrate the procedure:

(a) From the stage-discharge table, select a range in stage during medium flow, for example, from 3.0 to 4.0 m.

Suppose that the discharge at gauge height 3.0 m equals 186 m^3/s and the discharge at gauge height 4.0 m equals 339 m^3/s. The mean discharge for this range in stage would then equal 262 m^3/s.

However, you observe that at a mean gauge height of 3.5 m, the discharge is only 252 m^3/s. This represents a difference of 4% (10 divided by 262 x 100) which is not allowable.

(b) Select a smaller range, for example from 3.0 to 3.4 m. Calculate the mean discharge for this range in stage. Compare the mean discharge with the actual discharge at the mean gauge height for this range. Now you get a difference of 1%. This is too low, but 3.0 to 3.6 m gives 2%, which is satisfactory.

(c) Now try a range between 4.0 and 4.6 m. This gives a 1% difference, which is too low. Try between 4.0 and 5.0 m, which gives a 3% difference. Therefore, an allowable range of 0.8 m is about right.

(d) The range from 6.5 to 7.5 m will give 2%.

(e) After several such attempts, you will develop an approximate allowable range table. **When in doubt, subdivide.**

MINISTRY OF ENVIRONMENT LANDS & PARKS PAGE 1 OF 4
HYDROLOGY BRANCH
SURFACE WATER SECTION

SHERIDAN CREEK ABOVE MCLEESE LAKE GAUGE NO. 08MC045
STAGE DISCHARGE TABLE NO. 6 DATED 1996 APR 18 TO 1997 MAY 23

METRES	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009	METRES
0.15	0.022	0.023	0.024	0.025	0.026	0.027	0.028	0.029	0.030	0.031	0.15
0.16	0.032	0.033	0.035	0.036	0.037	0.039	0.040	0.041	0.042	0.044	0.16
0.17	0.045	0.046	0.048	0.049	0.050	0.051	0.053	0.054	0.055	0.057	0.17
0.18	0.058	0.060	0.061	0.063	0.065	0.066	0.068	0.070	0.072	0.073	0.18
0.19	0.075	0.077	0.078	0.080	0.082	0.083	0.085	0.087	0.089	0.090	0.19
0.20	0.092	0.094	0.096	0.098	0.100	0.102	0.105	0.107	0.109	0.111	0.20
0.21	0.113	0.115	0.117	0.119	0.121	0.124	0.126	0.128	0.130	0.132	0.21
0.22	0.134	0.136	0.139	0.141	0.143	0.146	0.148	0.150	0.153	0.155	0.22
0.23	0.158	0.160	0.162	0.165	0.167	0.169	0.172	0.174	0.176	0.179	0.23
0.24	0.181	0.184	0.186	0.189	0.191	0.194	0.196	0.199	0.201	0.204	0.24
0.25	0.207	0.209	0.212	0.214	0.217	0.219	0.222	0.224	0.227	0.229	0.25
0.26	0.232	0.235	0.238	0.241	0.244	0.246	0.249	0.252	0.255	0.258	0.26
0.27	0.261	0.264	0.267	0.270	0.273	0.275	0.278	0.281	0.284	0.287	0.27
0.28	0.290	0.293	0.296	0.299	0.302	0.305	0.308	0.311	0.314	0.317	0.28
0.29	0.320	0.323	0.326	0.329	0.332	0.335	0.338	0.341	0.344	0.347	0.29
METRES	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009	METRES
0.30	0.350	0.353	0.357	0.360	0.363	0.366	0.370	0.373	0.376	0.380	0.30
0.31	0.383	0.386	0.390	0.393	0.396	0.400	0.403	0.406	0.409	0.413	0.31
0.32	0.416	0.420	0.423	0.427	0.430	0.434	0.438	0.441	0.445	0.448	0.32
0.33	0.452	0.456	0.459	0.463	0.466	0.470	0.474	0.477	0.481	0.484	0.33
0.34	0.488	0.492	0.496	0.499	0.503	0.507	0.511	0.515	0.518	0.522	0.34
0.35	0.526	0.530	0.534	0.537	0.541	0.545	0.549	0.553	0.556	0.560	0.35
0.36	0.564	0.568	0.572	0.577	0.581	0.585	0.589	0.593	0.598	0.602	0.36
0.37	0.606	0.610	0.614	0.619	0.623	0.627	0.631	0.635	0.640	0.644	0.37
0.38	0.648	0.652	0.656	0.661	0.665	0.669	0.673	0.677	0.682	0.686	0.38
0.39	0.690	0.694	0.698	0.703	0.707	0.711	0.715	0.719	0.724	0.728	0.39
0.40	0.732	0.737	0.741	0.746	0.751	0.755	0.760	0.765	0.770	0.774	0.40
0.41	0.779	0.784	0.788	0.793	0.798	0.803	0.807	0.812	0.817	0.821	0.41
0.42	0.826	0.831	0.836	0.841	0.845	0.850	0.855	0.860	0.865	0.870	0.42
0.43	0.875	0.879	0.884	0.889	0.894	0.899	0.904	0.908	0.913	0.918	0.43
0.44	0.923	0.928	0.933	0.938	0.942	0.947	0.952	0.957	0.962	0.967	0.44

Figure F-4. First page of typical expanded stage-discharge table.

Figure F-4. First page of typical expanded stage-discharge table.

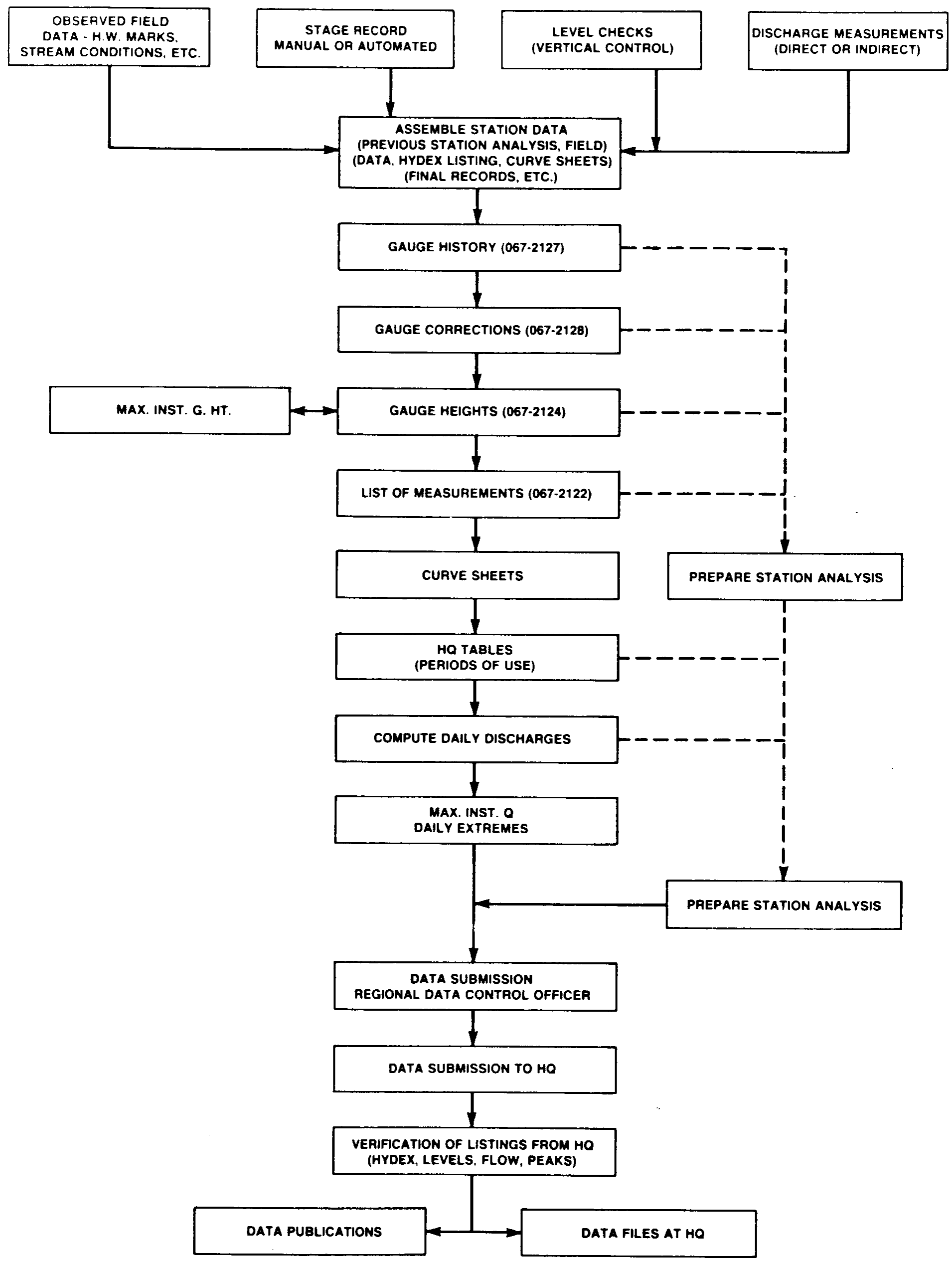

Figure F-5. Flowchart for manual computation of streamflow data.

F.2.9 Loop Curves

Sometimes the discharge for a given stage at a particular station is greater when the stream is rising than when it is falling. This produces a loop (or hysteresis) curve. On a simple stage-discharge curve, it will be found that measurements made on a rising stage tend to plot to the right of the curve, while those made on a falling stage tend to plot to the left. As stated in Rantz *et al.* (1982, page 414):

The discharge measurements for individual flood waves will commonly describe individual loops in the rating. In other words, "there will be a different loop for each flood". The departure of measurements from the rating curve for steady flow is of significant magnitude only if the slope of the stream is relatively flat and the rate of change of discharge is rapid. For gauging stations where this scatter of discharge measurements does occur, the discharge rating must be developed by the application of adjustment factors that relate steady flow to unsteady flow. (Unsteady flow refers to discharge at a site that changes appreciably with time, as in the passage of a flood wave.) An example of a stage-discharge curve of this type is shown in Figure F-6.

The detection and application of loop curves is limited to large rivers and therefore beyond the scope of this RIC Manual.

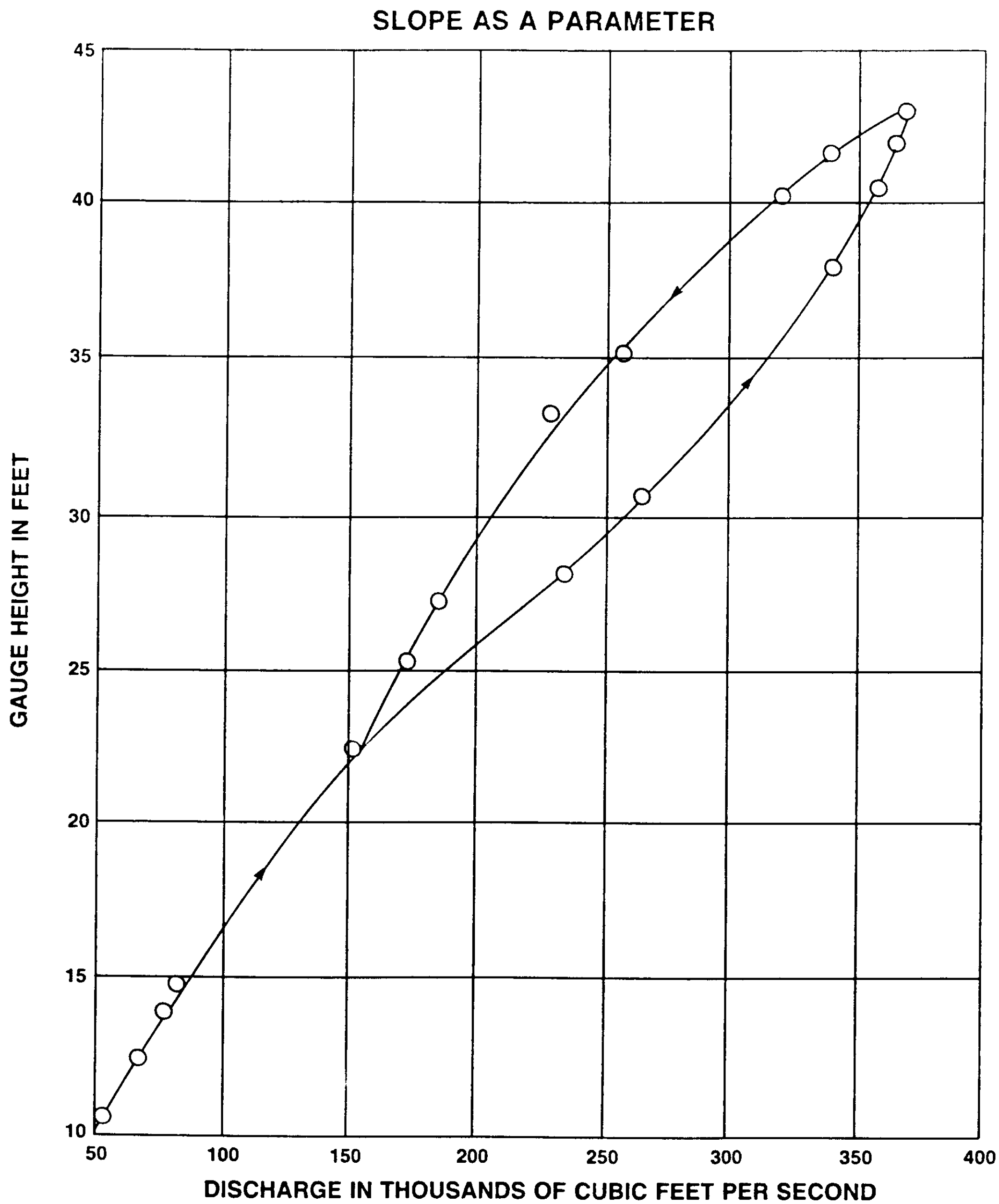

Figure F-6. Example of a stage-discharge loop.

F.3 Summary of Discharge Measurements AQU-05 Form

F.3.1 Introduction

Notes and records obtained in the field are the basis of the office computation of hydrometric survey data. It is essential that all data be identified at every step in the computation process. Once the daily gauge heights have been determined the Summary of Discharge Measurements Form AQU-05 must be completed for all discharge measurements obtained during the year.

An example is shown in Form AQU-05 (Figure F-7). The steps for completing this form are as follows:

(a) Enter the date of the discharge measurement. If a non-conventional technique, such as 1/4 point velocity culvert etc., was used in measuring the discharge, indicate the method of measurement in the “Remarks” column.

(b) Enter the name of the person and/or the organization who made the measurement, as appropriate.

(c) Enter the water temperature as obtained at the time of the measurement (this is particularly important when water temperature is near freezing).

(d) Enter the width, area, mean velocity and discharge, using 3 significant figures. If ice is present in the stream, or if the discharge is estimated, insert the appropriate reference or symbol in the “Remarks” column.

(e) Extract the weighted mean gauge observation corresponding to the measured discharge from the notes on the front sheet of the Discharge Measurement Form (Form AQU-03, Figures F-8a and F-8b). Apply the appropriate gauge correction from History of Gauge Levels (Form AQU-04, Figure F-9) to this observation and enter the result in the “Mean Gauge Height” column. If there are unusual conditions affecting the stage-discharge relation, such as inflow between the gauge and the measuring section, note this in the “Remarks” column. Gauge height must be recorded to 3 decimals (e.g., 1.342 m).

(f) If discharge measurements at a station are made at more than one location, a symbol should be entered under “Remarks” to distinguish them in the event that it is necessary to use the cross sectional area or the mean velocity.

(g) If any other information pertinent to the discharge measurement is obtained, note this in the “Remarks” column.

BRITISH COLUMBIA — RESOURCES INVENTORY COMMITTEE

Summary of Discharge Measurements for the year: 1996

Station Operating Agency/Firm: *BC ENVIRONMENT / RIB*

Stn. No.: *O8MC045* **Stn. Name:** *SHERIDAN CREEK ABOVE MCLEESE LAKE*

Date yy/mm/dd	Metered by	Meter Type	Meter Unit # Prop#	Water Temp (C)	Width (m)	Area (m2)	Mean Velocity (m/s)	Mean Gauge Height (m)	Discharge cms (m3/s)	From Stage Discharge Table No. Disch cms	Diff	%	No. Disch cms	Diff	%	Remarks
96/04/12	HO	PRICE	005 /--		5.60	3.11	1.520	0.918	4.73	4.850	-.12	-2.4	4.430	.30	+6.7	POLE MEASUREMENT
96/04/12	HO	PRICE	005 /--		5.25	3.22	1.560	0.955	5.01	5.280	-.27	-.51	4.860	.15	+3.1	POLE MEASUREMENT
96/04/14	HO	PRICE	005 /--		7.10	2.85	1.080	0.788	3.09	3.350	-.33	-9.8	2.990	.03	+1.0	
96/04/14	HO	PRICE	005 /--		7.00	2.85	1.060	0.774	3.02	3.490	-.40	-11.5	3.120	-.03	-1.0	
96/04/16	HO	PRICE	005 /--		6.80	2.70	1.020	0.744	2.77	3.070	-.30	-9.8	2.720	+.05	+1.8	
96/04/18	HO	PRICE	005 /--		6.15	2.22	1.010	0.688	2.25	2.560	-.31	-12.1	2.260	-.01	-0.4	
96/05/06	CH	PRICE	005 /--		3.55	0.88	0.418	0.301	0.37	0.353	+.013	+3.7				
96/05/22	HO	PRICE	005 /--		3.25	0.81	0.324	0.278	0.26	0.284	-.023	-8.1				DEBRIS REMOVED
96/06/26	HO	OSS	88-46 / 1		3.20	0.56	0.195	0.207	0.11	0.107	+.002	+1.8				FROM CONTROL
96/08/20	HO	OSS	93-08 / 1		3.15	0.54	0.129	0.190	0.07	0.075	-.006	-8.0				
96/10/30	JM	OSS	93-07 / 1		3.15	0.55	0.130	0.192	0.07	0.078	-.007	-9.0				

Computed by: *H.OVIE*	Checked by: D.RICHDALE	Approved by: *R.RICHARDS*
Date: *96/11/15* (y/m/d)	Date: *97/1/10* (y/m/d)	Date: *97/3/15* (y/m/d)

AQU-05 98/10

Figure F-7. Example of completed RIC Form AQU-05, Summary of Discharge Measurements for the Year _____.

BRITISH COLUMBIA

RESOURCES INVENTORY COMMITTEE

Discharge Measurement
(Complete Both Sides)

Station Operating Agency/Firm: BC ENVIRONMENT/RIB

Stn. No.: 08MC045 Stn.Name: SHERIDAN CREEK ABOVE MCLEESE LAKE

Date: 96/04/14 (yy/mm/dd) Metered by: H. OVIE

Location of Metering Section: HIGH FLOW SITE, 300M D/S OF SG

Temp: Air ______°C Water ______°C Weather: CLOUDY

	Time	O.G.	I.G.	Rec.
Begin	08:05	.790	4.859	.798
End	09:05	.785	4.854	.788
Mean		.788	4.856	.793
Gauge Correction: 0.000				

C.G.H. .788	Q 3.09	Area 2.85	Avg. V 1.06

Meter: Type PRICE. No. 005. Prop. No. ________.

Where V = Velocity (m/s) and n = Revolutions/sec.

Select one of the following equations:

(1) For Single Range Meters:

V = n	x	Slope	+	Intecept	m/s.
V = n	x	.6479	+	0.0059	m/s.

(2) For Multiple Range Meters:

	n(Min)		n(Max)	V =	n x Slope	+	Intercept	m/s.
IF		< n <		: V = n x		+		m/s.
IF		< n <		: V = n x		+		m/s.
IF		< n >		: V = n x		+		m/s.

Remarks: ____________________

____

RIC AQU-03 97/10

Figure F-8a. Example of completed RIC Form AQU-03, Discharge Measurement (front).

BRITISH COLUMBIA

Resources Inventory Committee

Discharge Measurement

(Complete Notes on Reverse Side)

Station Operating Agency/Firm: BC ENVIRONMENT/RIB

Stn. No.: 08MC045 Stn.Name: SHERIDAN CREEK ABOVE MCLEESE LAKE

OBSERVATIONS								COMPUTATIONS			
Meth.	Dist. from initial point (m)	Depth (m)	Depth of obs. (m)	Revs (no.)	Time (sec)	Cosine of flow angle	Velocity At point (m/s)	Velocity Mean in vert. (m/s)	Width (m)	Area (m^2)	Disch. (m^3/s)
LB	3.10	0.00									
.6	3.20	0.20		10	41			0.164	0.25	.052	0085
.6	3.50	0.52		4	40			0.071	0.40	.199	0140
.6	4.00	0.56		62	40			1.010	0.45	.254	2566
.6	4.40	0.65		82	40			1.334	0.30	.191	2542
.6	4.60	0.65		91	39			1.518	0.25	.163	2472
.6	4.90	0.66		103	42			1.595	0.35	.230	3670
.6	5.30	0.65		98	40			1.593	0.35	.227	3621
.6	5.60	0.63		89	40			1.447	0.30	.187	2709
.6	5.90	0.56		74	40			1.205	0.30	.171	2060
.6	6.20	0.57		78	43			1.181	0.35	.196	2311
.6	6.60	0.50		80	40			1.302	0.40	.198	2577
.6	7.00	0.39		59	40			0.962	0.35	.141	1358
.6	7.30	0.37		59	41			0.938	0.30	.111	1042
.6	7.60	0.35		56	40			0.913	0.35	.120	1098
.6	8.00	0.29		56	40			0.913	0.40	.118	1073
.6	8.40	0.26		63	43			0.955	0.35	0.91	0873
.6	8.70	0.23		41	40			0.670	0.30	0.68	0457
.6	9.00	0.18		19	41			0.306	0.35	0.60	0185
.6	9.40	0.09		8	44			0.124	0.40	.041	0050
.6	9.80	0.09		10	42			0.160	0.60	.036	0058
RB	10.20	0.00									
Totals									7.10	2.85	3.09

RIC AQU-03 97/10 COSINE

Figure F-8b. Example of completed RIC Form AQU-03, Discharge Measurement (back).

BRITISH COLUMBIA

RESOURCES INVENTORY COMMITTEE

History of Gauge Levels

Station Operation Agency/Firm: BC ENVIRONMENT/RIB

Stn. No.: 08MC045 Stn. Name: SHERIDAN CREEK ABOVE MCLEESE LAKE

BM # 2 Description LAG BOLT IN 0.6 M COTTONWOOD LB 40 M D/S OF S.G.

BM # 3 Description LAG BOLT IN 0.35 M COTTONWOOD LB 40 M D/S OF S.G.

BM # 4 Description LAG BOLT IN 0.22 M COTTONWOOD LB 55 M D/S OF S.G.

BM # Description

Elevation of Station Datum (GSC, or other): LOCAL (Note: Local datum is always 0.0)

History of Level Checks, Gauge Corrections, and Changes to Benchmarks and Auxiliary Gauges

Gauge Correction Data (m)							
Date (y/m/d)	Gauge Reading (m)	Gauge Correct.	BM or Ref. #	BM or Ref. #	BM or Ref. #	BM or Ref. #	Notes on Installation or Removal of Gauges, Benchmarks, Auxiliary Gauges, etc.
			BM-2	BM-3	BM-4		
92/3/30	0.396	0.000	1.393	1.513	2.622		(SG->BM-2->BM-3->BM-4)x2
93/8/12	0.223	-0.002	1.395	1.515			(SG->BM-2->BM-3)x2 BM-4 DESTROYED
94/5/2	0.270	0.002	1.390	1.511			(SG->BM-2->BM-3)x2
95/4/21	0.271	0.000	1.376	1.505			NEW ELEVATIONS FOR BM'S NEW LAG BOLT INSTALLED (SG->BM-2->BM-3)x2
96/4/16	0.740	-0.002	1.376	1.505			(SG->BM-3->BM-2->BM-3->SG)

RIC AQU-04

Figure F-9. Example of completed RIC Form AQU-04, History of Gauge Level.

F.3.2 Shift and Backwater Corrections

F.3.2.1 General

A shift is defined as an alteration in the s-d relation caused by a change in the stream control. The stage-discharge relation is not permanent at most stations but varies gradually or abruptly because of changes in the physical features of the control. If the change in the rating persists, this is an indication that a new rating curve should be prepared for this period of time. If the change is of short duration and is easily reversible (e.g., an obstacle hung up on the control), the original rating curve is still effective but, during this period, shifts or adjustments must be applied to the recorded stage before determining the corresponding discharge. Frequent discharge measurements must be made during any period to define the magnitude of the shift(s) when the condition is not correctable. For most gauging stations the stage-discharge curve represents the best-fit or average line and may not necessarily pass through all plotted points. That is, the stage-discharge relation is usually subject to minor random fluctuations.

Backwater is defined as a temporary rise in stage produced by an obstruction in the stream channel downstream of the gauge caused by ice, weeds, control structure, etc. The difference between the observed stage for a certain discharge and the stage as indicated by the stage-discharge relation for the same discharge is reported as the backwater at the station.

F.3.2.2 Computation of Shift and Backwater Corrections

The computation of shift and backwater corrections is as follows, (adapted from the Manual of Hydrometric Data Computation and Publication Procedures, published by Environment Canada 1980):

(a) For many stations, a shift in the station control or a backwater condition may occur at certain times during the year as a result of weed effect, beaver action or ice conditions. During such periods, shift or backwater corrections are determined from available discharge measurements. These corrections are entered on Form AQU-05 and used subsequently to compute daily corrections, which are applied in the determination of the daily discharges.

(b) However, apart from these measurements which plot off the curve for reasons indicated above, most of the measurements will plot somewhat off the curve as a result of normal scatter. For these, no correction is computed; however, it is normally found useful for purposes of expressing mathematically the degree of scatter to indicate for each measurement the percentage difference between measured discharge and the discharge indicated by the stage-discharge relation. These percentage differences are entered in the “Diff.” column on Form AQU-05. If desired, these differences may be expressed in cubic metres per second instead of percentage for discharges less than about 0.005 m^3/s.

(c) A discharge measurement made during the computation period may plot substantially off the stage-discharge curve. It is recommended that discharge measurements be computed and plotted on site and redone if it plots off the curve. This can often determine if it is a bad measurement or if a shift has occurred. However, sometimes the second measurement can not be done, or sometimes it is done and the departure can not be explained. If, after careful analysis and review, no satisfactory cause of its departure from the stage-discharge curve can be determined, the measurement should be eliminated from use in the computation. In this instance, do not enter any figure in the “Shift” or “Diff.” columns, but enter an explanatory note in the “Remarks” column on Form AQU-05, as well as on Station Analysis Form AQU-07. This should be a rare occurrence for good hydrometric stations and experienced technicians.

F.3.2.3 Distribution of Shift and Backwater Corrections

Several methods of distributing shifts may be used. Two of the more common methods are linear distribution by time and stage-shifting. These techniques will be briefly discussed here. A more comprehensive treatment of shifts may be found in Rantz *et al.* (1982), pages 354-360.

Linear Distribution By Time

If the date on which the change occurred is not known, assume that the change occurred uniformly and distribute the correction in accordance with one of the two following methods:

Divide the change in the correction by the number of days to find the "change per day". For example: Suppose the correction was found to be +0.005 on March 20 and +0.009 on March 30. The number of days involved is 10 and the change in correction is 0.004. The change per day is 0.0004. The corrections to be applied are shown to the nearest thousandth of a metre.

When the change is small and the number of days is large, the preferable method is to divide the number of days by the change in correction. For example:

A correction of +0.003 is applicable on May 25, but on October 15 is 0.006, a period of 144 days.

Solution: Three 0.001 m increments are applied at intervals of 48 days as follows:

No change in correction will be applied during the first one-half interval of 24 days, i.e., the correction +0.003 will be continued from May 25 to June 17; an increase of 0.001 in the correction will be applied during each of the next two intervals of 48 days, i.e., a correction of +0.004 from June 18 to August 4 and +0.005 from August 5 to September 21.

The remaining 0.001 change will be applied during the remaining one-half interval, i.e., the final correction of +0.006 will be applied from September 22 to October 15.

Stage-Shifting

Stage-shifting is normally done because of a temporary, or short-term condition at a gauging station. For example, perhaps a minor peak has occurred at a station, and discharge measurements indicate a significant change to the stage-discharge curve at higher stages. A short time later, a major flood drastically alters the stage-discharge relationship, requiring an entirely new stage-discharge curve. Instead of drawing two new curves with accompanying rating tables, the minor peak may be stage-shifted, and a new curve can be drawn for conditions following the major flood.

F.3.3 Symbols and Footnotes

It is important that a uniform system of symbols and footnotes be used in the production of daily discharge tabulations. The symbols (and footnotes) used by Environment Canada in the publication of Surface Water Data are set out below together with instructions on their use.

The following has been adapted from the "Manual of Hydrometric Data Computations and Publication Procedures", pages 12 and 13.

(a) ***"A" - Manual Gauge***
Use this symbol during open water periods to identify the use of one or more manual gauge observations to obtain a daily stage at a station where the water stage recorder was temporarily out of operation. Enter this symbol to the right of the daily discharge figure or to the right of the daily stage figure if no discharge data are shown. This symbol will also be used when the chart record is available for only part of a day. During a year when a recorder is installed, the symbol "A" will be used on all days prior to the chart records to identify manual gauge readings. Do not enter this symbol in any monthly or annual summary data, except for the extremes in the annual summary, if applicable. Do not use this symbol during ice periods. However, a footnote will be required if the recording gauge was not in operation in winter periods. Use of this symbol must be accompanied by an appropriate reference in a footnote (i.e., A - Manual gauge). The symbols "B" or "E" have precedence over the symbol "A".

(b) ***"B" - Ice Conditions***
Use this symbol to indicate that ice conditions in the stream have altered the open water stage-discharge relationship. The symbol is entered to the right of the daily discharge figure. This symbol will not be used for water level data. However, if it is required for specific stations, an appropriate explanation should be given in the Station Analysis Form AQU-07. Do not enter this symbol in any monthly or annual summary data except for the extremes in the annual summary, if applicable. Use of this symbol must be accompanied by an appropriate reference in a footnote (i.e., B - Ice conditions). The symbol "B" has precedence over the symbols "A" and "E".

(c) ***"D" - Dry***
Use this symbol to indicate that the stream or lake is "dry" or that there is no water at the gauge. This symbol is used without a footnote in the gauge height column.

(d) ***"E" - Estimated***
Use this symbol whenever the discharge during open water periods was determined by some indirect method, such as interpolation, significant high stage extension, comparison with other streams, or by correlation with meteorological data. If desired, the method of estimate may be given in a footnote. Enter this symbol to the right of the daily discharge or daily water level figure. Do not use this symbol during ice periods. Do not enter this symbol in any monthly or annual summary data except for the extremes in the annual summary, if applicable. Use of this symbol must be accompanied by an appropriate reference in a footnote (i.e., E - Estimated). The symbol "E" has precedence over the symbol "A".

(e) In summary, although only the symbols "A", "B", "D", or "E" will be used, only the symbols "A", "B" or "E" will be accompanied by a footnote in the data compilations or on printouts. For example, footnotes may be used if the symbol applies to one or more periods, or to explain that the recording gauge was not in operation during all or part of the winter period.

(f) The computer printouts for daily discharges and water levels will show a symbol for each day, where applicable.

F.3.4 Station Analysis

Although the Station Analysis Form AQU-07 will not be dealt with in this section, the reader should be aware that pertinent facts regarding the open water computations should be noted for eventual inclusion in the station analysis.

For instance, the reasons for the distribution of the gauge and shift corrections, including the stage-shifting; the period of use of stage-discharge tables; etc.

In particular, any deviation from the commonly practiced computation procedure should be tabulated in the station analysis.

F.3.5 Conclusion

This section has covered the derivation of stage-discharge curves and tables from discharge measurements, and the production of discharge data by combining stage data and the stage-discharge relationship. The stage-discharge curve must be determined by a manual process in order to give appropriate weighting to the discharge data. After that, data may be processed manually or by computerized methods.

There are a number of specialized software packages for hydrometric data processing, and some users have adapted more general software such as spreadsheets for this purpose. This section has described techniques as if data were being processed manually, as it is essential that the user be familiar with the rationale. Hydrometric computer packages can expedite data processing, but do not replace the knowledge and skill of a competent hydrometric technician. The judgments required at various stages of the process must be suitably documented, whether manual or computerized processing is used.

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G. Discharge Measurement Structures

G.1 Introduction

This section is intended to serve as a guide to the selection and installation of permanent and semi-permanent structures with a predetermined rating. The sampling of common pre-fabricated units included, each of which has been rated in laboratory test programs. In addition, all have effective discharge coefficients of less than 3% error when operated within their modular range and the other limits of application have been satisfied. With the exception of larger rectangular weirs, the capacities of the structures described do not exceed 4 m^3/s.

Larger units are available, but the cost of engineering and construction place them beyond routine applications. The need for rating verification for these structures becomes more important for the larger units or where the design is modified in any way. Reference to standard texts is recommended, as no details on the hydraulics or modular limits are provided. (Discharge Measurement Structures. Edited by M.G. BOS. Published by International Institute for Land Reclamation and Improvement/ILRI PO Box 45, 6700 AA Wageningen, The Netherlands.)

G.2 Purpose

The measurement of flow in natural streams is hampered by many factors, which undermine the reliability of metering equipment. These conditions include:

- Remote locations interfering with regular and timely visits.
- Access difficulty, steep banks, seasonal or poorly maintained roads.
- Movable bed and high sediment transport conditions resulting in control shifts, perhaps several during a single season.
- Metering trips must be repeated frequently and not all are productive.
- Poor metering sites, for example steep rocky gradients.
- Shallow flows where normal metering equipment is not acceptable.

Rated structures can be used in such situations to minimize or eliminate many of these problems. The initial installations costs can be high for major installations, but must be evaluated against repeated metering which can also be expensive and all too frequently wasted. The cost of buying and installing prefabricated structures can vary from about $2000 to $20 000, but can easily provide high quality data for many years with little or no metering.

G.3 Design

The selection of alternate flow measurement methods, particularly if involving larger streams with potentially destructive flows, should only be made after consultation with an hydraulic engineer or hydrometric specialist. These together with any larger measuring structures require the services of a structural engineer for final design.

G.3.1 Design Considerations

The selection of a streamflow measuring device, its location and installation should be based on sound information acquired before the design is finalized. Much or all of the following information should be acquired:

1. Duration of the proposed project
2. Expected range of discharge to be measured
3. Likelihood of flows above the expected range should be assessed in terms of:
    - device withstanding the stress of being over-topped
    - extreme events being measured
4. Geometry of the channel reach
5. Streambed gradient above and below the proposed site
6. Presence and extent of bedload and/or sediment transport
7. Presence of any downstream constriction which may cause elevated tailwater levels at higher flows
8. Permeability of streambanks, streambed and underlying strata
9. Frost line depth
10. Proximity of vehicle access (this may possibly include access by redi-mix truck or small load mix-trailer and travel time from depot)
11. Construction window for in-stream work

G.3.2 Selecting the Measuring Device

Initially, the choice of a measuring device for a particular location will depend on the conditions set out in the items 2 to 7 in the previous sub-section. Table G-1 enumerates the maximum and minimum discharges for the various sizes of devices together with their ability to prevent sedimentation and pass bedload and debris. With reference to Table G-1, and Figures G-1 and G-2, the placement of weir crests has an important dimension, p that is defined as the depth of the approach channel below the crest on the upstream side of the weir. It also is required in the ratio $\mathbf{h^1/p}$, listed with **p** in right hand column, and must be used to specify the placement of the various weir crests when these weirs are operating at capacity.

