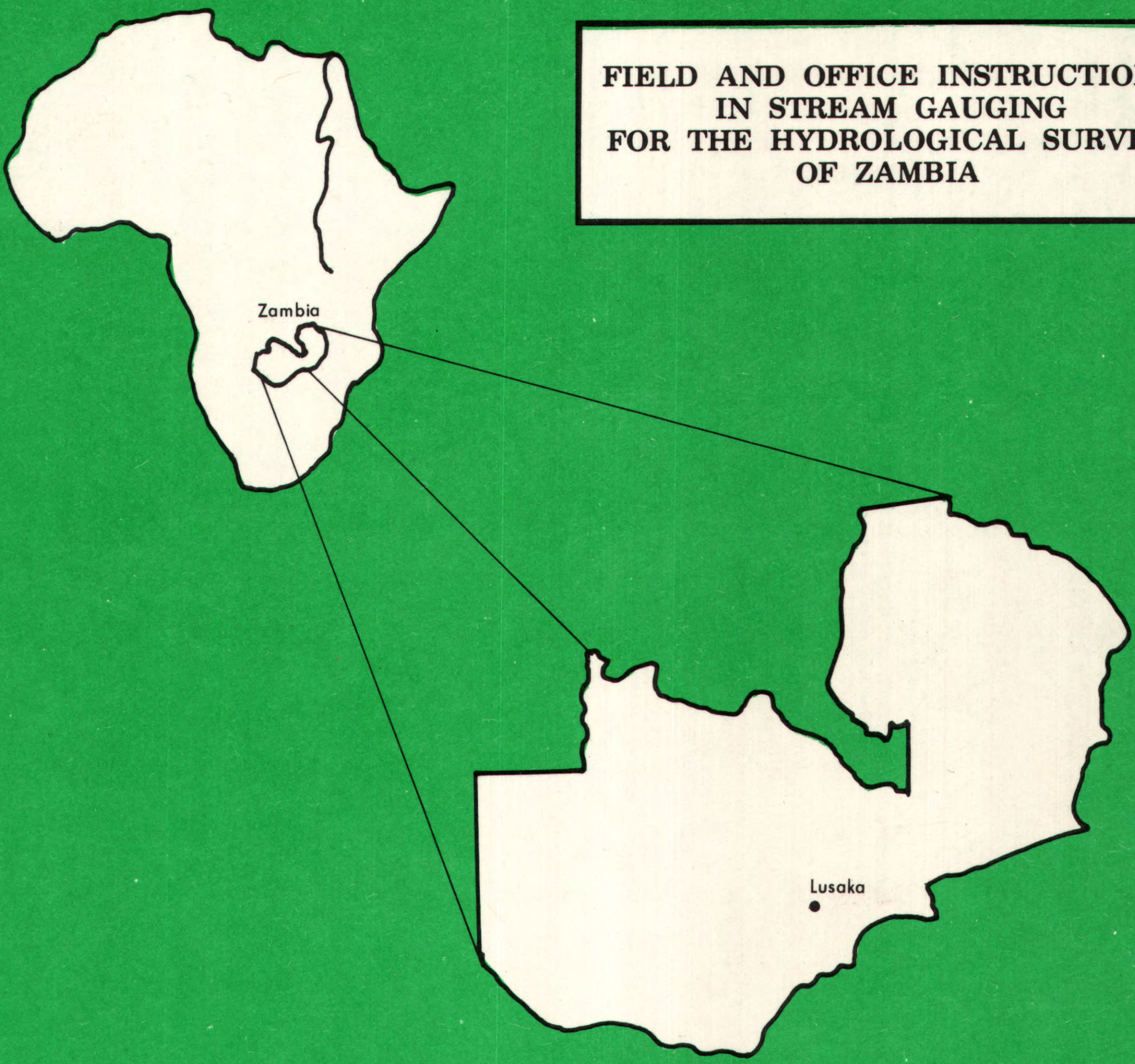
FIELD AND OFFICE INSTRUCTIONS IN STREAM GAUGING FOR THE HYDROLOGICAL SURVEY OF ZAMBIA



Prepared by the United States Geological Survey
in cooperation with
The Zambian Ministry of Rural Development,
Water Affairs Department, Hydrological Branch
under the auspices of the
United States Agency for International Development

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by

L. E. BIDWELL

U.S. GEOLOGICAL SURVEY

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PREFACE

The importance of water to the basic needs of man is self-evident and needs no particular emphasis. The importance of water to a developing economy cannot be overemphasized.

A few decades ago, hydrology was a division of hydraulic engineering and was a tool for project survey, plan, and design. Today hydrology still remains an important part of planning and management of water use projects, but it is imperative that surface and ground-water basic data networks be designed and operated from the standpoint of both present and future water needs. Water problems are ever increasing and ever changing and preparation for the future water demands of Zambia requires knowledge of the hydrology of the country instead of the examination of piecemeal samples for each water use project.

The hydrologic survey of Zambia needs to be under the guidance of competent and imaginative hydrologists solidly trained in all elements of basic data collection and analysis and not in the hands of water project planners. Hydrology is a science which requires the highest order of teamwork and the hydrologist will need the help and advice of many employees within the organization to operate the network, provide adequate research, and examine the water needs of the country. It must be thoroughly understood that communication is essential between the hydrological survey and water project planners from both the government and private sectors.

It is very important to define the aims and duties of the Hydrological Branch of the Water Affairs Department in a clear cut "Statement of Policy". Personal copies of the statement should be made available to all professional employees and technicians. The reasons for the existence of the Branch may be self-apparent to heads of the organization, but to all other employees the reasons may be vague and unknown. Every member of the technical and administrative staff would benefit by an understanding of the purpose of his work. Nebulous ideas of the function of a hydrological survey of Zambia serve little purpose to the employee making the plans or those who execute them. A dissemination and free flow of ideas in all directions is necessary in any scientific and creative organization.

The primary functions of the Hydrological Branch of the Water Affairs Department of Zambia are twofold:

1. Water resource appraisal which includes the inventory of all surface and ground waters;
2. Research, both basic and applied, in the science of water.

Possibly some function regarding water law is also conceivable, although attachment of a law enforcement function to water-resource investigations might weaken the position of the Branch as an unbiased scientific organization.

As the collection of basic streamflow data is a primary function of the Branch the following instructions for the collection, analysis and computation of streamflow records have been written.

C O N T E N T S

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GENERAL CONSIDERATIONS

This report is directed to the administrative and professional personnel of the Hydrological Branch and is designed to give specific instructions, detailed examples, and general direction to basic streamflow data collection and analysis in Zambia. It is not intended that these instructions should supplant the many outstanding publications on hydrology and streamflow. Instead, it is designed to present specific methods not readily found in published form and which have been assembled and tailored to conditions in Zambia. There is always the tendency to assume that exactness and accuracy cannot be achieved in the Hydrological Branch and consequently a competent analysis of basic data can be dispensed with. But, in fact, poor basic data needs better analyses and understanding than data of a higher caliber.

Many of the ideas presented in the instructions have been placed in use in the Hydrological Branch and have become an integral part of the Branch organization.

Stream gauging is the center of surface-water hydrology and the collection of reliable basic data is the first step toward adequate understanding of the hydrology of Zambia. These instructions should provide a firm foundation for a high standard of the collection, analysis, and computation of basic streamflow records, and are presented in two distinct parts: 1. Surface-water basic data collection in the field, and 2. Preparation of the basic data into usable streamflow records. Seven tables are included with the text. A list of references follows the text.

The appendices contain four parts: 1. Conversion tables for English and metric (S.I.) units; 2. Lists of terms frequently used in stream gauging; 3. Descriptions of a recommended filing system; and 4. Figures that illustrate the methods that are described in the text.

Some of the figures refer to a SAMPLE gauging station, Kawanda River near Chonta. Although this station does not exist, the descriptions and figures are composites derived from actual Zambian conditions and are used because they provide excellent examples for instructive purposes.

INSTRUCTIONS FOR THE FIELD COLLECTION

OF STREAMFLOW BASIC DATA

INTRODUCTION

The study of the hydrology of Zambia depends upon systematically collected basic data. The standards of collection should be consistent throughout the country and must not vary because of a present project use. Although hydrology includes water in all environments, these instructions are exclusively for streamflow basic data collection. Furthermore, data collection for chemical quality of water, sediment load and temperature will not be dealt with in this report.

Daily observations or continuous records of stage (water level, gauge height), and periodic measurements of discharge are necessary for the analysis and computation of reliable streamflow records. The collection of records of stage alone is a poor substitute for the continuous collection of both stage and discharge records at each gauging station. The records of stage are useful in some locations when the height of water is of interest, such as the design of structures near a river or lake or the operation of a reservoir. Intermittent records, except for the extremes, have relatively little value in hydrologic studies.

The methods of collection of both stage records (water levels, gauge heights) and discharge measurements are separate but integral parts of stream gauging and both will be covered in the instructions. Poor quality standards in either will reduce the quality of the final streamflow records.

Books and manuals which contain valuable information on the subject of stream gauging and river hydraulics are listed under "References." Reference to this material has been made throughout the instructions to prevent duplication.

ESTABLISHMENT OF GAUGING STATIONS

General

The gauging station is established to obtain a continuous record of stage and (or) discharge. A gauge is installed at the chosen site. This may be a staff (vertical or inclined), wire-weight, or chain gauge which is read once daily or oftener by a hired observer. In contrast, continuous record of stage is obtained by installation of an analog (graphic) or digital water-stage recorder in a shelter over a well. The recorder is usually referred to a tape or staff gauge in the well (inside gauge) although an outside reference gauge should also be installed and read to define the stage relationship of the well and river. An outside gauge is used as a test of the inside gauge. For example, this is necessary during periods of plugged intake or severe drawdown.

The well can be dispensed with by using a bubble gauge installation in which a plastic tube connects an orifice in the stream with the bubble gauge and water-stage recorder in the instrument shelter. This type of installation eliminates expensive well construction and is described in U.S.G.S. Techniques, Book 3, Chapters A6 and A7 (2,3), and Stevens Stream Gaging Equipment Catalog, Bulletin 18, pp. 2-5(4). Since the bubble gauge is not practical at the present time for use in Zambia, no further explanation or description is given.

Selection of a site

The selection of a gauge site in Zambia is one of the most important steps in the establishment of a gauging station. It involves many considerations which include economics, river hydraulics, and water use projects. The selection of the river and the general location of the gauge site should be determined by the staff hydrologists of the Hydrological Branch and depends upon the hydrologic network of Zambia and the needs of water management. Stations established because of water management problems leave little choice in location but those in the hydrologic network of Zambia allow some freedom of selection. In either case, the final site selection should be made by the chief of the hydrological survey and staff hydrologists well trained in streamflow basic data collection. A reconnaissance, or preliminary survey, could be made by a trained technical officer to determine access roads and bridges, rapids or falls, type and number of channels, overflow areas, height of banks, and flood information from local inhabitants. Valuable aid in selection of a number of tentative sites for gauging stations can be obtained from use of maps, pictures, previous notes, and aerial photographs. Every site must be examined in the field and detailed notes written on Form 101, Figure 1. The following items should be considered in selecting a gauging station site in Zambia:

Channel characteristics.--The relation of stage (water level) and discharge is controlled by a section or reach of river below the gauge. The section control may be artificial or natural and is any feature that eliminates the effect of other downstream conditions on the velocity of flow at the gauge. A dam, weir and flume are examples of an artificial control, whereas, a natural control may be a rock ledge crossing the channel, a boulder-covered rapids or a sand or gravel bar. The best control is one that doesn't change, is sensitive at low flows (a relative large change in stage for small change in discharge), and remains effective for a wide range in stage. If the river contains no section control, it is preferable to locate the gauge at the upper end of a straight reach of channel away from channel obstructions. This reach of uniform river channel controls the stage-discharge relation at the gauge and is a channel control. It is emphasized that the gauge should be installed upstream from the channel feature that has the best control characteristics. Additional descriptions are found in USGS Water Supply Paper 888, pp. 109-130 (7): USGS Techniques, Book 3, Chapter A6, pp. 2, 3 (2) Streamflow, Grover and Harrington, pp. 158-186 (5).

Backwater from downstream tributaries or other sources.-- This should be avoided if possible because the slope of the water surface is not always the same for a given stage. If such a site must be used it requires the continuous measurement of the slope of the water surface using a water-stage recorder at both ends of a straight reach of channel. See USGS Water Supply Paper 888, pp. 130-167 (7) and USGS Surface Water Techniques, Book 1, Chapter 12, pp. 15-32 (1).

Accessibility of site.--It is necessary to get to the gauging station for both maintenance and operation in both wet and dry seasons.

Availability of good discharge measurement sites.--The sites are usually different for low water and high water measurements but they should be nearby with no inflow or diversion between the measuring site and the gauge and control. If inflow or diversion does exist, these discharges must also be measured and added or subtracted from the main channel flow. Bridges should be examined for use in making high water measurements. Examine the area for possible cableway or boat measurement sites.

Availability of gauge sites relative to the control.--The gauge should be stable (few changes in datum). For example, staff gauges on steep river banks may be upset. Also, it is expensive to excavate for a gauge well in a rocky bank.

Flow bypassing the site.--An example of this is the gauging station on the Luanginga River at Kalabo. Many channels need to be measured during high floods at this station, which requires a large stream gauging party and a long time spent in measuring. No better site exists at Kalabo, but such conditions should be avoided if possible, and the site changed.

Opportunity to install an artificial control.--Weirs (or low dams) can be constructed below a gauge to stabilize the low-flow stage-discharge relation. Discharge measurements should be made to "rate" the control. Substantial flows can be measured with the current meter and low flow by volumetric means (catch the water in a bucket). A comprehensive discussion of artificial controls is found in Streamflow, Grover and Harrington, pp. 167-186 (5): USGS Water Supply Paper 888, pp. 117, 118 (7): USGS Techniques, Book 3, Chapter A6, pp. 3-5 (2).

The following is an outline of specific gauge location considerations:

Preliminary.--Office reconnaissance; the study of maps, pictures and aerial photographs.

1. Locate and mark most obvious sites to be examined in field (obvious control sections such as constrictions, rapids, and riffles may be seen).
2. Note all access roads, trails, and rivers.
3. Note obvious terraine (land) features on map.
    a. Overflow areas.
    b. Steep banks for confined flow.
    c. Divided (many) channels.
    d. Tributary (branch) locations for source of inflow or backwater.
    e. Note cities or villages.

f. Mark possible measuring sites.

4. Write route to be followed in the field reconnaissance.

5. General rule: Do as much preliminary office investigation as possible.

<u>Field reconnaissance</u>:

1. The river features (hydraulic and hydrologic).

   a. Stable and well defined section control. (Note that the control conditions are always of utmost importance). See page 6 of these instructions.

   b. Determine availability of all discharge measuring sections.

      (1) Low water wading section.

      (2) Medium and high flow boat, cableway, or bridge sections.

   c. Highwater marks of past floods.

   d. Examine possible overflow conditions.

   e. Examine bypass channels during flood flows.

   f. Investigate low flow conditions.

   g. Examine for possible backwater conditions from tributaries or vegetation (weeds, brush, leaves, etc.).

   h. Determine possibility of pollution or heavy silt loads in stream.

2. Installation of gauges.

   a. Access for material and men.

b. Note type of bank conditions.

(1) Stable conditions for staff gauge. Note if vertical or inclined staff gauge will be best.

(2) Determine if gauge well can be constructed. Consider type of excavation, materials, and accessibility.

(3) Cost and time involved should be noted.

Selection of the type of gauge

The method of installation is different for each type of gauge and it is important to recognize the type of gauge most suitable for the particular site. Consider the regimen of streamflow, the necessity for a continuous stage record over observer's gauge readings, and the type of installation that fits the physical features of the site. The observer may not be able to read the gauge on the crest of the flood; consequently a crest stage gauge should be added to the equipment at a non-recording gauge installation on flashy streams.

Detailed descriptions, illustrations, and explanations concerning the many types of gauges and water-stage recorders and their installation are given in USGS Water Supply Paper 888, pp. 184-197 (7); USGS Techniques, Book 3, Chapter A7 (3); and Streamflow, Grover and Harrington, pp. 106-119 (5).

There are advantages and disadvantages to each type of gauge. The low initial cost and the ease of installation of the non-recording gauges is offset by the necessary dependence on an observer to obtain accurate gauge readings a few times each day and on the crest of each rise in stage. A satisfactory gauge height record can be obtained from a non-recording gauge on a stream that has a low rate of change in stage. For example, the twice daily readings of the staff gauge at the gauging station Kafue River at Kasaka produces satisfactory record of daily mean gauge heights and peak stages.

Since a vertical staff gauge is easily damaged or destroyed by debris, animals or erosion, the construction of an inclined staff gauge on the same slope as the river bank may be the answer. There are two such installations in Zambia, at the gauging stations Luangwa River at Luangwa Bridge, and Zambezi River at Zambezi (Ballovale).

Staff gauges are the non-recording gauges established in Zambia although some sites are better suited to wire-weight gauge installations. For example, the staff gauge sections on the Luampa River at Luampa Road Bridge are attached to steel posts on the right bank about 300 feet downstream from the bridge. The bridge pipe railing makes an ideal support for a wire-weight gauge. An added reason for a change is the poor control at the present site compared to a stable rocky riffle just downstream from the bridge, Figures 2, 3 and 4.

A water-stage recorder is necessary on a flashy stream for accurately recording stage hydrographs during floods. The Mutama

River at Mutama Rapids is an example of a stream that needs a recorder installation. The installation of a recording gauging station is expensive because it requires a well and shelter. However, the advantages listed below outweigh the disadvantages on most streams:

1. Provide record of maximum and minimum stages.
2. Not dependent upon observer readings.
3. Form the basis for an accurate record of discharge.
4. Produce a continuous record of stage which is particularly important during periods of changing stage during floods or regulated discharge below reservoirs and power plants.