G.3.3 Installation

The installation of a rated structure is straightforward, but does require attention to a number of factors. These include:

1. Grade setting **-** two conditions must be satisfied to ensure accurate measurement. The approach velocity to the crest must be sufficiently low to maintain a negligible velocity head and the nappe must not be subject to downstream influences.
2. Sealing the streambed against seepage under the structure **-** any granular bed is susceptible to seepage. Prevention may involve the placement of a watertight membrane (plastic sheet or geotextile) on the streambed upstream of the structure.
3. Structural foundation - required for support, anchorage and preventing leakage.
4. Mounting the rating device **-** the primary concern is that it be level, aligned with the streamline, and well anchored

5. Wing walls - designed to maintain the minimum pool elevation and be watertight, and remain intact in the event of over-topping.

The information in Table G-1 illustrates the superiority of flume type measuring structures in situations where sediment and/or low bank geometry must be factored into the design. In addition flumes, particularly the H type, are more sensitive at low flows because the sides converge at the invert. For example, the capacities of the 2-m rectangular weir and the 4-foot HL flume are similar, however the sensitivity of low flow measurement in the HL flume is maintained to a flow rate which is one tenth that of the weir. In addition, the weir crest, in order to remain fully contracted at full capacity, must be set at an elevation of 2.0 m above the bed of an approach channel of at least 6 m breadth. The resulting pond characteristics must be maintained during the operating period of the weir so that approach velocities remain negligible. On the other hand, the throat elevation of the types of flumes listed require little or no elevation above the streambed and the dimensions of the approach channel need be no greater than those of the flume entrance. For purposes of comparison, the site geometry and other requirements are set out in Table G-2.

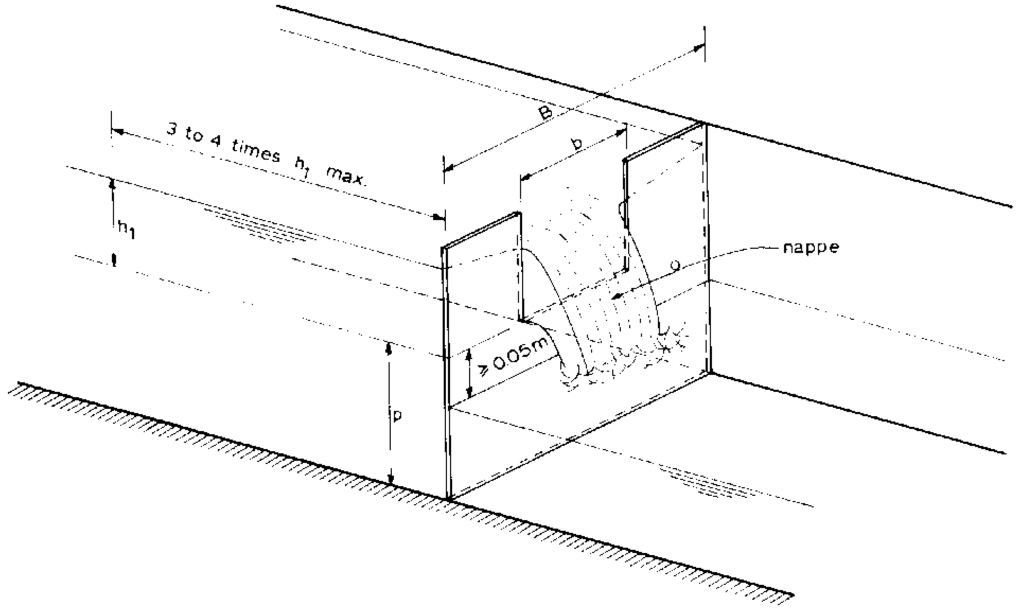
Table G-1. Operating limits for rated structures included in this Manual.

Device type	**Device size**	**Max. $h^{1\ a}$ (m)**	**Max. Q (m^3/s)**	**Min. h^1 (m)**	**Min. Q (m^3/s)**	**Debris capacity**	**Sediment capacity**	**h^1/p^b**	**Min. P^C (m)**
V-notch	90^0	0.60	0.390	0.05	0.0008	Very poor	Very poor	≤1.2	≥0.45
	120^0	0.60	0.765	0.05	0.0012	Very poor	Very poor	≤1.2	≥0.45
Montana	3-inch	0.339	0.33	0.03	0.0008	Very good	Good	N/A	N/A
Flume	6 inch	0.457	0.111	0.03	0.0015	Very good	Good	N/A	N/A
	9 inch	0.610	0.251	0.03	0.0025	Very good	Good	N/A	N/A
	12 inch	0.760	0.455	0.03	0.0033	Very good	Good	N/A	N/A
H flume	2.0 feet	0.604	0.309	0.03	0.0005	Fair	Fair	N/A	N/A
	2.5 feet	0.756	0.542	0.03	0.0008	Fair	Fair	N/A	N/A
	3.0 feet	0.908	0.857	0.03	0.0010	Fair	Fair	N/A	N/A
	4.5 feet	1.364	2.336	0.03	0.0014	Fair	Fair	N/A	N/A
HL flume	4.0 feet	1.218	3.292	0.05	0.0054	Good	Fair	N/A	N/A
Rectang.	b=1.0m	0.500	0.585	0.06	0.0267	Poor	Poor	≤ 0.5	≥ 0.3
Weir	b=1.5m	0.750	1.612	0.06	0.0402	Poor	Poor	≤ 0.5	≥ 0.3
	b=2.0m	1.000	3.308	0.06	0.0537	Poor	Poor	≤ 0.5	≥ 0.3
	b=3.0m	1.500	9.117	0.06	0.0807	Poor	Poor	≤ 0.5	≥ 0.3

[a] Head over the weir crest.

[b] Ratio of head over the crest and the height of the crest above the upstream bed.

[C] Height of crest above the upstream bed.


3 to 4 times h_1 max.
B
b
h_1
nappe
≥ 0.05m
p

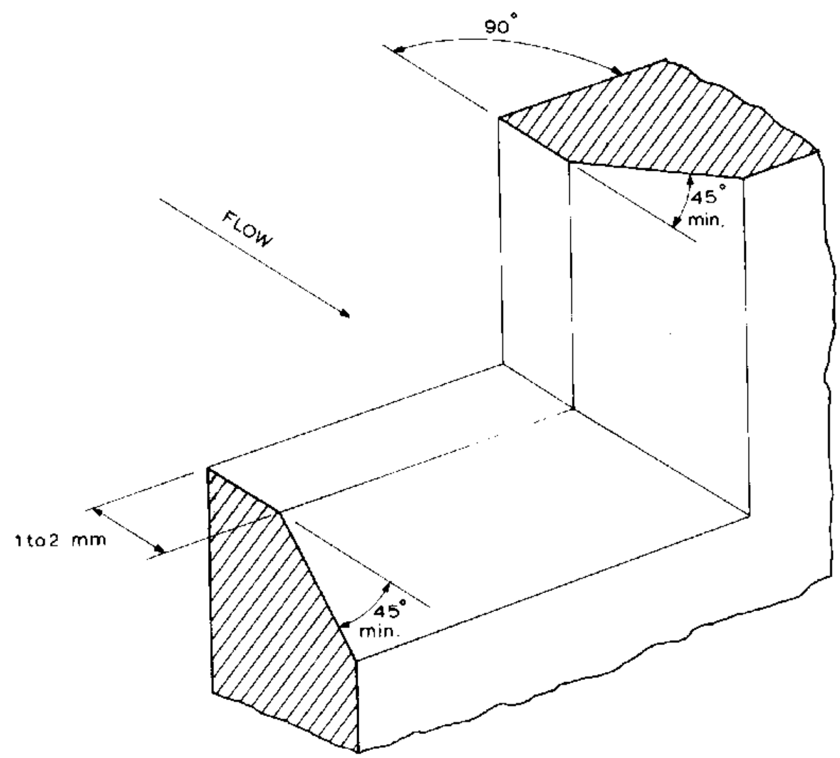
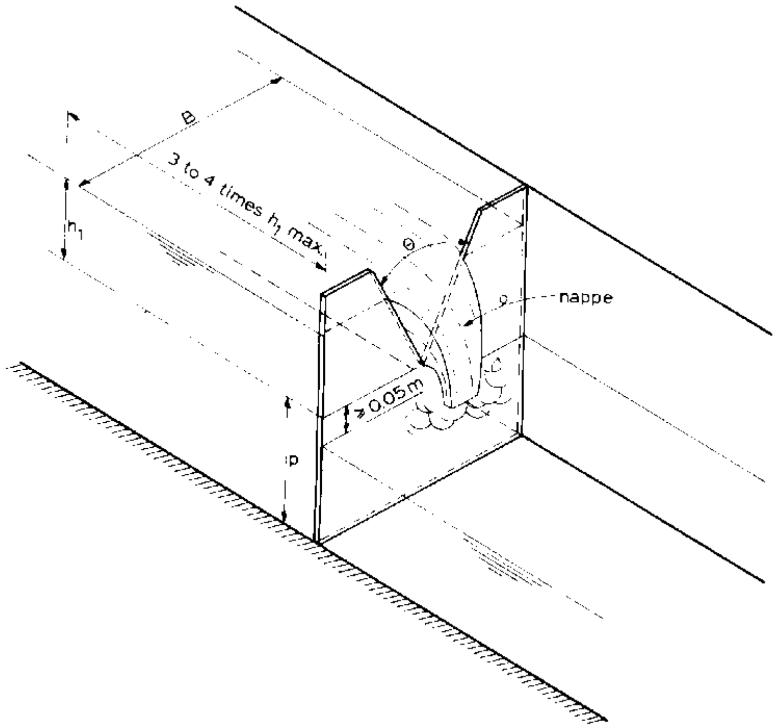

90°
45°
min.
FLOW
1 to 2 mm
45°
min.

Figure G-1. Top - Rectangular sharp-nested weir (thin-plate weir). Bottom - Enlarged view of crest and side of rectangular sharp-crested weir.


B
3 to 4 times h_1 max.
h_1
Θ
nappe
≥ 0.05m
p

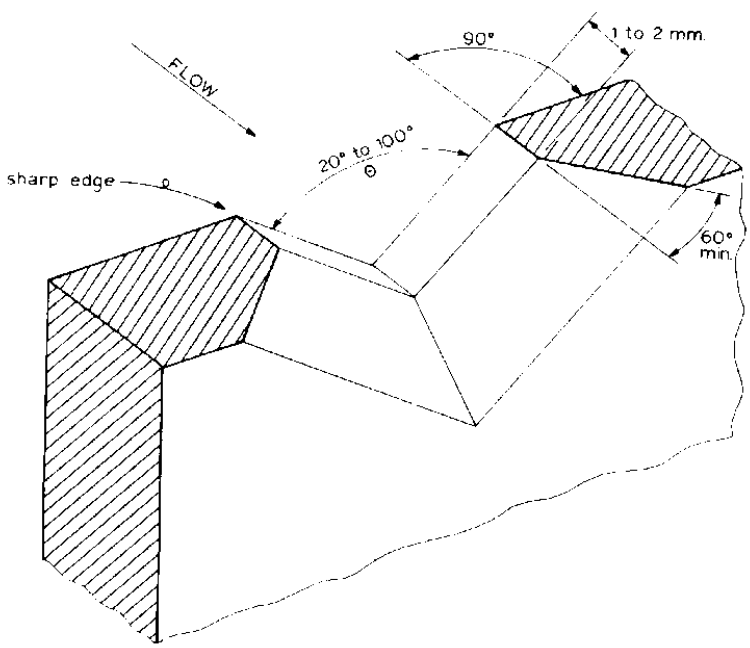

FLOW
90°
1 to 2 mm.
20° to 100°
Θ
sharp edge
60°
min.

Figure G-2. Top - V-notch sharp-crested weir. Bottom - Enlarged view of V-notch.

Table G-2. Comparison of two selected rated structures.

Rectangular weir, b = 3.0 m	**4.0-foot HL flume**
Rectangular weir, fully contracted with notch opening of 3.0 m wide x 1.0-m deep.	HL Flume with free-flowing nap.
Minimum width of approach channel =6 m.	Width of approach channel = 2.7 m.
Minimum height of banks, approach 3 m + freeboard for 1 in 50-year flood.	Height of rectangular channel walls 1.22 m + freeboard.
Length of weir notch bulkhead (must extend at least 1.5 m into each bank), 6 + 3 = 9 m. This bulkhead must also extend at least 0.75-m below the streambed.	The upstream ends of the approach channel walls should be keyed into their respective banks. This should extend at least 1.5-m into the banks and 0.75-m below the streambed.
The width and depth of the weir pond should be maintained for a distance upstream of the bulkhead equal to 9 times the maximum depth of flow over the crest. The upstream end of the pool should be designed to distribute flow across the approach channel to minimize the approach velocity during high flow.	The minimum length of the level rectangular approach channel is 2D (2.44-m).
If bedload movement and suspended sediment transportation is present, the upstream depth below the crest must be retained by a maintenance program. Failure to maintain the dimensions will result in a change to the coefficient of discharge with a resulting error which varies with stage. The infilling of weir ponds may be avoided by constructing a gravel/sediment arrestor pond a short distance upstream.	Sediment deposition seldom occurs within the flume and it has been observed that the flume gauge reading does not change when sediment deposits.

G.3.4 Site Conditions

Site conditions will usually determine the choice of a control structure for the measurement of flow at the desired location. The preceding subsection clearly shows the advantages of flume installations over weirs in most stream channels. The exception to such a choice is an installation at the outlet of a lake, pond or storage reservoir where neither sediment nor upstream excavation need be considered. In such a case a weir may be the most suitable choice. Most streams are defined as having or not having fish habitat, which has a direct bearing on timing of construction. Any stream designated as fish bearing requires approval of the Ministry of Environment, Lands and Parks (Appendix IV).

G.3.5 Erosion Protection

Unless a weir or flume is founded on bedrock downstream erosion protection of both streambed and banks will be required. The protection may include, but must not be restricted to, some form of stilling basin or a concrete slab. These are themselves structures which require protection against undermining and eventual failure. In the past, the downstream protection has usually consisted of properly sized rip-rap placed on a filter layer of coarse gravel overlying a layer of fine gravel. If broken rock is employed, the bank protection may be constructed, typically, with 1.5:1 slopes rising from a rock filled toe the depth of which must be at least twice the dimension of the rip-rap. The downstream end of the rip-rap must be keyed in to both the banks and streambed.

Geotextiles may also be used in conjunction with rip rap, concrete or other materials as part of the erosion protection. Engineering design may be required for erosion protection systems for large installation. Engineered systems based on proprietary materials are available.

G.4 Continuous Stage Recording

G.4.1 Flumes

The location of water level recorder intakes is defined in the fabrication sketches for the two types of flumes listed and described earlier. Descriptive information on H-flumes (Figure G-3) is added in Figure G-4 with the associated dimension table. Related discharge tables are included in Appendix V. The stilling well for use with these flumes is normally mounted against the outer face of the prefabricated flume and centered opposite the flumes point of measurement. This permits the use of a very short easily cleared intake pipe which should be threaded and screwed through a double thickness of stilling well wall which is drilled and tapped to suit.

> **Note:** Assuming ABS pipe is used for both stilling well and intake (metal pipe should be avoided as rapid heat conduction will result in frost formation) all fabrication can be accomplished on site. To form a double thickness wall, cut a patch from a length of scrap pipe (same diameter); using the correct solvent/glue and two large hose clamps, bond the patch in place.

> **Note:** A threaded socket (and removable threaded plug) at the outer end of the intake can facilitate the sealing of the stilling well. The well can be pumped out when the station is deactivated over the Winter. Both well and intake will remain ice free making reactivating in the Spring less onerous.

The base of the stilling well should be positioned at least 15 cm below the floor of the flume.

In some instances Montana (Figure G-5) or Parshall flumes have been installed at sites where the maximum flume capacity may occasionally be exceeded. If these events are quantified by current meter measurements, a reference gauge and recorder installed upstream will provide a more complete station record. A flume gauge is provided and both gauge readings recorded at each station visit. Installation requirements for an upstream gauge are the same as for weirs, see Section G.3.3.

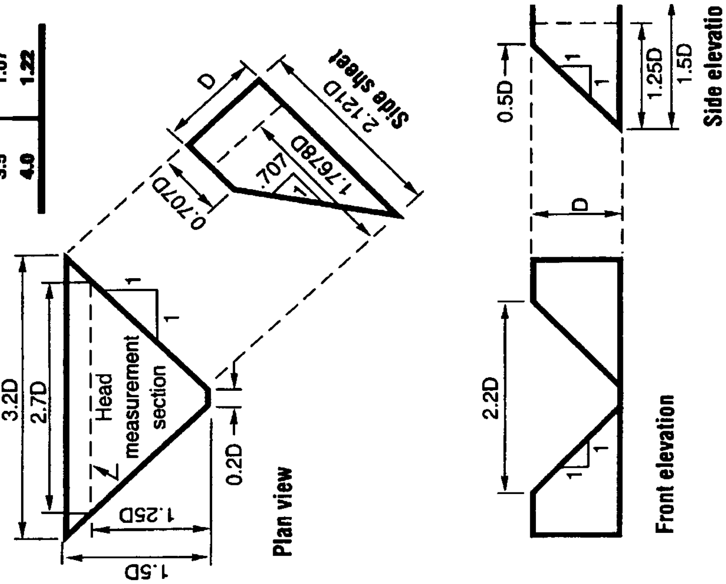
G.4.2 Weirs

Stilling wells should be installed in the weir pond against a stabilized vertical bank or wall. The well must be secured near the base and above the high water elevation. The reference gauge and intake must be positioned upstream of the crest at a distance 3 to 4 times the maximum height of water over the crest (to avoid drawdown effect).

Sample 120 V-notch weir is shown in Figure G-6.

Figure G-3. 2.5 foot H Flume set in concrete filled sacks. Cuisson Creek above Gibraltar Mine.

Depth D feet	Depth D meters
2.0	0.610
2.5	0.762
3.0	0.914
3.5	1.07
4.0	1.22



Depth D feet	Depth D meters
0.5	0.152
0.75	0.229
1.0	0.305
1.5	0.457
2.0	0.610
2.5	0.762
3.0	0.914
4.5	1.37

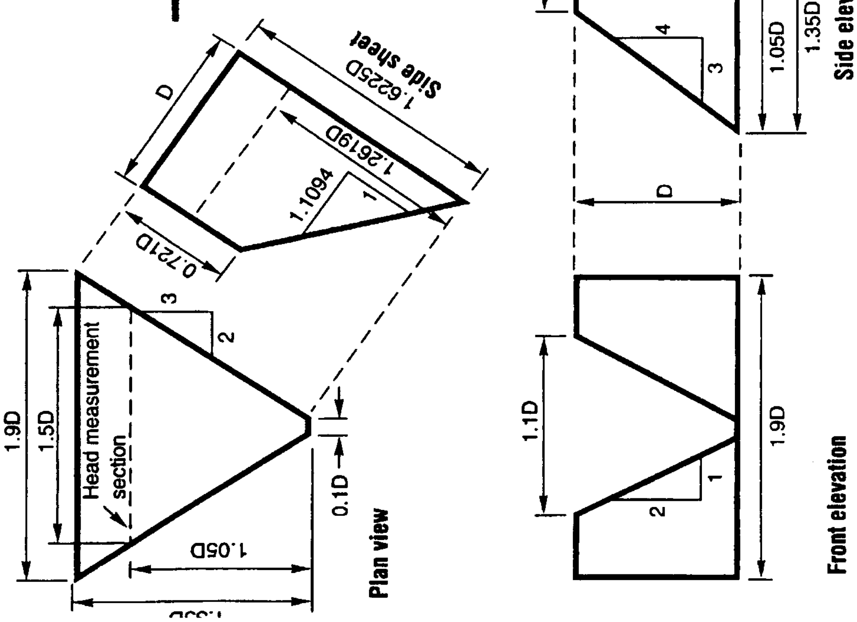


Figure G-4. Dimensions of HL-type (top) and H-type (bottom) Flumes.

Figure G-5. 6-inch Montana Flume set in concrete sack bulkhead. Bidwell Creek above Chilko River.

Figure G-6. 120° stainless steel weir plate set in re-enforced concrete. Whitehead Creek below Whitehead Lake (Summerland District water supply).

APPENDICES

Index to Appendices

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Appendix I. Glossary

The following glossary of selected hydrometric terms makes use of ISO Standards to which the reader is referred. All terms related to hydrometric operations, river hydraulics and stream sedimentation are defined under ISO Standards (ISO T72: 1988(E)). In addition a Glossary of Aquatic terms, including Hydrometric references is published by the Resources Inventory Committee.

Air line correction: The correction to the sounding line measurement corresponding to that part of the sounding line above the liquid surface.

Approach channel: The reach of the channel upstream of the gauging structure in which suitable flow conditions shall be established to ensure correct gauging.

Backwater: A rise in stage produced by an obstruction in the stream channel caused by ice, weeds, control structure, etc. It may be caused by channel storage for which the reservoir properties vary with the depth of flow at the given location. The difference between the observed stage for a certain discharge and the stage as indicated by the stage-discharge relation for the same discharge is reported as the backwater at the station.

Bank, right or left: The margin of a channel as viewed facing downstream. The expression “right” or “left” applies similarly to right or left abutments, cableway towers, etc.

Bench mark: A permanent, fixed reference point for which the elevation is known. It may when practicable, be related to GSC datum.

Broad-crested weir: A weir of such crest length in the direction of flow that critical flow occurs on the crest of the weir.

Control: The condition downstream from a gauging station that determines the stage discharge relation. It may be a stretch of rapids, a weir or other artificial structure. In the absence of such features, the control may be a less obvious condition such as a convergence of the channel or even simply the resistance to flow through a downstream reach. A shifting control exists where the stage-discharge relation tends to change because of impermanent bed or banks.

Crest stage gauge; A gauge, usually vertical, used to indicate a peak stage that has occurred since the previous setting.

Critical flow: The flow in which specific energy (depth of flow + velocity head) is a minimum for a given discharge; under this condition a small surface disturbance can not travel upstream. The ratio of inertia to gravity forces (Froude Number) is equal to unity.

Critical-depth flume: A Venturi flume in which the flow changes from sub-critical upstream to super-critical downstream in which the measurement of one water level, the upstream water level, allows a calculation of the discharge.

Cross section of a stream: A specified vertical plane through a stream bounded by the wetted perimeter and the free surface.

Discharge coefficient: A coefficient in the discharge equation, in general relating the actual discharge to a theoretical discharge.

Discharge, Q: The volume of liquid flowing through a cross section per unit of time. It is not synonymous with “flow”.

Discharge measurement: The determination of the rate of discharge at a gauging station on a stream, including an observation of ‘no flow’, which is classed as a discharge measurement.

Double-drum winch: A winch with two drums, one of which controls and measures the vertical displacement of hydrometric instruments and the other of which controls and measures the horizontal displacement of an unmanned cableway carriage.

Draw-down curve: The profile of the liquid surface when its surface slope exceeds the bed slope.

Drowned flow; submerged flow: The flow which is influenced by the water level downstream of the measuring structure.

Flat-V weir: A long-base weir with a triangular longitudinal profile. The height of the triangle increases linearly from the middle of the channel to the abutment of the weir.

Float gauge: A manual gauge consisting of a float that rides on the water surface, rising and falling with the surface. The float’s movements are transmitted to an indicating device.

Flood mark: A trace of any kind left by a flood on the banks, obstacles or flood plain. It may be used to determine the highest level attained by the water surface during the flood.

Flow: The movement of water in a channel without reference to rate, depth, etc.

Flume: A specially shaped open channel flow section that may be installed in a channel to measure discharge. Depending on the shape of the section, flumes may be termed Parshall, Montana H-flumes, cut-throat, etc.

Free flow; modular flow: A flow which is not influenced by the level of water downstream of the measuring device.

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

Gauge datum: The elevation of the zero of the gauge (referenced to bench marks, or GSC datum) to which the level of the liquid surface is related.

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; 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 metre mark of the gauge is set at the “gauge datum”.

Gauging section; measuring section: The cross section of an open channel in the plane of which measurements of depth and velocity are made.

Gauging station: The complete installation at a measuring site where systematic records of water level and/or discharge are obtained.

Head on (or over) the weir: Elevation of the water above the lowest point of the crest, measured at a point upstream. The distance upstream for the point of measurement depends on the type of weir used but is upstream of the transition zone from sub- to supercritical flow at full weir flow.

Hydraulic jump: The sudden passage of water in an open channel from super-critical depth to sub-critical depth, accompanied by energy dissipation.

Hydraulic mean depth; hydraulic radius: The quotient of the wetted cross sectional area and the wetted perimeter.

Ice, Anchor: One of three types of ice formed in streams. This ice forms on the streambed and results from loss of heat by radiation from the streambed to the atmosphere.

Ice, Frazil: One of three types of ice formed in streams. This consists of fine needles of ice which do not unite to form surface ice. Usually these needles float downstream and come together in a slushy mass.

Ice, Surface: One of three types of ice formed in streams. It is formed on the surface either as a fringe of shore ice or as a continuous ice cover from bank to bank.

Inclined gauge; ramp gauge: A gauge on a slope, generally graduated directly to indicate vertical gauge height.

Left [right] bank: The bank to the left [right) of an observer looking downstream.

Level check: The procedure followed to determine the movement of a gauge with respect to the gauge datum.

Manual gauge: A non-recording type of gauge from which observations of stage are obtained.

Mean velocity at a cross section: The velocity at a given cross section of a stream, obtained by dividing the discharge by the cross sectional area of the stream at that section.

Mean velocity depth: The depth below the surface at which the mean velocity on a vertical occurs.

Modular limit; point of incipient submergence: The condition of flow where a rising downstream level just begins to affect the discharge.

Painting: This refers to the wide ink trace on water level recorder analogue charts that is caused by short term water level fluctuations or by a malfunction in a recorder having a gas purge system.

Panel: The area at a vertical defined by the depth at that vertical multiplied by one-half of the distance between the preceding and the succeeding verticals.

Peak stage: The maximum instantaneous stage during a given period.

Point method (one-; two-; three-; five-; six-): Method of measuring the velocity in a vertical by placing a current-meter at a number of designated points in the vertical.

Open channel: The longitudinal boundary surface consisting of the bed and banks or sides within which the liquid flows with a free surface. The term “channel” generally means the deep part of a river or other waterway, and its meaning is normally made clear by a descriptive term, either stated or implied, such as “low water” channel, “main” channel, “artificial” channel.

Reach: A length of open channel between two defined cross sections.

Reference current-meter: A current-meter which is immersed at a fixed position in the cross section during the carrying out of a discharge measurement. For slight changes in discharge during the gauging operation, it is assumed that the change in velocity indicated by the reference current-meter is proportional to the change in discharge.

Reference point: A point of known elevation from which measurements may be made to a water surface. It is also known as a “measuring point”.

Sensitivity (of the stage-discharge relation): A measure of the change in stage at a gauging station due to a change in discharge. When a small increase in discharge produces a relatively large increase in stage, the relation is said to be sensitive. When a large increase in discharge produces a relatively small increase in stage, the relation is said to be insensitive.

Shift: A change in the stream control which alters the stage-discharge relationship. This change can be either temporary or permanent.

Slope-area measurement: A method of computing peak flow at a gauging station by determining the water surface profiles and channel dimensions over a short reach of a stream.

Slope-area method: An indirect method of discharge estimation in a reach based on the surface slope, the reach roughness, the wetted perimeter and flow areas of the various cross sections in the reach.

Sounding: The operation of measuring the depth from the free surface to the bed.

Stable [unstable] channel: A channel in which the bed and the sides remain stable unstable] over a substantial period of time and in which scour and deposition during the rising and falling stages are negligible [appreciable].

Staff gauge: A manual gauge consisting of a graduated plate or rod that is set vertically in streambed or attached to a solid structure.

Stage; gauge height; water level: The elevation of the free surface of a stream, lake or reservoir relative to a gauge-datum.

Stage: A general term used to describe the height of a water surface and, in a particular application, may be either a gauge height or a water elevation.

Stage-discharge relation: A curve, equation or table which expresses the relation between the stage and the discharge in an open channel at a given stream cross section.

Steady [unsteady] flow: Condition in which the discharge does not change [changes] in magnitude with respect to time.

Stilling basin: A pool downstream of a structure in which the velocity and the energy of the flow are reduced.

Stilling well: A well [tube] connected with the stream in such a way as to permit the measurement of the stage in relatively still conditions (natural surging dampened).

Stilling-well lag: During conditions of rising and falling stage in a channel, the difference at a given time between the channel stage and the stilling-well stage.

Stream: The generic term for water flowing in an open channel, e.g., including creeks and rivers.

Stream gauging; All of the operations necessary for measuring discharge.

Sub-critical flow: The flow in which the Froude number is less than unity and surface disturbances can travel upstream.

Submergence ratio: The ratio of the downstream measured head to the upstream total head over a weir, the crest being taken as the datum.

Sub-surface float: A float with its greatest drag below the surface for measuring sub-surface velocities.

Super-critical flow: The flow in which the Froude number is greater than unity and small surface disturbances can not travel upstream.

Surface draw-down: The local lowering of the water surface in an approach channel caused by the acceleration of the flow passing over an obstacle or through a control.

Surface float: A float with its greatest drag near the surface for measuring surface velocities.

Throat: The minimum cross sectional area within a flume. The throat may be rectangular, trapezoidal, U-shaped or of another specially designed shape.

Triangular-profile weir: A long-base weir having a triangular longitudinal profile.

Uniform flow: Flow in which the depth and velocity remain constant with respect to distance along the channel. Uniform flow is possible only in a channel of constant cross section.

Velocity-area method: Method of discharge determination deduced from the area of the cross section, bounded by the wetted perimeter and the free surface, and the integration of the component velocities in the cross section.

Velocity of approach; approach velocity: The mean velocity in an open channel at a known distance upstream of a measuring section.

Vertical: The vertical line in which velocity measurements or depth measurements are made.

Vertical velocity coefficient: The coefficient applied to a single, or an equivalent single, velocity determination at any depth in a vertical to infer the mean velocity on that vertical.

Wading rod: A light, hand-held, graduated, rigid rod, for sounding the depth and positioning the current meter in order to measure the velocity in shallow streams suitable for wading. It may also be used from boats or ice cover, at shallow depths.

Water level recorder: An instrument that records water levels in an analogue or digital form. The recorder may be actuated by a float or by any one of several other sensor types.

Weir: An overflow structure built across an open channel to measure the discharge in the channel. Depending on the shape of the opening, weirs may be termed rectangular, trapezoidal, triangular, etc.

Wet line correction: The correction to the sounding line measurement corresponding to that part of the sounding line below the liquid surface.

Wetted perimeter, P: The wetted boundary of an open channel at a specified section.

Wire-weight gauge: A gauge consisting essentially of a graduated wire or chain, weighted and lowered to make contact with the surface of the water. Contact with the water surface is determined visually.

Appendix II. Hydrometric Forms

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BRITISH COLUMBIA · RESOURCES INVENTORY COMMITTEE

Description of Hydrometric Station

☐ Original ☐ Revised

Station Operating Agency/Firm: ____________________

Stn. No.: ________ Stn. Name: ____________________

Latitude: _____°_____'_____" Longitude: _____°_____'_____"

Action (Established, Relocated, Closed)	Date (yy/mm/dd)	By Whom

Describe all station gauges, and locations. For chain gauge or wire weight, give length from end of weight to first marker: ____________________

Describe equipment, and location(s) for flow measurements at all stages:

Describe channel or other conditions affecting control or discharge measurement (variable, backwater, turbulence, vegetation, etc.): ________

Coefficient for 2/10 method: ☐ Zero flow at GH: ☐

RIC AQU-01 97/10

Site Sketch: (Show physical features, hydraulic control point, station components, metering section(s).)

Benchmarks: Describe fully. Give year established, elevation above station datum (zero of the gauge when first established). May be linked to other GSC datum.

(Complete both sides)

Figure II-1a. Form AQU-01 Description of Hydrometric Station (front).

Stn. No.: ________ Stn. Name: ____________________ Map Number (NTS): ________ Scale: ______

(Annotate to show station location, access route, and distances. Use 2 map scales if necessary.)

RIC AQU-01 97/10

Figure II-1b. Form AQU-01 Description of Hydrometric Station (back).

BRITISH COLUMBIA | RESOURCES INVENTORY COMMITTEE

Gauge Level Notes in Metres

Station Operating Agency Firm: ____________________

Stn. No.: __________ Stn. Name: ______________________________

Date: ___________ (yy/mm/dd) Gauge Ht.: ___________ Time: _________

Station	BS (m)	Ht. Inst. (m)	FS (m)	Elevation (m)	Elev. as Given (m)	BS or FS, in Feet *

*Check readings for rods that display both scales. Conversion Factor: (1 foot = 0.3048 metres).

RIC AQU-02 97/10

Elevation Means:

BM #	Established Elev. (m)	Mean Elev. (this date) (m)	Differences (m)

Comments on Elevation Changes: ______________________________

Gauge Correction: ______________________________

Date of Change (if known): ______________________________

Surveyed by: ______________________________

Computations by: ______________________________

Checked by: ______________________________

Additional Notes:

Figure II-2. Form AQU-02 Gauge Level Notes in Metres (front).