Emphasis must be given to the need for both an inside and an outside gauge at a water-stage recorder installation. The inside base gauge may be a tape gauge (float or electric) or a vertical staff gauge. The outside reference gauge may be a staff gauge (vertical or inclined), chain gauge, or wire-weight gauge. Refer to USGS Techniques, Book 3, Chapter A7 (3).

Installation and operation

It is not the writer's intent to give detailed design and methods of construction and installation at gauging stations since these are covered in the references that are listed in the Appendices. These instructions stress the items that are important in operation of the gauge but are often overlooked or misunderstood.

Datum of gauge

The stage (water level, gauge height) of a stream or lake is the height of the water surface above an established datum plane which is referred to the zero of the gauge. It may be a local arbitrary datum chosen for the particular site or the mean sea level datum. Every gauge should be referred to a mean sea level or national datum, wherever these have been established. As a substitute, the elevation or altitude may be obtained by a barometer or from a topographic map, respectively.

It is necessary to maintain one permanent gauge datum and this is accomplished by establishing bench marks that are referred to the zero of the gauge. The zero of the gauge must be below the zero flow on the control and, for shifting controls, considerably below to prevent negative gauge readings.

It is important to maintain a permanent datum for the sake of accuracy and two to three bench marks should always be established at each gauging station. These should be separated and located at protected sites, but in the general vicinity of the station for ease in running the levels between the bench marks and the gauges. A bolt driven into the lower trunk of a live tree is an acceptable bench mark if the tree is on solid ground and not susceptible to erosion. A more permanent bench mark is a bronze tablet, bolt or rod inserted into a concrete monument, bridge abutment or solid foundation. All bench marks should be located so a level staff (rod) can be held on it in a vertical position. The description and installation of bench marks is given in USGS Topographic Instructions, Leveling, Book 2, Chapters 2E1- 2E5, pp. 37-45 (6).

Water-stage recorders

General

The water-stage recorder produces a pen or pencil graph or a punched tape record of gauge height. It must be understood that both types of records may require time corrections (due to faulty clock operation) and gauge height corrections (datum and pen). In the most common type of installation (the only one used in Zambia) the recorder in the shelter or house over the well is actuated by a float that rides in the water below. This installation may be in the river bank or attached to a bridge pier or abutment with the bottom of the well directly in the water. In either case, the well must have a hydraulic connection with the river through intake (inlet) pipes, slots or holes. Pressure or bubble gauges are also available but are not recommended for use in Zambia.

The following features of recorder house and well design are of particular significance:

1. The bottom of the well should be at least 1 foot below the lowest possible stage.
2. In most cases, more than one intake is advisable. These will be for low, medium, and high stage.
3. The lowest intake at least 1/2 foot below the lowest stage.

4. The lowest intake at least 1/2 foot above the bottom of the well.

5. Flushing devices for intakes should be provided wherever silt is a problem (most cases). Devices installed in the well will prove most useful as they can be used without hauling in a power pump. Size of the well is a consideration in the installation of flushing devices. The flushing device is of particular importance in silt-laden streams. In small pipe wells, the size may prevent inside plumbing and the only means of flushing may be power pump to fill the well and a check valve for building up a head. It may be possible to put a gate valve in the well and a riser pipe outside with a tank or funnel on the top. Such construction invites vandalism, unless the flush tank or large funnel can be lifted off after flushing and stored in the gauge house. Then a cap must be placed on the riser pipe to prevent plugging. All these problems necessitate some improvisation for each particular station.

6. The intake should be large enough for the water level in the well to respond to changes in the water surface in the river but not so large as to permit surge and wave action in the river to effect the water level in the well directly. The design of intakes is given in USGS Techniques, Book 3, Chapter A7, p. 13 (3).

7. An intake pipe should be level and at right angle to the river flow.

8. A static tube can be placed on the intake pipe to prevent drawdown or pileup of the water level in the well.

9. The static tube is not intended simply to reduce the effective size of the intake pipe since this should be designed for each particular well. A large pipe cannot be effectively flushed by an ordinary hand pump with flush tank and almost always requires a power pump and probably extra field trips, both costly and inefficient.

10. The well should extend above the highest anticipated water.

11. The gauge house and well should be large enough for installation of an inside tape or staff base gauge.

12. A well cleanout door should be incorporated in the design of wells. Shallow wells less than 10 feet deep may not need a cleanout door.

13. The recorder should be level and anchored to an instrument shelf or support in a position that facilitates all service and maintenance. For a walk-in shelter, the space beneath the shelf should be open to the well so that the float can rise up to the bottom of the shelf. This allows the use of part of the house for recorder operation during extreme floods and cuts the cost of construction. In a reach-in shelter, the recorder is on the floor.

There are a number of excellent water-stage recorders available for gauging station installations. There are two types of analog (graphic) recorders in general use in stream gauging, the strip chart recorder and the drum recorder. In either case, the recorder supplies a continuous pen or pencil trace of water stage with respect to time on a chart. Usually in the strip chart recorder, the gauge height element moves the pen or pencil and the time element moves the chart. This is reversed in most horizontal drum recorders. The vertical drum recorders are of two types, for example 1) Kent weekly recorder: The gauge height element moves the pen or pencil up and down across the chart and the time element rotates the drum. 2) Stevens Type E: The time element moves the pen or pencil downward across the chart and gauge height element rotates the drum. The recording range in stage is not limited by the pen or pencil mechanism in the strip chart and most horizontal drum recorders. However, the length of the drum limits the recording range in stage on the Kent vertical drum recorder but not on the Stevens Type E. Specific considerations on operation of stage gauges are given in Techniques, Book 3, Chapter A7, p. 24 (3).

Gauge height scale

The gauge height scale on the recorder chart is always smaller than the actual gauge height in the stream. This relationship can be varied on all recorders but it is usual to have

1 foot on the chart equal to 6 or 12 feet of gauge height in the river. This is called a gauge height ratio of 1:6 or 1:12 and the scale chosen depends on the following characteristics of the river:

1. Rate of change of stage
2. Sensitivity of the control.
3. Range in stage.

Metric unit gauge height scales of 1:5 and 1:10 are about comparable to the 1:6 and 1:12 scales in the English units. A gauge height ratio of 10 to 12 or 5 to 12 may be considered for a gauging station on a flashy stream having a small catchment area.

A gauge height scale of 1:12 is recommended for streams similar to the lower Kafue and a 1:6 scale for streams having characteristics of the Chongwe or Mutama Rivers. Most streams in Zambia do not necessarily fit these samples but either a ratio of 1:6 or 1:12 (metric unit ratios of 1:5 or 1:10, respectively) will be satisfactory if the rate of change of stage is considered.

Time scale

The time scale chosen for the recorder depends upon the flashiness of the stream. On streams that are similar to the lower Kafue or Zambezi Rivers, a time scale of 0.05 inches per hour (1.2 inches per day) would be adequate although as a general rule, a time scale of about 0.10 inch per hour (2.4 inches per day) will be satisfactory for most streams in Zambia. Exceptions are recorder installations on streams having small drainage areas with very flashy characteristics. Peaks of a few minutes duration require an expanded time scale.

Maintenance and Service instructions

One recorder manufacturer makes the following statement which contains sound advice and is well worth repeating:

> "Water-stage recorders are designed to be as nearly foolproof as possible, but a certain amount of reasonable, intelligent supervision is not too much to ask. Where such is lacking, no instrument can be made perfect enough to insure 100 percent records."

Most strip chart recorders (Stevens A-35 is an example) with a time scale of 1.2 or 2.4 inches per day will usually operate satisfactorily for one to two months without servicing. Larger time scales will need servicing at shorter time intervals. A vast amount of paper on the take-up roll can cause recorder stoppage and the pen or pencil servicing depends upon the amount of trace on the chart. Removing the section of used chart is a part of service and must be done every 1 to 2 months. If the river is rising or falling rapidly at the time of the visit, the chart removal can be postponed until after the rapid change in stage.

The drum recorders require attention at fixed times, usually about once a week although some drum recorders will continue to revolve and record gauge height until the clock runs down.

Unsatisfactory recorder operation stems directly from the wrong choice of instrument or poor installation, service, and maintenance. The following is a list of reasons for no record from water-stage recorders:

1. Failure to clean and oil the bearings occasionally.
2. Failure to use reasonable care in maintaining the mechanical parts (pen carriage and track alignment, frayed clock and float cable, to name a few).
3. Failure to keep intakes open and silt out of well.
4. Failure to place recorder securely on a recorder shelf and keep instrument level.
5. Failure to replace stopped clock.
6. Failure to remove chart every 1 to 2 months on strip recorder.
7. Incorrect gauge readings.
8. Inaccurate setting of pens or pencils or failure to place them on paper.
9. Filling pen too full of ink.
10. Failure to start clock after winding.
11. Failure to note date, time, all gauge heights, pen setting, name of gauging station, reversal lines on strip recorder, and signature of field man making the inspection.
12. Failure to prevent small animals from entering, living and nesting in the gauge house and well.

It is mandatory to follow specific maintenance instructions to obtain complete and satisfactory recorder records. The following instructions should become a fixed part of the field operation at every recorder station:

1. The instrument house, well, and recorder should be kept clean at all times.
2. The recorder should be cleaned once a year and all bearings, track, spindles, and rack guides should be lightly oiled (heavy oiling causes dust collection). Bearings should be cleaned occasionally with a solvent such as benzine. (See instructions for each type of recorder).
3. At one or two month intervals, run pen carriage along track or rack, then clean and adjust if the movement is binding. Allow clock weight to run down on the Stevens A-35 recorder to exercise all time elements. Adjust if found binding in any way. Always control clock cable drum by placing hand on drum--otherwise the weight will drop into well and break clock cable and damage recorder.
4. The clock should be changed if found stopped and the cause appears to be a faulty clock. A spare clock should always be carried into the field by service personnel. A record of clock changes should be kept in station field file.
5. The Chelsea weight-driven clock on the Stevens A-35 is in proper adjustment when the balance wheel turns 1 1/2

times with no more than 60 inch-ounces of torque. An additional 1/2 to 1 lb. of clock weight can be added if the recorder causes clock stoppage. Never add so much additional weight to cause clock balance wheel to over bank (double click).

6. Check all clock and float cables at each service visit, Repair or replace all frayed cables. Frayed clock cable on a Stevens recorder can cause clock stoppage.
7. Check for loose cable or tape connections on all weights and float at each service visit and fasten if needed.
8. Check all intake pipes for plugging and well for silt deposits at every service visit. Clean and unplug, if necessary. Always carry equipment on trips to stations that need this type of service.
9. Examine all inside and outside gauges at each visit. Loose or missing gauge plates should be repaired. Information about cause and time of gauge changes should be noted on chart.
10. Notes regarding all items of maintenance should be written on Form H100.

Recorder operation instructions

The operation of a water-stage recorder requires the service of a skilled and careful technician. The continuous recorder

(Stevens A-35) with a time scale of 1.2 to 2.4 inches per day needs a paper change and servicing at one to two month intervals. Since the interval between servicing fits into a regular field trip by a trained hydrographer, this type of recorder can be installed in remote locations. The weekly recorder (Kent) needs weekly servicing and chart change and should be installed close to central offices of the Hydrological Branch unless skilled and competent observers can be obtained for the gauging station.

Kent (or vertical drum) recorder

1. Check if clock is running at start of inspection. To check look at pen or pencil trace on chart and listen to clock.
2. Inspect and read inside (if installed) and outside gauge and note the time of the readings.
3. Read the pencil and move carriage up and down by slight rotation of float wheel to mark the exact position of the pencil on the chart at the finish.
4. Remove the chart drum.
5. Write the gauge height, time, and date on the old chart and sign your name on the chart below the printed "STAFF GAUGE HEIGHT FINISH." If there is an inside and an outside gauge, write both readings on the chart and identify both by writing "In" for "Inside gauge" and "Out" for "Outside gauge" just before each gauge height. It is recommended that all reference to time be on the 24 hour basis, e.g., 0800, 1620, etc.

6. Remove the old chart from the drum.

7. Check the old chart at once for:

   (a) Loss or gain in time.

   (b) Clock stoppage.

   (c) Plugged intake or silted well.

   (d) Any other malfunction. Locate trouble on chart and write reason for the trouble and run arrow to position on the chart.

8. Change clock if necessary and write the date of change on the chart if the clock was changed and the number of the clocks removed and installed. A similiar record should be kept in the field file on Form H114. Clean intakes and well if necessary and clean and oil recorder, if needed.

9. Wind clock.

10. Sharpen or replace pencil.

11. Put new chart on drum.

12. Write on new chart the full name of station (river and location), dates and your signature just below the printed words "STAFF GAUGE HEIGHT START".

13. Read all the gauges, note time, and write gauge heights and time on chart.

14. Put drum on recorder.

    Note.- If stage is changing rapidly, care should be taken to set pen on correct gauge height.

15. Set pencil to the exact gauge height that is written on the top of chart and move pencil carriage up and down by slight rotation of the float wheel to mark position of

pencil start. Check pencil carriage for sloppy connections.

16. Check to see if clock is running.

17. Gently replace cover on recorder.

WARNING.- Never mark over the pencil trace in the field! Illustration of proper notes is found on the chart in Figure 47.

Stevens A-35 (strip chart-continuous) recorder

Recorder chart paper is affected by humidity and the Stevens paper is no exception. It is assumed that there is no change at the center and the amount of expansion or contraction from the center outwards is directly proportional to the distance from the center of the paper.

The same magnitude of error in gauge height at low stages represents a much larger percentage error in discharge than at high stages. To prevent expansion errors, it is necessary to keep the low stage pen trace close to the center of the chart. This is accomplished by estimating the lowest stage at the gauging station and setting the scale to keep the low stage trace near the center of the chart. This scale should be unchanged, with few exceptions, because many changes is a source of error and leads to more work in computation of gauge heights. This scale can be maintained by inking the recorder gauge height scale on the inside cover or front of the recorder at 1 or 2 inch intervals opposite the same values on the chart.

The following procedures must be used in servicing a continuous recorder installation:

1. Inspect and read all the gauges and note the time.
2. Open recorder and see if clock is running or stopped (listen and look at balance wheel movement).
3. Read pen and rotate float wheel slightly to mark finish position of pen.
4. Write the following notes on the chart and draw arrow to finish mark of pen and sign your notes:

   Full name of gauging station; example--"Mutama River at Mutama Rapids".

   Date.

   Outside gauge height.

   Inside gauge height.

   Pen gauge height.

   Time of reading gauges.

   Also write if clock is stopped.

   Your signature.
5. Raise pen off the chart and check for plugged intakes or silted well. If necessary, clean out intakes and well and lower pen and read inside gauge. If it reads different than before the cleaning, mark the difference on the chart by pulling a little paper (1 inch) through the recorder by winding slightly on the take-up roll. Make a note on the chart as follows and run an arrow to the pen trace:

Found after cleaning (Write this on the chart as a heading to the following notes)

Outside gauge height.

Inside gauge height.

Pen gauge height.

Time of reading.

Signature.

6. Mark the marginal reversal points by the following procedure (pen should be marking on the chart):

   (a) Loosen the float wheel from the hub by releasing the two thumb screws on the hub plate--look at arrows on hub.

   (b) Grasp the float wheel hub and run the pen carriage slowly through the reversal at each margin of the chart. Write note and flag "Found reversal here."

7. Raise the pen off the chart.

8. Loosen the paper from the drive roller and roll about 6 inches of paper on the take-up roller.

9. Tighten the paper on the drive roll and with a sharp knife cut the paper off at along the back edge of the metal writing surface.

10. Take out the take-up roll and loosen the paper by rotating core of take-up roll backwards and remove paper by slipping off end of roll. Replace take-up roll in recorder.

11. Inspect chart carefully for any indication of plugged intake or well, clock stoppage, gain or loss in time, and other malfunctions. Write any notes about trouble on the chart and draw arrow to spot on chart. Write dates on chart to determine loss or gain of time.
12. Change clock if necessary and/or wind clock. Fill pen 2/3 full of ink. Clean and oil the recorder at this time if this is the proper service period.
13. Attach cut end of paper to take-up roll and wind 2 laps of paper on roll.
14. Lower pen and slowly run pen across the paper to mark the reversal points at margins of chart (see procedure step 6). Adjust pen holder on pen carriage to reverse exactly on right (facing) margin of chart. Take up a little paper and check reversal and after proper adjustment, leave a new reversal mark at edge with the word flagged "Left reversal here."
15. Check pen to see if it is in the correct reversal position (the pen should move in the direction of increasing gauge height when the float is raised).
16. Read all gauges and note time.
17. Set pen to proper gauge height and time and tighten float wheel on hub. Mark exact start position of pen by slightly rotating float wheel.

18. Write the following notes on the chart:

Full name of gauging station.

Date.

Outside gauge height.

Inside gauge height.

Pen gauge height.

Time of reading gauges and pen.

Write signature.

Illustration of the proper notes is found on the chart, Figure 47.

WARNING.- Never mark over the pen trace in the field.

Digital (punch tape) record

The Ott digital water-stage recorder is a battery operated paper tape punch which records the gauge height on a 5 channel paper tape at 15, 30, or 60 minute intervals. The paper tape record must be run through a translator to produce a record in a medium suitable for computer programming.

The digital recorder is a serviceable but sophisticated instrument which requires expert servicing in the field. Lack of fresh batteries has also been a constant source of trouble in Zambia. Because of the difficulties in obtaining a usable record and the large amount of man-days spent on servicing, the Ott digital recorders are being withdrawn from field use and "mothballed" until a future date. No operating instructions are given here.