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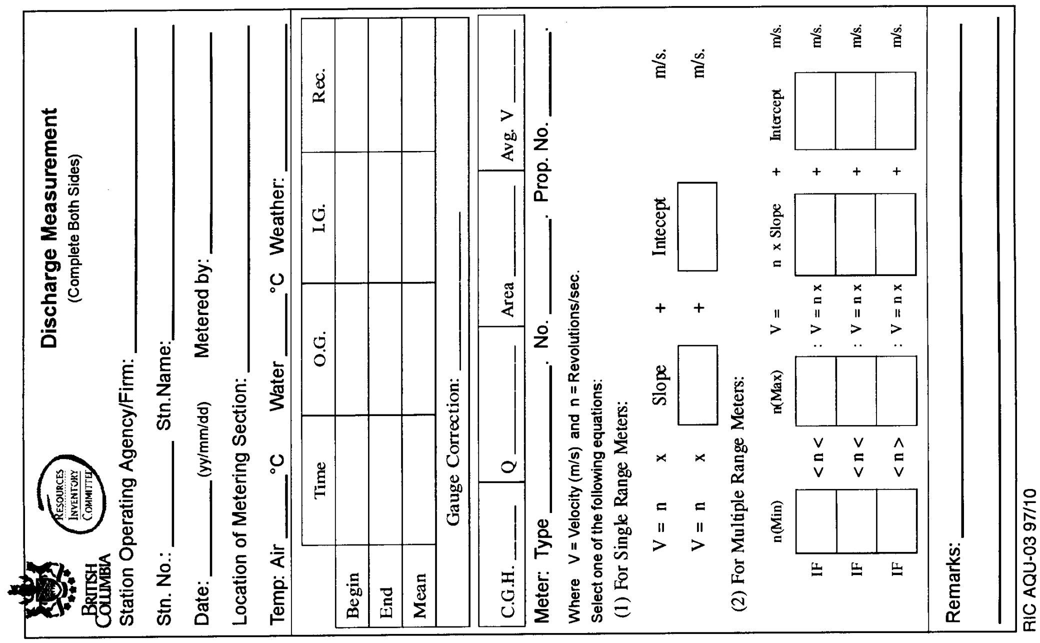


Discharge Measurement
(Complete Both Sides)

British Columbia — Resources Inventory Committee

Station Operating Agency/Firm: ____________

Stn. No.: ________ Stn.Name: ____________

Date: ________ (yy/mm/dd) Metered by: ____________

Location of Metering Section: ____________

Temp: Air ____ °C Water ____ °C Weather: ____________

	Time	O.G.	I.G.	Rec.
Begin				
End				
Mean				

Gauge Correction: ____________

C.G.H. ______ Q ______ Area ______ Avg. V ______

Meter: Type ______. No. ______. Prop. No. ______.

Where V = Velocity (m/s) and n = Revolutions/sec.

Select one of the following equations:

(1) For Single Range Meters:

V = n x [Slope] + [Intecept] m/s.

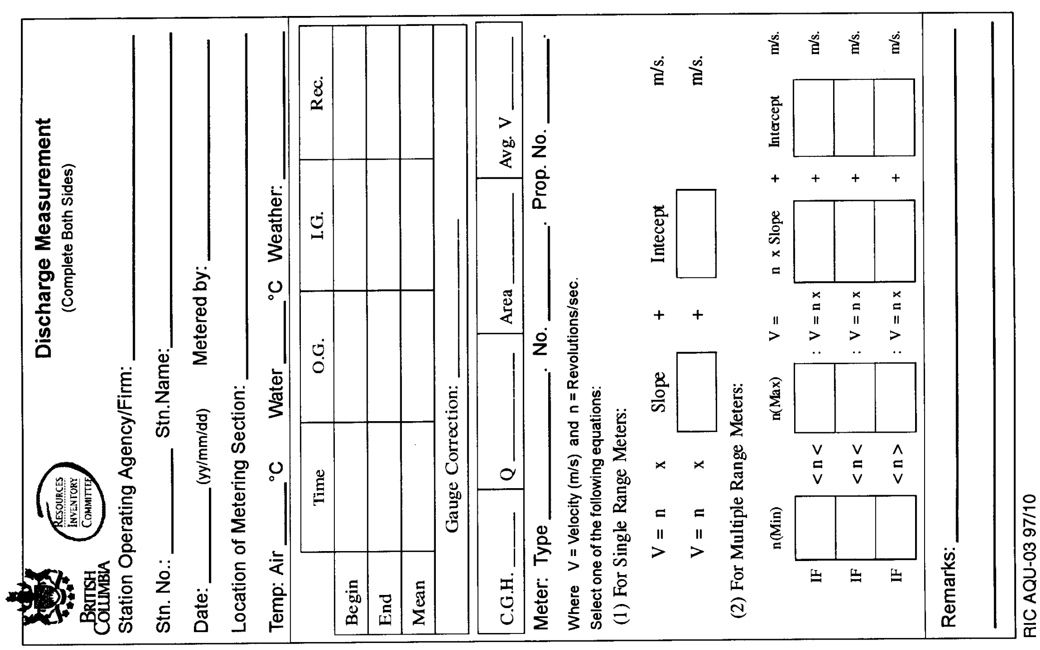
V = n x [ ] + [ ] m/s.

(2) For Multiple Range Meters:

	n(Min)		n(Max)	V =	n x Slope	+	Intercept	
IF		< n <		: V = n x		+		m/s.
IF		< n <		: V = n x		+		m/s.
IF		< n >		: V = n x		+		m/s.

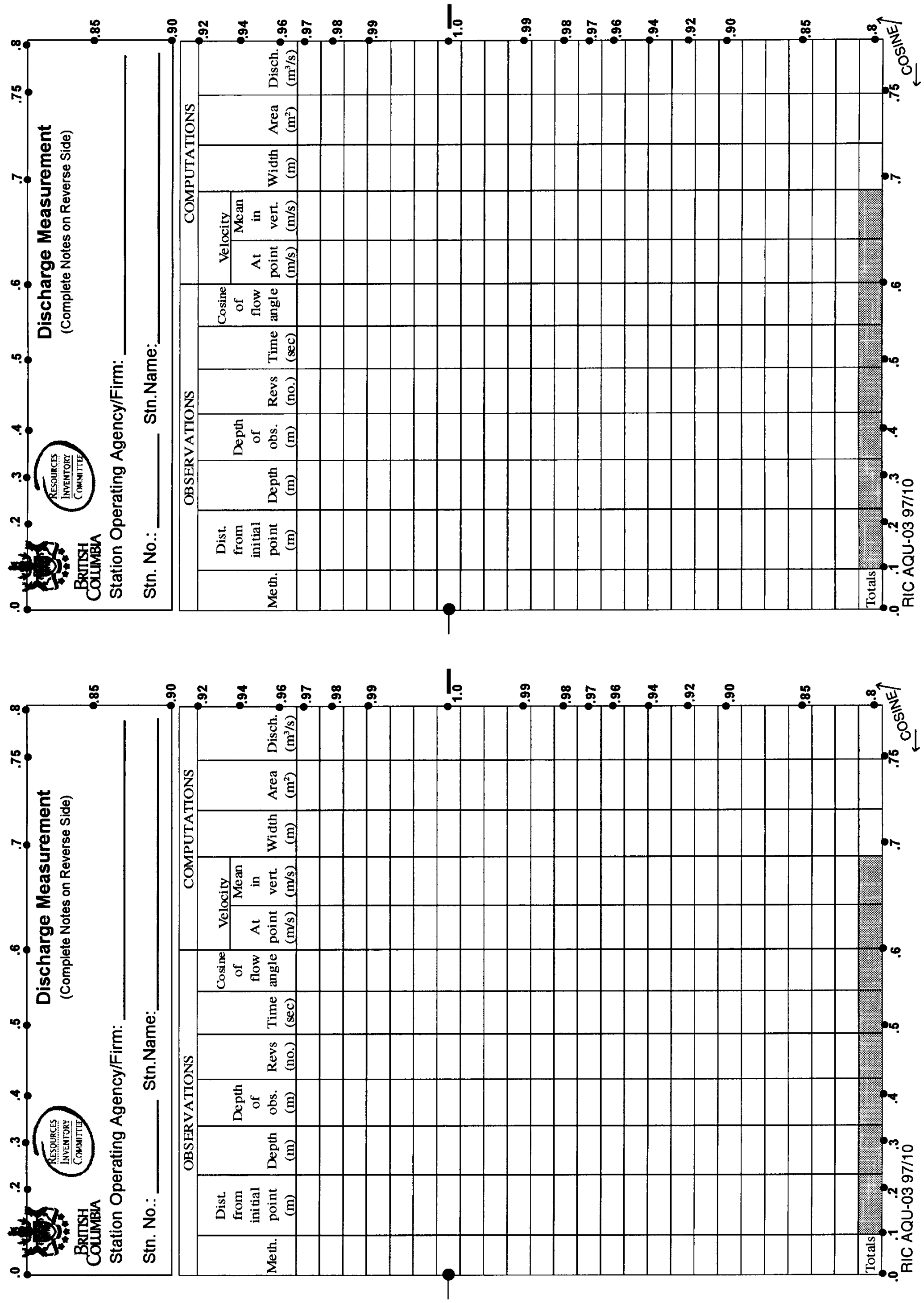
Remarks: ____________

RIC AQU-03 97/10



Discharge Measurement (Complete Both Sides) — RIC AQU-03 97/10

Figure II-3a. Form AQU-03 Discharge Measurement (front).



BRITISH COLUMBIA

RESOURCES INVENTORY COMMITTEE

Discharge Measurement
(Complete Notes on Reverse Side)

Station Operating Agency/Firm: ______

Stn. No.: ______ Stn.Name: ______

OBSERVATIONS							COMPUTATIONS				
Meth.	Dist. from initial point (m)	Depth (m)	Depth of obs. (m)	Revs (no.)	Time (sec)	Cosine of flow angle	Velocity At point (m/s)	Velocity Mean in vert. (m/s)	Width (m)	Area (m²)	Disch. (m³/s)
Totals											

BRITISH COLUMBIA

RESOURCES INVENTORY COMMITTEE

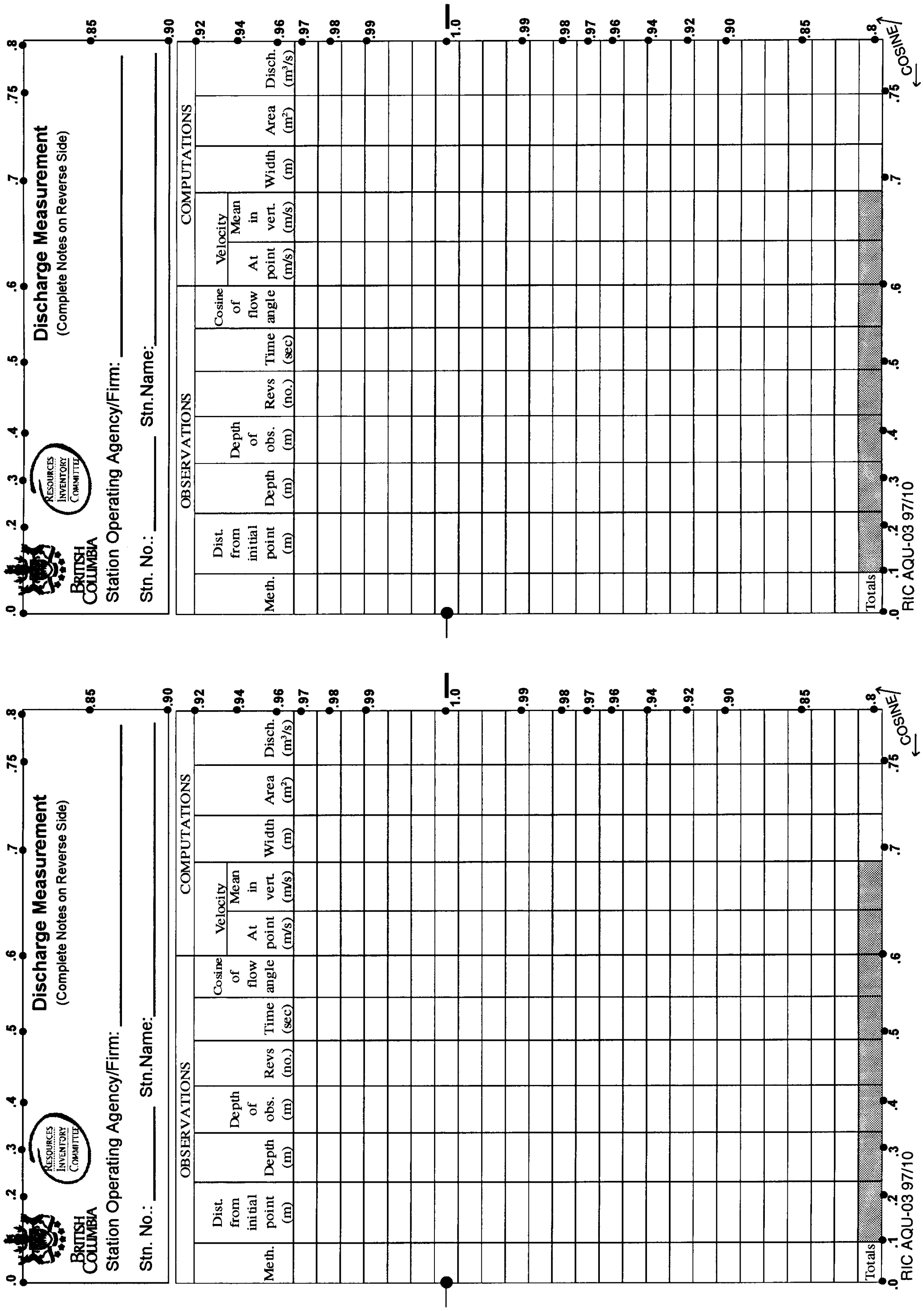
Discharge Measurement
(Complete Notes on Reverse Side)

Station Operating Agency/Firm: ______

Stn. No.: ______ Stn.Name: ______

RIC AQU-03 97/10

Figure II-3b. Form AQU-03 Discharge Measurement (back).



British Columbia — Resources Inventory Committee

Discharge Measurement
(Complete Notes on Reverse Side)

Station Operating Agency/Firm: ____________

Stn. No.: ________ Stn.Name: ____________

OBSERVATIONS							COMPUTATIONS				
Meth.	Dist. from initial point (m)	Depth (m)	Depth of obs. (m)	Revs (no.)	Time (sec)	Cosine of flow angle	Velocity At point (m/s)	Velocity Mean in vert. (m/s)	Width (m)	Area (m²)	Disch. (m³/s)
Totals											

COSINE .0 .1 .2 .3 .4 .5 .6 .7 .75 .8 .85 .90 .92 .94 .96 .97 .98 .99 1.0

RIC AQU-03 97/10

British Columbia — Resources Inventory Committee

Discharge Measurement
(Complete Notes on Reverse Side)

Station Operating Agency/Firm: ____________

Stn. No.: ________ Stn.Name: ____________

RIC AQU-03 97/10

Figure II-4. Form AQU-04 History or Gauge Levels.

British Columbia — Resources Inventory Committee

Summary of Discharge Measurements for the year: ________

Station Operating Agency/Firm: ________________

Stn. No.: ________ Stn. Name: ________________

Date yy/mm/dd	Metered by	Meter Type	Meter Unit # Prop#	Water Temp (C)	Width (m)	Area (m2)	Mean Velocity (m/s)	Mean Gauge Height (m)	Discharge cms (m3/s)	From Stage Discharge Table No. ___ Disch cms	Diff	%	No. ___ Disch cms	Diff	%	Remarks

Computed by: ________	Checked by: ________	Approved by: ________
Date: ________ (y/m/d)	Date: ________ (y/m/d)	Date: ________ (y/m/d)

RIC AQU-05 98/10

Figure II-5. Form AQU-05 Summary of Discharge Measurements for the Year _____

BRITISH COLUMBIA

RESOURCES INVENTORY COMMITTEE

Water Stage Recorder - Station Record for the Year ____

Station Operating Agency/Firm: ____

Stn. No.: ____ Stn. Name: ____

Manual Gauge: ☐ Staff. ☐ Chain. ☐ Wire Weight. ☐ Other. Zero of Trace is ____ cm from left margin.

Recording Gauge: Manufacturer ____ Model ____.

☐ Analogue ☐ Digital. ☐ Shaft Encoder: Manufacturer ____. Model ____.

☐ Transducer: Manufacturer ____. Model ____.

	Arrival					Departure								
	Time (PST)		Stage (m)			Time (PST)		Stage (m)						
Date (mm/dd)	Watch	Recorder	Outside Gauge	Inside Gauge	Recorder	Watch	Recorder	Outside Gauge	Inside Gauge	Recorder	Intakes Flushed (y/n)	Initials	Dir. of pen in rising stage ↑ ↓	Remarks on Metering, Level Check, etc.

RIC AQU-06 97/10

Figure II-6. Form AQU-06 Water Stage Recorder - Station Record for the Year _____

Station Analysis for the Year ______

BRITISH COLUMBIA — RESOURCES INVENTORY COMMITTEE

Station Operation Agency/Firm: ____________________

Stn. No.: ________ Stn. Name: ____________________

Operation Period: ________ (mm) to ________ (mm)

Manual Gauge: ☐Staff. ☐Chain. ☐Wire Weight. ☐Other.

Recording Gauge: Manufacturer ____________ Model ____________

☐Analogue ☐Digital ☐Shaft Encoder: Manufacturer ____________ Model ____________

☐Transducer: Manufacturer ____________ Model ____________

Recorder Referenced to: ☐Inside Gauge. ☐Outside Gauge.

Number of Level Checks Made: ________

☐Gauge Correction NOT Required.

☐Gauge Correction Required (see table at right).

mm	dd	hh	Correction

Discharge Record

Max. Instantaneous Discharge of ________ m^3/s GH = ________

occurred on ________ (mm/dd) at ________ (PST).

Number of open water measurements: ________

Measurements (with comments) that do not plot within acceptable percentage of H/Q Curve: ____________

Missing Period	Reason

Stage Discharge Relationship

	Curve No.	Start Date (m/d)	End Date (m/d)	Cause for the Shift
Previous Year				
Present Year				

Remarks: Discharge estimates for missing periods derived by graphical comparison to:

Climate Station(s) ____________________

Other Hydrometric Station(s) ____________________

DATA DECLARATION

I, ________________ , have reviewed for the above operating agency/firm, all data and operating information for this hydrometric station. It meets or surpasses the Provincial Standard Class ______ as defined by the Resources Inventory Committee *Manual of Standard Operating Procedures for Hydrometric Surveys in British Columbia.*

Date: ________________ Professional Seal/Signature: ________________

RIC AQU-07

Figure II-7. Form AQU-07 Station Analysis for the Year ______

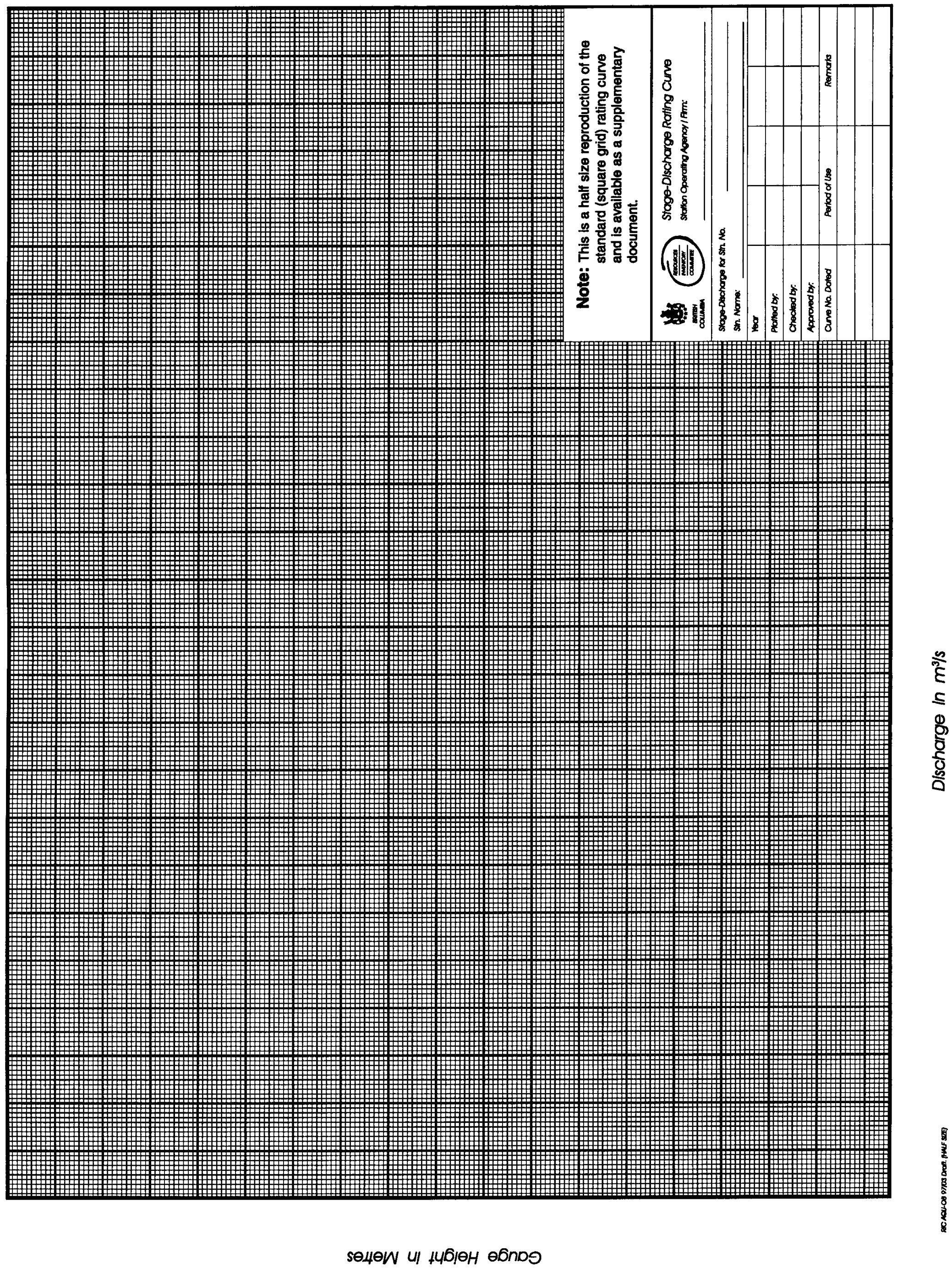


Figure II-8. Form AQU-08 Stage-Discharge Rating Curve (Reduced to half size).

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Appendix III. Analogue Recorders

Appendix III-1. Type F Water Level Recorder

a) Description

The Type F recorder is a horizontal drum type, with unrestricted drum rotation. The service interval for the Type F is limited to 7- or 28-day periods, depending on the gearing.

Unless retrofitted with a data logger add-on (Figure III-1), the Type F recorder is not recommended for general use in natural stream channels because it is difficult to extract hourly water level values during periods of significant change in stage. However, because the various water management agencies in BC own many Type F recorders, limited use of this *existing* equipment may be justified economically, e.g., to provide a record of stage at lakes or reservoirs, or to provide a record of flow rates, for licensing purposes, below diversion structures in rated channels designed to transport water at a near-constant rate.

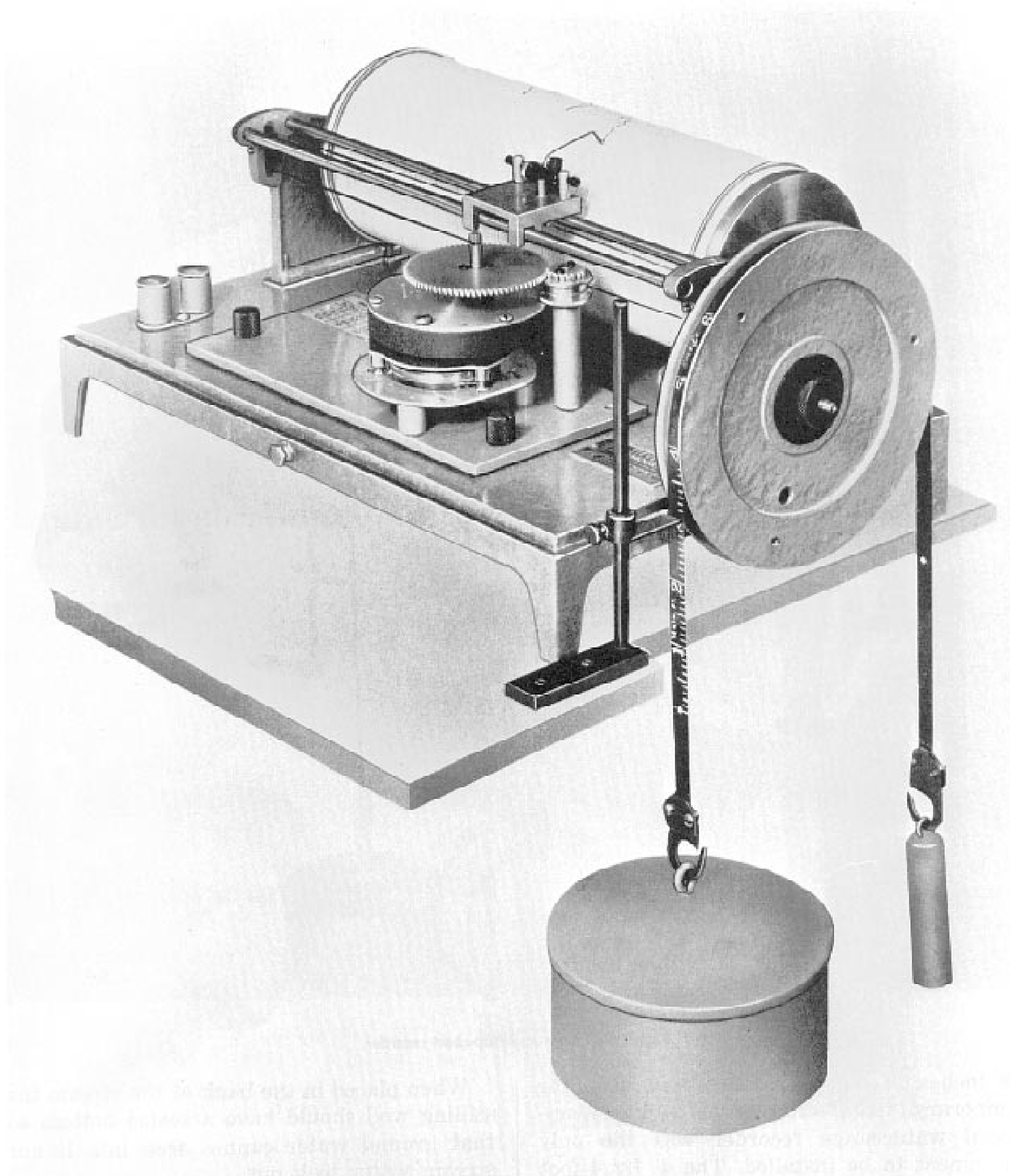


Figure III-1. Stevens Type F Recorder

Note: Type F recorders are fitted with electronic (DC), electric (AC), mechanically driven double spring 8-day or weight-driven clocks. The latter require a 5.44-kg weight in direct drive; this weight will travel 0.415 m over a 7-day period.

b) Installation

These instructions refer to installing existing recorders, i.e. those currently in the possession of an agency, not to new ones.

1. Bench check recorder. Obtain a copy of manufacturer's operating manual and spare parts list.

2. Endure all parts are in place and tested.
3. Check the condition of the braided copper wire that controls the lateral movement of the stylus carriage.
4. If the stylus is of the ink reservoir type, order a felt pen adapter and a supply of cartridges.
5. Check the gear that controls movement between the float line pulley and the chart drum. Normally the movement will be a 5:1 ratio, although finer definition may be desirable for some applications.
6. Remove and service the clock (see servicing clocks, Appendix III-3).
7. If clock drive is weight driven mechanical, examine the weight suspension wire and sprung weight attachment clamp.
8. Check the condition of the float, ensure the float suspension cable or tape is of sufficient length for the proposed location and that the counterweight matches the float size.
9. Order a supply of chart sheets, pen cartridges, and any replacement parts.
10. Bench test the recorder for several days on completion of maintenance. Observe clock accuracy and adjust as necessary. See section on clocks, part c of Appendix III-2.

    Note: There is a minimum internal diameter for the stilling well to provide clearance for the suspended float, counterweight, and clock weight. If a mechanical weight-driven clock is to be used, the recorder shelter floor should be placed at least 75 cm above the highest expected water level. If the weight becomes submerged, the effective weight is reduced and so is the accuracy of the clock regulator. (Stilling Wells, Instrument Shelters, and Float Sizes are discussed in Section C.2 and C.3.)

c) Data Logger Add-on

Type F graphic data recorders can be “converted” to produce electronic data by adding on a digital data logger. With the digital data logger add-on, the Type F becomes suitable for where longer term data retrieval service visits are desirable. The chart record is not improved in any way; however, the digital data logger will provide the necessary time/water level definition.

> **Note:** The constraints in the use of horizontal drum recorders indicated above do not apply to the European designed models in which the time base is drum rotation and the water level is recorded cross the length of the drum. Some models are fitted with a reverse recording mechanism offering unlimited stage range. The commonly used time scale, 2 mm per hour, requires servicing every 8 days.

Appendix III-2. Type A Water Level Recorder

a) Description

The Type A water level recorder is a continuous strip chart type, with stylus reversal. Type A recorders will operate under ideal conditions for up to 6 months.

The two Type A models are the A-35 and the A-71 recorder (Figure III-2); the models are essentially the same except A-35 has a metal casing and A-71 has a plastic casing.

The components described here are numbered in Figure III-3. Strip chart A25, specifically produced for the Type A recorder, is wound onto a 22-mm outside diameter aluminium tube called a supply roll (33). Using a friction system, the strip chart is propelled from the supply roll over a flat metal surface called the writing plate (15). From here it moves to an exactly aligned cylinder called the take-up cylinder (34). As the strip chart travels over the writing plate, a marking stylus produces a continuous line. The stylus is fixed to a carriage (23) that travels along guide rails. These guide rails ensure that the stylus moves continuously in a right angle direction to chart travel. The carriage moves along the guide rails by means of a continuous chain (31) meshed with a drive sprocket. The carriage drive has a reversal mechanism which allows the stylus to continue a rise or fall movement at the edge of the graduated chart margin.

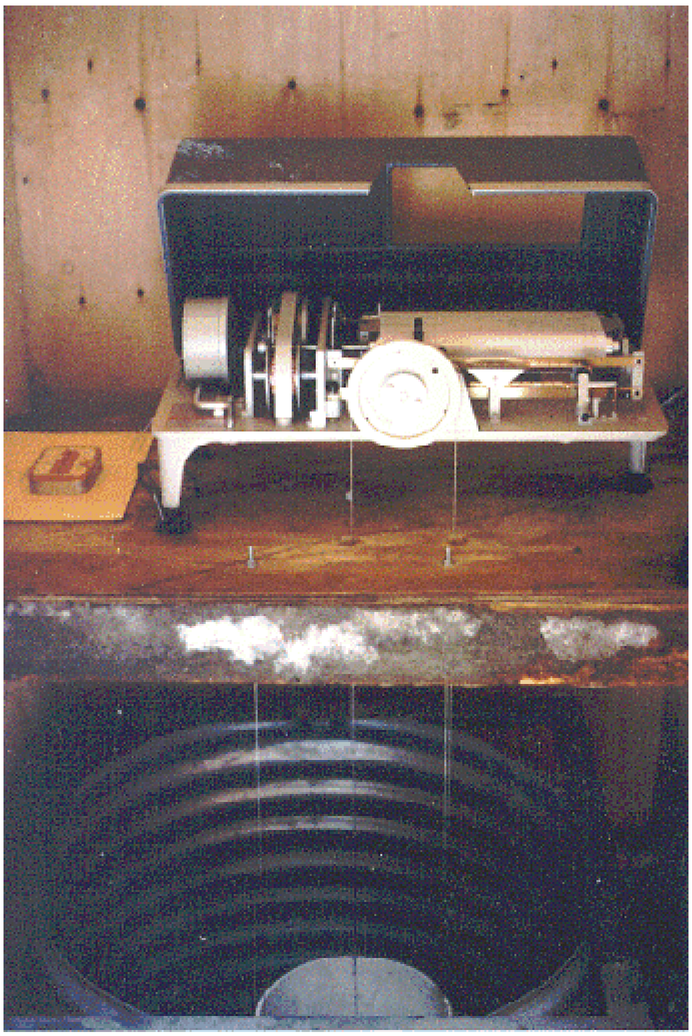


Figure III-2. Stevens Type A-71 recorder mounted over a stilling well

Important Note: The operating system was converted from Imperial to metric units before 1980; compatible chart paper must be used, i.e. with the same time scale. “Problems arising from Metric Scale Conversion” are discussed in Appendix III-2, Part e.

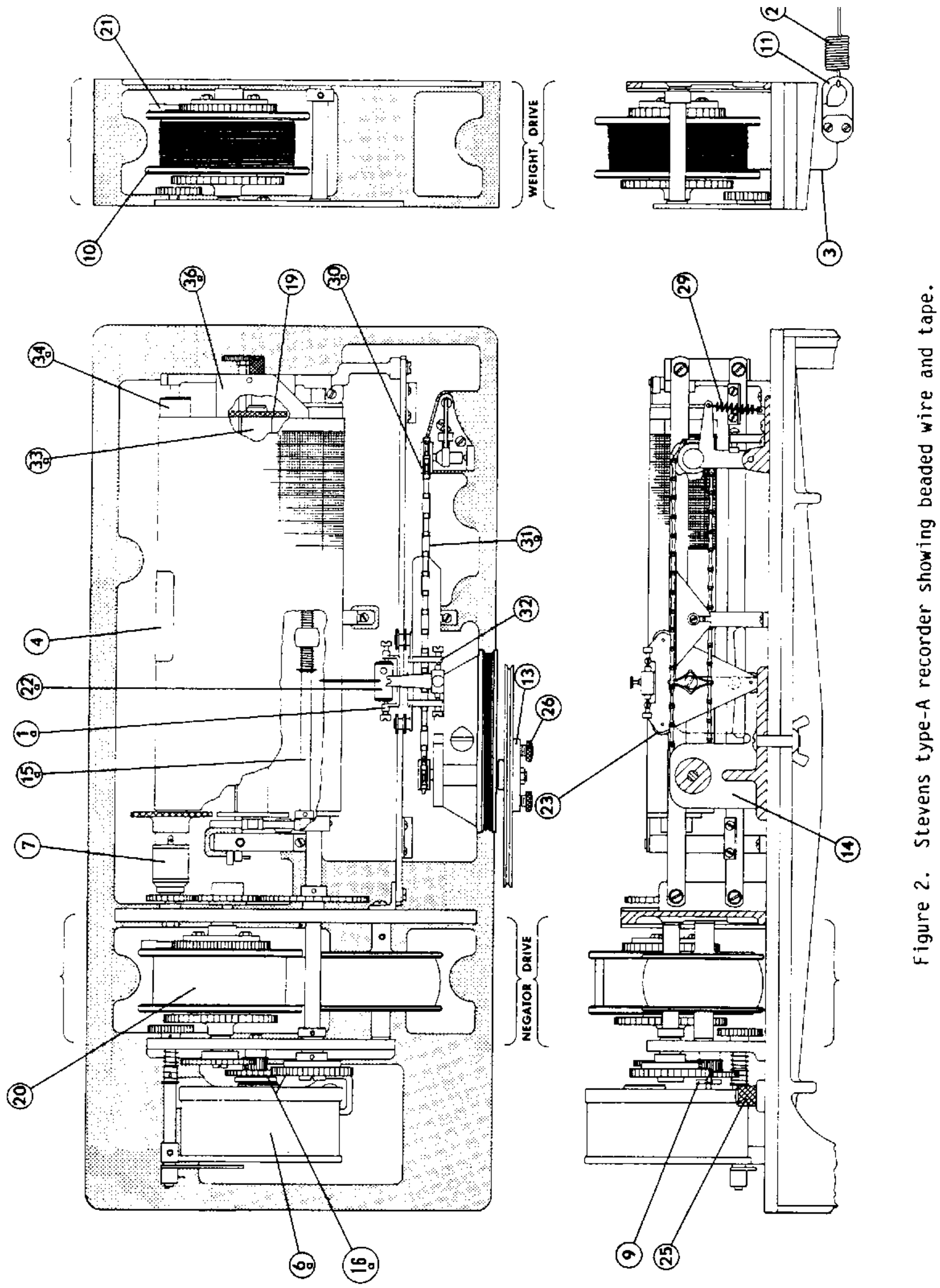


Figure III-3. Stevens Type A recorder.

b) Clockwork and Float Pulley Movement

The recorder requires two independent forces to establish the gauge height referenced to time. These forces are created by a clockwork (6) and a float counterweight (13).

Force is needed for the friction system to advance the strip chart. The force is regulated by a clockwork which advances the paper in precise relation to time, using a suspended weight, spring tension and electric motor or electronic timer.

Force is also needed so that the drive sprocket can produce motion in the continuous chain attached to the carriage and stylus. This power is generated through variation in the vertical movement of a float resting on a water surface. This movement is transferred through a flexible wire or tape, called a float line, which passes over the float pulley (13). It connects the float at one end and a counterweight at the other.

c) Clocks

A mechanical, electrical, or electronic clock regulates the rate that a strip chart travels in direct relation to the stylus trace of the water level. The accuracy of the stylus trace depends on the accurate regulation of the speed at which the chart travels.

The mechanical clock is the most common regulator used. It can accurately regulate a constant power source, but variations in the amount of power supplied will affect the accuracy of regulation. If the weight becomes submerged, the effective weight is reduced and so is the accuracy of the clock regulator. The operating duration of a mechanical clock depends upon the method used to provide the power. A weight-driven clock operates as long as the gravitational force generated by the driving weight remains in effect. A weight fall of 8 m powers the recorder chart drive for approximately 4.5 months. The weight fall distance can be reduced through a combination of sheaves and by increasing the weight.

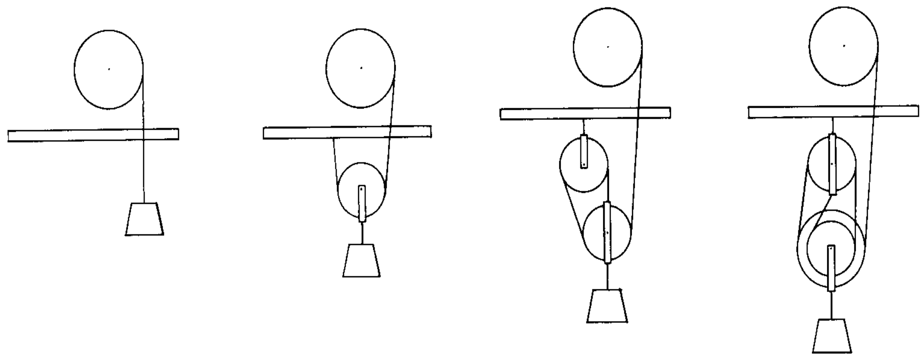
Figure III-4 illustrates several sheaf combinations.

Electronic clocks are DC-powered regulators which provide constant, precisely timed impulses of torque to power the travel of the strip chart. Rate of advance may be selected in multiples of 1.2 inches/day.

Electric clock regulators are AC-powered. They advance the strip chart in the same fashion as the electronic regulator; they depend on the quality and reliability of power from a commercial source.

Mechanical, electronic, and electric clock regulators which mount directly on the Type A recorder are interchangeable between recorders.

The clock is a precision instrument that requires careful handling and attention to detail. A more detailed explanation of clock drive systems, operation, removal, servicing, and re-installation is provided in Appendix III-4.



Example 1	Example 2	Example 3	Example 4
Clock (Chelsea) requires a 12 lb force (example 1). The mechanical advantage of the pulley system employed multiplied by 12 lb (5.44 kg) = required weight.	11.34 kg	17.24 kg	24.59 kg

Figure III-4. Sheaf combinations.

d) Accuracy and Sensitivity

Overall accuracy of the record produced by the Type A recorder is a function of clock performance, recorder mechanics and adjustment, while sensitivity refers to the extent of lag in the recording mechanism in following the change in water level.

Time accuracy can be varied through the selection of gearing options which govern the rate of chart travel. Irregular performance of the clock regulator will affect the recorder's accuracy. Accuracy of the water level chart trace can be changed or varied by selecting various float pulley sizes or geared pulley standard options. Improper adjustment of recorder parts reduces accuracy. For example, a loose marking stylus will lag in response to the carriage movement. A poorly secured float pulley clamp will also affect recorder accuracy by allowing variation in the related movement between float pulley and stylus carriage.

Sensitivity refers to the instrument's response to movement, such as the movement in the water level in relation to the chart trace. Sensitivity can be varied by the selection of float sensor components. Conditions described in Float Dynamics (Section G of Appendix III-2), affect the accuracy of instrument response.

e) Strip Charts

The Type A recorder accommodates 25-cm wide paper strips, wound onto a supply cylinder. Extremes in humidity can cause the paper strip chart to stretch and/or shrink, resulting in errors in recording time. These errors can be identified by using the time marker option described in Section III-5.

Note: Problems Arising from Metric Scale Conversion

The Governments of Canada and British Columbia transformed its system of weights and measures from the Imperial or English system to the SI system of units in 1977. All official government water measurements conducted since then have been done in the new system.

When Water Survey of Canada converted from Imperial to metric measure, all existing A-35 (Figure III-5) and A-71 recorders on their inventory underwent 'in house' mechanical change in addition to the stage scale metric conversion supplied by the manufacturer. The change included the machining of the chart drive rollers so that the chart rate of travel would be 60 mm per 24 hours, matching a Canadian manufacturers chart paper scale, these chart rolls are designated MA25 (Figure III-5). Such recorders are identified by a readily visible MMETRICO sticker and an 'M' stamped permanently into the end of the friction roller.

Provincial government and other agencies continue to use the time scale provided by the factory which is 60.96 mm (2.4") per 24 hours (Figure III-6), and, the equivalent chart time scale paper. These chart rolls, with metric horizontal graduations are designated A25 by the manufacturer, Leupold & Stevens, Inc.

Note: Using a 60 mm per day chart on a standard Steven's metric recorder will produce an accumulating time scale error of -23.5 minutes per day.

The A-71 is available in a choice of metric or Imperial units of measure. Be sure that any recorder received from a supplier provides the proper unit of stage measure.

Errors in recording water level occur when the strip chart shifts out of precise alignment as it travels from the supply cylinder to the take-up cylinder. Identify this error by a mark on the chart trace referenced at periodic intervals to actual water level. Minimize this error by carefully aligning the chart travel each time a chart is attached to the take-up cylinder. Errors in the water level trace may be significant, especially for deep stilling wells.

If the chart travels 60 (60.96) mm/day, the supply roll will last for approximately 400 days.

The time scale is marked in hourly divisions with a bold solid line every 24 hours. A bold dashed line identifies 1200 hours and the light dashed lines identify the hours 0600 and 1800 (Figure III-5).

Note: As the end of the chart supply approaches, a diagonal line appears on the chart indicating how many days remain in the chart supply. To determine the number of days remaining in the chart supply, multiply the distance (cm) between the diagonal line and the left border of the chart by 4. For example, if the time scale is 60 mm per day, and the distance from the left border to the diagonal line is 11.5 cm, there are about 46 days of chart paper remaining: 11.5 cm * 4 days/cm = 46 days.

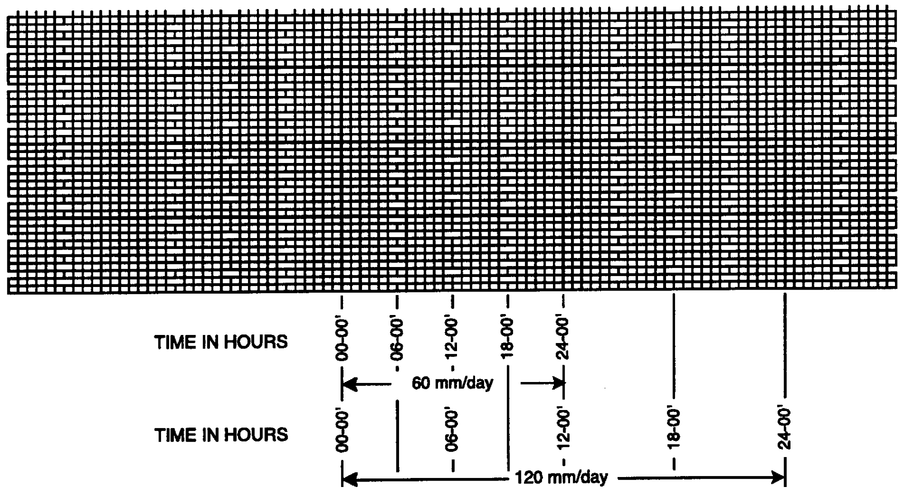


Figure III-5. Graphic controls of Canada Ltd. Strip chart (60 mm/day) specified by Environment Canada.

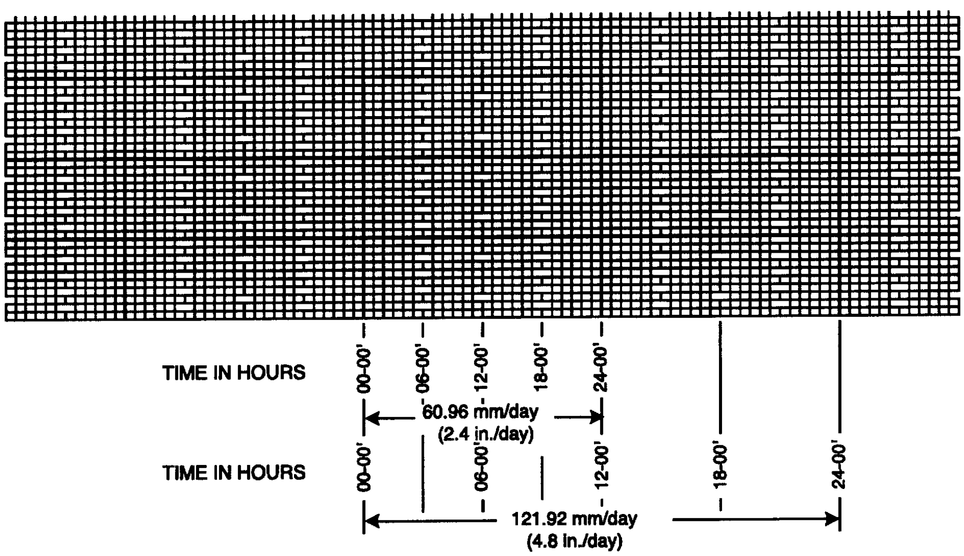


Figure III-6. Stevens strip chart (60.96 mm/day).

The water level scale depends on gearing used to drive the stylus across the strip chart, which in turn depends on expected water level change and the recording sensitivity. The most common chart scale used in British Columbia is 1 cm (chart) to 5 cm (water level). The water level scale is marked at 2-mm divisions with bold lines at 1-cm intervals. A 350-mm circumference float pulley produces a scale of 1:5.

For flash flooding or tidal effect, a less sensitive scale may by used. For a scale relationship of 1 cm (chart) to 10 cm (water level), the water level scale is marked at 2-mm divisions with bold lines at 2-cm intervals. Heavier lines accent the 10-cm intervals (Figure III-7). A 750-mm circumference float pulley produces a water level chart scale of 1:10.

The 1:5 scale is twice as sensitive as the 1:10 scale and allows for greater accuracy in recovering water level values from the chart trace. The 1:5 scale is normally chosen for most locations.

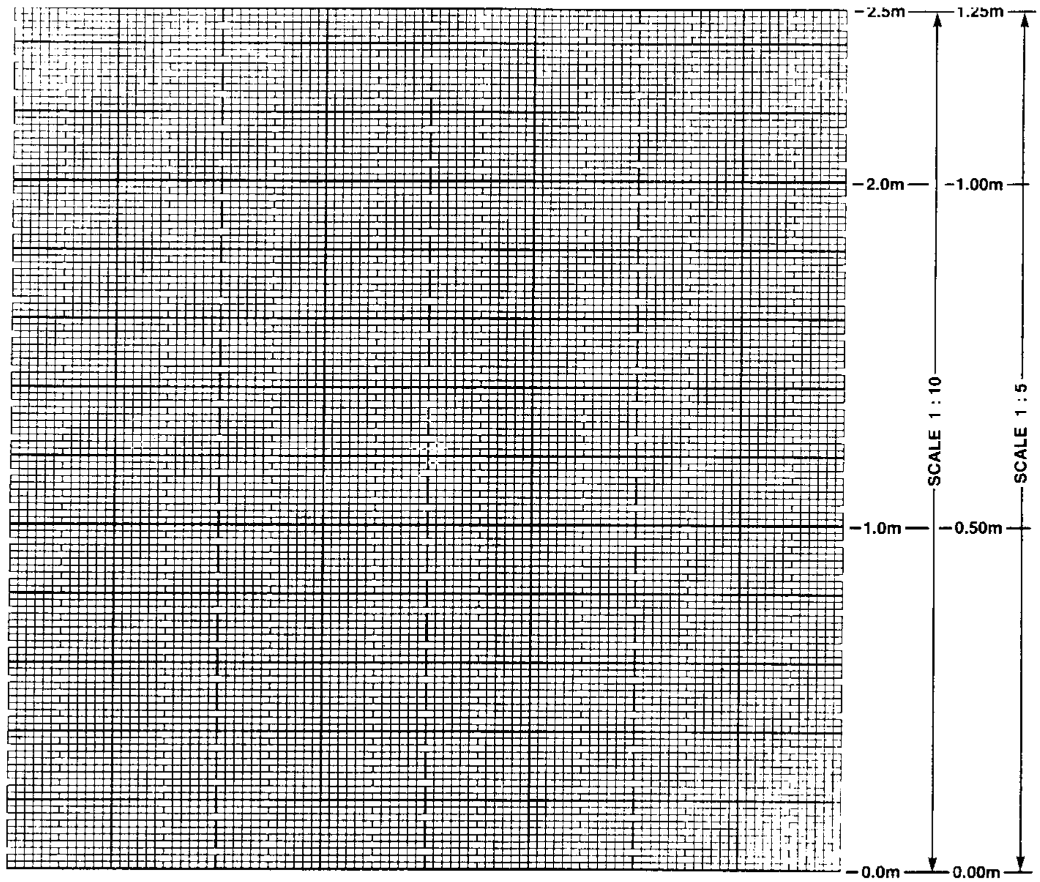


Figure III-7. Water level scale on the A25 strip chart.

g) Float Dynamics

The record from a float-actuated (float sensor) water level recorder depends on the instantaneous and accurate transfer of the float movement to the recorder. The sensitivity and accuracy by which this movement is transferred is influenced by:

- Float lag - the ability of the effective force produced by the float to overcome friction in the stylus drive mechanism.
- Line shift - the effect that the shifting weight of the float line or tape has on the depth of the float during changes in stage.
- Submergence of the counterweight - the buoyant force of water acting on the submerged counterweight and submerged portion of the float line or tape causes variations in line shift values.
- Dynamic effects on the float - in responding to oscillations in the water surface, the float can generate a broad painted stylus trace. The lag in float response time creates the inertial force which causes the upper and lower boundary of the painted trace to exceed the respective water level variation.

To ensure accurate rotation of the float pulley in relation to the float movement, slippage between the float line and pulley must be prevented by using either beaded wire or perforated invar-steel tape.

h) Installation

The proper installation and set-up of the Type A analogue recorder is critical. Any oversights will lead to measurement errors and failure of the operation. Therefore, careful attention should be given to all the following installation details:

1. Unpack the recorder at the instrument shelter.
2. Drill holes in the recorder shelf and in shelter floor to pass through the float line. Also drill a hole for the clock-weight line if the clock is weight driven. Label the holes “float” and “counterweight”. The recorder manufacturer provides a template for positioning the holes.
3. Position the recorder on the shelf. Level it using the adjustable legs. Screw the legs to the shelf so that the recorder can not move.
4. Install the float pulley by removing the hex nut on the front of the standard, unscrewing the retaining clamp and removing the washer. Place the float pulley (or sprocket if the recorder is actuated by a pressure sensor) on the shaft so that the flat side is to the recorder. Next, replace the washer, screw the retaining clamp on, and securely tighten the hex nut.
5. Pass the beaded cable through the holes in the shelf and floor, then attach the end hook for the float. Normally the float is on the left side of the pulley standard. If a beaded cable is used as a float line, position one bead so that it bears on the end hook clamp; this prevents slipping. Do not kink or tangle the beaded wire or tape.
6. To determine the correct line length, connect the counterweight and lower the assembly to the well bottom. Pass the tape line over the pulley and attach the float to the tape line at the point of maximum possible travel. Ensure that the counterweight falls freely to the minimum water level. The float and counterweight should pass each other without touching any obstructions in the well. Guide sheaves may have to be installed to achieve this. For example, guide sheaves must be used when a 250-mm (10-inch diameter) float is installed on a recorder with a 1254 m diameter pulley wheel.
7. To install a new chart roll, detach the writing table (Figure III-3 (36)) and remove the supply roll (Figure III-3 (33)). Next, remove the knurled washernut (Figure III-3 (19)) from the end opposite the flange and remove the old core. Put the new chart paper on the supply cylinder with the end flush against the flange. Next, tighten the washernut so that the supply roll can not slip off the cylinder. Place the supply roll in its bearings with the flange to the left. Once the supply cylinder is in place, connect the chart paper to the drive roller. To do this, make a right-angle crease in the paper about 20 mm from the end. Feed the end of the paper underneath the drive roller so that it passes between the drive roller and the friction rollers.
   Using the spring clamp, attach the end of the chart to the take-up roller. Roll some chart paper onto the take-up roller. Hold it taut to ensure that the paper is tracking squarely.
8. Fill the recorder pen reservoir carefully, using the eyedropper provided. Do not fill it completely because ink expands in hot weather. Ink splashed on the pen carriage or

the rails of the pen carriage may cause sticking. If the ink does not flow freely, cover the small breather hole with a finger and 'pump' on the fill hole with another finger. If this does not work, blow carefully on the fill hole until a small drop of ink appears at the end of the pen. Clean the bore of the pen with the fine wire provided for this purpose.

9. Check that the pen reversal mechanism operates properly by rotating the float pulley. Using the knurled nut on the pen holder, adjust the pen position so that the reversal points fall on the margins of the paper. Set the pen so that it is in direct drive. This will permit the pen to move laterally across the width of the chart at a right angle to the direction of chart feed. The pen will respond accurately during a rise in stage within the well. When the pen is set correctly, clamp the float pulley to the shaft by simultaneously turning the two knurled nuts on the clamp in opposite directions. It is useful to write the gauge reading of each paper margin on the edge of the metal writing table, and to set the left margin of the paper at an exact metre reading. These readings will change when the pen is reset.
10. For weight-driven recorders, guide the weight cable onto the drum so that it does not overlap. Wind the weight up to the floor of the instrument shelter so that the suspension spring is above the surface of the hole in the floor. Remove the clock and unwind enough cable to pass through the hole in the floor. Reinstall the clock carefully to ensure that the wide flange of the rear clock hold-down nut depresses the locking level.
11. To start the recorder clock, screw the crank handle into the end of the winding shaft. Wind the crank clockwise for weight-drive clocks and counter-clockwise for negator-spring drives. In the case of negator-spring drives, the crank must be pushed in to engage the winding mechanism; wind the spring until the warning mark (STOP) on the spring appears. Do <u>not</u> wind the spring to its entire extent because the clock will not operate. After winding the negator-spring clock, ensure that the pawl is disengaged from the ratchet. The winding shaft should be pushed out by a spring so that the pawl rides on the second uncut ratchet. Ensure that the winding gear is disengaged by observing it from the front of the recorder. Never attempt to wind a negator spring when the clock has been removed. To start an electric clock, simply plug it into a 115 V, 60 Hz electrical source.
12. To set the time clock, remove the tension on the paper take-up roller by pulling out the knurled disc on the right side of the recorder and rotating it in a direction away from the recorder. To take-up the slack in the paper, roll the chart to a time slot just short of the correct setting and push the disc back in. The chart may then be rolled to the correct time setting.
13. Rotate the float pulley enough to make an identifiable mark (about 10-mm long). Draw a line from the pen trace to a position over the small metal writing table under the chart. Make the appropriate notations on the chart as shown in Figure III-8).

Note: Instrument Transportation

The transfer of recorders and other instruments by public transport is a routine requirement that requires attention to detail. Before any shipments take place the manufacturer thoroughly bench-tests its recorders and adjusts the matching clock to ensure that the chart speed is accurate. The shipping carton contains separate packages for the float. float pulley, float tape or cable. connectors and counterweight. It may also contain ink, oil, pencils and chart paper. Other parts and accessories may also be individually wrapped. Any manufacturer's shipment should contain instrument's 'Instruction Manual', which contains the packing list. Check the packing list to ensure that all items are accounted for and that the recorder serial number corresponds.

A factory-delivered recorder has all moving parts secured with twine. Remove this twine and any pieces of packing material. Refer to the 'Instruction Manual' to ensure that the recorder is complete and operative. If possible. test the recorder for a few days before placing it at the data collection site. When you are sure that the recorder is complete and in working order, it is then ready for field installation.

Instruments often require shipment, whether it is to a site, returning to the dealer for service, and due care must be exercised to avoid damage and the resulting downtime or other inconvenience. The procedure is as follows:

- Secure all the moving parts, elastic bands are as effective and easier to apply than twine, tape may cause other trouble and is not recommended
- Repackage it in the same way it was received
- Make sure that the clock winding handle and the float pulley assembly are intact
- If the recorder uses a weight-driven clock assembly, include the clock weight and spring
- Add ink or pen cartridges and a fresh strip chart to the package.

On the sealed shipping carton, clearly mark 'Prepared for Installation' and note the type of clock drive (weight or negator spring). Attach a complete list of contents to help identify what additional components are needed before installing the recorder on site.

Appendix III-4. Clock Removal and Servicing

a) Servicing

Clock servicing or replacement is important to the operation of a hydrometric station equipped with a mechanical recorder. The following instructions are intended to minimize the problems which can be anticipated:

1. Remove a clock by screwing the winding handle into position.
2. Push the winding shaft and wind it until the safety pawl drops into the engaged position. If the safety pawl is not engaged, the weight-drive cable or negator spring will unwind uncontrollably, creating a serious hazard.
3. Remove the screws securing the clock to the recorder base. Slide out the clock, being careful not to disturb the safety pawl. Do not turn the winding handle when the clock is removed. Turning the winding handle releases the safety pawl which will result in the uncontrolled unwinding of the negator spring.
4. Remount the clock, slip the clock base over the stud on the recorder base at the mounting location. Wind the recorder drive to position the pins on the recorder time gear so they can enter the clock-drive bar slots. Slide the clock into position. Do not release the tension on the winding handle until the clock is in position. Install the mounting screws first. then disengage the safety pawl.
5. Regulate the clock timing mechanism to correct for time error noted during the just concluded time period by winding the recorder drive to engage the safety pawl, then unscrew the back cover of the clock to expose the time adjusting nut and rotate the

knurled adjusting nut (a one quarter turn left will slow the clock by approximately 30 seconds per day).

Note: Mark mechanical clocks with permanent identification and keep a performance and servicing record for each clock. Clean and oil the clock at least once every two years using a qualified clock repair service. Clocks operating at cold temperatures should be lubricated with “Moebius Syntalube Arctic” lubricant and be identified as ‘winterized.’ (Clock serial # is engraved on inner backing plate.)

AC Power Electric Clocks are used only where AC power is available. Accuracy depends on the continuity of 60 cycle AC power. If the power varies from 60 cycles or is momentarily interrupted, the accuracy of the chart is affected. It is difficult to identify these inaccuracies on the chart trace. Longer power interruptions often occur during periods when the data record is in increased demand. To remove and remount the electric clock requires no special precautions. Simply disconnect the power. unscrew the base mount. and slide the clock free. Reverse the procedure to remount. making sure the pins on the recorder time gear are engaged with the clock-drive bar slots.

The *Quartz Timer* regulator (DC electronic clock) requires a supply of the specified DC power. The duration and accuracy of continuous operation depend on the quality of the electronics and power supply continuity. Removal and remount are performed the same way with the electric clock. No special precautions are necessary. Connecting the power supply immediately activates the regulated chart travel. Follow manufacturer’s instructions for selecting the proper time scale and ensure that specified voltages are not exceeded.

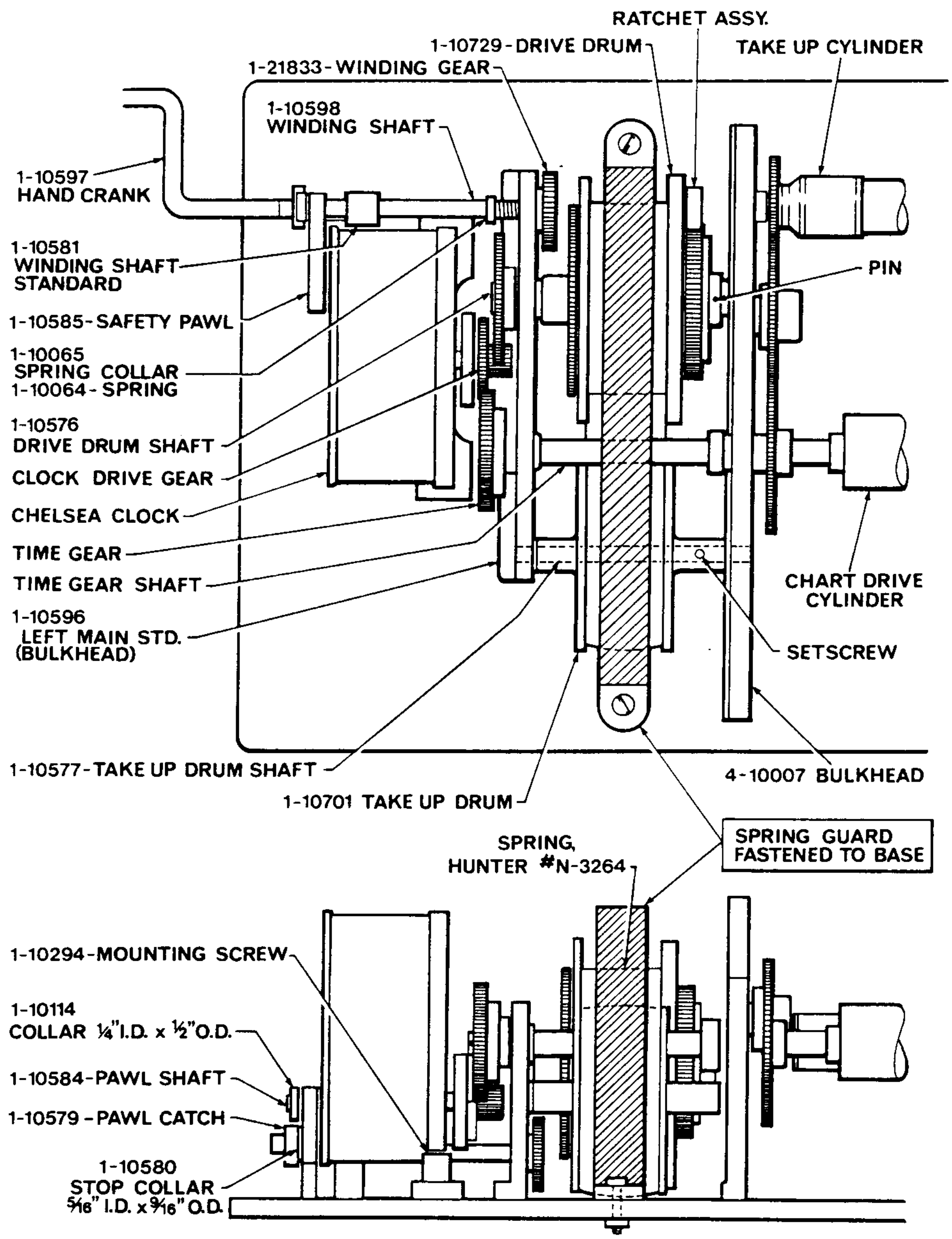
b) Negator-Spring Drive

A negator-spring drive (Figure III-9) is a power source used to drive the recorder chart. It consists of a length of spring-steel strap secured at one end to a storage drum. and secured at the other end to a winding drum. When the spring strap is forcefully wound to the winding drum, it stores energy. When the energy is released under the control of the clock regulator. the spring strap returns to the storage drum. Negator springs are designed to release a constant level of power for periods of 4.5 or 6 months as specified on the order.

The negator-spring drive is compact and fits neatly within the recorder cover. It allows for the use of the Type-A recorder where a weight drive is not possible or practical. A weight-drive recorder can be converted to a negator drive recorder fairly easily. Unfortunately, the negator drive can cause serious injury and must be *handled with caution*. The uncontrolled unwinding of a negator spring can be a frightening experience. ***It can also cause serious injury*** to the technician and damage to the recorder. If for any reason the negator spring must be unwound, carefully follow these procedures:

1. Remove the mechanical clock as directed in Section **Clock Removal & Servicing**.
2. Remove the chart from the take-up cylinder.
3. Remove the writing plate and chart supply roll.
4. Grasp the chart-drive cylinder (the larger cylinder in front) firmly with the right hand.
5. Rotate the cylinder towards you slightly to remove tension on the safety pawl**.**

6. Hold the cylinder very firmly while releasing the safety pawl with the left hand. Don’t be startled when the winding shaft gear springs out of engagement.
7. Using your grasp on the chart drive cylinder as a brake, allow the negator spring to unwind slowly and completely.
   Note: All negator-spring drives shall be fitted with a protective guard (as shown in the cross-hatched area in Figure III-8).



A35 RECORDER WITH NEGATOR SPRING

Figure III-8. Negator spring drive

Appendix III-5. Recorder Options and Accessories

a) Options

Type-A Recorder:

- negator-spring drive
- weight drive
- electric synchronous motor drive
- electronic regulator

Marking Stylus:

- liquid ink reservoir
- felt tip pen (requires special mounting bracket)

Float Pulley:

- beaded wire
- tape
- pulley circumference 375 mm - chart scale 1.25 m (standard)
- pulley circumference 750 mm - chart scale 2.50 m

Float Pulley Standard:

- gear equipped to provide specified chart scales
- 0.25 m
- 0.5 m
- 5.00 m
- 6.25 m
- 12.50 m

Time Scale:

- 60.96 mm (2.4’’) per day standard. (Graphic Controls of Canada Ltd. 60 mm per day)
- gearing options depend on type of chart drive

b) Accessories

Time Marker (Figure III-9): With this accessory, an auxiliary pen makes a jog at certain elapsed time intervals by marking in the left margin of the chart. The action is controlled by the clock so that the jogs correspond to clock time and not to time divisions on the chart. These jogs serve as a basis for applying corrections to the graph for possible errors due to humidity effects. Under standard humidity conditions, these jogs are at 60.96 mm intervals. An adjustable actuating ring allows for the initial synchronization of the jogs (DC electronic clock) requires a with the major chart divisions.

The time marker accessory can be purchased as a separate accessory for installation in the field.

It mounts on the front of the left writing plate standard and is held by one screw and positioned by a pin.

The actuator ring fits over the hub of the idler gear, with the slanted portion of the actuating tab situated on the side toward the chart.

Reversal Indicator (Figure III-10): This accessory eliminates possible confusion when interpreting graphs with reversals the margin. The indicator makes a continuous pen line in the right margin of the chart. When a stylus reversal occurs while the stage is still changing in the same direction, a jog is made in the line. This mark distinguishes a stylus reversal from a stage reversal. Short jogs in the pen line are made when the sprocket rotates clockwise, and long jogs appear when it rotates counterclockwise. The reversal indicator can be purchased as a separate accessory for installation in the field. It mounts on the right standard just to the rear of the tracks.

It is positioned by a pin and held in place by a screw and nut. The relative lengths of the ink-line jogs can be adjusted by loosening the lower set screw on the tripper arm hub and rotating the hub slightly. The chain must have three operating pins, one for the stylus carriage and two for the reversal indicator. For recorders made prior to January 1969, it is necessary to purchase a new chain with the three operating pins.

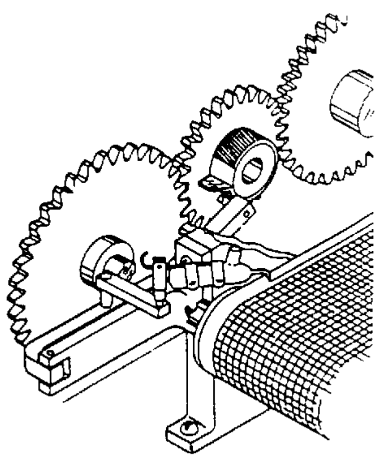


Figure III-9. Recorder chart elapsed time marker

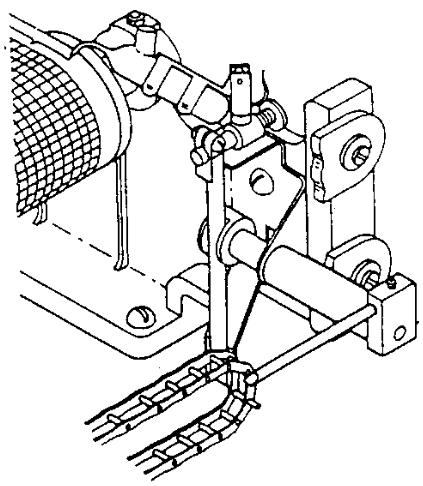


Figure III-10. Marking stylus reversal indicator

Appendix III-6. Recorder Dismantling and Reassembly

a) Partial Dismantling

Once you are familiar with the recorder in a friendly environment, on-site installation and servicing can be accomplished with greater confidence and ease.

Pen Carriage Assembly**:** (Assume the float pulley is engaged with the float cable or tape.) Mark the position of the upper guide rail before proceeding with the pen carriage assembly removal. To remove, disengage the pulley clamp by loosening the two knurled set screws. This allows free movement of the pen carriage assembly. Move the carriage to the centre and disengage the pin on the drive chain from the diamond-shaped slot at the back of the carriage. Next, move the carriage to the extreme right of the guide rails and loosen the screw that secures the right end of the upper guide rail. The end of the guide rail may now be pushed slightly downward to free the carriage rollers from the rails. Gently lift out the pen carriage. The drive chain may now be removed by slightly lifting the lever which applies spring tension to the right hand sprocket assembly. Disengage the chain from this sprocket and then the left sprocket. Remove the chain by lifting it up or sliding it out to the right along the recorder base.

b) Reassembly

Reverse the above procedure. When securing the upper guide rail. run the pen carriage once or twice along the rails to ensure there is no restriction of movement and that the rollers will not disengage.