Non-recording gauges

Staff

The vertical staff gauge is used at all gauging stations in Zambia with the exception of Luangwa River at Luangwa Bridge and the Zambezi River at Balovale (Zambezi) where inclined staff gauges are installed. At the recorder gauging stations, the staffs are used as outside base gauges to which the recorder is referenced. Although an outside gauge is necessary at each recorder installation, an inside gauge should be installed as the base gauge. A vertical staff gauge attached to an inside wall of the well makes an excellent base gauge. The vertical staff gauge plates used in Zambia are graduated in tenths of feet. This leaves much to be desired as gauge readings must be estimated between the tenth graduations if accurate discharge records are to be computed. A recommended staff gauge graduated in English units is shown in Figure 7. The tenth-foot graduated staff gauges are acceptable for the stage station, (see section on Accuracy, pp. 49-53). The method of installing the staff gauges on angle iron posts driven into the river channel beds and banks is satisfactory for the conditions encountered. At bridge sites the staff gauges can be attached to stable piers and abutments.

The inclined staff gauge can be used at stations where maintenance of a vertical staff gauge is impossible. The two installations of this type of gauge in Zambia are constructed by screwing vertical enameled staff gauge sections to a wood bedpiece attached to the top of a sloping concrete foundation running up the river bank. Because vertical staff gauge sections have been used on the inclined bedpiece, adjustments must be applied to each gauge reading. Although the conversion has been somewhat simplified by using a pre-computed conversion table, this method of obtaining the true gauge height is both extremely inefficient and a constant source of error. The object of using the inclined staff is to eliminate the maintenance problems common to the vertical staff gauge installation and, therefore, it is imperative to consider the following construction suggestions:

1. The concrete foundation should be made of high strength reinforced concrete.
2. A decay resistant wood bedpiece (a 2 x 6 is suitable) should be securely bolted to the top of the concrete foundation.
3. All up-bank drainage must be diverted away from the foundation or a site chosen with no erosion from up-bank drainage.
4. The slope of the concrete foundation should conform to the general slope of the river bank.
5. The sloping top of the gauge should be built flush with the surface of the river bank.
6. The gauge site should not be affected by river bank erosion (keep away from high velocities or eddies).

7. Construct the scale to read directly in gauge height and mark the graduations in place on the wood bedpiece directly from a bench mark by leveling.
8. Numerals and graduations should be made of non-rusting material. Consider materials made of aluminum, copper, bronze or enameled iron. Staples, nails, screws, or stiff metal strips make excellent graduation marks.

Wire-weight.

The installation of a wire-weight gauge, Figure 8, should be considered at gauging stations at bridge sites, especially with stations that have staff-gauge maintenance problems. This type of gauge requires a stable support and the rail or truss member of a steel or concrete road or railroad bridge offers an excellent location. The wire-weight gauge can be used as either the base gauge at a non-recording station or as the outside reference gauge at a recorder installation. A road bridge which is suitable for a wire-weight gauge support is shown in Figures 2 and 3 and excellent pictures and descriptions of the gauge are given in USGS Water Supply Paper 888, pp. 196, 197 (7): USGS Techniques, Book 3, Chapter A7, p. 21 (3); and Streamflow, Grover and Harrington, pp. 118, 119 (5).

Chain.

The chain gauge can be fastened to bridge rails and used as a substitute for a wire-weight gauge at stations unsuitable for staff gauge installation. The chain gauge can also be attached to a cantilever beam or bridge floor (no handrail) which are not usable for a wire-weight gauge support. See USGS Water Supply Paper 888, pp. 193, 194, Plate 24 (7): USGS Techniques, Book 3, Chapter A7, pp. 22, 23 (3); and Streamflow, Grover and Harrington, pp. 117, 118 (5).

Tape.

The two types of tape gauges in general use are (1) electric-tape gauge, Figure 9, and (2) float-tape gauge, Figure 10. They are installed in wells and used as an inside base reference gauge to a water-stage recorder although both can be read as a non-recording gauge by an observer during faulty recorder operation. Although the electric-tape gauge gives excellent results, it requires a battery and more maintenance and is not recommended for use in Zambia at this time. The gauge height mechanism of the Stevens water-stage recorder (strip chart or drum) can be actuated by a float-tape attachment which eliminates the use of two floats in the well and a separate inside base gauge. Detailed discussion and illustrations are given in USGS Water Supply Paper 888, pp. 194, 196 (7); USGS Techniques, Book 3, Chapter A7, pp. 21, 22 (3); and Stevens Stream Gaging Equipment Catalog, Bulletin 18 (4).

Crest-stage.

The crest stage gauge is a device for obtaining the gauge height or elevation of the flood crest in a river. This gauge has widespread use because it is reliable, simple, economical, and easy to install.

The most satisfactory type consists of a vertical 2-inch galvanized pipe containing a wood stick. A metal cup attached to the lower end of the stick contains ground cork that floats upward as water enters the pipe through a series of holes near the bottom of the pipe. A line of cork remains on the stick at the highest stage after the water recedes through the intake holes. Figures 11-16 show a variety of designs that have proven satisfactory in field use.

A few crest-stage gauges have been installed in Zambia and it is recommended that the network be expanded. They can be used for collecting peak stages at the following locations:

1. At sites where only information on peaks is desired (high-flow partial record stations).
2. Regular non-recording stations.
3. Continued collection of peak stages at discontinued stations.
4. Regular recording stations subject to trouble during floods (plugged intakes and silted wells).

The following instructions for location, installation, and operation are helpful at all crest-stage sites:

Location

The same location criteria for high flow as used for a regular gauging station applies when a crest-stage gauge is installed as a base gauge only. When a crest-stage gauge is installed as a supplemental gauge at a recording station or installed at a discontinued station, it should be set close to the same cross section as the intake but at a higher elevation.

When the crest-stage gauge is installed to help define the high-water profile, certain location requirements must be fulfilled.

Culverts--The headwater gauge should be located a distance upstream from the toe of the wingwall equal to the width of the entrance to the culvert at the toe of the wingwall. This gauge can also be used as a base gauge for defining the stage-discharge relation.

A tail water gauge, if necessary, should be located along the embankment close to the culvert exit.

Dams--The upstream gauge should be located upstream from the dam a distance equal to 2 1/2 to 3 times the maximum expected head. This gauge can also be used as a base gauge.

The downstream gauge, used to determine the degree of submergence, should be located immediately downstream from the dam in a position where it will represent the true downstream elevation and not be struck by water falling over the dam.

Contractions--The upstream gauge should be located one bridge-width (distance between abutments) upstream from the bridge opening. This gauge can also be used as a base gauge.

The downstream gauge should be located as near as possible to the downstream side of the bridge opening but not directly in the opening. It is desirable to have a gauge on each bank both upstream and downstream.

Slope-area--The gauges should be located at each end of the reach and on both banks if possible. For a dependable slope-area measurement the crest-stage gauge readings at the ends of the reach should be used in conjunction with full profile definition.

Installation

Crest-stage gauges can be attached to vertical walls or walls with some batter as wingwalls and abutments by means of the specially designed brackets. At many places a tree can be used for supporting the gauge. The gauge should be installed in a vertical position and in such a way that it can easily be raised or lowered.

At locations where nothing is available to support the crest-stage gauge, it may be attached to a wood or metal post set in the ground a distance of at least 2 feet. The post hole should be filled with concrete. Steel strap can be used to attach the gauge to the post. The gauge should be installed on the upstream or streamward side of the post to avoid the disturbances in the water-surface elevation that would be encountered on the downstream side, and to have a greater range in raising and lowering the pipe than would be possible on the shoreward side. Care should be exercised in the installation of the gauge to avoid the "pile up" area which occurs on the upstream side of the support in fast moving water.

Another type of crest-stage gauge installation consists of a 2-foot length of 2 1/2-inch pipe imbedded in a concrete block in the ground. The 2-inch pipe with the intake holes drilled in the pipe is inserted inside the 2 1/2-inch pipe, and the two pipes are bolted together below the intakes. The bolt serves as a pin for the gauge staff to rest on. This type of gauge has the advantage of eliminating the use of a wood post but has the disadvantage that the elevation of the intakes can not be changed very easily. Figures 13 and 14 show a pipe base that is driven into the ground and needs no concrete for support.

The length of a section of crest-stage gauge is limited to that from which a man can remove the staff. Several sections may be needed at one stream section.

If clearance above the gauge is a problem such as at a bridge pier under a cantilevered sidewalk, an aluminum venetian blind slat can be used in place of a rigid staff and then the blind slat can be snaked in and out of the top of the gauge.

At least two permanent reference marks should be established at each crest-stage gauge station.

Crest-stage gauges, especially those that may be inaccessible during high water, should be graduated in feet and in tenths of a foot (or in hundredths of a metre) by paint marks on the outside of the pipe so that current meter measurements can be easily referred to the gauge.

Operation

Crest-stage gauges should be serviced at regular intervals just as are recorders and other gauges at regular gauging stations unless it is certain that no peaks have occurred during a particular period. Levels should be run occasionally to be certain there has been no vertical movement of the gauge. Paint marks can be made as match points on the gauge to indicate any movement of the pipe with respect to the brackets.

The servicing procedure is as follows:

1. Remove the top cap with a pipe wrench.
2. Remove staff and mark with pencil the crestline and add the date of the inspection. Secondary rises after the highest rise will also leave cork lines.
3. Remove cork from the staff.
4. Measure from reference (bottom) end of staff to marks and record on Form H100. The staffs can be graduated with saw cuts for convenience in this step.
5. Show date of flood crests, if known, on Form H100.
6. Remove bottom cap (if available), clean, grease threads, replace in proper position.
7. Replace staff with cork in tin cup, grease threads, and replace top cap. Be certain vent hole is open in top cap.
8. Note and record control conditions.
9. Compare cork level with high-water marks on banks, trees, or other objects by means of a hand level.

10. Check for evidence on vertical movement of the gauge.

If the crest-stage gauge is in the water and the stage is falling or stationary, the procedure for servicing is the same as that outlined above except that step 6 is omitted. The staff should be replaced slowly so as not to cause a false cork level on the staff by the rapid displacement of volume. If the stage is rising, the staff should not be removed. The water surface should be referred to the painted graduation on the pipe any time the pipe is in the water.

If a rise considerably higher than the stage of the previous highest measurement has occurred, the hydrographer should stake out the high-water marks for an indirect measurement.

LEVEL CHECKS AT GAUGING STATIONS

General

A permanent datum of gauge must be maintained at every gauging station if records of stage and discharge are to be accurate (refer to "Datum of Gauge" p.14). Review the definition of bench mark and reference point in "Stream Gauging Terms" in the Appendices.

The maintenance of established gauge datum is done by leveling from bench marks and reference points to all gauges at the station. In order to obtain accuracy and to facilitate running levels at gauging stations, it is necessary to establish definite procedures of operation. This includes the preparation of data in the office prior to a trip for leveling as well as the leveling operation in the field at the gauging station.

Office preparation

The field man should be sure he has obtained the following information:

1. See that the Field Station Description (Figures 26 and 27) contains the most recent description and elevation of all bench marks and reference points.
2. See that the Level Summary (Figure 17) is up to date; if not, take the last year's levels and make a level summary on Form H114 as shown in Figure 17.
3. Obtain a supply of looseleaf level note sheets, Form H102.
4. Prepare to take a copy in the field of the Field Station Description, Level Summary, and Station Sketch.

General recommendations

The accuracy of stream flow and stage records is dependent upon accurate gauge heights and therefore all surveying instruments used in checking gauges must be properly maintained and adjusted. All surveying instruments used in hydrological survey work should have a critical inspection at least once a year by the employee who is designated and made responsible for surveying instrument maintenance. This should be done prior to the dry season, preferably January to March.

The level is the surveying instrument to determine differences in elevation and is used in checking and maintaining gauge datum. Basically, it consists of a telescope for sighting and a leveling device for making and keeping the line of sight horizontal. The leveling device may be a type of pendulum, in an automatic level, or a bubble in a cylindrical vial which requires manual manipulation.

Prior to leaving the office, each field officer should examine the level (or theodolite), tripod, and staff (rod) that has been issued to him and satisfy himself that it is in proper condition. All field officers should immediately return to the designated employee all damaged or poorly adjusted instruments. The final responsibility of using only properly adjusted and functioning surveying instruments rests with each officer who is in charge of the field work in each province, region or area.

Although a level is built for field use, it cannot be subjected to mistreatment and remain in adjustment. The following precautionary measures should be taken in the field:

1. In driving to a gauging station, the instrument must be carried in the lap of a responsible member of the level party or on a resilient shock-absorbing mat--never to bounce around in the bottom of a vehicle.
2. In use from one setup to another, the level is carried over the shoulder, mounted on the tripod, but if near trees or other obstructions, it is carried under the arm with the level in front, close to the person's body.

3. The tripod should be lowered gently to the ground and set firmly with legs far enough apart to assure stability.

4. The screws or bolts connecting the legs of the tripod to the head should be set firm, but not too tight. To check for proper leg tension, set the tripod with legs apart on level ground; when lifted by the head, the legs should fold in only slightly.

5. Never leave a level set up in the field unattended.

The basic requirement in leveling is that the line of sight (line of collimation) of the telescope must be perpendicular to the direction of gravity when the level is set up for observing. The accuracy of the results depends upon whether this requirement has been met. Although perfect adjustment is rarely obtained, accurate leveling can be obtained by keeping backsight and foresight distances about equal. In many instances, the location of bench marks can be arranged to facilitate equal distance backsights and foresights in leveling at gauging stations.

Since there are a variety of surveying instruments used in hydrological surveying in Zambia, no details of their care and adjustment is given. Instrument manufacturer's manuals and surveying books should be used for reference. An excellent manual is USGS Topographic Instructions, Leveling, Book 2, Chapters 2E1-2E5 (6).

Running levels to check datum of gauges

Since the theory of using a level is found in all surveying texts, no explanation of the theory is given in these instructions. Refer to the text books. However, it should be understood that the instrument (level) should be in adjustment and at each setup, attempt to keep equal distances between the level and all bench marks, reference points, gauges, and turning points that are sighted.

In addition to these general statements, the following procedures should be considered:

1. Prior to running the level check, locate all bench marks, gauges and reference points at the gauging station (use the field station description, if available). The levels should be started from the bench mark previously used as the initial point point if the level summary (Form H114) and appearance in the field suggests it has remained stable. Otherwise, use another bench mark that most nearly fits the requirement of stability.
2. Always use Form H102 for all your level notes. The Form H102 is designed for the "Height of Instrument" (or Height of Collimation) method of computing level notes. If you wish to use the "Rise and Fall" method, use the "Height of Instrument" column for "rises" with a plus sign, and "falls" with a minus sign. Use Figure 18 as an example.

3. Completely fill out the heading on the sheets. List all the bench marks and their known elevations on the top of the first Form H102 as shown in Figures 19 and 20. Be careful to use the correct river and station name, station number, locality, name of the party (both instrument and staff man), and the date (spell out month).
4. Remember that your level notes on Form H102 are the original field notes and are as important as discharge measurement notes. You are responsible for their legibility and accuracy. Make no erasures, cross out mistakes and write corrected figures above the crossed out figure. Your level notes will be a part of the permanent basic data for the station. Your name will show your ability to run level checks to gauges.
5. Set up the instrument at the desired location (follow the general note). Level the instrument. Care must be used in the conventional (dumpy type) spirit level to keep the bubble centered at every reading of the staff (rod). The automatic level keeps the line of sight level automatically if the instrument is approximately leveled by the circular bubble.

As a word of caution, see that the instrument tripod legs are well spread and firmly pressed into the ground, and if the setup is on a slope, it is preferable to have one leg extend up the slope. After setting, do not disturb by bumping the legs or unnecessary walking around the instrument until it is ready to be moved to the next setup.

6. The first backsight is on the bench mark that is decided upon for initial use in Step 1 above. The staff (rod) should be handled carefully and be in a vertical position when read by the instrument man. The staff man should stand back of the staff if possible and wave the top of the staff back and forth toward the instrument. The smallest staff reading is the correct reading. On a calm day, the staff can be kept vertical by balancing the staff on the bench mark, etc. Remember that the use of the level staff (rod) is as important in running accurate levels as the use of the instrument.

7. Take foresights on all bench marks, gauges, and reference points that can be sighted by the instrument. If all cannot be seen from this first setup, establish a change point (turning point) and continue on to the second setup. Never neglect running levels to any bench mark or gauge simply because it cannot be seen from the first setup.

8. Identify all the observed bench marks, gauges, etc. in the "Station" column and use "Remarks" column for added notes. See Figures 19 and 20.

9. The level circuit or traverse must always be closed back on the initial bench mark and if the error of closure is greater than 0.02 ft., the traverse must be rerun.

10. An easy way of using the "Height of Instrument" method is shown in Figures 19 and 20. This eliminates time spent in carrying the instrument to a new setup in the circuit and is especially useful where more than one setup is necessary for level checks at a gauging station. The following items should be examined in the examples:

    a. The instrument is set up, a backsight is taken on the initial bench mark, and foresights are taken on all other bench marks and gauges and change point, if needed, that can be sighted from this setup. See Part I, Figure 19. The instrument is reset by lifting, changing the tripod leg position, and releveling. Another backsight is taken to the same initial bench mark and foresights are retaken to the same bench marks, gauges, etc. used in the first setup. See Part II, Figure 19. The two elevations found for each bench mark and gauge should check within 0.02 ft., or a third check run should be made.

If all the bench marks and gauges are not visible from this first setup, the instrument is carried to the second position and the same procedure followed as at the first instrument position. See parts III and IV, Figure 19. It should be noted that the elevation of the bench mark or change point (turning point) used in the backsight in the second position is an average of the two elevations found in the first position.

b. A tape and weight, if properly used, can eliminate one or more change points (turning points) at gauging stations at bridge sites. See Figure 20. This applies when bench marks are on the bridge abutments or reference points are on the bridge rails. The tape and weight can also be used in recorder wells to measure down to the water surface from a reference point on the house floor or recorder shelf.