Float Pulley: Standard: After removing the pen carriage and drive chain, remove the float pulley standard by unscrewing the wing nut under the recorder base and lifting upward on the standard. A gentle tap may be required to loosen it from the mounting alignment studs hidden under its base. Align the base with the mounting studs. press it firmly in place, and replace the securing wing nut.

> **Note:** How to Release Negator-Spring Tension
>
> Refer to section b, ‘Negator-Spring of Appendix III-4 and follow the procedure described for unwinding. USE CAUTION.

c) Time Scale Gearing

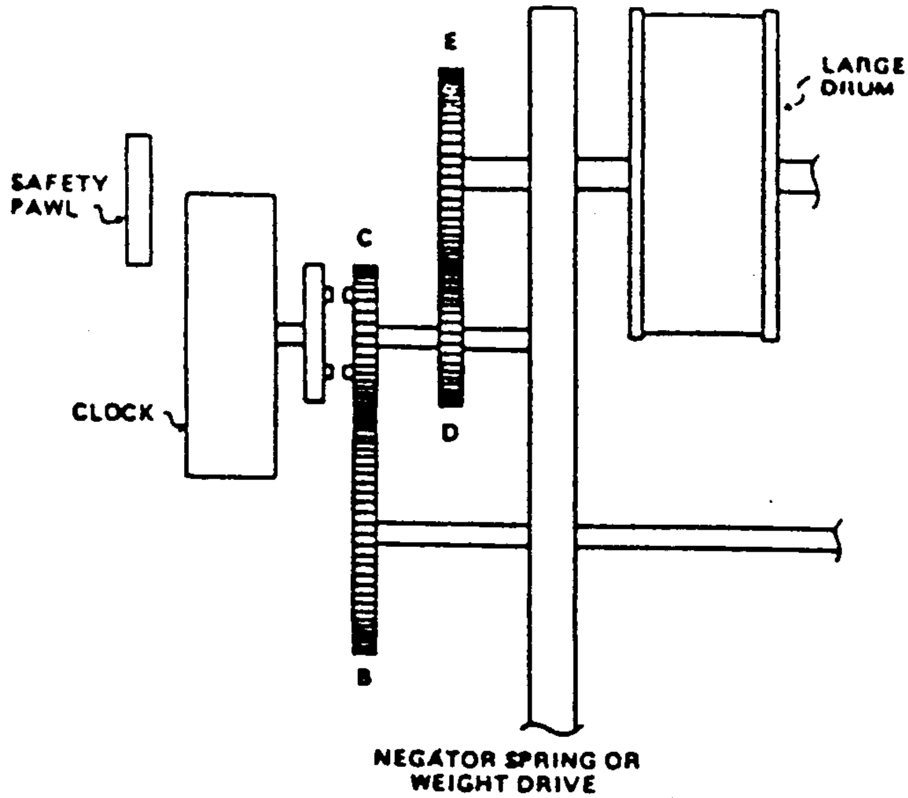
Provides a wide choice of chart travel rate (Figure III-11).

Individual gears are stamped with a number identifying the number of gear teeth. They may be used in combinations to provide the desired chart travel speed as shown in Figure III-11.

Have one or more examples of gear combinations on hand for demonstration purposes. Demonstrate the proper tolerance of gear mesh. At room temperature, a slight movement of the gears should be noticed.

Before removing any gears ensure that the clock regulator is removed. If a negator spring or clock-drive weight is used, they should be removed. It is not enough to simply have the safety pawl engaged.

The gears are held in place by a slotted cap screw threaded to the end of the driving shaft. For removal, simply detach the cap screw and slide the gears free. Upon reassembly or gear exchange, be certain to put all washers and shims in the proper order. Ensure that all gears are properly aligned and fully meshed. Test the recorder to make sure that the desired chart speed has been attained. Tie together, package, and properly identify all unused gearing combinations.



Scale Designation (mm/day)	Value of Chart Divisions: Major (30 mm)	Value of Chart Divisions: Minor (2.2 mm)	22.9 m Strip Chart Lasts	Gear Teeth (See Figure): B	C	D	E
30	24 hr	2 hr	2 yr	85	29	20	98
60	12 hr	1 hr	1 yr	66	45	14	65
120	6 hr	30 min	6 mo	66	90	20	86
180*	4 hr	20 min	4 mo	45	92	15	63
240*	3 hr	15 min	3 mo	44	120	16	62

NOTE: C & D gears are supplied on a common hub.
* Weight Driven only.

Figure III-11. Chart time scale gearing: negator and weight drive.

d) Recorder Servicing

Service the recorder on each visit to the gauging station and remove the chart every four to six weeks. <u>Service the recorder immediately upon arriving at a site,</u> then inspect it again before leaving to ensure that the instrument is operating and that no mistakes have been made. The steps in servicing are:

1. Visually inspect the recorder installation to determine whether any malfunction or damage has occurred. If the recorder clock has stopped, roll the chart forward before doing anything else. The vertical line at the end of the trace will show the range in stage during the stoppage.
2. Read the manual gauges and annotate the chart, as described in step (12) in the previous section on Installation. Observe the left side of the take-up roll to see if any ‘coning’ of the paper has taken place. Do not reset the pen or advance the chart unless the record will be computed manually.
3. Flush the intake system by closing the appropriate valve(s) and by filling the flush tank with water from the well. Observe the change in water level and the recovery rate when the valve(s) are reopened. If the water level in the well is slow to recover, more flushing may be required or repairs to the intake may be necessary. Intakes leading to a silty stream should be flushed on every visit.
4. Check the performance of any accessories in use, such as the reversal indicator, event marker, rain gauge or thermograph.
5. If the chart is to be removed, prepare to remove it by releasing the tension from the paper take-up roller. The roller tension is controlled by the knurled disc on the right side of the recorder. Pull the disc out and rotate it away from the recorder. Roll the chart forward so that there is about 100 mm of blank chart paper between the end of the record and the closest edge of the metal writing table. Cut off the chart paper at the front of the writing table. Do this **with a pencil point** or similar blunt object to avoid cutting the writing table below. Knife marks or other scratches on the table will soon cause the table to rust and stick to the chart.
6. Now remove the chart from the take-up roller by unwinding it while the take-up roller is still in its receptacle. Unwinding the chart has two advantages over the sliding-twist method of removing the chart. It prevents the chart from binding on the take-up roller and allows the technician to inspect the entire record obtained since the chart was last removed. Defects in the record, caused by a sticking float, pressure system malfunctions or other problems will be apparent on the chart. Corrective action may be taken before leaving the site.
7. Determine whether enough chart paper is available for use until the next planned visit to the station. Extra paper should be included for a margin of safety. Each small division (*2 mm*) between the warning line and the edge of the chart indicates that a one-day supply of paper will be available at the conventional chart speed.
8. If it is necessary to install a new chart roll, detach the writing table and remove the supply roll. Next, remove the knurled washer nut from the end opposite the flange and remove the old core. Put the new chart paper on the supply cylinder with the end flush against the flange. Next, tighten the washer nut so that the supply roll can not slip off the cylinder. The supply roll may then be placed in its bearings with the flange to the left. Once the supply cylinder is in place. The chart paper can be connected to the drive roller. To do this, make a right-angle crease in the paper about

20 mm from the end. Feed the end of the paper underneath the drive roller so that it passes between the drive roller and the friction rollers

9. Using the spring clamp, attach the end of the chart to the take-up roller. Roll some chart paper onto the take-up roller. Hold it taut to ensure that the paper is tracking squarely.
10. Check to ensure that the reversal mechanism is operating and that the margins are correct.
11. If the clock has gained or lost more than two hours a month since the last time the chart was removed, adjust the clock. Unscrew the cover and move the adjusting indicator toward “F” to make the clock run faster and toward “S” to make it run slower. Record these adjustments in the gauge house so that clock malfunctions may be detected and corrected.
12. When you arrive at the gauge house and discover that the recorder clock has stopped, replace it. Make sure that the pawl on a negator-spring recorder is engaged before you remove the clock. You may have to wind the spring slightly to engage the drive holes of the new clock. Do this by holding the clock near its correct position and by turning the spring take-up spool carefully by hand until the clock engages. Do not use the crank. When replacing the clock from a weight-driven recorder, remove the clock weight so that the clock-weight cable will not unwind if the locking lever is accidentally pressed. Remember to reattach the weight. Finally, ensure that the faulty clock is examined by a clock repairer.
13. Lubricate the recorder annually using the oil provided. Clean the recorder pen whenever necessary by using the cleaning wire provided, and refill it. If the ink in the pen dries out, a liquid cleaner such as Lysol can be used to clean it. Note that some solvents. such as alcohol. will dissolve the acrylic plastic reservoir. New recorders will normally be fitted with a bracket to hold a special felt tip pen cartridge. Many older units have been retrofitted with these brackets, the pen cartridge, which will normally last for at least 2 years, is secured in position by a spring clip and is easily replaced. The plastic cap supplied with each cartridge is removed and should be retained for replacement on the pen tip to prevent drying out if the recorder is shut down for the winter. The cartridge pen is virtually trouble free.
14. Read the inside and outside gauges, set the pen correctly, and make the required notations on the chart as described in step (12).
15. Before leaving the shelter, check the position of the pawl on a negator-spring clock, close the dust cover over the crank hole, and close the recorder lid.

Appendix III-7. Recorder Troubleshooting

Table III-1 lists problems occasionally encountered during the operation of Type-A recorders. Actions required to eliminate these problems are also identified.

Table III-1. Troubleshooting the operation of Type-A recorders.

Symptom	Possible cause	Action
Pen not inking or pen skipping.	• Dirty pen. • Ink supply exhausted. • Pen tip not flat on chart paper.	• Clean using cleaner wires. • Fill reservoir. • Adjust.

Symptom	Possible cause	Action
	• Lucite reservoir held too tightly in stylus carriage.	• Adjust.
Flat spot in trace at high water.	• Float jammed against floor. • Counterweight resting on bottom of well. • Beaded float wire caught on shelf or floor.	• Cut hole in floor to allow float to rise to shelf level. • Shorten float line. • Enlarge holes.
Flat spot in trace at low water.	• Bottom intake blocked or frozen. • Bottom intake not low enough. • Silt in well. • Counterweight caught on floor or shelf. • Beaded float wire caught on shelf or floor.	• Flush pipe or thaw. • Reinstall bottom intake. • Remove silt. • Lengthen float line. • Enlarge holes.
Discontinuity in trace on rise or fall in stage.	• Float or counterweight caught on obstruction or each other. • Layer of thin ice forming on water surface in the well. • Sticking reversal mechanism. • Beaded float wired caught on shelf/floor. • Clock stopped and restarted.	• Check path of float and counterweight through range in stage. • Check heating system. • Check for smooth operation and clean. • Enlarge holes. • Check/replace clock.
Water level in well is usually higher than that in stream.	• Groundwater inflow to well if well is not sealed.	• Temporarily open valves on intake pipes to maximum; seal well.
Water level is different from that in the stream (if intakes are clear most records will show signs of slight (“pen action”)).	• Float pulley is loose. • Beaded cable or float tape is disengaged. • Intake blocked by sediment deposition.	• Tighten. • Re-engage; check for possible reason, dirt in tape hole, etc. • Remove sediment.
Painting, particularly at high water.	• Intakes are too large. • Velocity effects on intakes.	• Close intake valves slightly. • Install static tubes on end of pipes.
Recorder clock stopped (if cause of failure is not apparent, replace clock).	• Negator spring engaged spring overwound or completely unwound. • Weight driven clock spring drawn up into hole in floor or	• Release pawl, carefully unwind spring, or wind as required. • Remove weight and unwind a little cable, or

Symptom	Possible cause	Action
	shelf, or weight dropped to its full extent. • Electric clock-power a step in the trace. • Extreme cold temperatures.	wind cable as required. • Check circuit breaker, supply voltage. • Lubricate using arctic lubricant, or heat the recorder.
Take-up cylinder falls from mounts.	• Corrosion or dirt on cylinder-mounting saddle. • Incorrect torque input from negator spring or drop weight.	• Clean and polish with fine emery paper, lubricate slightly. • Check torque, should be 300.380 mNm (42.54 oz. in.).
Clock runs extremely fast.	• Drive roll not engaged, take-up roll is pulling. • Recorder clutch dirty.	• Ensure rubber rollers that engage paper through drive roller are in contact. • Clean.
Clock stops within a few hours.	• Poor meshing of clock drive yoke with time gear pins. • Safety pawl gear engaged.	• Check for proper engagement of pins to yoke and possible binding; enlarge slots in clock drive yoke. • Make sure that the safety pawl is disengaged before leaving the station.

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Appendix IV. Water Act

Note: This is not the official version. The printed version issued by the Queen's Printer remains the official version. Copies may be obtained from Crown Publications Inc., 521 Fort Street, Victoria, BC V8W 1E7.

The Regulation

Part 7

Changes in and about a Stream

Authority to make a change in and about a stream

37

(1) A change in and about a stream must not proceed unless it is

(a) authorized by an approval, licence or order, or

(b) made in compliance with this regulation.

(2) If a change in and about a stream is authorized by an approval, licence or order, this regulation, except subsection (3), does not apply to the change in and about the stream.

(3) If the engineer is of the opinion that a proposed change in and about a stream may have a significant detrimental impact on the nature of the stream or stream channel, the engineer may require that an application for an approval or a licence be made in connection with the proposed change in and about a stream.

(4) The fact that a change in and about a stream meets the requirements of subsection (1) does not relieve the person carrying out the change in and about the stream from

(a) the requirement to comply with all applicable federal, provincial or municipal enactments, and

(b) if the change in and about a stream will occur on Crown land or land owned by another person, from the requirement to obtain the approval of the owner before proceeding.

Limits on the authority to make a change in and about a stream

38

(1) A person must not make a change in and about a stream unless that person

(a) provides, on request, information that the engineer, officer or habitat officer requires to assess the impact on the nature of the stream or stream channel, and

(b) once commenced, completes the change without delay except if a delay is necessary to preserve the nature of the stream or stream channel.

(2) A change in and about a stream must be designed, constructed and maintained in such a manner that the change does not pose a significant danger to life, property or the environment.

Failure to comply with this regulation when making a change in and about a stream

39 In addition to other remedies or penalties that may be imposed on a person who makes a change in and about a stream that does not comply with this regulation, the person must

(a) within 72 hours report the non-compliance to the closest regional office of the Ministry of Environment, Lands and Parks, and

(b) to remedy the non-compliance,

(i) take the measures the engineer specifies, and

(ii) comply with the terms and conditions described in section 42 that a habitat officer specifies.

Notification

40

(1) A person must not make a change in and about a stream unless that person

(a) notifies a habitat officer of the region of the Ministry of Environment, Lands and Parks in which the change in and about a stream will be located, by providing the information specified in the notification form available from the ministry, of the particulars of the proposed change at least 45 days prior to commencing to make the change, and

(b) obtains from a habitat officer the terms and conditions described in section 42 on which the change can proceed prior to commencing to make the change.

(2) Despite subsection (1), if a habitat officer has not contacted the person giving notice under subsection (1) (a) within 45 days of the receipt of the notice by a habitat officer, the person may proceed to make the change.

(3) A person who makes a change in and about a stream under section 44 (o) to (t) does not have to comply with subsection (1).

(4) A person who makes a change in and about a stream under section 44 (o) or (p) must

(a) within 72 hours report the change to a habitat officer, and

(b) take the measures the engineer specifies and comply with the terms and conditions described in section 42 that a habitat officer specifies respecting the change.

Protection of water quality

41 A person making a change in and about a stream must ensure that

(a) no substance, sediment, debris or material that could adversely impact the stream is

(i) allowed or permitted to enter or leach or seep into the stream from an activity, construction, worksite, machinery or from components used in the construction of any works, or

(ii) placed, used or stored within the stream channel,

(b) no standards or objectives published under section 2 (e) of the Environment Management Act by the Ministry of Environment, Lands and Parks for the protection of ambient water quality are exceeded or not attained now or in the future due to the change,

(c) there is no disturbance or removal of stable natural materials and vegetation in and about a stream that contribute to stream channel stability except as authorized under this regulation and in accordance with the terms and conditions specified by the habitat officer,

(d) temporary material, fill, bridge, culvert, pump, pipe, conduit, ditch or other structure used to assist in the construction of any works are constructed and maintained only during the period of construction, and are removed on completion of the works,

(e) all cast-in-place concrete and grouting is completely separated from fish bearing waters for a minimum of 48 hours,

(f) rock from acid-generating rock formations is not used for construction, and

(g) the stream is restored to its natural state on completion of the change in and about a stream.

Protection of habitat

42

(1) To protect habitat, a person making a change in and about a stream under this regulation, other than under section 44 (o) to (t), must make that change in accordance with terms and conditions specified by the habitat officer with respect to

(a) the timing window or the period or periods of time in the year during which the change can proceed without causing harm to fish, wildlife or habitat,

(b) the minimum instream flow or the minimum flow of water that must remain in the stream while the change is being made,

(c) the removal of material from the stream or stream channel in connection with the change,

(d) the addition of substance, sediment, debris or material to the stream or stream channel in connection with the change,

(e) the salvage or protection of fish or wildlife while the change is being made or after the change has been made,

(f) the protection of natural materials and vegetation that contribute to habitat or stream channel stability,

(g) the restoration of the work site after the change has been made, and

(h) the requirement to obtain an approval from the federal Department of Fisheries and Oceans in connection with the change.

(2) In addition to other remedies or penalties that may be imposed on a person who makes a change in and about a stream that damages habitat, the person must

(a) within 72 hours report the damage to a habitat officer, and

(b) restore and repair the habitat to its natural state or as directed by the habitat officer.

Protection of other water users

43

(1) A person making a change in and about a stream, other than a change under section 44 (o) to (t), must ensure that persons who are lawfully diverting or using water under the Water Act will not be adversely affected.

(2) Despite subsection (1), if persons who are lawfully diverting or using water under the Water Act may be adversely affected, a person proposing to make a change in and about a stream, other than a change under section 44 (o) to (t) must give 3 days notice to those persons prior to commencing to make the change and must provide an adequate supply of water to those persons, if required by those persons.

Authorization for changes in and about a stream

44 For the purposes of section 9 of the *Water Act*, the following changes in and about a stream may be made without the necessity of obtaining an approval or licence for that change, provided that the changes made in accordance with this regulation and in accordance with the terms and conditions, described in section 42, specified by a habitat officer

(a) the installation, maintenance or removal of a stream culvert for crossing a stream for the purposes of a road, trail or footpath, provided that

(i) equipment used for site preparation, construction, maintenance or removal of the culvert is situated in a dry stream channel or operated from the top of the bank,

(ii) in fish bearing waters, the culvert allows fish in the stream to pass up or down stream under all flow conditions,

(iii) the culvert inlet and outlet incorporate measures to protect the structure and the stream channel against erosion and scour,

(iv) if debris cannot safely pass, provision is made to prevent the entrance of debris into the culvert,

(v) the installation, maintenance or removal does not destabilize the stream channel,

(vi) the culvert and its approach roads do not produce a backwater effect or increase the head of the stream,

(vii) the culvert capacity is equivalent to the hydraulic capacity of the stream channel or is capable of passing the 1 in 200 year maximum daily flow without the water level at the culvert inlet exceeding the top of the culvert,

(viii) the culvert has a minimum equivalent diameter of 600 mm,

(ix) a culvert having an equivalent diameter of 2 metres or greater, or having a design capacity to pass a flow of more than 6 cubic metres a second, is designed by a professional engineer and constructed in conformance with that design,

(x) the culvert is installed in a manner which will permit the removal of obstacles and debris within the culvert and at the culvert ends,

(xi) the stream channel, located outside the cleared width, is not altered,

(xii) embankment fill materials do not and will not encroach on culvert inlets and outlets,

(xiii) the culvert has a depth of fill cover which is at least 300 mm or as required by the culvert manufacturer’s specifications,

(xiv) the maximum fill heights above the top of the culvert do not exceed 2 m, and

(xv) the culvert material meets the standards of the Canadian Standards Association;

(b) the construction, maintenance or removal of a clear span bridge, provided that

(i) the bridge and its approach roads do not produce a back water effect or increase the head in the stream,

(ii) the equipment used for construction, including site preparation, maintenance or removal of the bridge is situated in a dry stream channel or is operated from the top of the bank,

(iii) the hydraulic capacity of the bridge is equivalent to the hydraulic capacity of the stream channel, or is capable of passing the 1 in 200 year maximum daily flow, and the height of the underside of the bridge is also adequate to provide free passage of flood debris and ice flows, and

(iv) the bridge material meets the standards of the Canadian Standards Association, as applicable;

(c) the construction or maintenance of a pipeline crossing, provided that

(i) the pipeline and associated works are installed in a dry stream channel at a depth so that the top of the pipe is at least 1 metre below the lowest elevation of the bed of the stream, and

(ii) in the case of an aerial crossing, the crossing is constructed in accordance with the requirements prescribed in paragraph (b) for clear span bridges;

(d) the construction, maintenance or removal of a pier or wharf in a stream, provided that the ebb and flow of water and movement of material under the influence of waves or currents is not obstructed and that the requirements under section 37 (4) are met;
(e) the construction, maintenance or removal of a flow or water level measuring device in a stream by the Crown in right of either Canada or British Columbia, or their agents;
(f) the construction or removal of a fish fence, screen or fish or game guard across a stream by the Crown in right of either Canada or British Columbia, or their agents, provided that it is designed, constructed, maintained or used so as not to obstruct the flow of water in the stream;
(g) the restoration or maintenance of a stream channel by British Columbia or its agents;
(h) the restoration or maintenance of a stream channel by a municipality;
(i) the mechanical or manual cutting of annual vegetation within a stream channel;
(j) the restoration or maintenance of fish habitat by the Crown in right of either Canada or British Columbia, or their agents;
(k) the repair or maintenance of existing dikes or existing erosion protection works to their original state, provided that the dikes or works were functional during the previous year;
(l) the construction or maintenance of storm sewer outfalls, provided that the storm sewer outfall is designed by a professional engineer, and constructed, maintained and used so as not to obstruct the flow of water in the stream or to cause erosion or scour in the stream;
(m) the mechanical or manual control of Eurasian water milfoil and other aquatic vegetation by a landowner, a municipality or a local authority;
(n) the construction or maintenance of ice bridges, winter fords or snowfills,

(i) provided that the materials used are removed from the stream channel before ice breakup and that only clean ice and snow are used, and

(ii) in the case of ice bridges, provided any logs, timbers and other structural materials used can be removed in a safe manner;

(o) the construction or placement of erosion protection works or flood protection works during a flood emergency, but not including restoration works, declared under the Emergency Program Act, under the direction of the Crown in right of British Columbia, or its agents, or by a municipality;

(p) the clearing of an obstruction from a bridge or culvert by the Crown in right of British Columbia, or its agents, or by a municipality during a flood event when there exists a potential danger to life or property;
(q) the installation or cleaning of drain tile outlets;
(r) the repair or maintenance of the superstructure of a bridge, excluding its foundation, made in accordance with this regulation, particularly the terms and conditions specified in this regulation for the protection of water quality, habitat and water users;
(s) the installation, repair, maintenance or removal of fences, provided that the fencing materials

(i) are not in the stream channel,

(ii) do not block debris in the stream channel, and

(iii) do not interfere with navigation of the stream;

(t) a change in and about a stream to which a standard or regulation under the Forest Practices Code of British *Columbia Act* applies that is carried out

(i) by a person

(A) holding an agreement under the Forest Act or the Range Act or holding a special use permit under the Forest Practices Code of British Columbia Act, or

(B) referred to in section 58 (2) (c) of the Forest Practices Code of British Columbia Act, in the construction, modification, maintenance or de-activation of a road under that Act, or

(ii) by the Crown in right of British Columbia or by someone under contract to the Crown in right of British Columbia, provided that the person carrying out the change complies with the Forest Practices Code of British Columbia Act, including the regulations and standards established under it;

(u) the maintenance of a minor and routine nature by a public utility of its works;
(v) the removal of a beaver dam under section 9 of the Wildlife Act, provided that the removal is carried out in such a manner that downstream flooding and erosion do not occur;
(w) the construction of a temporary ford across a stream, provided that

(i) the construction occurs at a time in the year during which the construction can occur without causing harm to fish, wildlife or habitat,

(ii) the 1 in 10 year maximum daily flow over the ford is accommodated without the loss of the ford and without scouring the stream,

(iii) a stream culvert, if used, is designed and installed to pass the average low flow during the period of use,

(iv) the channel is protected against any anticipated erosion, during the period of construction and use of the ford, and also after the ford crossing is removed,

(v) sediment from approach ditches does not enter the stream,

(vi) the driveable running surface is erosion-free,

(vii) the stream remains in its channel and cannot be diverted down the road,

(viii) the ford will pass channel debris, and

(ix) the ford is removed at the end of the period of use at a time, prior to the next freshet, when the removal can proceed without causing harm to fish, wildlife or habitat,

(x) the construction of a temporary diversion around or through a worksite for the purposes of constructing or maintaining bridge abutments, constructing or maintaining piers other than bridge piers, or maintaining bridge piers or constructing works authorized under this section, provided that the worksite is no larger than the minimum area required, and

(i) if pumps, pipes or conduits are used to divert water around or through the worksite,

(A) pumps, pipes or conduits are sized to divert the 1 in 10 year maximum daily flow for the period of construction, and

(B) any pump or intake withdrawing water from fish bearing waters is screened in accordance with the Fish Screening Directive of the Department of Fisheries and Oceans Canada, or

(ii) if coffer-dams are used to isolate successive parts of the construction at the worksite,

(A) the coffer-dams are designed by a professional engineer and constructed in accordance with that design, and

(B) the natural channel remaining outside of the coffer-dams is adequate to pass the 1 in 10 year maximum daily flow during the period of construction, or

(iii) if ditches are used to divert flow around the worksite,

(A) the flow of water diverted remains within the stream channel,

(B) ditches are designed and constructed to divert the 1 in 10 year maximum daily flow around or through the worksite and are protected from any anticipated erosion during the period of construction and use of the ditch, and

(C) the ditches are completely backfilled and the area returned as closely as possible to the natural state within the construction period.

Note: A full discussion of the Regulation is found in *A User’s Guide to Working In and Around Water: Regulation Under British Columbia’s Water Act - June, 1997*. Water Management Branch, BC Ministry of Environment. 23pp.

Note: This is not the official version. The printed version issued by the Queen's Printer remains the official version. Copies may be obtained from Crown Publications Inc., 521 Fort Street, Victoria, BC V8W 1E7.

Notification for Proposed Works and Changes In and About a Stream under the Section 9 Regulation of the Water Act

Please refer to the application guidelines when completing this Notification Form

1. Applicant Name: ____

Address: ____

City & Province: ____

Postal Code: ________________ Phone:____________________

2. Location of Works:

Stream Name: ____

Location on Stream: ____

What stream\river\lake does it flow into?: _____________________________________

Address, if different from above: ____

Legal description of property: ____

3. Sketch Plan: attach a drawing showing lot boundaries, location of proposed works, stream direction and flow and location of buildings.

4. Proposed Timing:

Start (day/month/year): _____________________

Finish (day/month/year): ____________________

5. Type of Works (Check appropriate line)**:**

____ Road crossing culvert

____ Pipeline crossing in a naturally dry channel

____ Cutting annual vegetation

____ Storm sewer outfalls

____ Existing dike or erosion protection works repair or maintenance

____ Routine maintenance by a public utility

____ Fish habitat restoration or maintenance by government

____ Stream channel restoration or maintenance by a municipality or the province

____ Fish fences or screens, fish or game guards by government

____ Flow or water level measuring device by government

____ Clear span bridge

____ Pier or wharf

____ Ice bridge or winter ford

____ Aquatic vegetation control

Dimensions of the proposed works: Length: _____Width: ______ Diameter: _______

6. Do you own the land on which the works are to be located?

Yes ____ No _____ (check one)

If not, who owns the land?

Land Ownership: Private: _____Crown: _____ (check one)

Landowner's approval, if different from applicant:

Landowner Name: ____

Address: ____

Postal Code: ________________ Phone: _________________

Landowner's Signature: ____

(Attach tenure document for Crown land)

7. Who is Doing the Work?

Contractor: if different from applicant:

Company Name: ____

Contact Name: ____

Address: ____

Postal Code: ________________ Phone: _________________

The information on this notification form will be made available to the public under the freedom of information legislation, if requested.

8. Statement of Intent:

I declare that the information contained on this form is complete and accurate information. I have read, understood and will meet the requirements to construct works and changes in and about a stream in accordance with Section 7 of the Water Act and the Regulation.

Signed: _________________________________ Date: ______________________

<u>Ministry Use Only</u>:

_____ Meets the requirements to proceed under regulation

_____ Approval required

Notification for Proposed Works and Changes In and About a Stream under the Section 7 Regulation of the Water Act

Application Guidelines

Please fill in all sections of the form, incomplete forms do not constitute a notification and will not be processed.

1. Name and mailing address

Enter your name, mailing address and telephone number.

2. Location of works

- Identify the name of the stream on which you intend to carry out the proposed works.
- Specify where on the stream are the works to take place (e.g., distance from road crossing or confluence with another stream).
- Indicate what stream, river or lake the stream flows into.
- Indicate location of works if different from your mailing address.
- Enter a complete legal description of the property on which the works are to be carried out (e.g., Lot 1 of Section 31, Township 20, Range 12, W6M, Kamloops Division of Yale District, Plan 18411). This information is listed on your annual assessment or land tax notice, or you may obtain it by requesting a copy of your Certificate of Title from the appropriate Land Title Office.

3. Sketch Plan

Attach a drawing which clearly shows:

- the lot boundaries of the property on which the works are to take place
- the location of proposed works
- the stream and direction flow
- the location of house/building
- the approximate scale (e.g., 1 cm = 1 m)

A copy of part of a cadastral or topographic map or legal plan, at a reasonable scale, may be used for the drawing.

4. Proposed Timing

Indicate proposed start and finish of the works (day/month/year).

5. Type of Works

Identify the nature of the works by checking one of the boxes. Also, note the dimensions of the works and list length, width and diameter where appropriate.

6. Ownership of the Land

- If you own the land on which the works are to be carried out check "yes" and go to question 7.
- If you are not the owner of the land, indicate whether the land is privately owned or owned by the Crown.
- You must have the landowner's approval. The landowner must enter his/her address, telephone number and postal code and sign. If the land is owned by the Crown, please attach the appropriate tenure document.

7. Who is Doing the Work

If you are not carrying out the work, indicate contractor/company's name, mailing address, postal code and telephone numbers.

8. Statement of Intent

Make sure each section of the form is filled out and that the information is accurate and complete. After having read and understood the conditions outlined in the Section 7 Regulation, and ensured that your project meets all requirements, sign and date the form.

When your form is complete, send it along with the sketch plan to the BC Environment regional office located nearest to the proposed works. <u>This notification form must be completed, by providing the information specified, and must be received by a habitat officer in the nearest Ministry of Environment, Lands and Parks office at least 45 days prior to the proposed commencement of the work.</u>

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Appendix V. Discharge Tables for Rated Structures

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Table V- 1. Operating limits for rated structures

Table #	Device type	Device size	Max. h^1 [a] (m)	Max. Q (m^3/s)	Min. h^1 (m)	Min. Q (m^3/s)	Debris capacity	Sediment capacity	h^1/p [b]	Min. P [C] (m)
V-2	V-notch	90^0	0.60	0.390	0.05	0.0008	Very poor	Very poor	≤1.2	≥0.45
V-3		120^0	0.60	0.765	0.05	0.0012	Very poor	Very poor	≤1.2	≥0.45
V-4	Montana	3-inch	0.339	0.33	0.03	0.0008	Very good	Good	N/A	N/A
V-5	Flume	6 inch	0.457	0.111	0.03	0.0015	Very good	Good	N/A	N/A
V-6		9 inch	0.610	0.251	0.03	0.0025	Very good	Good	N/A	N/A
V-7		12 inch	0.760	0.455	0.03	0.0033	Very good	Good	N/A	N/A
V-8	H flume	2.0 feet	0.604	0.309	0.03	0.0005	Fair	Fair	N/A	N/A
V-9		2.5 feet	0.756	0.542	0.03	0.0008	Fair	Fair	N/A	N/A
V-10		3.0 feet	0.908	0.857	0.03	0.0010	Fair	Fair	N/A	N/A
V-11		4.5 feet	1.364	2.336	0.03	0.0014	Fair	Fair	N/A	N/A
V-12	HL flume	4.0 feet	1.218	3.292	0.05	0.0054	Good	Fair	N/A	N/A
V-13	Rectang.	b=1.0m	0.500	0.585	0.06	0.0267	Poor	Poor	≤ 0.5	≥ 0.3
V-14	Weir	b=1.5m	0.750	1.612	0.06	0.0402	Poor	Poor	≤ 0.5	≥ 0.3
V-15		b=2.0m	1.000	3.308	0.06	0.0537	Poor	Poor	≤ 0.5	≥ 0.3
V-16		b=3.0m	1.500	9.117	0.06	0.0807	Poor	Poor	≤ 0.5	≥ 0.3

[a] Head over the weir crest.

[b] Ratio of head over the crest and the height of the crest above the upstream bed.

[C] Height of crest above the upstream bed.

Table V- 2. Rating Curve For 90º V - Notch Weirs.

Discharge (m^3/s) for specified head (m) for fully contracted weir.

Head	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.050	0.0008	0.0008	0.0008	0.0009	0.0009	0.0010	0.0010	0.0011	0.0011	0.0012
0.060	0.0012	0.0013	0.0013	0.0014	0.0014	0.0015	0.0015	0.0016	0.0017	0.0017
0.070	0.0018	0.0018	0.0019	0.0020	0.0020	0.0021	0.0022	0.0023	0.0023	0.0024
0.080	0.0025	0.0026	0.0026	0.0027	0.0028	0.0029	0.0030	0.0031	0.0031	0.0032
0.090	0.0033	0.0034	0.0035	0.0036	0.0037	0.0038	0.0039	0.0040	0.0041	0.0042
0.100	0.0043	0.0044	0.0046	0.0047	0.0048	0.0049	0.0050	0.0051	0.0053	0.0054
0.110	0.0055	0.0056	0.0058	0.0059	0.0060	0.0061	0.0063	0.0064	0.0066	0.0067
0.120	0.0068	0.0070	0.0071	0.0073	0.0074	0.0076	0.0077	0.0079	0.0080	0.0082
0.130	0.0083	0.0085	0.0087	0.0088	0.0090	0.0092	0.0093	0.0095	0.0097	0.0099
0.140	0.0100	0.0102	0.0104	0.0106	0.0108	0.0110	0.0112	0.0114	0.0115	0.0117
0.150	0.0119	0.0121	0.0123	0.0125	0.0128	0.0130	0.0132	0.0134	0.0136	0.0138
0.160	0.0140	0.0142	0.0145	0.0147	0.0149	0.0152	0.0154	0.0156	0.0158	0.0161
0.170	0.0163	0.0166	0.0168	0.0171	0.0173	0.0176	0.0178	0.0181	0.0183	0.0186
0.180	0.0188	0.0191	0.0194	0.0196	0.0199	0.0202	0.0204	0.0207	0.0210	0.0213
0.190	0.0216	0.0218	0.0221	0.0224	0.0227	0.0230	0.0233	0.0236	0.0239	0.0242
0.200	0.0245	0.0248	0.0251	0.0254	0.0258	0.0261	0.0264	0.0267	0.0270	0.0274
0.210	0.0277	0.0280	0.0284	0.0287	0.0290	0.0294	0.0297	0.0301	0.0304	0.0307
0.220	0.0311	0.0315	0.0318	0.0322	0.0325	0.0329	0.0333	0.0336	0.0340	0.0344
0.230	0.0348	0.0351	0.0355	0.0359	0.0363	0.0367	0.0371	0.0375	0.0379	0.0383
0.240	0.0387	0.0391	0.0395	0.0399	0.0403	0.0407	0.0411	0.0415	0.0420	0.0424
0.250	0.0428	0.0432	0.0437	0.0441	0.0445	0.0450	0.0454	0.0459	0.0463	0.0468
0.260	0.0472	0.0477	0.0481	0.0486	0.0491	0.0495	0.0500	0.0505	0.0509	0.0514
0.270	0.0519	0.0524	0.0529	0.0533	0.0538	0.0543	0.0548	0.0553	0.0558	0.0563
0.280	0.0568	0.0573	0.0579	0.0584	0.0589	0.0594	0.0599	0.0605	0.0610	0.0615
0.290	0.0620	0.0626	0.0631	0.0637	0.0642	0.0648	0.0653	0.0659	0.0664	0.0670
0.300	0.0675	0.0681	0.0687	0.0692	0.0698	0.0704	0.0710	0.0715	0.0721	0.0726
0.310	0.0733	0.0739	0.0745	0.0751	0.0757	0.0763	0.0769	0.0775	0.0781	0.0786
0.320	0.0794	0.0800	0.0806	0.0812	0.0819	0.0825	0.0831	0.0838	0.0844	0.0849
0.330	0.0857	0.0864	0.0870	0.0877	0.0883	0.0890	0.0897	0.0903	0.0910	0.0915
0.340	0.0923	0.0930	0.0937	0.0944	0.0951	0.0958	0.0965	0.0972	0.0979	0.0984
0.350	0.0993	0.1000	0.1007	0.1014	0.1021	0.1029	0.1036	0.1043	0.1051	0.1056
0.360	0.1065	0.1073	0.1080	0.1088	0.1095	0.1103	0.1110	0.1118	0.1125	0.1131
0.370	0.1141	0.1149	0.1156	0.1164	0.1172	0.1180	0.1188	0.1196	0.1204	0.1210
0.380	0.1219	0.1228	0.1236	0.1244	0.1252	0.1260	0.1268	0.1276	0.1285	0.1291
0.390	0.1301	0.1310	0.1318	0.1326	0.1335	0.1343	0.1352	0.1360	0.1369	0.1376
0.400	0.1386	0.1395	0.1404	0.1412	0.1421	0.1430	0.1439	0.1448	0.1457	0.1464

Head	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.410	0.1475	0.1484	0.1493	0.1502	0.1511	0.1520	0.1529	0.1538	0.1548	0.1555
0.420	0.1566	0.1576	0.1585	0.1594	0.1604	0.1613	0.1623	0.1632	0.1642	0.1649
0.430	0.1661	0.1671	0.1680	0.1690	0.1700	0.1710	0.1720	0.1730	0.1739	0.1747
0.440	0.1759	0.1769	0.1779	0.1789	0.1800	0.1810	0.1820	0.1830	0.1840	0.1848
0.450	0.1861	0.1871	0.1882	0.1892	0.1903	0.1913	0.1924	0.1934	0.1945	0.1953
0.460	0.1966	0.1977	0.1988	0.1998	0.2009	0.2020	0.2031	0.2042	0.2053	0.2061
0.470	0.2075	0.2086	0.2097	0.2108	0.2119	0.2130	0.2142	0.2153	0.2164	0.2172
0.480	0.2187	0.2198	0.2210	0.2221	0.2233	0.2244	0.2256	0.2267	0.2279	0.2287
0.490	0.2303	0.2314	0.2326	0.2338	0.2350	0.2362	0.2374	0.2386	0.2398	0.2406
0.500	0.2422	0.2434	0.2446	0.2458	0.2471	0.2483	0.2495	0.2507	0.2520	0.2529
0.510	0.2545	0.2557	0.2570	0.2582	0.2595	0.2608	0.2620	0.2633	0.2646	0.2655
0.520	0.2671	0.2684	0.2697	0.2710	0.2723	0.2736	0.2749	0.2762	0.2775	0.2784
0.530	0.2802	0.2815	0.2828	0.2841	0.2855	0.2868	0.2882	0.2895	0.2909	0.2918
0.540	0.2936	0.2949	0.2963	0.2977	0.2990	0.3004	0.3018	0.3032	0.3046	0.3055
0.550	0.3073	0.3087	0.3101	0.3116	0.3130	0.3144	0.3158	0.3172	0.3186	0.3196
0.560	0.3215	0.3229	0.3244	0.3258	0.3273	0.3287	0.3302	0.3316	0.3331	0.3341
0.570	0.3361	0.3375	0.3390	0.3405	0.3420	0.3435	0.3450	0.3465	0.3480	0.3490
0.580	0.3510	0.3525	0.3540	0.3555	0.3571	0.3586	0.3601	0.3617	0.3632	0.3642
0.590	0.3663	0.3679	0.3694	0.3710	0.3726	0.3741	0.3757	0.3773	0.3789	0.3799
0.600	0.3820	0.3836	0.3852	0.3868	0.3884	0.3900	0.3917	0.3933	0.3949	0.3959
0.610	0.3981	0.3998	0.4014	0.4031	0.4047	0.4064	0.4080	0.4097	0.4113	0.4124
0.620	0.4147	0.4163	0.4180	0.4197	0.4214	0.4231	0.4248	0.4265	0.4282	0.4293
0.630	0.4316	0.4333	0.4350	0.4367	0.4385	0.4402	0.4419	0.4437	0.4454	0.4465
0.640	0.4489	0.4507	0.4524	0.4542	0.4560	0.4577	0.4595	0.4613	0.4631	0.4642
0.650	0.4667	0.4685	0.4703	0.4721	0.4739	0.4757	0.4775	0.4793	0.4812	0.4823
0.660	0.4848	0.4867	0.4885	0.4903	0.4922	0.4941	0.4959	0.4978	0.4996	0.5008
0.670	0.5034	0.5053	0.5072	0.5090	0.5109	0.5128	0.5147	0.5166	0.5186	0.5197
0.680	0.5224	0.5243	0.5262	0.5282	0.5301	0.5320	0.5340	0.5359	0.5379	0.5391
0.690	0.5418	0.5438	0.5457	0.5477	0.5497	0.5517	0.5537	0.5557	0.5576	0.5588
0.700	0.5616	0.5637	0.5657	0.5677	0.5697	0.5717	0.5738	0.5758	0.5778	0.5790

Table V- 3. Rating Curve For 120º V - Notch Weirs.

Discharge (m^3/s) for specified head (m) for fully contracted weir.

Head	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.050	0.0013	0.0014	0.0015	0.0015	0.0016	0.0017	0.0018	0.0018	0.0019	0.0020
0.060	0.0021	0.0022	0.0023	0.0024	0.0025	0.0026	0.0027	0.0028	0.0029	0.0030
0.070	0.0031	0.0032	0.0033	0.0034	0.0035	0.0037	0.0038	0.0039	0.0040	0.0042
0.080	0.0043	0.0044	0.0046	0.0047	0.0049	0.0050	0.0051	0.0053	0.0055	0.0056
0.090	0.0058	0.0059	0.0061	0.0063	0.0064	0.0066	0.0068	0.0070	0.0071	0.0073
0.100	0.0075	0.0077	0.0079	0.0081	0.0083	0.0085	0.0087	0.0089	0.0091	0.0093
0.110	0.0095	0.0097	0.0100	0.0102	0.0104	0.0106	0.0109	0.0111	0.0114	0.0116
0.120	0.0118	0.0121	0.0123	0.0126	0.0128	0.0131	0.0134	0.0136	0.0139	0.0142
0.130	0.0145	0.0147	0.0150	0.0153	0.0156	0.0159	0.0162	0.0165	0.0168	0.0171
0.140	0.0174	0.0177	0.0180	0.0184	0.0187	0.0190	0.0193	0.0197	0.0200	0.0203
0.150	0.0207	0.0210	0.0214	0.0217	0.0221	0.0224	0.0228	0.0232	0.0235	0.0239
0.160	0.0243	0.0247	0.0251	0.0255	0.0258	0.0262	0.0266	0.0270	0.0275	0.0279
0.170	0.0283	0.0287	0.0291	0.0295	0.0300	0.0304	0.0308	0.0313	0.0317	0.0322
0.180	0.0326	0.0331	0.0335	0.0340	0.0345	0.0349	0.0354	0.0359	0.0364	0.0369
0.190	0.0373	0.0378	0.0383	0.0388	0.0393	0.0398	0.0404	0.0409	0.0414	0.0419
0.200	0.0424	0.0430	0.0435	0.0441	0.0446	0.0452	0.0457	0.0463	0.0468	0.0474
0.210	0.0480	0.0485	0.0491	0.0497	0.0503	0.0509	0.0515	0.0521	0.0527	0.0533
0.220	0.0539	0.0545	0.0551	0.0557	0.0564	0.0570	0.0576	0.0583	0.0589	0.0596
0.230	0.0602	0.0609	0.0615	0.0622	0.0629	0.0635	0.0642	0.0649	0.0656	0.0663
0.240	0.0670	0.0677	0.0684	0.0691	0.0698	0.0705	0.0712	0.0720	0.0727	0.0734
0.250	0.0742	0.0749	0.0756	0.0764	0.0772	0.0779	0.0787	0.0795	0.0802	0.0810
0.260	0.0818	0.0826	0.0834	0.0842	0.0850	0.0858	0.0866	0.0874	0.0882	0.0891
0.270	0.0899	0.0907	0.0916	0.0924	0.0933	0.0941	0.0950	0.0958	0.0967	0.0976
0.280	0.0984	0.0993	0.1002	0.1011	0.1020	0.1029	0.1038	0.1047	0.1056	0.1065
0.290	0.1075	0.1084	0.1093	0.1103	0.1112	0.1122	0.1131	0.1141	0.1150	0.1160
0.300	0.1170	0.1180	0.1189	0.1199	0.1209	0.1219	0.1229	0.1239	0.1249	0.1259
0.310	0.1270	0.1280	0.1290	0.1301	0.1311	0.1322	0.1332	0.1343	0.1353	0.1364
0.320	0.1375	0.1385	0.1396	0.1407	0.1418	0.1429	0.1440	0.1451	0.1462	0.1473
0.330	0.1485	0.1496	0.1507	0.1518	0.1530	0.1541	0.1553	0.1564	0.1576	0.1588
0.340	0.1600	0.1611	0.1623	0.1635	0.1647	0.1659	0.1671	0.1683	0.1695	0.1708
0.350	0.1720	0.1732	0.1744	0.1757	0.1769	0.1782	0.1794	0.1807	0.1820	0.1832
0.360	0.1845	0.1858	0.1871	0.1884	0.1897	0.1910	0.1923	0.1936	0.1949	0.1963
0.370	0.1976	0.1989	0.2003	0.2016	0.2030	0.2044	0.2057	0.2071	0.2085	0.2098
0.380	0.2112	0.2126	0.2140	0.2154	0.2168	0.2182	0.2197	0.2211	0.2225	0.2240
0.390	0.2254	0.2269	0.2283	0.2298	0.2312	0.2327	0.2342	0.2357	0.2371	0.2386
0.400	0.2401	0.2416	0.2431	0.2447	0.2462	0.2477	0.2492	0.2508	0.2523	0.2539

Head	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.410	0.2554	0.2570	0.2585	0.2601	0.2617	0.2633	0.2649	0.2665	0.2681	0.2697
0.420	0.2713	0.2729	0.2745	0.2762	0.2778	0.2794	0.2811	0.2827	0.2844	0.2860
0.430	0.2877	0.2894	0.2911	0.2928	0.2945	0.2962	0.2979	0.2996	0.3013	0.3030
0.440	0.3047	0.3065	0.3082	0.3100	0.3117	0.3135	0.3152	0.3170	0.3188	0.3206
0.450	0.3224	0.3241	0.3259	0.3278	0.3296	0.3314	0.3332	0.3350	0.3369	0.3387
0.460	0.3406	0.3424	0.3443	0.3461	0.3480	0.3499	0.3518	0.3537	0.3556	0.3575
0.470	0.3594	0.3613	0.3632	0.3651	0.3671	0.3690	0.3709	0.3729	0.3749	0.3768
0.480	0.3788	0.3808	0.3828	0.3847	0.3867	0.3887	0.3907	0.3928	0.3948	0.3968
0.490	0.3988	0.4009	0.4029	0.4050	0.4070	0.4091	0.4112	0.4132	0.4153	0.4174
0.500	0.4195	0.4216	0.4237	0.4258	0.4279	0.4301	0.4322	0.4343	0.4365	0.4386
0.510	0.4408	0.4429	0.4451	0.4473	0.4495	0.4517	0.4539	0.4561	0.4583	0.4605
0.520	0.4627	0.4649	0.4672	0.4694	0.4717	0.4739	0.4762	0.4784	0.4807	0.4830
0.530	0.4853	0.4876	0.4899	0.4922	0.4945	0.4968	0.4991	0.5015	0.5038	0.5061
0.540	0.5085	0.5108	0.5132	0.5156	0.5180	0.5203	0.5227	0.5251	0.5275	0.5299
0.550	0.5324	0.5348	0.5372	0.5396	0.5421	0.5445	0.5470	0.5495	0.5519	0.5544
0.560	0.5569	0.5594	0.5619	0.5644	0.5669	0.5694	0.5719	0.5745	0.5770	0.5795
0.570	0.5821	0.5846	0.5872	0.5898	0.5923	0.5949	0.5975	0.6001	0.6027	0.6053
0.580	0.6079	0.6106	0.6132	0.6158	0.6185	0.6211	0.6238	0.6265	0.6291	0.6318
0.590	0.6345	0.6372	0.6399	0.6426	0.6453	0.6480	0.6507	0.6535	0.6562	0.6590
0.600	0.6617	0.6645	0.6673	0.6700	0.6728	0.6756	0.6784	0.6812	0.6840	0.6868
0.610	0.6896	0.6925	0.6953	0.6982	0.7010	0.7039	0.7067	0.7096	0.7125	0.7154
0.620	0.7183	0.7212	0.7241	0.7270	0.7299	0.7328	0.7358	0.7387	0.7416	0.7446
0.630	0.7476	0.7505	0.7535	0.7565	0.7595	0.7625	0.7655	0.7685	0.7715	0.7746
0.640	0.7776	0.7806	0.7837	0.7867	0.7898	0.7929	0.7959	0.7990	0.8021	0.8052
0.650	0.8083	0.8114	0.8145	0.8177	0.8208	0.8240	0.8271	0.8303	0.8334	0.8366
0.660	0.8398	0.8429	0.8461	0.8493	0.8525	0.8558	0.8590	0.8622	0.8654	0.8687
0.670	0.8719	0.8752	0.8785	0.8817	0.8850	0.8883	0.8916	0.8949	0.8982	0.9015
0.680	0.9048	0.9082	0.9115	0.9148	0.9182	0.9216	0.9249	0.9283	0.9317	0.9351
0.690	0.9385	0.9419	0.9453	0.9487	0.9521	0.9556	0.9590	0.9625	0.9659	0.9694
0.700	0.9728	0.9763	0.9798	0.9833	0.9868	0.9903	0.9938	0.9973	1.0009	1.0044

Table V- 4. 3" Montana Flume - under free-flow discharge in L/s.

Computed from the Formula $Q = 0.1771h_a^{1.55}$

Head	0.0	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.02										
0.03	0.77	0.81	0.85	0.90	0.94	0.98	1.02	1.07	1.11	1.16
0.04	1.21	1.25	1.30	1.35	1.40	1.45	1.50	1.55	1.60	1.65
0.05	1.70	1.76	1.81	1.87	1.92	1.98	2.03	2.09	2.15	2.20
0.06	2.26	2.32	2.38	2.44	2.50	2.56	2.62	2.68	2.75	2.81
0.07	2.87	2.94	3.00	3.06	3.13	3.20	3.26	3.33	3.40	3.46
0.08	3.53	3.60	3.67	3.74	3.81	3.88	3.95	4.02	4.09	4.17
0.09	4.24	4.31	4.39	4.46	4.53	4.61	4.69	4.76	4.84	4.91
0.10	4.99	5.07	5.15	5.23	5.30	5.38	5.46	5.54	5.62	5.70
0.11	5.79	5.87	5.95	6.03	6.12	6.20	6.28	6.37	6.45	6.54
0.12	6.62	6.71	6.79	6.88	6.97	7.05	7.14	7.23	7.32	7.41
0.13	7.50	7.59	7.68	7.77	7.86	7.95	8.04	8.13	8.22	8.32
0.14	8.41	8.50	8.60	8.69	8.78	8.88	8.97	9.07	9.16	9.26
0.15	9.36	9.45	9.55	9.65	9.75	9.85	9.94	10.04	10.14	10.24
0.16	10.34	10.44	10.54	10.64	10.75	10.85	10.95	11.05	11.15	11.26
0.17	11.36	11.46	11.57	11.67	11.78	11.88	11.99	12.09	12.20	12.31
0.18	12.41	12.52	12.63	12.74	12.84	12.95	13.06	13.17	13.28	13.39
0.19	13.50	13.61	13.72	13.83	13.94	14.05	14.16	14.28	14.39	14.50
0.20	14.62	14.73	14.84	14.96	15.07	15.19	15.30	15.42	15.53	15.65
0.21	15.76	15.88	16.00	16.11	16.23	16.35	16.47	16.59	16.70	16.82
0.22	16.94	17.06	17.18	17.30	17.42	17.54	17.66	17.79	17.91	18.03
0.23	18.15	18.27	18.40	18.52	18.64	18.77	18.89	19.01	19.14	19.26
0.24	19.39	19.51	19.64	19.77	19.89	20.02	20.15	20.27	20.40	20.53
0.25	20.66	20.78	20.91	21.04	21.17	21.30	21.43	21.56	21.69	21.82
0.26	21.95	22.08	22.21	22.34	22.48	22.61	22.74	22.87	23.01	23.14
0.27	23.27	23.41	23.54	23.67	23.81	23.94	24.08	24.21	24.35	24.49
0.28	24.62	24.76	24.89	25.03	25.17	25.31	25.44	25.58	25.72	25.86
0.29	26.00	26.14	26.28	26.42	26.56	26.70	26.84	26.98	27.12	27.26
0.30	27.40	27.54	27.68	27.83	27.97	28.11	28.25	28.40	28.54	28.68
0.31	28.83	28.97	29.12	29.26	29.41	29.55	29.70	29.84	29.99	30.14
0.32	30.28	30.43	30.58	30.72	30.87	31.02	31.17	31.32	31.46	31.61
0.33	31.76	31.91	32.06	32.21	32.36	32.51	32.66	32.81	32.96	33.12

Table V- 5. 6" Montana Flume - under free-flow discharge in L/s.

Computed from the Formula $Q = 0.3812h_a^{1.580}$

Head	0.0	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.03	1.5	1.6	1.7	1.7	1.8	1.9	2.0	2.1	2.2	2.3
0.04	2.4	2.5	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2
0.05	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.4
0.06	4.5	4.6	4.7	4.8	5.0	5.1	5.2	5.3	5.5	5.6
0.07	5.7	5.8	6.0	6.1	6.2	6.4	6.5	6.6	6.8	6.9
0.08	7.0	7.2	7.3	7.5	7.6	7.8	7.9	8.0	8.2	8.3
0.09	8.5	8.6	8.8	8.9	9.1	9.2	9.4	9.6	9.7	9.9
0.10	10.0	10.2	10.3	10.5	10.7	10.8	11.0	11.2	11.3	11.5
0.11	11.7	11.8	12.0	12.2	12.3	12.5	12.7	12.8	13.0	13.2
0.12	13.4	13.6	13.7	13.9	14.1	14.3	14.4	14.6	14.8	15.0
0.13	15.2	15.4	15.5	15.7	15.9	16.1	16.3	16.5	16.7	16.9
0.14	17.1	17.3	17.4	17.6	17.8	18.0	18.2	18.4	18.6	18.8
0.15	19.0	19.2	19.4	19.6	19.8	20.0	20.2	20.4	20.7	20.9
0.16	21.1	21.3	21.5	21.7	21.9	22.1	22.3	22.5	22.8	23.0
0.17	23.2	23.4	23.6	23.8	24.1	24.3	24.5	24.7	24.9	25.2
0.18	25.4	25.6	25.8	26.1	26.3	26.5	26.7	27.0	27.2	27.4
0.19	27.6	27.9	28.1	28.3	28.6	28.8	29.0	29.3	29.5	29.7
0.20	30.0	30.2	30.5	30.7	30.9	31.2	31.4	31.7	31.9	32.1
0.21	32.4	32.6	32.9	33.1	33.4	33.6	33.9	34.1	34.3	34.6
0.22	34.8	35.1	35.4	35.6	35.9	36.1	36.4	36.6	36.9	37.1
0.23	37.4	37.6	37.9	38.2	38.4	38.7	38.9	39.2	39.5	39.7
0.24	40.0	40.2	40.5	40.8	41.0	41.3	41.6	41.8	42.1	42.4
0.25	42.6	42.9	43.2	43.5	43.7	44.0	44.3	44.5	44.8	45.1
0.26	45.4	45.7	45.9	46.2	46.5	46.8	47.0	47.3	47.6	47.9
0.27	48.2	48.4	48.7	49.0	49.3	49.6	49.9	50.1	50.4	50.7
0.28	51.0	51.3	51.6	51.9	52.2	52.5	52.7	53.0	53.3	53.6
0.29	53.9	54.2	54.5	54.8	55.1	55.4	55.7	56.0	56.3	56.6
0.30	56.9	57.2	57.5	57.8	58.1	58.4	58.7	59.0	59.3	59.6
0.31	59.9	60.2	60.5	60.8	61.1	61.4	61.8	62.1	62.4	62.7
0.32	63.0	63.3	63.6	63.9	64.2	64.6	64.9	65.2	65.5	65.8
0.33	66.1	66.4	66.8	67.1	67.4	67.7	68.0	68.4	68.7	69.0
0.34	69.3	69.6	70.0	70.3	70.6	70.9	71.3	71.6	71.9	72.2
0.35	72.6	72.9	73.2	73.6	73.9	74.2	74.5	74.9	75.2	75.5
0.36	75.9	76.2	76.5	76.9	77.2	77.5	77.9	78.2	78.6	78.9
0.37	79.2	79.6	79.9	80.3	80.6	80.9	81.3	81.6	82.0	82.3
0.38	82.6	83.0	83.3	83.7	84.0	84.4	84.7	85.1	85.4	85.8
0.39	86.1	86.5	86.8	87.2	87.5	87.9	88.2	88.6	88.9	89.3
0.40	89.6	90.0	90.3	90.7	91.0	91.4	91.8	92.1	92.5	92.8
0.41	93.2	93.5	93.9	94.3	94.6	95.0	95.3	95.7	96.1	96.4
0.42	96.8	97.2	97.5	97.9	98.3	98.6	99.0	99.4	99.7	100.1
0.43	100.5	100.8	101.2	101.6	101.9	102.3	102.7	103.1	103.4	103.8
0.44	104.2	104.6	104.9	105.3	105.7	106.1	106.4	106.8	107.2	107.6
0.45	108.0	108.3	108.7	109.1	109.5	109.9	110.2	110.6	111.0	111.4

Table V- 6. 9" Montana Flume - under free-flow discharge in L/s.

Computed from the Formula $Q = 0.5354h_a^{1.530}$

Head	0.0	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.03	2.5	2.6	2.8	2.9	3.0	3.2	3.3	3.5	3.6	3.7
0.04	3.9	4.0	4.2	4.3	4.5	4.7	4.8	5.0	5.1	5.3
0.05	5.5	5.6	5.8	6.0	6.2	6.3	6.5	6.7	6.9	7.0
0.06	7.2	7.4	7.6	7.8	8.0	8.2	8.4	8.6	8.8	9.0
0.07	9.2	9.4	9.6	9.8	10.0	10.2	10.4	10.6	10.8	11.0
0.08	11.2	11.4	11.7	11.9	12.1	12.3	12.5	12.8	13.0	13.2
0.09	13.4	13.7	13.9	14.1	14.4	14.6	14.8	15.1	15.3	15.6
0.10	15.8	16.0	16.3	16.5	16.8	17.0	17.3	17.5	17.8	18.0
0.11	18.3	18.5	18.8	19.0	19.3	19.6	19.8	20.1	20.4	20.6
0.12	20.9	21.2	21.4	21.7	22.0	22.2	22.5	22.8	23.1	23.3
0.13	23.6	23.9	24.2	24.4	24.7	25.0	25.3	25.6	25.9	26.2
0.14	26.4	26.7	27.0	27.3	27.6	27.9	28.2	28.5	28.8	29.1
0.15	29.4	29.7	30.0	30.3	30.6	30.9	31.2	31.5	31.8	32.1
0.16	32.4	32.7	33.1	33.4	33.7	34.0	34.3	34.6	34.9	35.3
0.17	35.6	35.9	36.2	36.6	36.9	37.2	37.5	37.9	38.2	38.5
0.18	38.8	39.2	39.5	39.8	40.2	40.5	40.8	41.2	41.5	41.8
0.19	42.2	42.5	42.9	43.2	43.6	43.9	44.2	44.6	44.9	45.3
0.20	45.6	46.0	46.3	46.7	47.0	47.4	47.7	48.1	48.5	48.8
0.21	49.2	49.5	49.9	50.2	50.6	51.0	51.3	51.7	52.1	52.4
0.22	52.8	53.2	53.5	53.9	54.3	54.6	55.0	55.4	55.8	56.1
0.23	56.5	56.9	57.3	57.6	58.0	58.4	58.8	59.2	59.5	59.9
0.24	60.3	60.7	61.1	61.5	61.9	62.2	62.6	63.0	63.4	63.8
0.25	64.2	64.6	65.0	65.4	65.8	66.2	66.6	67.0	67.4	67.8
0.26	68.2	68.6	69.0	69.4	69.8	70.2	70.6	71.0	71.4	71.8
0.27	72.2	72.6	73.0	73.5	73.9	74.3	74.7	75.1	75.5	75.9
0.28	76.4	76.8	77.2	77.6	78.0	78.4	78.9	79.3	79.7	80.1
0.29	80.6	81.0	81.4	81.8	82.3	82.7	83.1	83.6	84.0	84.4
0.30	84.9	85.3	85.7	86.2	86.6	87.0	87.5	87.9	88.3	88.8
0.31	89.2	89.7	90.1	90.5	91.0	91.4	91.9	92.3	92.8	93.2
0.32	93.7	94.1	94.6	95.0	95.5	95.9	96.4	96.8	97.3	97.7
0.33	98.2	98.6	99.1	99.5	100.0	100.5	100.9	101.4	101.8	102.3
0.34	102.8	103.2	103.7	104.2	104.6	105.1	105.6	106.0	106.5	107.0
0.35	107.4	107.9	108.4	108.8	109.3	109.8	110.3	110.7	111.2	111.7
0.36	112.2	112.6	113.1	113.6	114.1	114.5	115.0	115.5	116.0	116.5
0.37	117.0	117.4	117.9	118.4	118.9	119.4	119.9	120.4	120.8	121.3
0.38	121.8	122.3	122.8	123.3	123.8	124.3	124.8	125.3	125.8	126.3
0.39	126.8	127.3	127.8	128.3	128.8	129.3	129.8	130.3	130.8	131.3
0.40	131.8	132.3	132.8	133.3	133.8	134.3	134.8	135.3	135.8	136.3
0.41	136.8	137.4	137.9	138.4	138.9	139.4	139.9	140.4	141.0	141.5
0.42	142.0	142.5	143.0	143.5	144.1	144.6	145.1	145.6	146.1	146.7
0.43	147.2	147.7	148.2	148.8	149.3	149.8	150.3	150.9	151.4	151.9
0.44	152.5	153.0	153.5	154.1	154.6	155.1	155.7	156.2	156.7	157.3
0.45	157.8	158.3	158.9	159.4	159.9	160.5	161.0	161.6	162.1	162.6
0.46	163.2	163.7	164.3	164.8	165.4	165.9	166.5	167.0	167.6	168.1
0.47	168.7	169.2	169.7	170.3	170.9	171.4	172.0	172.5	173.1	173.6
0.48	174.2	174.7	175.3	175.8	176.4	177.0	177.5	178.1	178.6	179.2
0.49	179.8	180.3	180.9	181.4	182.0	182.6	183.1	183.7	184.3	184.8

Head	0.0	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.50	185.4	186.0	186.5	187.1	187.7	188.2	188.8	189.4	190.0	190.5
0.51	191.1	191.7	192.2	192.8	193.4	194.0	194.6	195.1	195.7	196.3
0.52	196.9	197.4	198.0	198.6	199.2	199.8	200.3	200.9	201.5	202.1
0.53	202.7	203.3	203.9	204.4	205.0	205.6	206.2	206.8	207.4	208.0
0.54	208.6	209.2	209.7	210.3	210.9	211.5	212.1	212.7	213.3	213.9
0.55	214.5	215.1	215.7	216.3	216.9	217.5	218.1	218.7	219.3	219.9
0.56	220.5	221.1	221.7	222.3	222.9	223.5	224.1	224.7	225.3	225.9
0.57	226.6	227.2	227.8	228.4	229.0	229.6	230.2	230.8	231.4	232.0
0.58	232.7	233.3	233.9	234.5	235.1	235.7	236.4	237.0	237.6	238.2
0.59	238.8	239.4	240.1	240.7	241.3	241.9	242.6	243.2	243.8	244.4
0.60	245.0	245.7	246.3	246.9	247.6	248.2	248.8	249.4	250.1	250.7
0.61	251.3									

Table V- 7. 12" Montana Flume - under free-flow discharge in L/s.

Computed from Formula Q =4b * $h_a^{1.522}$ * $b^{0.026}$, and b = width in feet = 1.0 (0.3048 m).

Head	0.0	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.03	3.3	3.5	3.7	3.8	4.0	4.2	4.4	4.6	4.8	5.0
0.04	5.1	5.3	5.5	5.7	6.0	6.2	6.4	6.6	6.8	7.0
0.05	7.2	7.5	7.7	7.9	8.2	8.4	8.6	8.8	9.1	9.3
0.06	9.5	9.8	10.0	10.3	10.6	10.8	11.0	11.3	11.5	11.8
0.07	12.1	12.3	12.6	12.9	13.2	13.4	13.7	14.0	14.2	14.5
0.08	14.8	15.1	15.4	15.6	16.0	16.2	16.5	16.8	17.1	17.4
0.09	17.7	18.0	18.3	18.6	18.9	19.2	19.5	19.8	20.1	20.5
0.10	20.8	21.1	21.4	21.7	22.1	22.4	22.7	23.0	23.3	23.7
0.11	24.0	24.3	24.7	25.0	25.4	25.7	26.0	26.4	26.7	27.1
0.12	27.4	27.8	28.1	28.5	28.8	29.2	29.5	29.9	30.2	30.6
0.13	31.0	31.3	31.7	32.1	32.5	32.8	33.2	33.5	33.9	34.3
0.14	34.7	35.0	35.4	35.8	36.2	36.6	36.9	37.3	37.7	38.1
0.15	38.5	38.9	39.3	39.7	40.1	40.5	40.9	41.3	41.7	42.1
0.16	42.5	42.9	43.3	43.7	44.1	44.5	44.9	45.3	45.7	46.2
0.17	46.6	47.0	47.4	47.8	48.3	48.7	49.1	49.5	50.0	50.4
0.18	50.8	51.2	51.7	52.1	52.6	53.0	53.4	53.8	54.3	54.7
0.19	55.2	55.6	56.1	56.5	57.0	57.4	57.8	58.3	58.7	59.2
0.20	59.6	60.1	60.6	61.0	61.5	61.9	62.4	62.9	63.3	63.8
0.21	64.2	64.7	65.2	65.6	66.2	66.6	67.1	67.5	68.0	68.5
0.22	69.0	69.4	69.9	70.4	70.9	71.4	71.8	72.3	72.8	73.3
0.23	73.8	74.3	74.8	75.3	75.8	76.2	76.7	77.2	77.7	78.2
0.24	78.7	79.2	79.7	80.2	80.8	81.2	81.7	82.2	82.8	83.3
0.25	83.8	84.3	84.8	85.3	85.9	86.3	86.8	87.4	87.9	88.4
0.26	88.9	89.4	90.0	90.5	91.1	91.5	92.1	92.6	93.1	93.6
0.27	94.2	94.7	95.2	95.8	96.4	96.8	97.4	97.9	98.5	99.0
0.28	99.5	100.1	100.6	101.2	101.8	102.3	102.8	103.4	103.9	104.4
0.29	105.0	105.6	106.1	106.7	107.3	107.8	108.3	108.9	109.4	110.0
0.30	110.6	111.1	111.7	112.2	112.9	113.4	113.9	114.5	115.1	115.6
0.31	116.2	116.8	117.4	117.9	118.6	119.1	119.7	120.2	120.8	121.4
0.32	122.0	122.6	123.1	123.7	124.4	124.9	125.5	126.1	126.6	127.2
0.33	127.8	128.4	129.0	129.6	130.2	130.8	131.4	132.0	132.6	133.2
0.34	133.8	134.4	135.0	135.6	136.2	136.8	137.4	138.0	138.6	139.2
0.35	139.8	140.4	141.0	141.6	142.3	142.8	143.5	144.1	144.7	145.3
0.36	145.9	146.5	147.2	147.8	148.5	149.0	149.6	150.3	150.9	151.5
0.37	152.1	152.8	153.4	154.0	154.7	155.3	155.9	156.5	157.2	157.8
0.38	158.4	159.1	159.7	160.3	161.0	161.6	162.3	162.9	163.5	164.2
0.39	164.8	165.5	166.1	166.8	167.5	168.0	168.7	169.3	170.0	170.6
0.40	171.3	171.9	172.6	173.3	174.0	174.6	175.2	175.9	176.5	177.2
0.41	177.9	178.5	179.2	179.8	180.6	181.2	181.8	182.5	183.2	183.8
0.42	184.5	185.2	185.8	186.5	187.3	187.9	188.5	189.2	189.9	190.6
0.43	191.2	191.9	192.6	193.3	194.0	194.6	195.3	196.0	196.7	197.4
0.44	198.0	198.7	199.4	200.1	200.9	201.5	202.2	202.9	203.5	204.2
0.45	204.9	205.6	206.3	207.0	207.8	208.4	209.1	209.8	210.5	211.2
0.46	211.9	212.6	213.3	214.0	214.8	215.4	216.1	216.8	217.5	218.2
0.47	219.0	219.7	220.4	221.1	221.9	222.5	223.2	223.9	224.6	225.4
0.48	226.1	226.8	227.5	228.2	229.0	229.7	230.4	231.1	231.8	232.6
0.49	233.3	234.0	234.7	235.5	236.3	236.9	237.7	238.4	239.1	239.8

Head	0.0	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.50	240.6	241.3	242.0	242.8	243.6	244.2	245.0	245.7	246.5	247.2
0.51	247.9	248.7	249.4	250.2	251.0	251.6	252.4	253.1	253.9	254.6
0.52	255.4	256.1	256.9	257.6	258.4	259.1	259.9	260.6	261.4	262.1
0.53	262.9	263.6	264.4	265.2	266.0	266.7	267.4	268.2	268.9	269.7
0.54	270.5	271.2	272.0	272.8	273.6	274.3	275.1	275.8	276.6	277.4
0.55	278.1	278.9	279.7	280.4	281.3	282.0	282.8	283.5	284.3	285.1
0.56	285.9	286.6	287.4	288.2	289.1	289.8	290.5	291.3	292.1	292.9
0.57	293.7	294.5	295.2	296.0	296.9	297.6	298.4	299.2	300.0	300.8
0.58	301.5	302.3	303.1	303.9	304.8	305.5	306.3	307.1	307.9	308.7
0.59	309.5	310.3	311.1	311.9	312.8	313.5	314.3	315.1	315.9	316.7
0.60	317.5	318.3	319.1	319.9	320.8	321.5	322.4	323.2	324.0	324.8
0.61	325.6	326.4	327.2	328.0	328.9	329.7	330.5	331.3	332.1	332.9
0.62	333.8	334.6	335.4	336.2	337.1	337.9	338.7	339.5	340.3	341.2
0.63	342.0	342.8	343.6	344.5	345.4	346.1	347.0	347.8	348.6	349.5
0.64	350.3	351.1	352.0	352.8	353.7	354.5	355.3	356.1	357.0	357.8
0.65	358.6	359.5	360.3	361.2	362.1	362.9	363.7	364.5	365.4	366.2
0.66	367.1	367.9	368.8	369.6	370.6	371.3	372.2	373.0	373.9	374.7
0.67	375.6	376.4	377.3	378.1	379.1	379.9	380.7	381.6	382.4	383.3
0.68	384.1	385.0	385.9	386.7	387.7	388.5	389.3	390.2	391.0	391.9
0.69	392.8	393.6	394.5	395.4	396.3	397.1	398.0	398.9	399.7	400.6
0.70	401.5	402.3	403.2	404.1	405.1	405.8	406.7	407.6	408.5	409.4
0.71	410.2	411.1	412.0	412.9	413.8	414.6	415.5	416.4	417.3	418.2
0.72	419.1	419.9	420.8	421.7	422.7	423.5	424.4	425.3	426.2	427.1
0.73	427.9	428.8	429.7	430.6	431.6	432.4	433.3	434.2	435.1	436.0
0.74	436.9	437.8	438.7	439.6	440.6	441.4	442.3	443.2	444.1	445.0
0.75	445.9	446.8	447.7	448.6	449.6	450.5	451.4	452.3	453.2	454.1
0.76	455.0	455.9	456.8	457.7	458.7	459.6	460.5	461.4	462.3	463.2

Table V- 8. 2.0' H-Flume under free flow conditions in L/s.