11. It has been found that many staff gauge plates have not been cut off by the manufacturer exactly on the marked reading. Always use the actual value when placing the bottom of the level staff on the top or bottom of the gauge. (You may have to use a steel tape or rule to obtain the actual value).

12. All staff gauges should be reset if in error by 0.03 ft. or greater. All tape and wire-weight gauges should be

reset if found in error by 0.01 ft. or greater. Levels must be rerun to all gauges reset and the time of change written in the level notes. See Parts IV and V, Figure 19.

13. Levels must always be run to the water surface near the gauge. Care must be taken to have the bottom of the staff on the water surface. This can be done in a soft location by placing the bottom of the level staff on the top of a stone or stick at the water's edge that has been pushed down until the top is exactly at the water surface.

14. The gauges must be read (time noted) before and after resetting. See Part V, Figure 20.

15. A summary and notes should be made to clearly show what you have done at each gauging station. See Figures 18 and 19.

16. Write a note to show your reasons why a gauge has become out-of-level or completely upset and estimate date of change.

17. The level note computations will be checked by a responsible person in the regional and/or central office in Lusaka.

18. Clearly indicate, with dates, old bench marks that have been destroyed and new bench marks that have been established.

19. Sample level notes to a crest-stage gauge is shown in Figure 21.

20. Levels run to a wire-weight or tape gauge are noted in Figure 20. Although these gauges are not presently being used in Zambia, the notes can be kept for future reference.

21. The following procedure should be followed in checking a wire-weight gauge by levels:

    a. Obtain elevation of check bar by sighting instrument on level staff, rule, or steel tape placed on top of check bar.

    b. Set up instrument (level) at the lowest elevation possible, obtain correct Height of Instrument (HI) by backsight on bench mark, reference point, or change point, and lower weight of wire-weight gauge until bottom of weight is on line of sight of instrument. Read wire-weight gauge dial.

    c. If wire-weight gauge dial reads differently than the HI of instrument, correct by loosening drum, and rotating drum until dial reading coincides with HI. Then tighten drum securely.

    d. Raise weight and set bottom of weight on check bar and read dial. This is the correct reading to check the gauge each week and during discharge measurements.

e. Lower weight to line of sight and recheck gauge reading with Height of Instrument.

f. The elevation of check bar found directly by levels is not always the same as the gauge reading with bottom of weight on check bar. This arises from imperfections in the gauge and the fact that the gauge should be set to read correctly at the lowest gauge height possible as described in procedure "b."

g. Obtain elevation of water surface near wire-weight gauge by instrument (level) and read gauge height from wire-weight gauge. This should be done before and after changing the dial reading of the gauge.

22. On the 1st January 1971, Zambia will go metric. This does not change these instructions although statements regarding specific English units in procedure items 9, 10a, and 12 must be changed to equivalent metric units.

ACCURACY AND SOURCES OF ERROR

An accurate gauge height record is necessary for the determination of accurate and usable stage and discharge records. The refinement of gauge readings should not be confused with accuracy of the gauge-height record. Well designed staff gauges can usually be read within two hundredths of a foot. Gauge heights at recording stations with an inside gauge can be obtained to the nearest hundredth of a foot.

The sources of error for all non-recording gauges are concerned with the gauge reader or hydrographer. The gauge reader must be adequately trained, constantly supervised, and periodically checked. Neglect or carelessness in any of these items will result in a lower quality of gauge-height record. The water level (gauge height) book should be inspected at each visit and the supervising hydrographer should always enter his gauge reading in the book, together with time of observation and his initials for identification. Previous periods of doubtful or no gauge readings should be questioned. Explanations or unusual conditions that require lengthy notes should be written by the hydrographer on Form H100. Although the accuracy of gauge heights is dependent upon the gauge reader (observer), his ability to obtain good and reliable readings to a necessary refinement is directly related to the design of the gauge and the location of the gauge in the river.

The Hydrological Branch intends to install wire-weight gauges at a few appropriate bridge sites. The gauge is operated by lowering a weight until the bottom touches the surface of the water. This is very easily seen from many feet above the water surface because the correct reading occurs when the water surface near the bottom of the weight reflects a slight deformation (it has the appearance of a slight bubble). The gauge reader then reads the gauge height on a counter on the gauge. After instruction and thorough schooling in gauge operation, the gauge reader can obtain readings that are generally correct within a hundredth of a foot, or the equivalent metric unit.

There are many designs of staff gauges and it is important to have a design that is easily read and with graduations that leave little to the estimation of the gauge reader. A highly visible vertical staff gauge used in many countries is porcelain enameled iron with black numerals and graduations on a white background, shown in Figure 22. The staff gauge presently used in Zambia is of this type but is graduated in English units at 10th foot intervals. The gauge is made in 4-foot sections, each section overlapping the next higher section by 1 foot. It is unfortunate that the graduations are in tenths of feet since the intermediate gauge heights (hundredths of feet) must be estimated. Many observers have not been trained to use decimals and they estimate gauge heights between the 10ths of feet by using fractions 1/4, 1/2, and 3/4. An observer's reading of 31-1/2 means a 3.15 foot gauge height and a fair assumption is that the observer's reading may be in error by 0.05 foot. An error in gauge height of this magnitude represents a 10 percent error in discharge at a 2-foot stage using the representative discharge rating table, Figures 54 and 55.

In contrast, some other countries use staff gauges graduated in 0.02 foot intervals which require little or no estimation. A little thought shows the fallacy of using the staff gauge graduated in tenths of feet, if accurate stage and discharge records are desired. It takes far greater training to estimate gauge heights on a poorly designed gauge than to simply read a gauge reading from a well marked staff gauge.

Metrication, including the hydrologic units used in stream gauging, begins in Zambia on 1st January 1971. The change over to the new metric unit staff gauges will take time. This can be done in two ways: 1) Use a transitional period in which both types of gauges are in use; or 2) remove the present staff gauges and immediately replace with the metric staffs. (It is obvious that all the staff gauges in Zambia cannot be replaced at one time so this statement refers to each station individually). The second method is to be preferred. It is imperative that the hydrographer should carefully instruct the observer on reading the new metric staff gauge. The numerals and graduations of the metric staff is important and Figure 23 shows a recommended design with two alternative graduations, "A" and "B". With average vision, either design can be accurately read to within 5 mm at a distance of 7 metres. Design "A" requires no estimation if read to 5 mm and personal errors owing to estimation will probably be less than 0.01 foot. In comparison to the staff gauge with graduations at 0.1 feet intervals, the gauge heights from design "A" will be correct within 2 percent of discharge from a rating similar to that in Figures 55 and 56. Any metric scale with the smallest marked divisions similar in size to the 0.1 foot graduations on the old staff gauges will be both difficult to read and be the source of probable errors 5 times as large as with design "A" and "B", Figure 23. It is recommended that the metric gauges be read to hundredths of a meter (centimeter) although gauge heights at stations with stable, sensitive controls and good measuring conditions could very well be carried to half centimeters.

The frequency of gauge readings for non-recording gauges is an important factor in the accuracy of the resultant stage and discharge records. Two readings per day is sufficient on rivers similar to the lower Kafue River. On flashy streams, two or three readings per day are needed plus additional readings during periods of rapid changes in stage, especially on the crest of rises. A crest-stage gauge is a necessity for obtaining peak stages on some streams. On most streams during the dry weather recession, once a day reading is sufficient.

The sources of error for recording gauges have been covered in the section on Water-stage recorders, pp. 15-23.

FIELD GAUGING STATION DESCRIPTION

General

The description will be in two parts, "Preliminary" and "Final". It is necessary to have specific information concerning the station recorded in the office immediately upon its establishment. This applies to all types of gauging stations, whether stage or discharge, short term or long term, and partial record or complete record. This preliminary or advanced description is placed in the current station file and will be combined later with the data entered on field form H122a (or Form H101, Figure 1) titled "Data for Field Station Description," Figures 24 and 25, and used to write the final Field Gauging Station Description on Forms H103 and H104, Figures 26 and 27. Upon completion of Forms H103 and H104, the preliminary description and data form will be placed in the gauging station back file of miscellaneous field notes. Instructions for the preparation of the two parts of the description, with examples, are given in the following notes:

Preliminary description

The data recorded in the preliminary description gives the Lusaka office station information to fill the temporary needs prior to receiving complete data.

The preliminary data should include (Figure 28):

1. Name of river basin.
2. Full station name, river, and town or physical feature of reference.
3. Date of establishment. This is the date the records start, not the date the gauge was installed.
4. Specific location.
5. Remarks.

This information has been neglected in the past and is so inadequate that it is impossible to locate some gauging stations on a map or refer them to tributaries, bridges, town, or other pertinent physical features.

Similar data should be provided for Miscellaneous discharge measurements.

Final description

The final Field Gauging Station Description is typed on Form H103 but should include sketches, Forms H105 or H106 (Figure 29), maps, and photographs.

The text should be complete and the data exact and concise as taken from the form used in collecting the data in the field. The sketch need not be exactly to scale and should include the gauge, control, bench marks, access road or trail, and all measuring sections. Two sketches may be included, one for the general location and the other an expanded scale sketch showing details in the vicinity of the gauge. These sketches need not be elaborate although they should provide general answers concerning the gauging station site. The map may be a section of a large topographic or planimetric map. Photographs are of utmost help in the analysis of basic data and should show reaches of river upstream and downstream from the gauge, controls, and measuring sections.

A revised description should be written if a major change is made in the station location, equipment, or regimen of flow.

DISCHARGE MEASUREMENTS

General

The discharge of a river is the quantity of water flowing past a cross-section of the river in a unit of time. The unit in which discharge is usually expressed in English units is cubic feet per second, or cusec. Comparably, in the metric system, the unit is cubic meters per second, or cumecs. Although these are the commonly used units of rate of flow in stream gauging, other units are used less frequently.

The procedure of measuring the cross-sectional area of a stream and the velocity of flow past the section is known as the velocity-area method of measuring discharge. The most common method of measuring the velocity is by means of a current meter. The area is determined separately by means of soundings and by measurements of the distances across the stream from an initial point on the bank to the points of sounding. The product of the velocity and area is the discharge. Less common methods are:

1. Weirs.
2. Flumes.
3. Volumetric.
4. Floats.
5. Tracers.
6. Surveys of channel dimensions and water-surface slope.

Current meter discharge measurements

Excellent instructions on the use of the current meter in making a discharge measurement are given in USGS Techniques, Book 3, Chapter A8, (3) and should be studied by all stream gaugers. USGS Water Supply Paper 888 also contains valuable instructions.

The hydrographer should compute the discharge measurement and plot it on the field rating curve sheet before leaving the gauging station. Measurements more than 5 percent off a defined curve should be checked and if still off, a check measurement should be made. On streams with badly shifting control or only fair to poor measuring conditions, substitute 10 percent for the above 5 percent limit. It is especially important to carefully compute the measurements of high floods since the whole upper end of a rating may depend upon the measurement and if there is a shift, the office staff and hydrographers should be alerted to the necessity for follow-up measurements. In planning follow-up discharge measurements, the computations and mean gauge height should be examined and checked in the office. However, on flashy streams, the decision to make additional discharge measurements may rest on the judgement of the hydrographer at the station.

Theory of method

A current-meter measurement is the summation of the products of the partial areas of the stream cross-section and their respective average velocities. The formula

$$Q = S\ (av)$$

represents the computation where "Q" is total discharge, "S" is a summation symbol, "a" is an individual partial cross-section area, and "v" is the corresponding mean velocity of the flow normal to the partial area. Therefore, the total discharge of a stream is the summation of the discharges for all the partial sections.

All current meter discharge measurements in Zambia are made by the midsection method. In this method of measurement, it is assumed that the average velocity at each location (vertical) represents the mean velocity in a partial rectangular area. The area extends horizontally from half the distance from the preceding meter location to half the distance to the next meter location, and vertically, from the water surface to sounded depth.

In Figure 30, the depths taken (d_2, d_3, d_4, d_5, ...d_n) are considered as the mean for each of the partial sections. For example, the heavily outlined partial section has a mean depth which is "d_4" and a width which is half the distance between "d_3" to "d_4" <u>plus</u> half the distance between "d_4" to "d_5". The mean velocity for the same partial section (marked by heavy outline) is the velocity obtained from the current meter placed in the vertical marked "d_4". The section at the river's edge (marked 1 in the sketch) is computed similarly; the depth may be zero, or at a vertical bank "d_n", it may be some measurable depth. The width, however, is the distance from the water's edge half way to the next vertical, or half way to "d_2" in the sketch. The velocity may or may not be zero at the water's edge but is assumed to be the mean of the partial section just described. The mid-section method of making and computing a discharge measurement eliminates the averaging of the velocities and depths to obtain the mean velocity and depth, respectively, in each partial section. The 0.6 depth setting of the current meter will give the mean velocity of the vertical (or section) for depths below 2-5 feet. For depths greater than 2.5 feet the .2-.8 depth settings of the current meter are used, the velocities for these two positions must be averaged to obtain the mean velocity in the vertical (or section).

The measuring section

The availability of a measuring section is one of the items considered in selection of a gauging station site. A current meter discharge measurement can be made by the following methods:

Wading

Boat

Bridge

Cableway

The choice of one method in favor of any other depends upon the physical conditions encountered at the river. The following characteristics of the reach of river should be considered in selecting a measuring section:

1. A straight reach with the threads of velocity parallel to each other. Measuring at a bend in the river should be avoided wherever possible.
2. Stable streambed free of large rocks, weeds, and protruding obstructions which would cause turbulence.
3. A flat streambed profile to eliminate vertical components of velocity. Avoid measuring at the upstream edge of a riffle if other sites are available.

Since it is usually not possible to satisfy all these conditions, select the best reach using these criteria and then choose the exact cross-section for measuring.

Preparation for measuring

1. String a tag-line or measuring tape for measurements made by wading, from a boat at sites without permanent marked cables, or from an unmarked bridge.
2. The line should be at right angles to the direction of flow to avoid horizontal angles in the cross-section.
3. The cableways or frequently used bridges should have neat and inconspicuous graduations painted on the cable or bridge rail. Use these markings but be sure the spacing of the marks is known.
4. Examine the cross-section and determine the spacing of the verticals. Generally use about 25 to 30 partial sections.

5. Both the velocity and cross-sectional area are being determined and a smooth cross-section and even velocity distribution will require fewer partial sections than a rough cross-section with uneven velocity distribution. Remember that the ideal measurement is one in which no partial section has in it more than 5 percent of the total discharge. In some measuring sections, this may be impractical but under most conditions, no partial section should have more than 10 percent of the total discharge in it. The correct spacing has a definite influence on the accuracy of the discharge measurement. The discharge measurement in Figure 31 had 5.2 percent of the total discharge in the partial section with the greatest discharge.
6. Equal spacing of the verticals across the entire cross-section is not recommended unless the discharge is very well distributed. Closer spacing of the verticals should be made in the areas of greatest discharge. Make the width of the partial sections less as the depths and velocities become greater.
7. Every field file should have a copy of the current rating curve if one has been drawn. Space the verticals so the discharge in each vertical is about 5 percent of the discharge from the rating curve. If a rating is not available, examine past measurements to get some idea of the magnitude of discharge for the prevailing stage.

8. After the cross-section has been selected and the spacing of the verticals (stationing) has been determined, assemble the appropriate equipment.

9. Assemble the discharge measurement note sheets, Forms H107, and H108, in the field note book. Write in the date (spell out the month) and correct name of river and location. See Figure 31.

10. Read all the gauges, note the time, and record this on the top line of Form H108. Also identify the stream bank as LB or RB (left bank or right bank, respectively, when looking downstream) and record this also on the top line with the starting time of the measurement. See Figure 31.

11. Remember to record the time periodically during the measurement. This is used to compute the mean gauge height of the discharge measurement if there is a large change in stage during the measurement. Make it a habit to record the time at every 15 to 20 minute intervals and at the end of each measurement note sheet, as well as at the beginning and end of the discharge measurement. Also record the time at intermediate places, such as at piers and before and after stoppages due to equipment repairs. Always record the time on the basis of the 24-hour day, e.g., 0810 or 1430.

12. When the measurement is completed, record the bank and time of finish. See Figure 31.

Computation of the measurement

English units

The total discharge of the measurement is the summation of the discharges for the partial sections obtained by multiplying the mean velocity times the area. Although the rating tables for the Pygmy or Price meters show the lower velocities to thousands, it is recommended that the velocity be recorded only to hundredths, regardless of the type of meter used. An exception would be measurement of total discharge of less than 1 cubic feet per second where under excellent measuring conditions the velocities might be carried to thousands.

Refinement in computation of area and discharge depends on the magnitude as follows:

Magnitude	Places
Less than 1	2 or 3 (see below)
1 or greater	3

Generally it is not justified to carry area or discharge figures below 1.00 to thousands unless the total flow is a few tenths of a cubic foot per second, the measuring conditions are very good, and the control is stable. The total discharge should be rounded to 3 significant figures above 1.00 cubic feet per second and below 1.00 to hundredths. Judgment should be used by the hydrographer in modifying the rules when necessary and the hydrologist should always be consulted.

Metric units

Use rounding and significant figure rules that are comparable to those recommended for the English units.

Making the measurement

General Procedure

After the above preparations and recommendations have been taken and understood, follow the general procedures listed below:

1. Write on the note sheet the distance from the initial point to the edge of the water and measure the depth of water at the edge and record.
2. After the depth is recorded, determine the method of setting the meter to be used. Normally this is either the 0.6 or the .2 and 0.8 method, and should be used according to Table 1. Use of the pygmy meter is not recommended for depths less than 0.3 foot. If the depths are less than 0.3 foot seek another measuring section or prepare one described in the section on wading measurement, paragraph 5. When neither the depths or cross-section can be found or altered to fit the minimum depth recommendations the pygmy meter can be used at depths less than 0.3 foot. If this is done care must be used and an understanding that the accuracy of the discharge measurement may be lowered by the shallow depth.