Head	0.0	0.002	0.004	0.006	0.008
0.02			0.47	0.54	0.61
0.03	0.68	0.76	0.84	0.93	1.02
0.04	1.12	1.22	1.33	1.44	1.55
0.05	1.67	1.79	1.82	2.05	2.19
0.06	2.33	2.48	2.63	2.79	2.95
0.07	3.11	3.29	3.46	3.64	3.83
0.08	4.02	4.21	4.41	4.62	4.83
0.09	5.04	5.27	5.49	5.72	5.96
0.10	6.20	6.45	6.70	6.96	7.22
0.11	7.49	7.76	8.04	8.33	8.62
0.12	8.91	9.22	9.52	9.84	10.2
0.13	10.5	10.8	11.1	11.5	11.8
0.14	12.2	12.5	12.6	13.3	13.7
0.15	14.0	14.4	14.8	15.2	15.6
0.16	16.1	16.5	16.9	17.3	17.8
0.17	18.2	18.7	19.1	19.6	20.1
0.18	20.5	21.0	21.5	22.0	22.5
0.19	23.0	23.5	24.1	24.6	25.1
0.20	25.7	26.2	26.8	27.3	27.9
0.21	28.5	29.1	29.7	30.2	30.9
0.22	31.5	32.1	32.4	33.3	34.0
0.23	34.6	35.3	35.9	36.6	37.3
0.24	38.0	38.7	39.4	40.1	40.8
0.25	41.5	42.2	42.9	43.7	44.4
0.26	45.2	46.0	46.7	47.5	48.3
0.27	49.1	50.0	50.7	51.5	52.3
0.28	53.2	54.0	54.9	55.7	56.6
0.29	57.3	58.3	59.2	60.1	61.0
0.30	61.9	62.9	63.8	64.7	65.7
0.31	66.6	67.6	68.6	69.5	70.5
0.32	71.5	72.5	73.5	74.6	75.6
0.33	76.6	77.7	78.7	79.7	80.8
0.34	81.9	83.0	84.1	85.2	86.3
0.35	87.5	88.6	89.7	90.9	92.0
0.36	93.2	94.4	95.6	96.7	97.9
0.37	99.2	100	102	103	104
0.38	105	107	108	109	110
0.39	112	113	114	116	117
0.40	118	120	121	123	124
0.41	128	127	128	130	131
0.42	132	134	135	137	138
0.43	170	141	143	144	146
0.44	147	148	150	152	154
0.45	155	157	158	160	162
0.46	163	165	167	168	170
0.47	172	173	175	177	179
0.48	180	182	184	186	187
0.49	189	191	193	195	196

Head	0.0	0.002	0.004	0.006	0.008
0.50	198	200	202	204	206
0.51	208	210	211	213	215
0.52	217	219	221	223	225
0.53	227	229	231	233	235
0.54	237	240	242	244	246
0.55	248	250	252	254	256
0.56	259	261	263	265	267
0.57	270	272	274	276	279
0.58	281	283	286	288	290
0.59	293	295	297	300	302
0.60	305	307	309		

Table V- 9. 2.5' H-Flume under free flow conditions in L/s.

Head	0.0	0.002	0.004	0.006	0.008
0.02				0.65	0.73
0.03	0.82	0.91	1.01	1.11	1.22
0.04	1.33	1.45	1.57	1.69	1.82
0.05	1.96	2.10	2.25	2.40	2.55
0.06	2.71	2.88	3.05	3.23	3.41
0.07	3.59	3.78	3.98	4.18	4.39
0.08	4.60	4.82	5.04	5.27	5.51
0.09	5.75	5.99	6.24	6.50	6.76
0.10	7.02	7.30	7.58	7.86	8.15
0.11	8.44	8.75	9.05	9.36	9.68
0.12	10.0	10.3	10.7	11.0	11.4
0.13	11.7	12.1	12.4	12.8	13.2
0.14	13.6	14.0	14.4	14.8	15.2
0.15	15.6	16.0	16.4	16.9	17.3
0.16	17.6	18.2	18.7	19.1	19.6
0.17	20.1	20.6	21.1	21.6	22.1
0.18	22.6	23.1	23.6	24.2	24.7
0.19	25.2	25.8	26.4	26.9	27.5
0.20	28.1	28.7	29.2	29.8	30.5
0.21	31.1	31.7	32.3	33.0	33.6
0.22	34.2	34.9	35.6	36.2	36.9
0.23	37.6	38.4	39.0	39.7	40.4
0.24	41.1	41.9	42.6	43.4	44.1
0.25	44.9	45.6	46.4	47.2	48.0
0.26	48.8	49.6	50.4	51.2	52.0
0.27	52.9	53.7	54.6	55.4	56.3
0.28	57.2	587.1	59.0	59.9	60.8
0.29	61.7	62.7	63.5	64.5	65.4
0.30	66.4	67.3	68.3	69.3	70.3
0.31	71.3	72.3	73.3	74.3	75.3
0.32	76.4	77.4	78.5	79.5	80.6
0.33	81.7	82.8	83.9	85.0	86.1
0.34	87.2	88.3	89.5	90.6	91.8
0.35	93.0	94.1	95.3	96.5	97.7
0.36	98.9	100	101	102	104
0.37	105	106	108	109	110
0.38	112	113	114	115	117
0.39	118	119	121	122	124
0.40	125	126	128	129	131
0.41	132	134	135	136	138
0.42	139	141	142	144	145
0.43	147	149	150	152	153
0.44	155	156	158	160	161
0.45	163	165	166	168	169
0.46	171	173	175	176	178
0.47	180	181	183	185	187
0.48	198	190	192	194	196

Head	0.0	0.002	0.004	0.006	0.008
0.49	198	199	201	203	205
0.50	207	209	211	213	215
0.51	216	218	220	222	224
0.52	226	228	230	232	234
0.53	236	239	241	243	245
0.54	247	249	251	253	255
0.55	257	260	262	264	266
0.56	268	271	273	275	277
0.57	280	282	284	286	289
0.58	291	293	296	298	301
0.59	303	305	308	310	313
0.60	315	317	320	322	325
0.61	327	330	332	335	337
0.62	340	343	345	348	350
0.63	353	355	358	361	363
0.64	366	369	371	374	377
0.65	380	382	385	388	391
0.66	393	396	399	402	405
0.67	408	410	413	416	419
0.68	422	425	428	431	434
0.69	437	440	443	446	449
0.70	452	455	458	461	464
0.71	467	470	474	477	480
0.72	483	486	489	493	496
0.73	499	502	506	509	512
0.74	515	519	522	525	529
0.75	532	535	539	542	

Table V- 10. 3.0' H-Flume under free flow conditions in L/s.

Head	0.0	0.002	0.004	0.006	0.008
0.02					
0.03	0.96	1.06	1.18	1.29	1.41
0.04	1.54	1.67	1.81	1.95	2.09
0.05	2.25	2.40	2.57	2.74	2.91
0.06	3.09	3.27	3.46	3.66	3.86
0.07	4.06	4.28	4.49	4.72	4.95
0.08	5.18	5.42	5.66	5.92	6.17
0.09	6.43	6.70	6.98	7.26	7.54
0.10	7.83	8.13	8.44	8.75	9.06
0.11	9.38	9.71	10.0	10.4	10.7
0.12	11.1	11.4	11.8	12.2	12.5
0.13	12.9	13.3	13.7	14.1	14.5
0.14	14.9	15.4	15.8	16.2	16.7
0.15	17.1	17.6	18.0	18.5	19.0
0.16	19.4	19.9	20.4	20.9	21.4
0.17	21.9	22.4	13.0	23.5	24.0
0.18	24.6	25.1	25.7	26.3	26.8
0.19	27.4	28.0	28.6	29.2	29.8
0.20	30.4	31.1	31.7	32.3	33.0
0.21	33.6	34.3	35.0	35.6	36.3
0.22	37.0	37.7	38.4	39.1	39.8
0.23	40.5	41.3	42.0	42.8	43.5
0.24	44.3	45.1	45.8	46.6	47.4
0.25	48.2	49.0	49.8	50.7	51.5
0.26	52.3	53.2	54.0	54.9	55.8
0.27	56.6	57.5	58.4	59.3	60.2
0.28	61.2	62.1	63.0	64.0	64.9
0.29	65.9	66.8	67.8	68.8	69.8
0.30	70.8	71.8	72.8	73.8	74.9
0.31	75.9	77.8	78.0	79.1	80.2
0.32	81.2	82.3	83.4	84.5	85.7
0.33	86.8	87.9	89.1	90.2	91.4
0.34	92.5	93.7	94.9	96.1	97.3
0.35	98.5	99.7	101	102	103
0.36	105	106	107	109	110
0.37	111	112	114	115	116
0.38	118	119	120	122	123
0.39	125	126	127	129	130
0.40	132	133	135	136	138
0.41	139	141	142	144	145
0.42	147	148	150	151	153
0.43	154	156	158	159	161
0.44	163	164	166	167	169
0.45	171	173	174	176	178
0.46	179	181	183	185	186
0.47	188	190	192	194	195
0.48	197	199	201	203	205

Head	0.0	0.002	0.004	0.006	0.008
0.49	207	208	210	212	214
0.50	216	218	220	222	224
0.51	226	228	230	232	234
0.52	236	238	241	243	245
0.53	246	248	251	253	255
0.54	257	259	261	263	266
0.55	268	270	272	274	277
0.56	279	281	283	286	288
0.57	290	293	295	279	300
0.58	302	304	307	309	312
0.59	314	317	319	321	324
0.60	326	329	331	334	336
0.61	339	341	344	347	349
0.62	352	354	357	360	362
0.63	365	368	370	373	376
0.64	378	381	384	387	389
0.65	392	395	398	400	403
0.66	406	409	412	415	418
0.67	420	423	426	429	432
0.68	435	438	441	444	447
0.69	450	453	456	459	462
0.70	465	468	471	475	478
0.71	481	484	487	490	491
0.72	497	500	503	506	510
0.73	513	516	519	523	526
0.74	529	533	536	539	543
0.75	546	550	553	556	560
0.76	563	567	570	574	577
0.77	581	584	588	592	595
0.78	599	602	606	610	613
0.79	617	620	624	628	632
0.80	635	639	643	647	650
0.81	654	658	662	666	669
0.82	673	677	681	685	689
0.83	693	697	701	705	709
0.84	713	717	721	725	729
0.85	733	737	741	745	749
0.86	753	757	762	766	770
0.87	774	778	783	787	791
0.88	759	800	804	808	813
0.89	817	821	826	830	835
0.90	839	843	848	852	857

Table V- 11. 4.5' H-Flume under free flow conditions in L/s.

Head	0.0	0.002	0.004	0.006	0.008
0.02					
0.03	1.39	1.53	1.68	1.84	2.00
0.04	2.17	2.35	2.53	2.72	2.91
0.05	3.12	3.32	3.53	3.76	3.98
0.06	4.22	4.46	4.70	4.95	5.21
0.07	5.48	5.75	6.02	6.31	6.60
0.08	6.90	7.20	7.52	7.83	8.16
0.09	8.49	8.82	9.17	9.52	9.88
0.10	10.2	10.6	11.0	11.4	11.8
0.11	12.2	12.6	13.0	13.4	13.8
0.12	14.3	14.7	15.1	15.6	16.1
0.13	16.5	17.0	17.5	18.0	18.5
0.14	19.0	19.5	20.0	20.5	21.0
0.15	21.6	22.1	22.7	23.2	23.8
0.16	24.4	25.0	25.6	26.2	26.8
0.17	27.4	28.0	28.6	29.2	30.0
0.18	30.5	31.2	31.9	32.5	33.2
0.19	33.9	34.6	35.3	36.0	36.7
0.20	37.4	38.2	38.9	39.7	40.4
0.21	41.2	42.0	42.7	43.5	44.3
0.22	45.1	45.9	46.8	47.6	48.4
0.23	49.3	51.1	51.0	51.8	52.7
0.24	53.6	54.5	55.4	56.3	57.2
0.25	58.1	59.1	60.0	61.0	61.9
0.26	62.9	63.9	64.8	65.8	66.8
0.27	67.8	68.9	69.9	70.9	72.0
0.28	73.0	74.1	75.1	76.2	77.3
0.29	78.4	79.5	80.6	81.7	82.8
0.30	84.0	85.1	86.3	87.4	88.6
0.31	89.8	91.0	92.2	93.4	94.6
0.32	95.8	97.0	98.3	99.5	101
0.33	102	103	105	106	107
0.34	109	110	111	113	114
0.35	115	117	118	119	121
0.36	122	124	125	126	128
0.37	129	131	132	134	135
0.38	137	138	140	141	143
0.39	144	146	148	149	151
0.40	152	154	155	157	159
0.41	160	162	164	165	167
0.42	169	170	172	174	176
0.43	177	179	181	183	184
0.44	186	188	190	192	193
0.45	192	197	199	201	203
0.46	205	207	208	210	212
0.47	214	216	218	220	222
0.48	224	226	228	230	232

Head	0.0	0.002	0.004	0.006	0.008
0.49	234	236	238	240	243
0.50	245	247	249	251	253
0.51	255	257	260	262	264
0.52	266	268	271	273	275
0.53	277	280	282	284	287
0.54	289	291	294	296	298
0.55	301	303	305	308	310
0.56	313	315	317	320	322
0.57	325	327	330	332	335
0.58	337	340	343	345	348
0.59	350	353	355	358	361
0.60	363	366	369	371	375
0.61	377	380	382	385	388
0.62	390	393	396	399	402
0.63	405	407	410	413	416
0.64	419	422	425	427	430
0.65	433	436	439	442	445
0.66	448	451	454	457	460
0.67	463	466	470	473	476
0.68	479	482	485	488	491
0.69	495	498	501	504	537
0.70	511	514	517	520	524
0.71	527	530	534	537	540
0.72	544	547	551	554	557
0.73	561	564	568	571	575
0.74	578	582	585	589	592
0.75	596	599	603	606	610
0.76	614	617	621	625	628
0.77	632	636	639	643	647
0.78	650	654	658	662	666
0.79	669	673	677	681	685
0.80	689	693	696	700	704
0.81	708	712	716	720	724
0.82	728	732	736	740	744
0.83	748	752	757	761	765
0.84	769	773	777	781	786
0.85	790	794	798	802	807
0.86	811	815	820	824	828
0.87	833	837	841	846	850
0.88	855	859	863	868	872
0.89	877	881	886	890	894
0.90	899	904	909	913	918
0.91	922	927	932	936	941
0.92	946	950	955	960	965
0.93	969	974	979	984	988
0.94	993	998	1000	1010	1010
0.95	1020	1020	1030	1030	1040
0.96	1040	1050	1050	1060	1060
0.97	1070	1070	1080	1080	1090
0.98	1093	1098	1103	1108	1114

Head	0.0	0.002	0.004	0.006	0.008
0.99	1119	1124	1129	1134	1140
1.00	1145	1150	1156	1161	1166
1.01	1172	1177	1182	1188	1193
1.02	1198	1204	1209	1215	1220
1.03	1226	1231	1237	1242	1248
1.04	1253	1259	1265	1270	1276
1.05	1281	1287	1292	1299	1304
1.06	1310	1316	1321	1327	1333
1.07	1339	1345	1350	1356	1362
1.08	1368	1374	1380	1386	1392
1.09	1398	1403	1409	1415	1421
1.10	1427	1434	1440	1446	1452
1.11	1458	1464	1470	1476	1482
1.12	1489	1495	1501	1507	1513
1.13	1520	1526	1532	1539	1545
1.14	1551	1558	1564	1570	1577
1.15	1583	1590	1596	1603	1609
1.16	1616	1622	1629	1635	1642
1.17	1648	1655	1661	1668	1675
1.18	1681	1688	1695	1701	1708
1.19	1715	1722	1728	1735	1742
1.20	1749	1756	1763	1769	1776
1.21	1783	1790	1797	1804	1811
1.22	1818	1825	1832	1839	1846
1.23	1853	1860	1867	1875	1882
1.24	1889	1896	1903	1910	1918
1.25	1925	1932	1939	1947	1954
1.26	1961	1969	1976	1983	1991
1.27	1998	2006	2013	2020	2028
1.28	2035	2043	2050	2058	2066
1.29	2073	2081	2088	2096	2104
1.30	2111	2119	2127	2134	2142
1.31	2150	2158	2165	2173	2181
1.32	2189	2197	2205	2212	2220
1.33	2228	2236	2244	2252	2260
1.34	2268	2276	2284	2292	2300
1.35	2308	2317	2325	2333	2341
1.36	2350	2360	2370	2349	2357

Table V- 12. 4.0' HL-Flume under free flow conditions in L/s.

Head	0.0	0.002	0.004	0.006	0.008
0.02				2.00	2.23
0.03	2.48	2.74	3.01	3.30	3.59
0.04	3.90	4.22	4.55	4.89	5.24
0.05	5.61	6.98	6.37	6.77	7.18
0.06	7.60	8.04	8.48	8.94	9.41
0.07	9.89	10.4	10.9	11.4	11.9
0.08	12.5	13.2	13.6	14.2	14.8
0.09	15.4	16.0	16.6	17.2	17.9
0.10	18.6	19.2	19.9	20.6	21.3
0.11	22.1	22.8	23.5	24.3	25.1
0.12	25.9	26.7	27.5	28.3	29.1
0.13	30.0	30.9	31.3	32.6	33.5
0.14	34.5	35.4	36.3	37.3	38.3
0.15	39.2	40.2	41.2	42.3	43.3
0.16	44.4	45.4	46.5	47.6	48.7
0.17	49.8	50.9	52.1	53.2	54.4
0.18	55.6	56.8	58.0	59.2	60.5
0.19	61.6	63.0	64.3	65.6	66.9
0.20	68.2	69.6	70.9	72.3	73.7
0.21	75.1	76.5	77.9	79.4	80.8
0.22	82.3	83.8	85.3	86.8	88.3
0.23	89.9	91.4	93.0	94.6	96.2
0.24	97.8	99.5	101	103	104
0.25	106	108	110	111	113
0.26	115	117	118	120	122
0.27	124	126	128	130	131
0.28	133	135	137	139	141
0.29	143	145	147	149	151
0.30	154	156	158	160	162
0.31	164	166	169	171	173
0.32	175	177	180	182	184
0.33	187	189	191	196	196
0.34	199	201	203	206	208
0.35	211	213	216	219	221
0.36	224	226	229	231	234
0.37	237	239	242	245	248
0.38	250	253	256	259	262
0.39	264	267	270	273	276
0.40	279	282	285	288	291
0.41	294	297	300	303	306
0.42	309	312	315	319	322
0.43	325	328	331	335	338
0.44	341	345	348	351	355
0.45	358	361	365	368	372
0.46	375	379	382	386	389
0.47	393	396	400	404	407
0.48	411	415	418	422	426

Head	0.0	0.002	0.004	0.006	0.008
0.49	430	433	437	441	445
0.50	449	453	457	460	464
0.51	468	472	476	480	481
0.52	488	493	497	501	505
0.53	509	513	517	522	526
0.54	530	534	539	543	547
0.55	552	556	560	565	569
0.56	574	578	583	587	592
0.57	596	601	606	610	615
0.58	620	624	629	634	638
0.59	644	648	653	638	662
0.60	667	672	677	682	687
0.61	692	697	702	708	712
0.62	717	722	727	733	738
0.63	743	748	753	759	764
0.64	769	775	780	785	791
0.65	796	802	807	813	818
0.66	824	829	835	840	846
0.67	851	857	863	869	874
0.68	880	886	892	897	903
0.69	909	915	921	927	933
0.70	939	945	951	957	963
0.71	969	975	981	987	993
0.72	1000	1006	1012	1018	1025
0.73	1031	1037	1044	1050	1056
0.74	1063	1069	1076	1082	1089
0.75	1095	1102	1109	1115	1122
0.76	1128	1135	1141	1149	1155
0.77	1162	1169	1176	1183	1189
0.78	1196	1203	1210	1217	1224
0.79	1231	1238	1245	1252	1260
0.80	1267	1274	1281	1288	1296
0.81	1303	1310	1317	1325	1332
0.82	1339	1347	1354	1362	1369
0.83	1377	1384	1392	1399	1407
0.84	1415	1422	1430	1438	1445
0.85	1453	1461	1467	1477	1485
0.86	1492	1500	1508	1516	1524
0.87	1532	1540	1548	1556	1564
0.88	1573	1581	1589	1597	1608
0.89	1613	1622	1630	1639	1647
0.90	1655	1664	1672	1681	1689
0.91	1698	1706	1715	1723	1732
0.92	1741	1749	1758	1767	1776
0.93	1784	1793	1802	1811	1820
0.94	1829	1838	1847	1856	1865
0.95	1874	1883	1892	1901	1910
0.96	1919	1929	1938	1947	1956
0.97	1966	1975	1984	1994	2003
0.98	2013	2022	2031	2041	2051

Head	0.0	0.002	0.004	0.006	0.008
0.99	2060	2070	2080	2089	2099
1.00	2109	2118	2128	2138	2148
1.01	2158	2168	2177	2187	2197
1.02	2207	2217	2227	2237	2248
1.03	2258	2268	2287	2288	2299
1.04	2309	2319	2329	2340	2350
1.05	2360	2371	2382	2392	2403
1.06	2413	2424	2434	2445	2446
1.07	2466	2477	2488	2499	2509
1.08	2520	2531	2542	2553	2564
1.09	2575	2586	2597	2608	2619
1.10	2630	2641	2652	2664	2675
1.11	2686	2697	2709	2720	2732
1.12	2743	2754	2766	2777	2789
1.13	2800	2812	2824	2835	2847
1.14	2859	2870	2882	2894	2906
1.15	2918	2930	2941	2953	2965
1.16	2977	2989	3002	3014	3026
1.17	3038	3050	3062	3074	3087
1.18	3099	3111	3124	3136	3149
1.19	3161	3147	3186	3199	3211
1.20	3224	3236	3249	3262	3274
1.21	3287	3300	3313	3326	

Table V- 13. 1-m rectangular Weir with End Contractions Discharge Table with Head in Meters. Formulas: Discharge (L/s) = 1838 (1.0-0.2H) $H^{1.5}$

Head	Discharge	Head	Discharge
0.005		0.255	224.6
0.010		0.260	231.0
0.015		0.265	237.4
0.020		0.270	243.9
0.025		0.275	250.5
0.030		0.280	257.1
0.035		0.285	263.7
0.040		0.290	270.4
0.045		0.295	277.1
0.050		0.300	283.9
0.055		0.305	290.7
0.060	26.69	0.310	297.6
0.065	30.06	0.315	304.5
0.070	33.56	0.320	311.4
0.075	37.19	0.325	318.4
0.080	40.92	0.330	325.4
0.085	44.77	0.335	332.5
0.090	48.73	0.340	339.6
0.095	52.80	0.345	346.8
0.100	56.96	0.350	353.9
0.105	61.22	0.355	361.2
0.110	65.58	0.360	368.4
0.115	70.03	0.365	375.7
0.120	74.57	0.370	383.1
0.125	79.20	0.375	390.4
0.130	83.91	0.380	397.8
0.135	88.71	0.385	405.3
0.140	93.58	0.390	412.7
0.145	98.54	0.395	420.2
0.150	103.6	0.400	427.8
0.155	108.7	0.405	435.4
0.160	113.9	0.410	443.0
0.165	119.1	0.415	450.6
0.170	124.5	0.420	458.3
0.175	129.8	0.425	466.0
0.180	135.3	0.430	473.7
0.185	140.8	0.435	481.4
0.190	146.4	0.440	489.2
0.195	152.1	0.445	497.1
0.200	157.8	0.450	504.9
0.205	163.6	0.455	512.8
0.210	169.4	0.460	520.7
0.215	175.4	0.465	528.6
0.220	181.3	0.470	536.6
0.225	187.3	0.475	544.5
0.230	193.4	0.480	552.6
0.235	199.5	0.485	560.6
0.240	205.7	0.490	568.7
0.245	212.0	0.495	576.7
0.250	218.3	0.500	584.8

Table V- 14. 1.5-m rectangular Weir with End Contractions Discharge Table with Head in Meters. Formulas: Discharge (L/s) = 1838 (1.50-0.2H) $H^{1.5}$

Head	Discharge	Head	Discharge	Head	Discharge
0.005		0.255	342.9	0.505	922.8
0.010		0.260	352.8	0.510	935.9
0.015		0.265	362.8	0.515	949.0
0.020		0.270	372.9	0.520	962.1
0.025		0.275	383.0	0.525	975.3
0.030		0.280	393.2	0.530	988.6
0.035		0.285	403.5	0.535	1002
0.040		0.290	413.9	0.540	1015
0.045		0.295	424.4	0.545	1029
0.050		0.300	434.9	0.550	1042
0.055		0.305	445.5	0.555	1056
0.060	40.20	0.310	456.2	0.560	1069
0.065	45.29	0.315	466.9	0.565	1083
0.070	50.58	0.320	477.8	0.570	1096
0.075	56.06	0.325	488.7	0.575	1110
0.080	61.72	0.330	499.6	0.580	1124
0.085	67.55	0.335	510.7	0.585	1137
0.090	73.55	0.340	521.8	0.590	1151
0.095	79.71	0.345	533.0	0.595	1165
0.100	86.02	0.350	544.2	0.600	1179
0.105	92.49	0.355	555.5	0.605	1193
0.110	99.11	0.360	566.9	0.610	1207
0.115	105.9	0.365	578.4	0.615	1221
0.120	112.8	0.370	589.9	0.620	1235
0.125	119.8	0.375	601.5	0.625	1249
0.130	127.0	0.380	613.1	0.630	1263
0.135	134.3	0.385	624.8	0.635	1277
0.140	141.7	0.390	636.6	0.640	1291
0.145	149.3	0.395	648.4	0.645	1305
0.150	157.0	0.400	660.3	0.650	1320
0.155	164.8	0.405	672.2	0.655	1334
0.160	172.7	0.410	684.2	0.660	1348
0.165	180.7	0.415	696.3	0.665	1363
0.170	188.9	0.420	708.4	0.670	1377
0.175	197.1	0.425	720.6	0.675	1391
0.180	205.5	0.430	732.8	0.680	1406
0.185	214.0	0.435	745.1	0.685	1420
0.190	222.5	0.440	757.5	0.690	1435
0.195	231.2	0.445	769.9	0.695	1449
0.200	240.0	0.450	782.3	0.700	1464
0.205	248.9	0.455	794.8	0.705	1479
0.210	257.9	0.460	807.4	0.710	1493
0.215	267.0	0.465	820.0	0.715	1508
0.220	276.1	0.470	832.7	0.720	1523
0.225	285.4	0.475	845.4	0.725	1537
0.230	294.8	0.480	858.2	0.730	1552
0.235	304.2	0.485	871.0	0.735	1567
0.240	313.8	0.490	883.9	0.740	1582
0.245	323.4	0.495	896.8	0.745	1597
0.250	333.1	0.500	909.8	0.750	1612

Table V- 15. 2-m Rectangular Weir with End Contractions Discharge Table with Head in Meters. Formulas: Discharge (L/s) =1838 (2.0-0.2H)H$^{1.5}$

Head	Discharge	Head	Discharge	Head	Discharge	Head	Discharge
0.005		0.255	461.3	0.505	1253	0.755	2229
0.010		0.260	474.7	0.510	1271	0.760	2250
0.015		0.265	488.2	0.515	1289	0.765	2271
0.020		0.270	501.8	0.520	1307	0.770	2293
0.025		0.275	515.5	0.525	1325	0.775	2314
0.030		0.280	529.4	0.530	1343	0.780	2335
0.035		0.285	543.4	0.535	1362	0.785	2356
0.040		0.290	577.4	0.540	1380	0.790	2377
0.045		0.295	571.6	0.545	1398	0.795	2399
0.050		0.300	585.9	0.550	1417	0.800	2420
0.055		0.305	600.3	0.555	1436	0.805	2441
0.060	53.70	0.310	614.8	0.560	1454	0.810	2463
0.065	60.52	0.315	629.4	0.565	1473	0.815	2484
0.070	67.60	0.320	644.1	0.570	1492	0.820	2506
0.075	74.94	0.325	658.9	0.575	1511	0.825	2527
0.080	82.51	0.330	673.9	0.580	1530	0.830	2549
0.085	90.32	0.335	688.9	0.585	1549	0.835	2571
0.090	98.36	0.340	704.0	0.590	1568	0.840	2592
0.095	106.6	0.345	719.2	0.595	1587	0.845	2614
0.100	115.1	0.350	734.5	0.600	1606	0.850	2636
0.105	123.8	0.355	749.9	0.605	1625	0.855	2658
0.110	132.6	0.360	765.4	0.610	1645	0.860	2680
0.115	141.7	0.365	781.0	0.615	1664	0.865	2702
0.120	151.0	0.370	796.7	0.620	1683	0.870	2723
0.125	160.4	0.375	812.5	0.625	1703	0.875	2745
0.130	170.1	0.380	828.4	0.630	1722	0.880	2768
0.135	179.9	0.385	844.3	0.635	1742	0.885	2790
0.140	189.9	0.390	860.4	0.640	1762	0.890	2812
0.145	200.0	0.395	876.5	0.645	1781	0.895	2834
0.150	210.4	0.400	892.8	0.650	1801	0.900	2856
0.155	220.8	0.405	909.1	0.655	1821	0.905	2878
0.160	231.5	0.410	925.5	0.660	1841	0.910	2901
0.165	242.3	0.415	942.0	0.665	1861	0.915	2923
0.170	253.3	0.420	958.6	0.670	1881	0.920	2945
0.175	264.4	0.425	975.2	0.675	1901	0.925	2968
0.180	275.7	0.430	992.0	0.680	1921	0.930	2990
0.185	287.1	0.435	1009	0.685	1941	0.935	3013
0.190	298.7	0.440	1026	0.690	1962	0.940	3035
0.195	310.4	0.445	1043	0.695	1982	0.945	3058
0.200	322.2	0.450	1060	0.700	2002	0.950	3080
0.205	334.2	0.455	1077	0.705	2023	0.955	3103
0.210	346.3	0.460	1094	0.710	2043	0.960	3126
0.215	358.6	0.465	1111	0.715	2064	0.965	3148
0.220	371.0	0.470	1129	0.720	2084	0.970	3171
0.225	383.5	0.475	1146	0.725	2105	0.975	3194
0.230	396.2	0.480	1164	0.730	2125	0.980	3217
0.235	408.9	0.485	1181	0.735	2146	0.985	3240
0.240	421.8	0.490	1199	0.740	2167	0.990	3263
0.245	434.9	0.495	1217	0.745	2188	0.995	3285
0.250	448.0	0.500	1235	0.750	2209	1.000	3308

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Table V- 16. 3-m Rectangular Weir with End Contractions Discharge Table with Head in Meters. Formulas: Discharge (L/s) =1838 (3.0-0.2H) $H^{1.5}$

Head	Discharge	Head	Discharge	Head	Discharge
0.005		0.255	98.0	0.505	1912
0.010		0.260	718.3	0.510	1940
0.015		0.265	738.9	0.515	1968
0.020		0.270	759.7	0.520	1996
0.025		0.275	780.6	0.525	2024
0.030		0.280	801.7	0.530	2052
0.035		0.285	823.0	0.535	2081
0.040		0.290	844.5	0.540	2109
0.045		0.295	866.1	0.545	2138
0.050		0.300	887.9	0.550	2167
0.055		0.305	909.9	0.555	2195
0.060	80.71	0.310	932.1	0.560	2224
0.065	90.98	0.315	954.4	0.565	2254
0.070	101.6	0.320	976.8	0.570	2283
0.075	112.7	0.325	999.5	0.575	2312
0.080	124.1	0.330	1022	0.580	2341
0.085	135.9	0.335	1045	0.585	2371
0.090	148.0	0.340	1068	0.590	2401
0.095	160.4	0.345	1092	0.595	2430
0.100	173.2	0.350	1115	0.600	2460
0.105	186.3	0.355	1139	0.605	2490
0.110	199.7	0.360	1162	0.610	2520
0.115	213.4	0.365	1186	0.615	2550
0.120	227.4	0.370	1210	0.620	2581
0.125	241.7	0.375	1235	0.625	2611
0.130	256.2	0.380	1259	0.630	2641
0.135	271.0	0.385	1283	0.635	2672
0.140	286.1	0.390	1308	0.640	2703
0.145	301.5	0.395	1333	0.645	2733
0.150	317.1	0.400	1358	0.650	2764
0.155	333.0	0.405	1383	0.655	2795
0.160	349.1	0.410	1408	0.660	2826
0.165	365.5	0.415	1433	0.665	2858
0.170	382.1	0.420	1459	0.670	2889
0.175	399.0	0.425	1484	0.675	2920
0.180	416.0	0.430	1510	0.680	2952
0.185	433.3	0.435	1536	0.685	2983
0.190	450.9	0.440	1562	0.690	3015
0.195	468.6	0.445	1588	0.695	3047
0.200	486.6	0.450	1615	0.700	3079
0.205	504.8	0.455	1641	0.705	3111
0.210	523.2	0.460	1668	0.710	3143
0.215	541.8	0.465	1694	0.715	3175
0.220	560.6	0.470	1721	0.720	3207
0.225	579.7	0.475	1748	0.725	3239
0.230	598.9	0.480	1775	0.730	3272
0.235	618.3	0.485	1802	0.735	3304
0.240	637.9	0.490	1830	0.740	3337
0.245	657.8	0.495	1857	0.745	3370
0.250	677.8	0.500	1885	0.750	3402

Head	Discharge	Head	Discharge	Head	Discharge
0.755	3435	1.005	5183	1.255	7104
0.760	3468	1.010	5220	1.260	7144
0.765	3501	1.015	5257	1.265	7184
0.770	3534	1.020	5294	1.270	7224
0.775	3568	1.025	5331	1.275	7264
0.780	3601	1.030	5368	1.280	7304
0.785	3634	1.035	5405	1.285	7344
0.790	3668	1.040	5443	1.290	7384
0.795	3701	1.045	5480	1.295	7424
0.800	3735	1.050	5517	1.300	7465
0.805	3769	1.055	5555	1.305	7505
0.810	3803	1.060	5592	1.310	7545
0.815	3837	1.065	5630	1.315	7586
0.820	3871	1.070	5668	1.320	7626
0.825	3905	1.075	5705	1.325	7667
0.830	3939	1.080	5743	1.330	7708
0.835	3973	1.085	5781	1.335	7748
0.840	4007	1.090	5819	1.340	7789
0.845	4042	1.095	5857	1.345	7830
0.850	4076	1.100	5895	1.350	7871
0.855	4111	1.105	5933	1.355	7911
0.860	4145	1.110	5971	1.360	7952
0.865	4180	1.115	6009	1.365	7993
0.870	4215	1.120	6048	1.370	8034
0.875	4250	1.125	6086	1.375	8075
0.880	4285	1.130	6124	1.380	8117
0.885	4320	1.135	6163	1.385	8158
0.890	4355	1.140	6201	1.390	8199
0.895	4390	1.145	6240	1.395	8240
0.900	4425	1.150	6279	1.400	8281
0.905	4461	1.155	6317	1.405	8323
0.910	4496	1.160	6356	1.410	8364
0.915	4532	1.165	6395	1.415	8406
0.920	4567	1.170	6434	1.420	8447
0.925	4603	1.175	6473	1.425	8489
0.930	4639	1.180	6512	1.430	8530
0.935	4674	1.185	6551	1.435	8572
0.940	4710	1.190	6590	1.440	8613
0.945	4746	1.195	6629	1.445	8655
0.950	4782	1.200	6668	1.450	8697
0.955	4818	1.205	6708	1.455	8739
0.960	4855	1.210	6747	1.460	8781
0.965	4891	1.215	6787	1.465	8822
0.970	4927	1.220	6826	1.470	8864
0.975	4963	1.225	6865	1.475	8906
0.980	5000	1.230	6905	1.480	8948
0.985	5036	1.235	6945	1.485	8990
0.990	5073	1.240	6984	1.490	9033
0.995	5110	1.245	7024	1.495	9075
1.000	5146	1.250	7064	1.500	9117

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Appendix VI. Discharge Measurement Field Data and Calculation (DMFDC) V. 1.2

Developed by: Gordon Clark and Jeff Pitt of G.McG. Clark & Associates, Hydrological Services, 1997 for the RIC Standards Manual.