   The standard current meter is known to give erratic results in the zone from the water surface to 0.5 foot

Table 1

Current-meter and velocity-measurement method for various depths

Depth of water (feet)	Current Meter	Position of meter
2.5 ft. and above	Price or Watts	0.2 and 0.8
1.5 ft. to 2.5 ft.	Price or Watts	0.6
0.3 ft. to 1.5 ft.	Pygmy	0.6

Note: The pygmy meter is a shallow depth meter, not a low velocity meter. Use comparable metric units after metrication or equipment calibrated in metric units.

Table 2

Velocity-measurement method for various suspensions and depths

	Minimum depth (feet)	
Suspension 1/	0.6 method	0.2 and 0.8 method
15C.5, 30C.5	1.2	2.5
50C.55	1.4	2.8
50C.9	2.2	4.5
75C1.0, 100C1.0, 150C1.0	2.5	5.0

1/ The numerals preceding the "C" is the weight of the sounding weight, in pounds. The letter "C" represents "Columbus," which is the shape of weight that offers the least resistance to flowing water. The numerals following the "C" are the distance in feet between the bottom of the sounding weight and the center of the meter bucket wheel. For example, the 50C.55 means 1) the sounding weight is 50 pounds in weight, 2) the weight is "C" shaped in design, and 3) the current meter should be attached to the hanger bar at the ".55" marked hole or 0.55 feet above the bottom of the 50 pound sounding weight.

below the surface and Table 2 is designed to prevent using the meter in this zone. For instance, if a 50C.55 sounding weight is required because of the stream velocity the minimum depth of water in which it should be used is 1.4 feet and 2.8 feet with the 0.6 method and the 0.2 and 0.8 method, respectively.

3. Compute the setting of the meter for the particular method to be used.
4. Set the meter and allow the meter to become adjusted to velocity. Usually a few seconds is sufficient.
5. Count the revolutions for a period of 40-70 seconds. Start the stopwatch with the first click counting zero not one.
6. End the count on a convenient number given in the meter rating table.
7. Read the time to nearest second, or if the hand is on a half-second, always read to the even second.
8. Record revolutions and time on Form H108. See Figure 31.
9. When the velocity is to be observed at more than one seting (0.2 and 0.8 method), reset the meter and proceed with steps 5-8 above.
10. Move to the next vertical and repeat the above procedure.
11. When the direction of flow is not at right angles to the cross-section, find the horizontal coefficient from the Form H108. See Figure 34. Record the angle coefficient in the column at left edge of Form H108. Multiply the measured velocity by this coefficient and record in the

correct column. See Figure 31. Details and recommendations concerning specific type of current-meter measurements are described below.

Zero flow determination

The point of zero flow is the lowest point on the control and is the point at which the last flow of water past the gauge will continue down the river. It is determined by measuring the depth of water over the lowest point on the control and subtracting such a depth from the gauge height at that particular time. The measurement of depth can be made with a wading rod, or any rule or stiff tape.

The gauge height of zero flow should be determined frequently in the field and if depth of water allows, should be determined at the time of each discharge measurement at gauging stations with unstable controls.

The importance of the zero flow determination is emphasized for three general reasons: 1) the gauge height of zero flow defines a low-water extension when discharge measurements are not available; 2) It defines the gauge height at which flow ceases and can be used chronologically in the separation of flow and no flow periods; and 3) It defines shifts in the control and stage-discharge relation.

It is generally impossible to obtain a zero flow determination at gauging stations on large rivers, e.g., Kafue River at Kasaka. Zero flow can be measured in the field on most small streams, e.g., Chongwe River at Chongwe Bridge.

The points (gauge height) of zero flow should be plotted on every rating curve sheet when the discharge measurements are plotted.

Wading measurement

1. Wading measurements are preferred because it is usually easier to choose a good cross-section. Good wading sections in an alluvium channel and a rocky channel are shown in Figures 32 and 33, respectively.
2. See Table 1 for the details of determining whether to use the 0.6 or .2-.8 method with the Price, Pygmy, and Watts meters. The same recommendations should be used with the Ott meter.
3. If a Price meter is used in a cross-section with an average depth greater than 1.5 ft., do not change to a Pygmy meter for a few depths less than 1.5 feet, or vice versa.
4. Do not use either meter if velocities are less than 0.2 feet per second.
5. Prepare a cross-section to increase velocities and depths if necessary. Build earth dikes if necessary to confine flow, eliminate dead water, and increase velocity. Do not build dike between gauge and control. Carry a shovel and spend time in preparing the low-stage measuring cross-section. It is time well spent. After preparing, wait for flow to stabilize.

6. Stand in a position that least affects the velocity of the water passing the meter. Face the bank and hold the wading rod at the tagline. Stand 1 to 3 inches downstream from the tagline and 18 inches or more from the rod. In narrow channels, avoid standing in water if legs occupy a large part of cross-section. Measure from bank or bridge channel with plank.
7. Remember to keep rod vertical.
8. In a soft channel bottom, do not disturb bottom by walking near tagline and if rod sinks into mud, measure depth to surface of mud and do not let rod sink during velocity reading.
9. Measure the horizontal angles if the flow is not at right angles to the tagline.

<u>Boat measurement</u>

1. Use slack cable or tagline.
2. If there is boat traffic on the river, station man on bank to lower tagline. Place cloth streamers on tagline for traffic to see.
3. If no tagline is used, position boat by range poles or flags and obtain distance by stadia and theodolite or sextant. Hold boat in position by motor or anchor.
4. Consider the suspension of meter by using wading rod for shallow depths (under 10 feet) and low velocities.

5. Use reel and sounding weights for deep sections. See section on "Use of Sounding Reels."

6. The up and down movement of boat caused by wave action seriously affects velocity reading. Wait for calm day if too windy for good measurement.

Bridge measurement

1. Advantage of using upstream side of bridge:
    a. Flow generally more favorable.
    b. Drift can be seen.
    c. River bottom less apt to scour than at downstream side.

2. Advantages of using downstream side of bridge:
    a. Vertical angles more easily measured.
    b. Flow lines of stream straighten out by passing through opening.
    c. Drift caught on meter is more easily removed than similar collection at upstream side.

3. Choice of side of bridge to use depends upon the condition at each individual bridge.

4. Use either handline or sounding reel supported on crane. See section on "Use of sounding reels" and "Use of handline."

5. Choice of method (.6, .2-8, etc.) depends upon the conditions at the bridge. See Table 2.

6. Long bridges with many piers or multiple openings may require more than the 25 partial sections.
7. Keep meter several feet away from piers and abutment if velocities are high. Estimate velocity and depth at the the face of the piers, write "Est. 1/2 Vel. as at 32 feet" and "Est. depth 22.0 feet."
8. Use care in measuring horizontal angles around piers.
9. Use penta contact of meter for high velocities.

Cableway measurement

1. With few exceptions, sounding reels are used to measure from cableways. See section on "Use of sounding reels."
2. Use Table B in the general instructions for choice of method (.6, .2-.8) for setting the meter for velocity readings.
3. The car may oscillate for a short time after moving from one vertical to another. Wait until the oscillations are negligible.
4. Always carry side-cutting pliers. If drift is caught and can't be released, cut the sounding line before it breaks to insure safety.
5. Use the two-table method of correcting for vertical angles where river is swift and deep.

Measuring deep swift rivers. Two table method--discharge measurement

In deep swift rivers, corrections must be made for meter drifting downstream and also for horizontal angles, if occurring. The procedure is as follows:

1. Measure and record vertical distance from the water surface to the top pulley on the boom.
2. Place bottom of sounding weight at water surface and set counter to read zero.
3. Lower weight to bed of stream and read and record observed depth and vertical angle with weight entirely supported by the sounding line.
4. To obtain vertical depth of water with aid of correction table:
    a. Enter Table 3 with vertical angle and distance above water surface (vertical length) and obtain air correction--and record to nearest tenth of a foot.
    b. Subtract the air correction from the observed depth to obtain wet-line depth--and record.
    c. Enter Table 4 with vertical angle and the wet-line depth computed above to obtain water correction--and record to nearest tenth of a foot.
    d. Subtract water correction from wet-line depth to obtain vertical depth of water--and record.

    Note: If large horizontal angles occur, use Table 5 to obtain the additional degrees that should be added to the vertical angles before entering Tables 3 and 4.

5. Obtain 0.8 setting.

   a. Compute 0.2 of vertical depth and raise the meter this distance from the bottom position minus the distance between meter and bottom of weight.

   b. Check vertical angle and if changed by more than 5 degrees, use step (1) or (2) below.

      (1) If vertical angle is increased lower meter the difference between air corrections for this 0.8 depth position and sounding position (weight at bottom of river).

      (2) If decreased the meter is raised the difference between air corrections for this 0.8 depth position and sounding position.

   c. Observe and record velocity of 0.8 depth position.

6. Obtain 0.2 setting.

   a. Raise the meter until counter reads 0.2 of vertical depth plus distance between meter and bottom of weight.

   b. Check vertical angle and from Table 3 find correction by using vertical angle and the vertical length above water plus 0.2 of vertical depth, plus distance bottom of weight is below meter and lower the meter equal to this correction. Use to tenths of a foot.

   c. Observe and record velocity for the 0.2 depth position.

Table 3 —Air-correction table, giving difference, in feet, between vertical length and slant length of sounding line above water surface for selected vertical angles

Vertical length (feet)	Vertical angle of sounding line at protractor																	Vertical length (feet)
	4°	6°	8°	10°	12°	14°	16°	18°	20°	22°	24°	26°	28°	30°	32°	34°	36°	
10	0.02	0.06	0.10	0.15	0.22	0.31	0.40	0.51	0.64	0.79	0.95	1.13	1.33	1.55	1.79	2.06	2.36	10
12	.03	.07	.12	.19	.27	.37	.48	.62	.77	.94	1.14	1.35	1.59	1.86	2.15	2.47	2.83	12
14	.03	.08	.14	.22	.31	.43	.56	.72	.90	1.10	1.32	1.58	1.86	2.17	2.51	2.89	3.30	14
16	.04	.09	.16	.25	.36	.49	.64	.82	1.03	1.26	1.51	1.80	2.12	2.48	2.87	3.30	3.78	16
18	.04	.10	.18	.28	.40	.55	.73	.93	1.16	1.41	1.70	2.03	2.39	2.78	3.23	3.71	4.25	18
20	.05	.11	.20	.31	.45	.61	.81	1.03	1.28	1.57	1.89	2.25	2.65	3.09	3.58	4.12	4.72	20
22	.05	.12	.22	.34	.49	.67	.89	1.13	1.41	1.73	2.08	2.48	2.92	3.40	3.94	4.54	5.19	22
24	.06	.13	.24	.37	.54	.73	.97	1.24	1.54	1.88	2.27	2.70	3.18	3.71	4.30	4.95	5.67	24
26	.06	.14	.26	.40	.58	.80	1.05	1.34	1.67	2.04	2.46	2.93	3.45	4.02	4.66	5.36	6.14	26
28	.07	.15	.28	.43	.63	.86	1.13	1.44	1.80	2.20	2.65	3.15	3.71	4.33	5.02	5.77	6.61	28
30	.07	.17	.29	.46	.67	.92	1.21	1.54	1.93	2.36	2.84	3.38	3.98	4.64	5.38	6.19	7.08	30
32	.08	.18	.31	.49	.71	.98	1.29	1.65	2.05	2.51	3.03	3.60	4.24	4.95	5.73	6.60	7.55	32
34	.08	.19	.33	.52	.76	1.04	1.37	1.75	2.18	2.67	3.22	3.83	4.51	5.26	6.09	7.01	8.03	34
36	.09	.20	.35	.56	.80	1.10	1.45	1.85	2.31	2.83	3.41	4.05	4.77	5.57	6.45	7.42	8.50	36
38	.09	.21	.37	.59	.85	1.16	1.53	1.96	2.44	2.98	3.60	4.28	5.04	5.88	6.81	7.84	8.97	38
40	.10	.22	.39	.62	.89	1.22	1.61	2.06	2.57	3.14	3.79	4.50	5.30	6.19	7.17	8.25	9.44	40
42	.10	.23	.41	.65	.94	1.29	1.69	2.16	2.70	3.30	3.97	4.73	5.57	6.50	7.53	8.66	9.91	42
44	.11	.24	.43	.68	.98	1.35	1.77	2.26	2.82	3.46	4.16	4.95	5.83	6.81	7.88	9.07	10.39	44
46	.11	.25	.45	.71	1.03	1.41	1.85	2.37	2.95	3.61	4.35	5.18	6.10	7.12	8.24	9.49	10.86	46
48	.12	.26	.47	.74	1.07	1.47	1.93	2.47	3.08	3.77	4.54	5.40	6.36	7.43	8.60	9.90	11.33	48
50	.12	.28	.49	.77	1.12	1.53	2.02	2.57	3.21	3.93	4.73	5.63	6.63	7.74	8.96	10.31	11.80	50
52	.13	.29	.51	.80	1.16	1.59	2.10	2.68	3.34	4.08	4.92	5.86	6.89	8.04	9.32	10.72	12.28	52
54	.13	.30	.53	.83	1.21	1.65	2.18	2.78	3.47	4.24	5.11	6.08	7.16	8.35	9.68	11.14	12.75	54
56	.14	.31	.55	.86	1.25	1.71	2.26	2.88	3.59	4.40	5.30	6.31	7.42	8.66	10.03	11.55	13.22	56
58	.14	.32	.57	.89	1.30	1.78	2.34	2.98	3.72	4.55	5.49	6.53	7.69	8.97	10.39	11.96	13.69	58
60	.15	.33	.59	.93	1.34	1.84	2.42	3.09	3.85	4.71	5.68	6.76	7.95	9.28	10.75	12.37	14.16	60
62	.15	.34	.61	.96	1.39	1.90	2.50	3.19	3.98	4.87	5.87	6.98	8.22	9.59	11.11	12.79	14.64	62
64	.16	.35	.63	.99	1.43	1.96	2.58	3.29	4.11	5.03	6.06	7.21	8.48	9.90	11.47	13.20	15.11	64
66	.16	.36	.65	1.02	1.47	2.02	2.66	3.40	4.24	5.18	6.25	7.43	8.75	10.21	11.83	13.61	15.58	66
68	.17	.37	.67	1.05	1.52	2.08	2.74	3.50	4.36	5.34	6.44	7.66	9.01	10.52	12.18	14.02	16.05	68
70	.17	.39	.69	1.08	1.56	2.14	2.82	3.60	4.49	5.50	6.62	7.88	9.28	10.83	12.54	14.44	16.52	70
72	.18	.40	.71	1.11	1.61	2.20	2.90	3.71	4.62	5.65	6.81	8.11	9.55	11.14	12.90	14.85	17.00	72
74	.18	.41	.73	1.14	1.65	2.27	2.98	3.81	4.75	5.81	7.00	8.33	9.81	11.45	13.26	15.26	17.47	74
76	.19	.42	.75	1.17	1.70	2.33	3.06	3.91	4.88	5.97	7.19	8.56	10.08	11.76	13.62	15.67	17.94	76
78	.19	.43	.77	1.20	1.74	2.39	3.14	4.01	5.01	6.13	7.38	8.78	10.34	12.07	13.98	16.09	18.41	78
80	.20	.44	.79	1.23	1.79	2.45	3.22	4.12	5.13	6.28	7.57	9.01	10.61	12.38	14.33	16.50	18.89	80
82	.20	.45	.81	1.27	1.83	2.51	3.30	4.22	5.26	6.44	7.76	9.23	10.87	12.69	14.69	16.91	19.36	82
84	.20	.46	.83	1.30	1.88	2.57	3.39	4.32	5.39	6.60	7.95	9.46	11.14	12.99	15.05	17.32	19.83	84
86	.21	.47	.85	1.33	1.92	2.63	3.47	4.43	5.52	6.75	8.14	9.68	11.40	13.30	15.41	17.73	20.30	86
88	.21	.48	.87	1.36	1.97	2.69	3.55	4.53	5.65	6.91	8.33	9.91	11.67	13.61	15.77	18.15	20.77	88
90	.22	.50	.88	1.39	2.01	2.75	3.63	4.63	5.78	7.07	8.52	10.13	11.93	13.92	16.13	18.56	21.25	90
92	.22	.51	.90	1.42	2.06	2.82	3.71	4.73	5.90	7.22	8.71	10.36	12.20	14.23	16.48	18.97	21.72	92
94	.23	.52	.92	1.45	2.10	2.88	3.79	4.84	6.03	7.38	8.90	10.58	12.46	14.54	16.84	19.38	22.19	94
96	.23	.53	.94	1.48	2.14	2.94	3.87	4.94	6.16	7.54	9.09	10.81	12.73	14.86	17.20	19.80	22.66	96
98	.24	.54	.96	1.51	2.19	3.00	3.96	5.04	6.29	7.70	9.27	11.08	12.90	15.16	17.56	20.21	23.13	98
100	.24	.55	.98	1.54	2.23	3.06	4.08	5.15	6.42	7.86	9.46	11.28	13.26	15.47	17.92	20.62	23.61	100

Table 4 —Wet-line table, giving difference, in feet, between wet-line length and vertical depth for selected vertical angles

Wet-line length, in feet	Vertical angle of sounding line at protractor																	Wet-line length, in feet
	4°	6°	8°	10°	12°	14°	16°	18°	20°	22°	24°	26°	28°	30°	32°	34°	36°	
10	0.01	0.02	0.03	0.05	0.07	0.10	0.13	0.16	0.20	0.25	0.30	0.35	0.41	0.47	0.54	0.62	0.70	10
12	.01	.02	.04	.06	.09	.12	.15	.20	.24	.30	.36	.42	.49	.57	.65	.74	.84	12
14	.01	.02	.04	.07	.10	.14	.18	.23	.29	.35	.41	.49	.57	.66	.76	.87	.98	14
16	.01	.03	.05	.08	.12	.16	.20	.26	.33	.40	.47	.56	.65	.76	.87	.99	1.12	16
18	.01	.03	.06	.09	.13	.18	.23	.30	.37	.45	.53	.63	.73	.85	.98	1.12	1.26	18
20	.01	.03	.06	.10	.14	.20	.26	.33	.41	.50	.59	.70	.82	.94	1.09	1.24	1.40	20
22	.01	.04	.07	.11	.16	.22	.28	.36	.45	.55	.65	.77	.90	1.04	1.20	1.36	1.54	22
24	.01	.04	.08	.12	.17	.24	.31	.39	.49	.60	.71	.84	.98	1.13	1.31	1.49	1.68	24
26	.02	.04	.08	.13	.19	.25	.33	.43	.53	.64	.77	.91	1.06	1.23	1.41	1.61	1.81	26
28	.02	.04	.09	.14	.20	.27	.36	.46	.57	.69	.83	.98	1.14	1.32	1.52	1.74	1.95	28
30	.02	.05	.10	.15	.22	.29	.38	.49	.61	.74	.89	1.05	1.22	1.42	1.63	1.86	2.09	30
32	.02	.05	.10	.16	.23	.31	.41	.52	.65	.79	.95	1.12	1.31	1.51	1.74	1.98	2.23	32
34	.02	.05	.11	.17	.24	.33	.44	.56	.69	.84	1.01	1.19	1.39	1.60	1.85	2.11	2.37	34
36	.02	.06	.12	.18	.26	.35	.46	.59	.73	.89	1.07	1.26	1.47	1.70	1.96	2.23	2.51	36
38	.02	.06	.12	.19	.27	.37	.49	.62	.78	.94	1.12	1.33	1.55	1.79	2.07	2.36	2.65	38
40	.02	.06	.13	.20	.29	.39	.51	.66	.82	.99	1.18	1.40	1.63	1.89	2.18	2.48	2.79	40
42	.03	.07	.13	.21	.30	.41	.54	.69	.86	1.04	1.24	1.47	1.71	1.98	2.28	2.60	2.93	42
44	.03	.07	.14	.22	.32	.43	.56	.72	.90	1.09	1.30	1.54	1.80	2.08	2.39	2.73	3.07	44
46	.03	.07	.15	.23	.33	.45	.59	.75	.94	1.14	1.36	1.61	1.88	2.17	2.50	2.85	3.21	46
48	.03	.08	.15	.24	.35	.47	.61	.79	.98	1.19	1.42	1.68	1.96	2.27	2.61	2.98	3.35	48
50	.03	.08	.16	.25	.36	.49	.64	.82	1.02	1.24	1.48	1.75	2.04	2.36	2.72	3.10	3.49	50
52	.03	.08	.17	.26	.37	.51	.67	.85	1.06	1.29	1.54	1.82	2.12	2.45	2.83	3.22	3.63	52
54	.03	.09	.17	.27	.39	.53	.69	.89	1.10	1.34	1.60	1.89	2.20	2.55	2.94	3.35	3.77	54
56	.03	.09	.18	.28	.40	.55	.72	.92	1.14	1.39	1.66	1.96	2.28	2.64	3.05	3.47	3.91	56
58	.03	.09	.19	.29	.42	.57	.74	.95	1.18	1.44	1.72	2.03	2.37	2.74	3.16	3.60	4.05	58
60	.04	.10	.19	.30	.43	.59	.77	.98	1.22	1.49	1.78	2.10	2.45	2.83	3.26	3.72	4.19	60
62	.04	.10	.20	.31	.45	.61	.79	1.02	1.26	1.54	1.84	2.17	2.53	2.93	3.37	3.84	4.33	62
64	.04	.10	.20	.32	.46	.63	.82	1.05	1.31	1.59	1.89	2.24	2.61	3.02	3.48	3.97	4.47	64
66	.04	.11	.21	.33	.48	.65	.84	1.08	1.35	1.64	1.95	2.31	2.69	3.12	3.59	4.09	4.61	66
68	.04	.11	.22	.34	.49	.67	.87	1.12	1.39	1.69	2.01	2.38	2.77	3.21	3.70	4.22	4.75	68
70	.04	.11	.22	.35	.50	.69	.90	1.15	1.43	1.74	2.07	2.45	2.86	3.30	3.81	4.34	4.89	70
72	.04	.12	.23	.36	.52	.71	.92	1.18	1.47	1.79	2.13	2.52	2.94	3.40	3.92	4.46	5.03	72
74	.04	.12	.24	.37	.53	.73	.95	1.21	1.51	1.84	2.19	2.59	3.02	3.49	4.03	4.59	5.17	74
76	.05	.12	.24	.38	.55	.74	.97	1.25	1.55	1.88	2.25	2.66	3.10	3.59	4.13	4.71	5.30	76
78	.05	.12	.25	.39	.56	.76	1.00	1.28	1.59	1.93	2.31	2.73	3.18	3.68	4.24	4.84	5.44	78
80	.05	.13	.25	.40	.58	.78	1.02	1.31	1.63	1.98	2.37	2.80	3.26	3.78	4.35	4.96	5.58	80
82	.05	.13	.26	.41	.59	.80	1.05	1.34	1.67	2.03	2.43	2.87	3.35	3.87	4.46	5.08	5.72	82
84	.05	.13	.27	.42	.60	.82	1.08	1.38	1.71	2.08	2.49	2.94	3.43	3.96	4.57	5.21	5.86	84
86	.05	.14	.28	.43	.62	.84	1.10	1.41	1.75	2.13	2.55	3.01	3.51	4.06	4.68	5.33	6.00	86
88	.05	.14	.28	.44	.63	.86	1.13	1.44	1.80	2.18	2.60	3.08	3.59	4.15	4.79	5.46	6.14	88
90	.05	.14	.29	.45	.65	.88	1.15	1.48	1.84	2.23	2.66	3.15	3.67	4.25	4.90	5.58	6.28	90
92	.06	.15	.29	.46	.66	.90	1.18	1.51	1.88	2.28	2.72	3.22	3.75	4.34	5.00	5.70	6.42	92
94	.06	.15	.30	.47	.68	.92	1.20	1.54	1.92	2.33	2.78	3.29	3.84	4.44	5.11	5.83	6.56	94
96	.06	.15	.31	.48	.69	.94	1.23	1.57	1.96	2.38	2.84	3.36	3.92	4.53	5.22	5.95	6.70	96
98	.06	.16	.31	.49	.71	.96	1.25	1.61	2.00	2.43	2.90	3.43	4.00	4.63	5.33	6.08	6.84	98
100	.06	.16	.32	.50	.72	.98	1.28	1.64	2.04	2.48	2.96	3.50	4.08	4.72	5.44	6.20	6.98	100

Table 5 —Degrees to be added to observed angles to obtain actual vertical angles

Observed vertical angle	Horizontal angle					
	8° cos=0.99	12° cos=0.98	16° cos=0.96	20° cos=0.94	24° cos=0.91	28° cos=0.88
8°	0.1	0.2	0.3	0.5	0.8	1.0
12°	.1	.3	.5	.8	1.1	1.5
16°	.1	.4	.6	1.0	1.4	2.0
20°	.2	.4	.7	1.2	1.7	2.4
24°	.2	.5	.8	1.4	2.0	2.8
28°	.2	.5	1.0	1.5	2.2	3.0
32°	.2	.6	1.0	1.6	2.4	3.3
36°	.2	.6	1.1	1.7	2.5	3.4

7. See Figure 35 for sample computation.

8. Complete theory and explanation of the two table method is given in USGS Techniques, Book 3, Chapter A8, pp. 47-53 (8).

Use of sounding reels

The Watts sounding reel has a counter for obtaining depths which can only be reset to zero. Some U.S.G.S. sounding reels have depths counters and others have computing depth indicators. Both types can be set to any desired numeral including zero. This is a decided advantage since the sounding line can be tagged a known distance above the center of the meter cups and the counter set to this reading. The tags can be cloth streamers of different colors, for example, red at 10 foot and blue at 20 feet, etc. In deep swift rivers, a tag is set at the water surface and the depth indicator is set to read that particular depth. Then the sounding weight is lowered to the bottom of the river. This procedure essentially places the reel at the water surface which eliminates the air corrections in Table 3. Keeping the meter below the surface is also helpful during debris laden floods.

The computing depth indicator is used in the following manner:

1. Set the indicator to zero when the center of the meter cups is at the water surface.

2. Lower the sounding weight and meter until the weight touches the bottom of the river.
3. Add to the indicator reading the distance that the bottom of the sounding weight is below the middle of the meter. This distance is the one obtained from the first column in Table 2, for example, .5, .55, .9 or 1.0 feet.
4. The 0.8 depth position is set by raising the weight and meter until the indicator hand is over the depth mark.
5. The 0.2 depth position is set by raising the weight and meter until the hand on the indicator points to two tenths of the depth on the main dial.

Mean gauge height of discharge measurement

The mean gauge height of a discharge measurement is the mean height of the stream during the period the measurement was made.

Both the mean gauge height and the discharge are used in plotting the discharge measurement on graph paper (rating curve form) to establish the stage-discharge relationship, commonly known as the rating curve. Consequently, an accurate determination of the mean gauge height is as important as an accurate measurement of discharge.

The computation of the mean gauge height presents no problem when the change in stage is small (generally less than 0.1 foot) because the mean may be obtained by inspection. For example, rivers that are slow to change in stage, such as the Kafue River at Kasaka, the mean gauge height is obtained by inspection or by averaging the gauge heights at the beginning and end of the measurement.

However, discharge measurements must also be made on flashy streams during floods, when the change in stage during the measurement may be large. The sample discharge measurement in Figure 31 shows a gauge height change from 3.11 feet at the start to 3.48 feet at the end. Since this discharge measurement was made over a flood crest, it is necessary to obtain intermediate gauge heights in order to define the stage hydrograph during the measurement. As previously explained, every hydrographer should record the time of start and finish of the discharge measurement and at intermediate times during the measurement. At recording stations, the gauge heights for these intermediate times can be picked off the recorder chart but at non-recording gauges, the gauge must be actually read or estimated from a graph based on gauge readings. In the sample, Figure 31, the gauge was read at hours 0805, 0830, 0910, 0940, and 1020, in order to define the stage hydrograph.

If the change in stage is large (generally over 0.1 foot), the mean gauge height is obtained by weighting the gauge-heights rather than by inspection.

Figure 36 shows two methods of weighting the gauge heights, graphical and arithmetic. In either method, a gauge height graph as shown on the upper left curve of the figure.

The arithmetic computation of the mean gauge height for the sample discharge measurement in Figure 31 is shown on the Form H108 at the bottom of Figure 36. Some of the gauge heights are taken from the graph because the gauge was not read at the same time as noted in the discharge measurement notes. For example, the time noted at the bottom of sheet No. 2 is hour 0900, whereas the gauge reading of 3.50 feet was made at hour 0910. Consequently, the gauge height of 3.47 feet was obtained from the graph.

The lower part of Form H108, Figure 36, presents the shortcut method which eliminates multiplication of large numbers. The results of the computation are the same for both methods.

The curve in the upper right of Figure 36 shows the graphical method for obtaining the weighted mean gauge height. A cumulative sum of the partial discharges is obtained for each recorded hour in the measurement. For example, at hour 0900 the cumulative sum is 40.8 cusecs. The curve is plotted as follows:

1. The vertical gauge height scale is the same as that used for the gauge height graph.
2. Establish a reasonable discharge scale on the horizontal axis of the graph paper slightly to the right of the gauge height graph.
3. Enter the gauge height graph at the hour the discharge measurement was started (hour 0810 in the sample) and follow down to the intersection with the gauge height graph at A. This is the gauge height at the start of

the measurement. Plot a point opposite this gauge height on the discharge scale at B (zero discharge for the start).

4. Enter at hour 0830 and follow down to C, then across to D (16.7 cusecs) and plot a point. Continue plotting until the end of the measurement is reached at hour 1015 and discharge 81.8 cusecs.
5. Connect the plotted points B, D, F, H and J with a series of straight lines.
6. Connect the centers of the adjacent segments with straight lines. This is done successively until one final connecting line a-b is drawn, the center of which defines the weighted mean gauge height of 3.44 feet.
7. If there is an odd number of segments to the gauge height-discharge graph, the centers of first two segments are connected, then the center of this connecting line is connected to the center of the third segment, etc., until all segments have been connected and the weighted mean gauge height is obtained.

Channel storage correction

If the discharge is measured at a distance from the control during a change in stage, the discharge passing the control during the measurement will not be the same as the measured discharge. This difference is caused by the effects of channel storage between the control and the measuring section. Although the channel storage is negligible if there is little change in stage, the effect may be appreciable during a large change in stage and a channel storage adjustment must be used to adjust the measured discharge. As a general rule, do not apply this adjustment unless the total discharge of the measurement is changed by 3 percent or more.

Adjustment is made for channel storage by applying to the measured discharge a quantity (discharge) obtained by multiplying the water surface area by the average rate of change in stage in the reach. The method of computation is as follows:

1. Calculate or estimate, if necessary, the distance (length of reach) between the measuring section and the control. Use a map, vehicle speedometer, or pacing to obtain the distance in feet.
2. Calculate the average width of the channel in the reach. Use a map to scale off the width or directly measure a few widths of channel in the field to assist in computing the average for the reach.
3. If a large scale map is available, the surface area can be determined directly by a planimeter.
4. Calculate the average change in stage in the reach from the change in stage obtained at each end of the reach. Use the change in gauge height for the end at the control and set a temporary gauge or point at the measuring section. This temporary point need not be elaborate but a tree, post, staff gauge plate, or mark on a bridge rail can be used. Set a mark at the start and finish

of the discharge measurement and the difference measured by a tape or rule will be the change in stage.

5. The average rate of change in stage is the change computed in step 4 above divided by the elapsed time during the measurement.

Figure 37 is the front sheet of a discharge measurement that is affected by channel storage and needs an adjustment. This measurement was made 0.8 mile downstream from the control and the sample computation follows:

1. Length of reach is 0.8 x 5280 = 4224 feet.
2. Average width of channel = 200 feet.
3. The gauge height change at gauge during the measurement = 0.46 foot. Gauge height change at measurement site during the measurement 0.36 foot.

   Average change in stage = (0.46 + 0.36) ÷ 2 = 0.41 foot.
4. The measurement was completed in 1 hour 10 minutes = 70 minutes.
5. The volume of water going into storage is 4224 x 200 x 0.41 = 346,368 cu. ft.
6. The elapsed time of the measurement is 70 x 60 = 4200 seconds.
7. The average rate of water going into storage in cusecs (discharge) $= \frac{346,368}{4200} =$ 82.5 cusecs.

Since this discharge measurement was made downstream from the control and the stage was rising (water going into storage), the 82.5 cusecs must be added to the measured discharge. What it means is that 82.5 cusecs of the discharge passing the control did not reach the measuring section but was used in raising the stage 0.41 foot in the reach of river between the control and the measuring section. On a falling stage, the water would have come out of storage and the measured discharge would have been larger than that passing the control. If this was the case, the storage correction of 82.5 cusecs would have to be subtracted from the measured discharge.

Had the discharge measurement of Figure 37 been made upstream from the control and on a rising stage, the channel storage adjustment must be subtracted from the measured discharge, whereas on a falling stage, a similar adjustment must be added. Detailed analysis is given in USGS Techniques, Book 3, Chapter A8, pp. 54-56 (8). This is not a difficult adjustment to understand or compute and every Technical Officer and hydrographer should know its application. Draw a sketch to help to visualize how the water is going into or coming out of storage.

Time of travel adjustment

It is possible to adjust the mean gauge height of a discharge measurement for the travel time of a flood wave between the control and the measuring section. The time of travel of a flood wave is assumed as 1.3 times the mean velocity for the discharge measurement.

It is necessary to calculate the distance between the control and the measuring section. The time of travel of the flood wave is the length of reach divided by product of 1.3 and the mean velocity of the measurement.

This time adjustment is added or subtracted from the recorded times on the measurement notes as follows:

1. The time of travel adjustment is subtracted from the observed time at the gauge if the measurement is made either below the gauge on a rising stage or above the gauge on a falling stage.
2. The time-of-travel adjustment is added to the observed time at the gauge if the measurement is made either below the gauge on a falling stage or above the gauge on a rising stage.
3. The sample computation from Figure 37 is as follows:

   Velocity of a flood wave = 1.3 x mean velocity

   L = Length of reach = 0.8 x 5280 = 4224 feet.

   V = 4.06 feet per second (Mean velocity of the discharge measurement)

   $$\text{Time of travel} = \frac{4225}{1.3 \times 4.06} = \frac{4224}{5.28} = 800 \text{ seconds}$$

   $$\frac{800}{60} \text{ sec} = 13 \text{ minutes time adjustment}$$

This measurement was made below the gauge on a rising stage and the 13 minute time adjustment must be subtracted from the time at the gauge. This means that a graph of gauge heights must be plotted and the gauge heights for the adjusted times must be picked from the graph. Figure 37 shows a copy of the front sheet and graph of gauge heights that are used in the computations.

Either the channel storage method or the time-of-travel method is used, although generally the channel storage correction will give the most accurate results.

INSTRUCTIONS FOR THE

PREPARATION OF GAUGING STATION RECORDS

INTRODUCTION

These instructions pertain to the preparation of streamflow records either in the Lusaka office or in any regional or provincial office of the Hydrological Branch. The instructions, which are divided into three general sections, 1) Basic Field Data, 2) Ratings, and 3) Discharge Computations, have been written to provide consistent, logical, and scientific methods for conversion of basic surface water basic data to accurate and usable data.

Examples have been provided to illustrate the explanations in the text. Alternate methods and ideas are occasionally provided because the outdoor laboratory of stream gauging is notorious for the variety of conditions.