The executable program, **DMFDC** is available on the Internet as part of the RIC Manual, and may be downloaded for field use:

Multis.xls MultiT.xlt Stnds.xls StndT.xlt

Table of Contents

1.0 Introduction to DMFDC

The Discharge Measurement Field Data and Calculation (DMFDC) Excel program calculates and displays stream flow data in a user friendly, Windows based environment. Users can enter stream flow data and see the results instantly. Many features have been included in the DMFDC program to give the user more flexibility than has been available in the past. For example, there is an entry in DMFDC pages to input the equations for meters. This prevents users from having to alter the equations contained in the many cells every time a different meter is used.

The DMFDC program is composed of two types of worksheets. The first type of worksheet is called "Stnd.xls", the second worksheet type is called "Multi.xls". The only difference between the two types of worksheets is their size. "Stnd.xls" worksheets are designed for measurement sessions that consist of only single vertical measurements like "point six" and "point five" measurements. Therefore there are 25 rows for stream flow data to be entered in the "Stnd.xls" worksheet. The "Multi.xls" worksheet is designed to handle "two" and "three" point measurements. To handle the extra rows required for these measurements "Multi.xls" worksheets have 62 rows available for stream data to be entered. Beyond the number of rows for data entries, the two worksheets are exactly the same in every respect.

Each of the worksheets are broken up into two sections. The first part of a worksheet is called "Section 1: Site Information", the second part of a worksheet is labeled "Section 2: Data Entry". Each section describes a different aspect of a measurement session.

Section 1 contains data that describes many conditions and variables of the measurement session. Examples of items that are entered into the Section 1 are station name, temperatures and meter equations. Section 2 accepts actual stream flow data input from the user. Items like rotor revolutions and water depth are entered into Section 2 by the user. As data is entered into Section 2, results such as velocities and discharges are displayed in real time. Each row in Section 2 represents a single measurement, although two and three point measurements occupy two and three rows respectively.

2.0 Entering Data into a DMFDC Worksheet

2.1 Section 1: Site Information

As previously noted, the "Section 1: Site Information" portion of the worksheet contains all the environmental data for the stream, as well as other variables.

The following entries are made in Section 1:

- Station Operating Agency/Firm, Station Number and Station Name
- Date
- Metered by
- Location and Time of Metering
- Weather and Air and Water Temperatures

- Gauge Heights and Corrections
- Pen Corrections
- Meter Type, Number and Fan Number (meters with interchangeable impellers)
- Method of Suspension *
- Meter Equation *
- Remarks

* Valid data must be entered to receive accurate output.

Although most of the input into Section 1 is for descriptive purposes only, (i.e. temperatures and station names) there are several cells that display calculations. For example, when start and end values for the pen correction and inside gauge are entered, the mean of each will be displayed. When the start and end outside gauge heights are entered, the resulting mean height will be added to any gauge correction to produce a corrected gauge height. In addition, once Section 2 has been filled with stream data, the “Total Discharge”, “Total Area” and “Average Velocity” entries in Section 1 will be automatically updated.

Section 1 also requires input that determines how data is calculated in Section 2.

For example, specifying the Method of Suspension is a critical entry in Section 1.

The method of suspension entered by the user will appear in the “Method of Suspension” title to confirm the correct setting. The method of suspension directly effects the Depth of Observation. If the Cable and Weight suspension method is active, the depth of observation will be measured from the water surface to the stream bed. When the Standard or Bridge Rod method of suspension is selected, the depth of observation will be measured from the stream bed to the surface of the water, finally if the Top Setting Rod method is employed, no depth of observation will be calculated.

To choose a method of suspension, enter a value in the “Method of Suspension” portion of Section 1 that describes the desired method. The three methods and their respective values are displayed below.

Table 1. Methods of Suspension

Value for Method of Suspension	Method of Suspension
1	Top Setting Rod
2	Standard of Bride Rod
3	Cable and Weight

Entering an equation for the meter type is another important input found in Section 1. The equation for a meter is entered in the “Meter Type” portion of Section 1. A meter can have a single range or a multiple range. To enter an equation for a single range meter, enter the slope and intercept into the appropriate headings of the box labeled “Single Range Meter Equation”. To enter an equation for a multiple range meter, enter the slopes and intercepts into the appropriate headings of the box labeled “Multiple Range Meter Equation”. If the equation for the multiple range meter only has two lines instead of three, simply enter the equation into the first two lines of the “Multiple Range Meter Equation” box.

Certain meter equations contain intercepts that are subtracted from the rest of the equation. In contrast, intercepts are always added to the equations in the “Meter Type” box. To subtract an intercept from an equation, simply enter the intercept as a negative number. For example, if the equation was: V = 0.251*n - 0.004, enter 0.251 for the slope and -.004 for the intercept. If the maximum revs/seconds for an equation is unknown, choose a value that will be higher than the highest possible value (i.e. 99).

Ideally, users should ensure that only one meter range has equation(s) entered into it. If both meter range boxes have valid equations entered, the single range meter equation will be used and the multiple range meter equations will be ignored. To confirm which meter range is activated, refer to the “Meter Type” heading above the two meter range boxes. This heading indicates which meter type is selected based on the equations entered. Initially, it will display “No Meter Range Selected”. After a valid equation(s) is entered into one of the meter ranges this heading will describe the range selected. It is critical that one of the meter ranges are activated before entering data into a “Section 2”. If a range is not selected, the output of the “Sheet” will be completely invalid.

2.2 Section 2: Data Entry

Section 2 of the worksheet contains all the actual stream data of the measurement session. Values such as water depth, method and revolutions of fan are entered here. “Section 2” also displays the results of such input, such as calculated velocities and areas.

There are two main sections in “Section 2”. The first section is the “Observations” section which covers the first seven columns from the left. The second section is the “Computations” section which covers the remaining six columns.

The Columns in the “Observations” section:

- Method
- Distance From Initial Point
- Depth
- Depth of Observation *
- Revs
- Time
- Cos of Flow

* indicates that no user input is permitted in column.

The Columns in the “Computations” section:

- Velocity: at Point *
- Velocity: Mean in Vertical *
- Width *
- Area *

- Discharge *
- Sum *

* indicates that no user input is permitted in column.

User input is only allowed in six of the seven columns in the “Observations” section and no input is permitted in the “Computations” section.

The “Method” column, or left most column, is used for inputting the method of measurement used for each corresponding row. There are many methods available for taking measurements. Each method is described below.

Single Point (Point Five) measurement (code 5). A single measurement taken at a relative depth of 0.5. Values should be entered for “Distance From Initial Point”, “Depth”, “Revs”, “Time”. The user may enter a value into the “Cos of Flow” column, but this is an optional entry. If no entries exist in the “Cos of Flow” column, it is assumed that no cosine correction is required. The depth is the same regardless which suspension method is employed. *See note Cos entry*.

Single Point (Point Six) measurement (code 6). Represents a single measurement taken at a relative depth of 0.6. The depth of observation is calculated either from the water surface down if the cable and weight suspension method is chosen, or from the stream bed up if the standard or bridge rod suspension method is selected. Values should be entered for “Distance From Initial Point”, “Depth”, “Revs”, “Time”. The user may enter a value into the “Cos of Flow” column, but this is an optional entry. If no entries exist in the “Cos of Flow” column, it is assumed that no cosine correction is required. *See note Cos entry*.

Two Point measurement (code 2). Two vertical measurements are taken at depths of 0.2 and 0.8. The depths of observations are calculated either from the water surface down if the cable and weight suspension method is chosen, or from the stream bed up if the standard or bridge rod suspension method is selected. The two point method requires two rows to complete. In the first row of the method, (the row with the 2 in the method column), enter values for “Distance From Initial Point”, “Depth”, “Revs”, “Time”. This row represents the first of two vertical measurements. The second measurement should be entered in next row and only requires that the “Revs” and “Time” be entered, even the “Method” column should remain blank in the second row. The user may enter values into the “Cos of Flow” column for both vertical measurements, but these are optional entries. If no entries exist in the “Cos of Flow” columns, it is assumed that no cosine corrections are required. *See note Cos entry.*

Three Point measurement (code 3). The depths of observations are calculated either from the water surface down if the cable and weight suspension method is chosen, or from the stream bed up if the standard or bridge rod suspension method is selected. The three point method requires three rows to complete. For the first row of the method, (the row with the 3 in the method column), enter values for “Distance From Initial Point”, “Depth”, “Revs”, “Time”. This row represents the first of three vertical measurements. The second measurement should be entered in next row and only requires that the “Revs” and “Time” be entered, the “Method” column for this row should remain blank. The third measurement should be entered immediately after the row containing the second measurement and only requires that the "Revs" and "Time" be entered, the "Method" column for this row should remain blank. The user may enter a value into the "Cos of Flow" column for all three vertical measurements, but these are optional entries. If no entries exist in the "Cos of Flow" column, it is assumed that no cosine corrections are required. *See note Cos entry.*

Note 1, Cos entry: The angle of flow through a X-sect is applied to the velocity of each panel affected. The cosine value of any flow that deviates from right-angles to the X-sect is entered in the cos of flow column, e.g., an angle of about 15° would have an entry of 0.96 which is applied to the velocity at the point. Thus, if it is observed that angles of flow change at differing depths, these angular coefficients may be entered in each row of a 2 or 3 point measurement. Angular flow entries may also be made in conditions of reverse flow.

Note 2: Reverse flow entry may be accomplished by entering a negative value in the revolutions column, i.e. -75.

Beginning of the measurement (code B). It is used at the very beginning as well as directly after an "S" occurs. Enter values in the "Distance from Initial Point" and "Depth" columns.

Estimated Velocity (code E). This is used to estimate the velocity in locations where the fan is too close to the edge to get a proper measurement. It can be used after a "B" or before an "S" or a 'T". Enter values in the "Distance from Initial Point", "Depth" and "Cos of Flow" columns. The new estimated velocity is calculated by multiplying the value in the "Cos of Flow" column with the velocity that is adjacent to the estimate. The (mean in the vertical) value in the adjacent vertical is used for the comparison, i.e. an estimated 66% flow of the adjacent vertical is entered as 0.66 in the cos of flow column.

Temporary Stop (code S). For example, if an obstacle was sticking out of the water in the middle of a measurement, making a velocity check impossible, enter "S" at it's edge. The next row's method must be a "B" located at the obstructions far edge. Enter values in the "Distance from Initial Point" and "Depth" columns.

Terminates measurement session (code T). It is the absolute last measurement. Enter values in the "Distance from Initial Point" and "Depth" columns. A "T" should always be the very last row's method.

The second column, "Distance From Initial Point", represents the distance from where the measurements started to the current measurement position. The user inputs the distances from shore along this column for each measurement. This value always gets larger as the measurement goes across the creek. The distance is measured in meters.

The third column, "Depth" , represents the depth of the water for the current measurement. ***The depth should always be larger than 0 (i.e. 001).*** A depth of 0 will cause problems with some of the calculations. The user inputs this value which is measured in meters.

The fourth column, “Depth of Observation”, is NOT for user input. This column displays the depth of measurement, which indicates the depth at which the velocities are measured. In the case of standard or bridge rod, this number reflects the depth from the surface, in the case of cable and weight this number reflects the depth from the bottom, and in the case of top setting rod, there is no “Depth of Observation” value calculated.

The fifth column, “Revs.”, is where the user entries the number of full revolutions the fan completes in the time specified.

The sixth column, “Time”, is where the user enters the time for each vertical measurement. The measurement is timed in seconds.

The seventh column, “Cos of Flow”, indicates the Cosine of the flow angle. This value corrects the velocity based on any differences between the angle of the waters flow vs. the angle that the fan is being held at. This value is optional. If it is entered, it is multiplied to the raw velocity to produce a corrected velocity representing more accurately the effects of the flow angle on velocity measured by the meter.

The remaining columns are found in the “Calculations” section. They are not for user input. They are strictly calculations based on the data that the user input in the “Observations” section of the “Sheet”.

3.0 DMFDC and WindowsCE

DMFDC worksheets are very flexible. They can be used in the office or the field. If DMFDC is used in the office, data that has been collected in the field can be input into a worksheet for processing. In addition, DMFDC can be carried into the field using a hand-held computer, running WindowsCE. In fact, DMFDC worksheets are designed to allow the user to see all important data in the narrow screen of a hand-held WindowsCE computer. Use of a WindowsCE computer allows measurements to be entered directly into the computer as they are taken in the stream. This allows output to be viewed in real time throughout the measurement. Users can make corrections during and after the measurement and see the results of the corrections instantly. The workbooks can be brought back to the office and transferred from WindowsCE to a desktop for permanent storage.

3.1 Instructions for using DMFDC worksheets with WindowsCE

3.1.1 Creating Worksheets from Templates

The two DMFDC worksheets, Stnd and Multi, are distributed as a Excel 5.0 templates, with the extensions “.XLT”. There are several advantages that templates have over standard worksheets. The first advantage is that many Excel worksheets can be created easily from just one template and secondly, the contents of templates can not be permanently altered by the user. To create a new worksheet based on a DMFDC template, just open the template. Microsoft Excel creates a copy of the template to work on, leaving the original template intact.

To create a new worksheet from one of DMFDC's templates, complete the following procedures:

1. Start Microsoft's Excel.
2. Open one of DMFDC's two templates from Excel using the "Open" command located in the "File" main menu item.
3. Save the new worksheet using the "Save As..." command located in the "File" main menu item. It is recommended to name worksheets after the Station's ID number they represent. This allows for easy identification of worksheets without having to view their contents.

Following the above instructions will generate a new blank worksheet with the extension type "XLS". It is important to transfer DMFDC worksheets, and not DMFDC templates to WindowsCE because Pocket Excel can not work with templates.

3.1.2 Transferring Worksheets to WindowsCE

Before a WindowsCE hand-held computer can be used to enter streamflow data, the DMFDC worksheet(s) must be transferred to it. The following steps will allow a DMFDC worksheet to be transferred into a WindowsCE hand-held computer from either a desktop or laptop PC.

1. Ensure that HPC Explorer is installed on either a laptop or desktop computer. The computer with HPC Explorer will be the "host" for the WindowsCE computer. Connect the "host" to the WindowsCE computer using the cable provided with the WindowsCE system. Refer to the WindowsCE instruction manual for details regarding the installation of HPC Explorer and connecting a WindowsCE computer to a host computer.
2. Confirm that both computers are turned on.
3. From the host computer start HPC Explorer. The installation process of Explorer should have placed an icon on the desktop called "HPC Explorer". Double clicking this icon will start HPC Explorer. HPC explorer will immediately begin connecting to the WindowsCE computer as soon as it starts. See Figure 1.

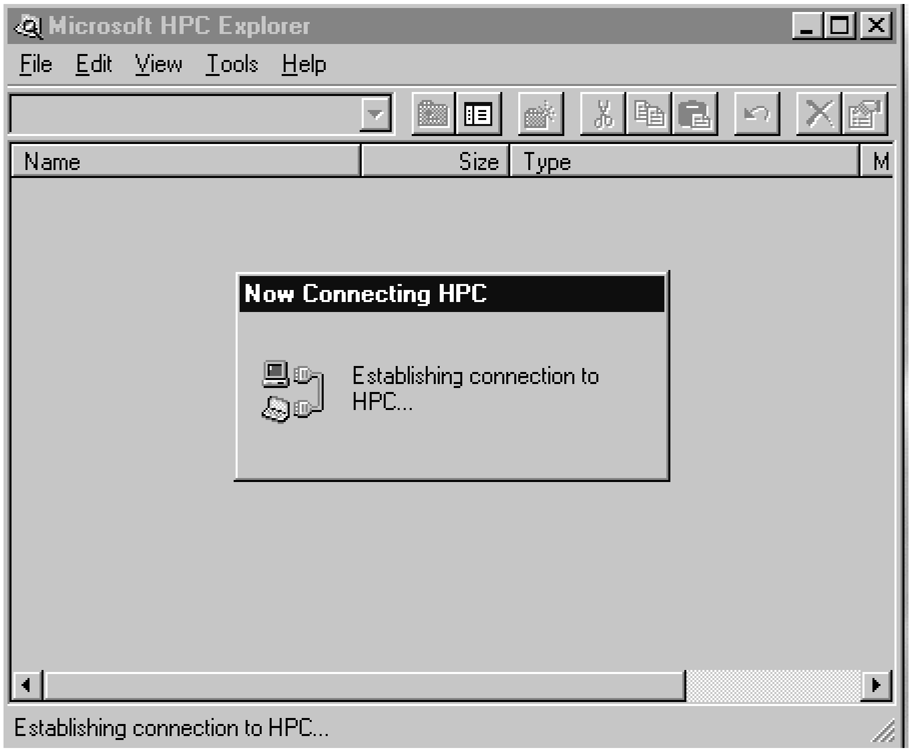

Figure 1: Example of screen when HPC Explorer connects to “host” computer.

4. From the host computer, start Windows Explorer. Explorer can be found in the Start - Programs menu.

5. Position the Windows Explorer and HPC Explorer windows so they are side by side. In the HPC Explorer window double click on the “My Handheld PC” icon, then on the “My Documents” icon. A list of all the files in the WindowsCE computer should be displayed in the HPC Explorer window.

6. The computers are now ready to transfer files between each other. To transfer a file between computers simply click on the desired file and drag it from one window to the next. If the left mouse button is used to drag the file will be automatically copied to the destination, if the right mouse button is used the user will be given the choice of copying or moving the file. Wherever the user lets go of the button after dragging a file is the location that the file will be transferred to (Figure 2). A window will appear called “Copy and Convert to HPC”. At this point the worksheet will be converted to WindowsCE format and copied to the WindowsCE computer. After the “Copy and Convert to HPC” window closes the transfer is complete.

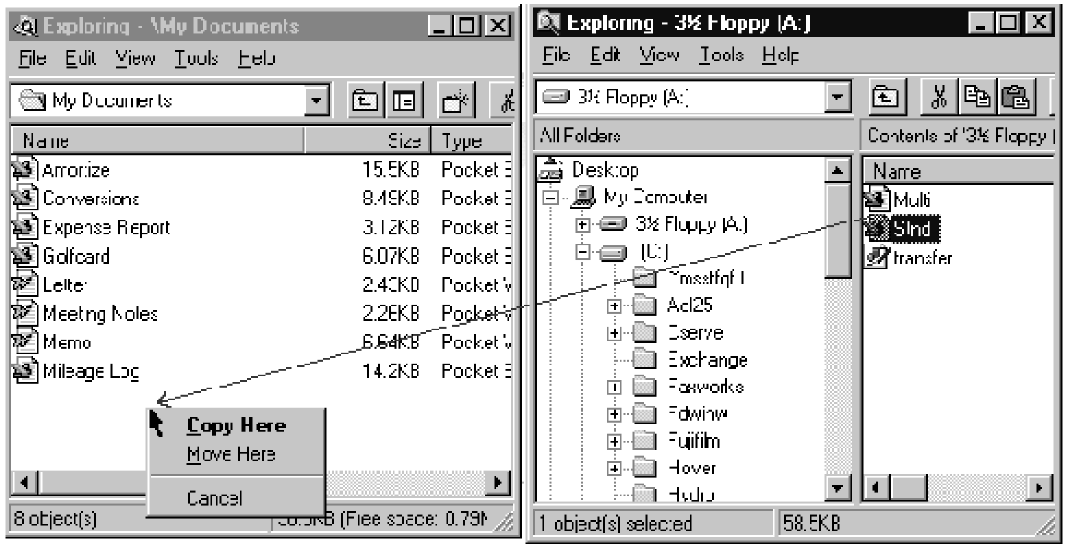

Figure 2: Example of dragging Stnd.xls from Windows Explorer (on right) to HPC Explorer (on left).

3.1.3 Data Entry with WindowsCE

Once a worksheet has been transferred to a WindowsCE computer, the next step is to open the worksheet. To open a worksheet from WindowsCE, complete either one of the following procedures:

Method 1: From the WindowsCE computer, start Microsoft's Pocket Excel. This is usually done by double clicking on the "Microsoft Pocket Excel" icon on the desktop. Open one of DMFDC's two templates using the "Open" command located in the "File" main menu item.

Method 2: From the WindowsCE computer, navigate to the directory that the desired worksheet exists and double click on it.

Data can now be entered into the worksheet exactly the way it is entered on a regular computer. The main difference between data entry in WindowsCE vs. a regular laptop or desktop is that WindowsCE computers generally do not have a mouse. Instead, WindowsCE computers allow users to physically touch the portion of the screen where they want the cursor to move to. Touching a location on the screen of a WindowsCE machine is equivalent to moving a mouse pointer to the location and clicking the mouse button. A "pen" is usually supplied to facilitate touching the WindowsCE screen accurately without damaging it.

WindowsCE machines take longer to process input by the user. It is common for a WindowsCE computer to have a few second delay when entering data into a cell.

3.1.4 Saving Worksheets in WindowsCE

When all the data has been entered into either the Stnd.xls or Multi.xls sheet, it is time to save the worksheet. To save the new worksheet in WindowsCE, use the "Save As..." command located in the "File" main menu of Pocket Excel. It is important to use the "Save As..." command and not the "Save" command. If the "Save" command is used, the blank copy of the worksheet in WindowsCE will be saved full of data. This would force the user to transfer another blank worksheet to the WindowsCE computer if another measurement was to be started. If “Save As...” is used, a new worksheet, named by the user, would be created with the recently entered data stored in it. The original blank worksheet, either “Stnd.xls” or “Multi.xls”, will remain blank ready to be used again. This method allows for many sheets to be created within a WindowsCE computer without the need to transfer a new worksheet each time a measurement is conducted. If the computer stops responding during the save process, reconfigure the WindowsCE memory to allow for storage. Refer to Section 3.2 in this document or to the WindowsCE manual for additional details on configuring memory.

Worksheets are normally named after the Station’s id number they represent. This allows for easy identification of workbooks without having to view their contents.

3.1.5 Transferring Worksheets from WindowsCE

After creating and saving worksheets in WindowsCE, they can be transferred back to a laptop or desktop where they can be added to a workbook for permanent storage. The steps used to transfer a DMFDC worksheet to WindowsCE can be used to transfer it back to the “host” computer. Open Windows explorer and HPC Explorer and drag the files from WindowsCE back to the “host” system. It is important to understand that wherever the user drags the file to is the final destination for the file. If the user wishes to transfer the worksheet to a specific directory, that directory should be visible before beginning to drag the file.

3.1.6 Inserting Worksheets into Workbooks

After the generated worksheets have been transferred from a WindowsCE computer to a laptop or desktop, they can be added to their appropriate workbook. Although there are many ways to move a worksheet into a workbook, an easy method is outlined below.

To move DMFDC sheets to an existing workbook:

1. In the host computer, start Microsoft Excel.
2. Open the workbooks you want to move sheets to and from.
3. Select the sheet or sheets you want to move.
4. From the Edit menu, choose “Move Or Copy Sheet...”.
5. In the “To Book” box, select the destination workbook.
6. In the Before Sheet box, select where you want the sheet or sheets inserted.
7. Choose the OK button.

If no workbook exists for a station it is also possible to create a new workbook.

To move DMFDC sheets to a new workbook:

1. In the host computer, start Microsoft Excel.
2. Open the workbooks you want to move sheets from.
3. Select the sheet or sheets you want to move.
4. From the Edit menu, choose “Move Or Copy Sheet...”.

5. In the “To Book” box, select New Book.
6. Choose the OK button.

A new workbook is created containing only the sheet or sheets you moved. The workbook can be named to fit the users application.

3.2 WindowsCE Limitations

Users should be aware of how much memory is available in their WindowsCE computer while creating worksheets with it. Depending on which DMFDC template is loaded, users may be restricted in the number of worksheets that they can have loaded in their WindowsCE at any given time. The Stnd.xls sheet was designed to save memory in WindowsCE applications because it takes up less space than a Multi.xls sheet. It is important to note that the size of worksheets can vary based on certain conditions. For example, when a worksheet is transferred from the host to a WindowsCE computer, the reformatting process to allow WindowsCE read the worksheet doubles the worksheet’s size. When calculating memory requirements it is advisable to use the size of WindowsCE worksheets to avoid unanticipated memory problems. The following table provides information on the sizes of different workbooks under different conditions. It will allow you to calculate how many worksheets will fit into the memory of your particular WindowsCE computer. Note: One Megabyte = 1024 Kilobytes.

Table 2. Worksheet sizes

Worksheet State	Stnd.xlt	Multi.xlt
Worksheet in PC Format	60 Kilobytes	115 Kilobytes
Worksheet in WindowsCE Format	89 Kilobytes	208 Kilobytes

If the number of workbooks a user is required to create exceeds the memory capacity of the WindowsCE computer, a laptop should be available to transfer worksheets to. This will free up the WindowsCE computer to continue generating additional worksheets, while the laptop stores all the generated worksheets. It is strongly recommended that a computer running WindowsCE have 4 or more megabytes of memory for optimal performance with DMFDC worksheets.

It is often possible to configure how memory is used in WindowsCE computers. Users can determine if they want more memory to be reserved for storage or for use by applications. To fit the greatest number of sheets in a WindowsCE computer, it is advisable to reserve just enough memory to run a DMFDC worksheet while leaving as much space as possible for storage. For a complete breakdown of the usage of memory in a WindowsCE computer, click on Start, Settings, System. This will bring up the System Properties window, click on the Memory tab at the top of the window for a detailed analysis of your memory. From this location memory can be balanced between storage space or application.

If two or more people are taking the measurement, it may be more convenient to use a laptop as opposed to a WindowsCE platform. Laptops are able to handler input quicker than typical WindowsCE machines.

Section 1: Site Information

Discharge Measurement Field Data and Calculation

Section 1: Site Information

Station Operating Agency/Firm: RESOURCES INVENTORY BR., WATER INVENTORY SECT.

Stn. No.: 08NC004 Stn.Name: SHERIDAN CREEK

Date: 97/04/09 (yy/mm/dd) Metered by: H. OVIE

Location of Metering Section: STD. XSECT.

Temp: Air 08 °C Water 02 °C Weather: CLEAR

	Time	O.G.	I.G.	Rec.
Begin	10:30AM	0.61		
End	11:00AM	0.61		
Mean		0.61	0	0
Gauge Correction: 0				

C.G.H. 0.61	Q 1.905	Area 1.964	Avg. V 0.791

Meter: Type OSS PC1. No. 93-07. Prop. No. 3.

Method of Suspension: Top Setting Rod is Selected.

Options: 1 = Top Setting Rod. 2 = Standard Bridge Rod. 3 = Cable & Weight.

Method of Suspension: 1

Meter Type: Single Range Meter is Selected.

V = Velocity (m/s) and n = Revolutions/sec.

Fill in ALL fields of only One of the following meter types and leave the other blank. If both equations are fillled, the single range equation will be used.

(1) For Single Range Meters:

V = n	x	Slope	+	Intecept	m/s.
V = n	x	0.2529	+	0.0048	m/s.

(2) For Multiple Range Meters:

	n(Min)		n(Max)	V =	n x Slope	+	Intercept	m/s.
IF		< n <		: V = n x		+		m/s.
IF		< n <		: V = n x		+		m/s.
IF		< n >		: V = n x		+		m/s.

Remarks: ____________________

Methods Description:

2 = Two point measurement, 0.2 and 0.8 depths are measured. 3 = Thre point measurement, 0.2 and 0.6 and 0.8 depths are measured. 5 = Point 5 measurement, 0.5 depth is measured (.88 coeffecient applied). 6 = Point 6 measurement, 0.6 depth is measured. B = Waters edge, used at the start of all measurements, and after any "S" method. E = Estimated velocity. S = Stop at the far edge of the channel, always followed with a "B".

T = Terminates measurement session.

Section 2: Data Entry

Section 2: Data Entry

Observations							Computation					
							Velocity					
Method	Dist. from init. point (m)	Depth (m)	Depth of obs. (m)	Revs. (no.)	Time (s)	Cos of flow	At point (m/s)	Mean in vertical (m/s)	Width (m)	Area (m^2)	Disch. (m^3/s)	Sum (m^3/s)
B	2.800	0.001			40							
6	3.000	0.14		11	40		0.074	0.074	0.3	0.030	0.002	0.002
6	3.200	0.22		11	40		0.074	0.074	0.2	0.044	0.003	0.005
6	3.400	0.28		34	40		0.220	0.220	0.2	0.059	0.013	0.018
6	3.600	0.45		116	40		0.738	0.738	0.2	0.088	0.065	0.083
6	3.800	0.54		218	40		1.383	1.383	0.2	0.106	0.147	0.230
6	4.000	0.56		248	40		1.573	1.573	0.2	0.111	0.175	0.405
6	4.200	0.54		250	40		1.585	1.585	0.2	0.109	0.172	0.577
6	4.400	0.54		223	40		1.415	1.415	0.2	0.108	0.153	0.730
6	4.600	0.55		207	40		1.414	1.414	0.2	0.110	0.144	0.874
6	4.800	0.55		209	40		1.326	1.326	0.2	0.110	0.146	1.020
6	5.000	0.56		207	40		1.314	1.314	0.2	0.111	0.146	1.166
6	5.200	0.53		194	40		1.231	1.231	0.2	0.107	0.131	1.297
6	5.400	0.52		226	40		1.434	1.434	0.2	0.104	0.149	1.446
6	5.600	0.5		206	40		1.307	1.307	0.2	0.099	0.130	1.576
6	5.800	0.45		146	40		0.928	0.928	0.2	0.090	0.084	1.660
6	6.000	0.41		135	40		0.858	0.858	0.25	0.102	0.088	1.747
6	6.300	0.38		108	40		0.688	0.688	0.3	0.110	0.076	1.823
6	6.600	0.24		74	40		0.473	0.473	0.3	0.077	0.036	1.859
6	6.900	0.22		12	40		0.081	0.081	0.3	0.066	0.005	1.865
6	7.200	0.2		4	40		0.030	0.030	0.3	0.058	0.002	1.866
6	7.500	0.13		3	40		0.024	0.024	0.3	0.042	0.001	1.867
6	7.800	0.14		42	40		0.270	0.270	0.3	0.042	0.011	1.879
6	8.100	0.14		47	40		0.302	0.302	0.3	0.042	0.013	1.891
6	8.400	0.14		53	40		0.340	0.340	0.3	0.041	0.014	1.905
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