Basic data (see "Definitions" section) must be properly identified in both time and place, otherwise they lose value. In the proper interpretation, basic data includes gauging station records, both stage (water level) and discharge, partial records, such as low flow or high flow, and miscellaneous discharge measurements.

Since the instructions concerning the collection of surface water basic data are in the section "Instructions for the Field Collection of Surface Water Basic Data," it is assumed that field data and notes are available for the station data analysis and have been collected by the recommended methods. Quite often the hydrologist must use greater ingenuity and understanding in analyzing meager and poor field data than with those rated excellent.

The methods of filing the data processed in the office are contained in this section although an explanation of a workable and efficient office filing system is outlined in the section "Office Filing System for Surface Water Basic Data and Records." All professional and technical personnel should be aware of the importance of systematic recording and filing of the basic data and records.

ANALYSIS OF STREAMFLOW RECORDS

General

The necessity for writing and recording clearcut and consistent analyses of all basic streamflow records must be emphasized and a detailed discussion follows.

The written gauging station analysis contains a description of all the factors that determine the manner in which the record was computed as well as the reason for any procedure that was followed. The analysis is analogous to the scientific report a consultant would submit concerning an investigation of a proposed scheme or project.

It is absolutely necessary to carefully prepare the written analysis of streamflow basic data in a uniform format for each station year of record for two reasons: 1) Preparation of a written analysis in a prescribed format requires the hydrologist to sort out the basic data in a scientific and orderly manner. It helps him to remember all pertinent information and not fall into careless and slovenly habits of thought, and 2) it presents in a chronological sequence the basic data, procedures, and reasons concerning the station records in a way that can be reviewed, understood, and checked for both the current and past years.

The analyses for Kafue River at Kasaka for water years 1967 and 1968, pp. 164-167, have been written to show a practical application of the instructions to the records for a discharge station. The analysis for a stage station, which is illustrated on pp.168,169, will be shorter, because the Rating and Discharge paragraphs are unnecessary, and for some stage stations, the Remarks paragraph is also eliminated.

Since the caliber of station records depends upon consistently complete analyses, it is recommended that the following arrangement and description of methods be used for all reports that contain analyses of station records. These instructions should be used as a guide although many details will change because of the unlimited variety of the streamflow characteristics of natural channels.

Contents and description of the station analysis

Equipment

A short statement of the type of installation should be given such as "Water-stage recorder with integral float-tape gauge in standard half-length metal shelter over a 24-in. corrugated metal pipe in well on right bank," or "Staff gauge fastened to tree on left bank." In the second sentence, describe the various types of gauges available such as "Inside and outside staff gauges available for reference," or "Tape-and-weight gauge and type A wire-weight gauge available for reference." Describe the type and location of structure available for high-water measurements. Give the type of artificial control following this statement if one exists. Report any major changes in equipment that have a bearing on the accuracy of the records, such as a recorder replacing a staff gauge or a new cableway erected to provide a better measuring section, together with the date on which the change took place. If no change in equipment was made during the year, it will be sufficient to say, "No change." Repairs that do not affect the gauge-height record or stage-discharge relation, such as painting, replacing walkways, repairing doors, etc., need not be mentioned in the station analysis.

Gauge-height Record

Under this heading give the type of water-stage recorder and its gauge-height ratio. Identify the base reference gauge. Discuss the continuity, reliability, and accuracy of the gauge-height record. If the gauge-heights for certain periods are determined from a graph based on gauge readings or are estimated or interpolated, so indicate. List all periods of missing record with a brief explanation. If large instrumental errors of time or gauge height affected the record, they should be briefly discussed.

Datum Corrections

Prepare a summary statement regarding the levels run during the year, giving the date of the levels, the reference marks to which the levels are referred, and the magnitude of the errors found in the setting of the gauges. Then give the hydrologist's conclusions, stating whether or not any changes in the gauge were necessary or made and the reasons for them. Also prepare a similar statement for levels run before or after the water year, if they are used in connection with the datum corrections for the year in question. If no corrections were necessary, so state with the reason. Following are some examples of level check statements:

Levels of 20th October, 1965, by C. R. Brickhill from B.M. No. 1 (elev. 23.84 ft., gauge datum) found B.M. No. 2 at elevation 25.43 ft. gauge datum and the new staff gauge as follows:

Section 8-21	0.005 ft. low (reads 0.005 ft. high)
Section 20-33	0.005 ft. low (reads 0.005 ft. high)

These sections were established on 15th October, 1965, and no changes made to the gauge at time of levels. Water level found at 13.44 ft. at hour 1120 by level and the gauge read 13.45 ft. at water level at same time.

No levels run during year. Gauge heights, referred to outside staff gauge, were used as recorded.

Rating

This part of the analysis should begin with a paragraph that describes the channel conditions affecting the rating and should be in sufficient detail to orient a person who is unfamiliar with the station. This statement is reviewed each year and revised to fit current conditions. Include the following items and describe their effect on the rating:

1. Channel width and bed material.
2. Distances upstream and downstream to curves in channel or other pertinent features.
3. Location and type of material of control.
4. Height of channel banks, type of vegetation on banks, and their relation to overflow during periods of flood flow.

5. Any condition or feature that may cause abnormal fluctuation in discharge.

In the remainder of this section include a discussion of the following:

1. Number and type of discharge measurements and observations of no flow.
2. Trend of plotting of measurements with respect to rating curve.
3. Reasons for changing ratings.
4. Basis for development and accuracy of ratings.
5. Periods of use and identification of ratings.
6. Reliability of measurements and reasons for weighting or disregarding any.

Discharge

This section of the analysis discusses the methods used to compute discharges. Explain the distribution of shifts with special emphasis on unusual procedures or diagrams used. Discuss the determination of discharge for periods of doubtful, fragmentary, or missing gauge-height record, backwater, or other special conditions. Refer to hydrographic comparisons and any special devices or methods used in the determination.

Remarks

The first statement in this section pertains to the accuracy rating of the daily discharges. "Excellent" indicates that, in general, the error in the daily records is believed to be less than 5 percent; "good," less than ten percent; "fair," less than 15 percent; and "poor," probably more than 15 percent. These accuracy ratings do not refer to stage stations. Under some conditions the accuracy of the computed discharge may be questionable and of doubtful or of low quality. If this is the case periods of no gauge-height record, high water, low water, backwater, shifting control, or other unusual conditions are often given a lower accuracy rating than those computed directly from a well defined segment of the rating curve. Usually this section includes the statements that are in the "Remarks" paragraph of the manuscript and station description. Information included is as follows:

1. Amount and type of diversions for irrigation above the station.
2. Upstream reservoirs that affect the record, including month and year of establishment if there has been any change subsequent to the start of the record.
3. Flow which bypasses station.
4. Supplemental records pertinent to the station.
5. Credit to another agency which furnishes a portion of the data.

6. Any other condition or fact pertinent to the record.

Signature and Date

Following the "Remarks" paragraph and on separate lines, show the name of the hydrologist writing the analysis and the date of its completion. If more than one hydrologist worked on the analysis, the name of each concerned is to be shown. (This also refers to the hydrologist that checks the analysis).

Summary

The Station Analysis is the only permanent record of the methods used in computing the record. It is rewritten each year and consists of six principal parts:

1. Equipment.--A brief description of the station and its equipment.
2. Gauge-height record.--A discussion of the continuity and accuracy of the gauge-height record.
3. Datum corrections.--A discussion of any levels run during the year and resulting datum corrections.
4. Rating.--A brief discussion of channel and control conditions at the gauge followed by a discussion of the reasoning in determining the rating curves and tables used during the year.
5. Discharge.--A discussion of how discharge was determined during periods when the stage-discharge relation is affected by unusual conditions.

6. Remarks.--Make a statement in regard to the general accuracy of the records; include reference to any regulation, diversions, bypass flow, or supplemental records pertinent to the record.

The hydrologist who writes and checks the analysis affixes his name and the date at the bottom of the analysis. It should be remembered that a comprehensive station analysis can eliminate the need for a large amount of re-analysis in future years.

PREPARATION OF BASIC FIELD DATA

General

Many new field forms for the recording of streamflow data have been designed, printed, and placed in use. The reasons for the new forms are:

1. New methods of computation required different layout of forms.
2. Looseleaf forms are necessary for efficient filing and retrieval of basic data. Formerly the original notes were recorded in bound notebooks and copied at least twice. The original notes could not be found and used for study and examination during analysis.
3. The accumulation of basic field data year after year requires more compact filing. Use of 5" x 8" form size greatly reduces the space requirement.

4. The original notes must be filed by gauging station for ease in use in analyses. The size of the form should conform to available file size, i.e., 5" x 8".
5. The new forms are made for a small notebook and designed for a one man use in the field.
6. The smaller size forms are efficient and easy to use in the office. They take up only a fraction of the space on the desk as compared to the foolscap size sheet.

The observer's gauge height (water level) book has not been redesigned although it is bulky and inefficient. However, a suggested size is 10" x 8", which can be folded and filed in a 5" x 8" drawer. This problem should be examined critically in the future.

Check-in of incoming field data

All incoming field data must be promptly checked in by the designated officer. The record book should give a visual daily check of all gauge readings, recorder charts, level notes, discharge measurements and miscellaneous field notes. Figure 38, which is shown at 1/2 scale, illustrates an excellent type of record book. The time sequence of all the data or lack of data can be seen at a glance since the actual size sheet is 11" x 21".

The review of the incoming field data is necessary to prevent regression in field work by both gauge readers and hydrographers.

Constant supervision is a must since the accuracy of the discharge and stage records is dependent upon all the basic field data collection system. One serious fault which appears on both the old and new forms is the wasteful use of space at the top by an enlarged and widely spaced title. The form is for utilitarian use and much needed space has been wasted. This should be rectified at the next printing of forms.

The following procedure for dealing with incoming streamflow basic data has been initiated in the Lusaka office of the Hydrological Branch:

1. All incoming field data will be sent to the officer-in-charge of the computing section, irrespective of whether the data is sent by mail or brought in by hand. This data includes observer's gauge height records, recorder charts, discharge measurements, level notes, miscellaneous field notes, station descriptions and maps. This officer will have general responsibility for seeing the data is dealt with in an efficient and orderly manner.
2. The officer-in-charge will see that incoming data is correctly labelled and dated. He will mark the gauge height records, discharge measurements and level notes coming from regular stations on the bar charts. If data is consistently sent in with an incomplete or

incorrect station name, he will bring it to the attention of the appropriate observer or field officer.

3. All basic data will then be sent to the Senior Hydrological Engineer who will inspect and pass it back to the officer-in-charge.
4. The officer-in-charge will then send the level notes, miscellaneous field notes, station descriptions, etc., to the hydrologist-in-charge for checking. After checking, these will be returned and filed in the appropriate 5" x 8" drawer or as otherwise indicated by the hydrologist, who will raise any queries with the field staff concerned.
5. The officer-in-charge of the computing section will also send all discharge measurements to the hydrologist-in-charge for preliminary checking; however, when these are returned to him, he will be responsible for seeing that the current meter rating was applied correctly and the arithmetic checked by automatic data processing. He will mark the results of computer check on the measurement notes, number the measurement notes, and enter the measurement data on the current Form H110 for the station (Figure 48). Preparation of this form is given on p.168. Finally he will see that the measurement is filed in the appropriate 5" x 8" drawer.

6. The officer will plot each discharge measurement on the copy of the rating curve sheet bound in the rating curve binder. He will see if the measurement plot appears satisfactory, but if there is any question, he will notify the hydrologist.

7. The officer-in-charge of the computing section examines the gauge height record for periods of no or doubtful record and will contact the appropriate field staff, if necessary. He will see that all recorder charts are dated. He now turns the gauge height record over to a computing section clerk for processing and filing.

8. Note that there is no division of work by catchment and all computing section staff must cooperate to see that the work load is efficiently done. It is the responsibility of the officer-in-charge of the computing section to delegate the work to those under his supervision and all requests for data by other employees should be routed through the officer-in-charge.

Filing system for field data

The new forms for field use, H100, H101, H102, H107 and H108 are 5" x 8" and can be filed conveniently in a 5" x 8" card file. Form H109 is a larger discharge measurement form which is used when vertical angles are part of the computation of the discharge measurement. It is 10" x 8" and is folded once and filed along with the other 5" x 8" forms. These basic data should be filed alphabetically by gauging station name.

A file card protruding 1/2 inch above the 5" x 8" data forms contains the station name and separates the data by station. It is suggested that these separator cards be a distinctive color. Each station file contains discharge measurement notes, level notes, and miscellaneous notes. These should be segregated and a file card used to label and separate each category of notes.

Finally, these basic data files must be separated into current and back data files which are identical in design. The basic data is moved from the current to the back data file upon completion of the analysis and computation of the yearly records.

The files for the stage stations (water level) will contain only the level notes and the miscellaneous notes, otherwise they are similar to the discharge stations.

The reasons for recommending this system of filing are given in the section on "Filing System."

PREPARATION OF GAUGE HEIGHT (WATER LEVEL) RECORD

General

Every gauge height (water level) record, whether from a manual gauge or water-stage recorder, must be processed by a careful and systematic method. To insure that errors are not overlooked and the accuracy of the final records is understood, the prescribed procedure of computing gauge heights must be followed for every station for every year.

All gauge height records received in the office are checked in according to the procedure described in the preceding section. Periods of no or doubtful record have been determined and the field staff alerted to the trouble.

Although there is a basic similarity in the method of processing the observers' record and the water-stage recorder charts, the instructions are separated for simplicity and clarity. Follow the Progress Report Form, Figures 39 and 40, for all station analyses. Sign all computations and all checking, and Be Proud of Your Work. Rubber stamps can be designed and used to advantage to denote computation, checking, listing, and dates.

Non-recording (manual) gauge-height record

The following three steps in preparation of the gauge height record will be presently done on a current basis as a part of the "check-in" procedure:

1. Enter in the observer's gauge height record sheet all hydrographer's gauge readings from discharge measurements or miscellaneous notes. The hydrographer should have made these entries at the time of his visit but check to see if everything has been entered.
2. Compute the daily mean gauge height by averaging all the readings including those made by the hydrographer and record in the appropriate column on the record sheet.

Never erase, obscure or obliterate any observer's or hydrographer's entries.

3. If any errors are found, bring it to the attention of the officer-in-charge of the computation section.

The following procedure is done as a part of the station analysis for both stage (water level) and discharge stations:

4. Attach a copy of the STATION PROGRESS REPORT, Figures 39 and 40, to the brown envelop that is used for the station computation file.

5. Collect the current station file (see Filing Section), level and miscellaneous notes from the previous and current year together with the next year's notes (if available), discharge measurements, and the gauge height record.

6. Wherever possible, estimate periods of missing gauge readings on the basis of records for nearby stations, rainfall records, high water marks, miscellaneous notes, and the shape of the recession curve or flood hydrograph. If no estimates can be made, label them as periods of no gauge height record. For discharge stations, the daily mean discharges will be computed for the no gauge height record during the final comparison of the hydrographs.

7. Plot a graph of gauge heights for all periods of rapidly changing stage. Use all gauge readings. Follow the example given in Figures 41 and 42. Examine rainfall records, other recorder charts, previous year's record, etc., as a help in determining the shape of the graph. To save work, understand that rivers that are slow to change need not be considered; example is the middle and lower reaches of the Kafue River. In general, the reasons for using the plotted graph are:

   a. Stage station.--The gauge height graph is necessary at stage stations because it provides a more accurate daily mean gauge height and peak stage than is obtained from averaging the observer's readings and using the maximum gauge reading as the peak of the rise. If a crest-stage gauge is installed, the maximum recorded gauge height should be plotted and used in the graph construction.

   b. Discharge station.--In addition to the reasons given under the "Stage Station," the graph is necessary for the discharge station because it provides a means for integrating the discharge for each day. The integration is performed by averaging the discharge for intervals of the day. Every graph must be checked and both the computer and checker must place his signature on the graph and the date of completion.

8. Subdivide the gauge heights for discharge stations as shown in Figures 41 and 42.
9. Compute the daily mean gauge height from the plotted gauge height graph by either graphical or arithmetical methods for stage stations. The graphical method is recommended because it is both fast and accurate to use. The explanation and illustration of the method is in Figure 43.
10. List the extremes on Form 114. Follow the example in Table 6.
11. Attach the graph to the observer's gauge height record sheet. It becomes a part of the permanent basic gauge height record.
12. Enter all daily mean gauge heights obtained from the graph in the appropriate column of the observer's gauge height record and place a "g" (for graph) beside the number; an example is shown in Figure 44.
13. Write the "Gauge height" paragraph of the Analysis.
14. Compute the datum corrections and enter on Form H113. See Figure 45.
15. Enter datum corrections on the observer gauge height record sheets and apply to the computed daily mean gauge heights to obtain the correct daily mean gauge heights.

16. Write the "Datum Correction" paragraph of the Analysis.

Water-stage recorder

Preparation of recorder charts is usually more complicated than preparation of observer's readings because the pen trace may need both time and gauge height corrections. The instructions in this section will not refer to records from a digital recorder. The preliminary check-in has been done and includes identity of no or doubtful records (clock stoppage, plugged intake, etc.) and the dating of all the days. The following written procedure is recommended although the charts in Figures 46 and 47 will provide the best explanation to the preparation of the daily mean gauge heights from the water-stage recorder charts. Although recorders are both strip chart and drum, in general, the preparation as follows is similar for both types:

<u>Follow illustrations carefully at all steps</u>

1. Determine if all hydrographer's gauge readings and notes are on the chart. Enter those that have been missed.
2. Compute and apply all time corrections and denote days by vertical marks at hour 2400.
3. Check all dates on the charts.
4. Place gauge height scale on chart.
5. Compute gauge height (pen) corrections and distribute. See Figures 46 and 47.

6. Compute daily mean gauge heights for days of rapid change-in-stage by the method recommended in step 8 under the "Non-recording gauge height record" and illustrated in Figures 46 and 47. For days of little or no change in stage, the daily mean can be obtained by observation or by use of the plastic straight edge described in Figure 43. Enter the daily mean gauge heights directly on the chart. See example, Figures 46 and 47.

Carefully examine the chart for faint signs of pen or pencil trace during periods of intermittent recorder record. Fill in between the faint marks with pencil dashes, but never draw over any trace however faint, because these are basic data and must be preserved. In filling in periods, make use of rainfall records, records from nearby stations, observer's gauge readings and notes, recession curve, and the shape of the flood hydrograph. After the trace has been estimated, the daily mean gauge heights are computed by the same method as for complete recorder record. The periods of no gauge height record will be noted and for discharge stations, the daily mean discharge will be computed at a later time directly on the hydrograph when the final comparisons are made. At a clock stoppage, the recorder trace shows the range in stage during the period stopped. If rain occurred, this range may not be the maximum and minimum daily mean gauge heights.

7. Attach a copy of the STATION PROGRESS REPORT, (Figures 39 and 40) to the brown envelope that is used as the station computation file.
8. Collect the current station file (see Filing Section), level and miscellaneous notes from the previous and current year, together with those from the next year (if available), discharge measurements, and the recorder chart and observer's readings.
9. Write the "gauge height" paragraph of the Analysis.
10. Compute the datum corrections and enter them on Form H113. See Figure 45.
11. Enter datum corrections on recorder chart and apply to daily mean gauge heights and gauge heights for intervals of the day. If the datum corrections are to be applied by the computer, they need not be used to compute the correct mean gauge heights on the chart. However, this should be clearly stated on the chart and the corrections entered on the chart since this will prevent mistakes in the future.
12. List the extremes on Form H114. Follow example in Table 6.
13. Write the "Datum corrections" paragraph of the Analysis.

Listing and preparation of record of daily mean gauge heights

If the automatic data processing is to be used, the daily mean gauge heights are punched directly from the values notes on the observer's record sheets or the recorder charts for stage station. At discharge stations where some days are integrated, the gauge heights punched will be the daily means, or for subdivided days, the gauge heights for intervals of a day. Instructions regarding punching will be given in the automatic data processing instructions. For manual computation of discharge, the gauge heights are listed on the discharge computation form, Figures 69 and 70.

For stage stations, the computation of the daily mean gauge heights completes the record and the "Remarks" paragraph of the Analysis is written at this time. For manual computation, the daily mean gauge heights are listed by the hydrological year in monthly columns and the monthly and yearly values of mean gauge height and maximum and minimum gauge heights are computed. The gauge heights, including the monthly and yearly computations, are carried to hundredths of a metre in the metric units. In both systems, there should be an option to use thousandths if future gauging stations warrant this refinement.

5m—G246 12-69

Table 6
Extremes, yearly peaks and minimum

H 114

HYDROLOGICAL SURVEY OF ZAMBIA

Mutama River at Mutama Rapids.

Extremes - Hydro year 196-

Peaks

Date	Time	Gauge Height	Discharge (cfs)
23 Dec 196-	1315	14.25	6,920
2 Feb 196-	1520	12.02	4,200
12 Mar 196-	1715	13.85	6,360

Minimum

Date	Time	Gauge Height	Discharge (cfs)
12 Nov to 15 Dec 196-	—	2.31	(16.8) 17 cfs

Listed by J E Bidwell 3 Aug. 196-
Checked by JH Heser 16 Aug 196-

Note.- The extremes for all stage and discharge stations should be systematically entered on a copy of this form according to the Progress Report and filed in the Current Computation brown envelope. Sign for both listing and checking. At non-recording stations the peak stages are obtained from the graph based on gauge readings or flood mark from a crest-stage gauge.

RATING

General

The continuous or daily records of discharge at gauging stations are computed from records of stage (water level) and the discharge rating for the channel. The simple discharge rating defines the relationship between the stage and the discharge of the stream. The rating at some gauging stations may be a more complex relationship between stage, slope, discharge and other variables. The rating may also take the form of the basic weir formula, $Q = Clh^{3/2}$, where the gauging station control is a designed weir or dam.

The discharge ratings are usually determined from the measurements of discharge and stage at the gauging station. The discharge measurements are usually made by the current meter but since other methods can be used, a review of the section on Discharge Measurements is recommended. Although weirs may be installed as controls, it is emphasized that these should be "rated" in the field by discharge measurements (not necessarily by current meter at all stages). Theoretical ratings of weirs can give deceptive results because of differing physical conditions at each weir site and they should be checked in the field or by a model study.

The majority of discharge ratings in Zambia will consist of simple relations between the stage and discharge and these instructions concerning the rating curve will be confined to this type of stage-discharge relation. References will be made to more complete texts and instructions concerning the complex ratings.

Upon completion of the rating, the RATING paragraph of the Analysis is written.

Control

The relationship of stage to discharge is determined or controlled by the physical characteristics of the river channel and overflow area at and downstream from the gauging station. The combination of all these physical features is known as the CONTROL of the station. The features that constitute the control at low water are most often not the control at medium or high water. Very likely the control changes to a downstream location as the discharge increases from low to high flow. Knowledge of the control conditions is important in understanding the stage-discharge relation of the gauge station because the shape and curvature of the rating curve varies as the control changes with the increase in discharge. It is also necessary to understand the stability of the control. Shifts may occur because of the collection of debris, change in velocity of approach, scour or fill of sand, gravel and boulders, and the change of submergence. Deposition or removal of sand between the boulders or crevices in rock ledges may show up as shifts in the stage-discharge relation.

The interpretation of the discharge measurements relative to the rating curve requires judgment gained by experience and an understanding of the physical properties of the station control. Refer to Water Supply Paper 888, pp. 109-130 (7), Surface Water Techniques, Book 1, Chapter 12 (1), and Streamflow, Grover and Harrington, pp. 267-280 (5).

Preparation of rating

Listing of discharge measurements, Form H110

The discharge measurements are numbered and listed currently on Form H110 during the field data check-in procedure, step 5, p. 98. Every discharge measurement should be numbered and listed regardless of accuracy or whether the measurement has been used or discarded. This includes indirect measurements. These forms should then be filed in the current station file. The listing of discharge measurements on all Forms H110 should follow a definite rule because consistency in routine jobs results in efficiency and accuracy. The following methods (Figures 48-51 are examples) should be used in listing on Form H110:

1. Check all listed data prior to plot on the rating curve sheet, Form H116.
2. Sign for listing and checking on the Form H110.
3. Use a new form or forms for each hydrological year and list all the discharge measurements made at the station during the year. Include the last measurement

of the preceding year and all the measurements in the succeeding year that are used in the analysis. Also list any other measurements from past years if they are used in the analysis. Quite often this includes the highest discharge measurements made at the station.

4. Leave a blank line between calendar years and insert the year in that line.
5. Although this was not done in the example, Figure 48, leave a blank line between the hydrological years, as a help.
6. Fill in all columns completely (except the shift adjustment and percent difference column that will be completed as the rating table is completed.
7. Give the actual measured discharge. If the discharge has been adjusted for channel storage or other reasons, insert the adjusted discharge figure followed by an asterisk above the measured discharge figure and use a footnote at the bottom of the form to explain the adjustment. The adjustment computations should always be attached to the discharge measurement notes because they become a part of the basic notes.
8. Add all pertinent notes in the Remarks column and use an extra line if the column is too small. The notes should include changes in datum, use of a temporary gauge, special measuring conditions, debris on control, depths obtained indirectly (cross-section), etc.

9. The Method means .6, .2-.8, surface, etc.

10. The gauge height change and time should be such that the rate of change of stage can be computed. The gauge height change and time should be for the exact time of making the discharge measurement. Time can be used to tenths of an hour for convenience. If long delays occur during the measurement because of meter trouble, etc., indicate the time and gauge height change for each period of measuring. Short delays can generally be ignored.

11. The checked Forms H110 should be inked or typed carbon back so that copies can be printed.

12. The original Form H110 should be filed in the current station file but removed to the back data file after the next year's records have been analyzed and computed. One copy should be placed in the field station file and kept current by the hydrographer--each discharge measurement is listed after it has been made and computed in the field.

Preparing the rating curve sheet, Form H116 or logarithmic form

The stage-discharge relation at a discharge gauging station is generally developed from a graphical analysis of the plot of discharge measurements on rectangular or logarithmic graph paper. At gauging stations with a dam, weir or flume control, the stage-discharge relation may be developed theoretically but in all such cases the rating should be checked in the field. Theoretical ratings will not be considered in these instructions because many excellent references are available on the subject.

The stage-discharge relation takes two forms of expression: 1) graphical, Form H116 or equivalent, rating curve that is used in the development of the stage-discharge relation, and 2) numerical, Form H112, rating table that is used for computation of discharge. The rating curve is considered in this section.

The rectangular-coordinate graph paper, Form H116, is recommended for most of the rating curves at present in Zambia because:

1. It is easily understood by both technicians and laymen.
2. The pattern of low water shifts with time is more easily seen on a rectangular graph.
3. The point of zero flow can be plotted directly on the graph.

The following definite advantages to the use of log-paper are listed for comparison:

1. The range-in-stage for which different controls are effective can be identified.
2. Averaging discharge measurements is easy because the percent deviation scaled off on the graph paper is the same throughout the range of discharge.
3. The general shape of the rating curve is more easily defined.

The preparation of the rating curve sheet, Form H116, is an important step in the analysis of the gauging station records. It must be complete, accurate, and perfectly clear in all respects. Follow Figure 52 carefully in the preparation of Form H116. Specific recommendations in the construction are:

1. Always use the vertical axis for the gauge height scale and the horizontal axis for the discharge scale.
2. Choose both scales so that the user of the curve may determine the coordinates with a minimum of time and effort. Avoid using scales containing 3 or 8 or their multiples by 10, etc. Scales of 4 or its multiples of 10, etc., may be used but it is better to use 1, 2, 2.5, 5, 10, or their multiples of 0.1, 10, etc., for each inch of scale (or similar metric scale) for both gauge height and discharge.
3. It is desirable to have one main curve and a medium and low water expanded curve. See Figure 52. A station that has a small range in stage and discharge may only require a single curve. Remember this is a work sheet and ease of plotting and interpretation, together with accuracy in use, should always be considered. The expanded curves are used because it increases accuracy for those particular ranges expanded, and in addition, more space is provided for the measurement plot.

Generally, provision should be made for the plot of zero flow on the low-water scale.

4. Mark each curve as low-water curve, medium-water curve, and high-water curve.
5. Place the numerals of the gauge height and discharge scales both inside and outside the margin of the graph paper in a way to avoid confusion. See Figure 52.
6. Indicate the plotted discharge measurement point by a small open circle about 1/8" in diameter. Use a template or drop bow pen. Draw a fairly thin guide line using a 2 or 3 mm. rapidograph pen and print the measurement number horizontally at the end of the line. Keep the guide line length uniform at about 1 inch long. Run the guide lines to the edge of the circle, not into the circle. It is good practice to draw all the guide lines at a 45° slope with the axes of the graph paper. Some exceptions may arise on a rating curve sheet that has been used a number of years.
7. If the slope or rate of change in stage, etc., is used, enter this figure for the measurement along the discharge measurement guide line.
8. Indicate the number and the exact period of use of each rating curve on the sheet and run a guide line from these to every curve on the sheet for identification. Keep all lettering horizontal. See Figure 52.

9. If velocity and area curves are used, they can probably be plotted on the right side of the sheet. If there is no room on the rating curve sheet, use a separate graph paper.

10. Fill in the complete name of the gauging station. Complete all marginal notes and enter the number of all discharge measurements plotted on the sheet. Indicate each year during which one or more measurements have been plotted on the curve sheet. Indicate the maximum and minimum gauge heights. Always sign for plotting and checking the discharge measurements for all years indicated. See Figure 52.

11. In the construction of a new rating curve for stations with past analyzed records, the current year's measurements may not be sufficient. For example, the high-flow stage-discharge relation generally remains more stable than the lower relationship and on flashy streams, the peak flows may not have been measured each year. Therefore, it is wise to use the previous high-stage discharge measurements and if no better high-water curve can be defined, incorporate the last high-water curve into the new low and medium-water curve; otherwise the only high-water rating curve and table become lost through neglect. Usually the older high-water measurements have been plotted on the curve sheet but if an entirely new sheet

is prepared, replot the previous high-water measurements and print a note similar to the following on the rating curve sheet:

> "Note. All discharge measurements above 20,000 cusecs (or cumecs) are plotted."

12. Draw the rating curve for the preceding year on every newly prepared curve sheet.
13. Plot discharge measurements which have been made after the current year if they are used in defining the current rating curve.

Drawing the rating curve

Although all rating curves are considered as averages of the discharge measurements, the question always arises as to what measurements should be used to define the rating. Discharge measurements are subject to errors and if they are all made under exactly the same control conditions, they will plot either plus or minus from the true rating curve. Change in the stage-discharge relation occurs at most stations with natural controls. Artificial controls are usually more stable although the rating can also change owing to the collection of debris, variations in the approach velocity, and changes in the surface of the control.

A study of each discharge measurement is necessary to determine which ones were made under similar control conditions. If the control is stable and the discharge measurements plot within an acceptable percentage of the latest rating curve, that curve will remain in use. A new rating curve will be drawn only when there is positive proof from the plot of additional measurements that a change has occurred in the stage-discharge relation. However, if one or more measurements plot off the current curve but more recent ones again plot within an acceptable percentage of the rating, the current rating can be continued and shift corrections applied for a period as defined by the one or more scattered measurements. The scatter of measurements should be random. However, a group of measurements that plot within acceptable limits of the rating curve may be used to define a new rating if the plot shows a definite trend or change in the stage-discharge relation. Since a change in the stage-discharge relation for a permanent gauging station is caused by a physical change in the control, care must be taken to determine the period of use of every rating. Rarely does the change occur at the exact end of the hydrological year. A new rating may be started at the beginning of the hydrological year if additional measurements show last year's rating was in error and if the change in ratings cause no excessive jump in the computed daily mean discharges. In this case, a smoother transition in discharge records can be obtained by the use of shift corrections at the beginning of the year. If the additional discharge measurements prove that last year's records are in error, they must be revised. Shift corrections will give a smooth transition in discharge whenever a new rating is used and the actual change in the stage-discharge relation was gradual and not abrupt.

At a station with a scarcity of discharge measurements and poor definition, a search of past records may provide information regarding the best shape for the rating curve. Minor shifts in the stage-discharge relation do not cause most rating curves to change radically in shape, or cross over each other. However, the shape may change materially where the control conditions have been substantially altered by bank erosion, quarrying on the control, channel straightening and diversion, dam and bridge construction, clearing of channel banks and flood plains, major channel changes caused by floods, etc. Construction of an accurate rating curve requires a thorough knowledge of the station control and a record of the changes in the control conditions.

Since flood measurements may be affected by as many errors as those made at other stages, the high-water rating curve should average the high flow measurements and not necessarily pass through the highest one if it creates an unreasonable shape. A long extension of the high-water rating curve above the highest discharge measurement must not be made unless the physical features of the river are considered. Use of a log extension is dangerous unless used with caution because the same curvature (or straight line) of the rating curve only applies where the control conditions remain unchanged. A log plot, velocity-area curves, and an examination of the shape and size of the controlling section of the channel and flood plain will help in defining the shape of the high-water curve. It is emphasized that the peak or maximum discharge should be obtained from the rating and not from a discharge measurement made on the crest of the flood unless the measurement plots on the rating curve. Indirect measurements at peak flows should be made if current meter measurements are impossible or absent. This is not emphasized because trained personnel are not available in Zambia.

In general, most discharge measurements rated as good by the hydrographer should be within 5 percent (plus or minus) of the true discharge. Fair rated measurements are generally within 8 percent and poor measurements over 8 percent. A discharge measurement that is rated excellent, within 2 percent, is rare because the natural field conditions and measuring methods do not generally warrant such an assumption. Since most well-made discharge measurements are assumed to be within 5 percent (plus or minus) of the true rating, it is recommended that generally we hold to this figure in drawing the average curve (the final smoothing and shaping is done with the rating table). Exceptions may always occur; for example, if only fair discharge measurements can be made at a station, hold to the 8 percent limits in drawing the average rating curve. This flexibility in averaging discharge measurements requires judgment gained by the analysis of the basic data and experience in the study of a variety of gauging station records. The discharge measurements that deviate a greater percentage are used to define a new curve or temporary shift corrections. An excellent report of discharge ratings which should be studied is USGS Surface Water Techniques, Book 1, Chapter 12 (1).

The decision should now be made regarding the ratings to be used throughout the year (or period of the year). Generally the latest rating will be continued, either for the entire year or for a shorter period followed by another rating which may or may not be new. It is recommended that the number of ratings used each year be limited to three. If a gauging station has greater variability in ratings than this, consider the application of shifting control adjustments.

<u>Rating table, Form H112</u>

Although the rating curve on Form H116, or its equivalent, is a graphical expression of the stage-discharge, it is not in a convenient form for computation and checking discharge records. To alleviate this shortcoming, the curve is converted to tabular arrangement on Form H112. The descriptions and illustrations regarding the rating table are given in English units but two samples of Forms H112 and H112a, Figures 53 and 54, are suggested for the metric (S.I.) unit use. The detailed instructions should be used for either system.

The rating table in general follows the rating curve but is closer to the actual stage-discharge relation because:

1. The rating table is smoothed mathematically to eliminate the inaccuracies inherent in drafting the rating curve on graph paper.

2. The rating table is the basis for computing the percent deviation of each discharge measurement and is shaped to average the designated rating measurements within the correct percentage.

The computation of the rating table requires experience and an understanding of the accuracy requirements. The following steps will facilitate table preparation:

1. Prepare the table in Pencil.
2. Complete all the headings on Form H112, this includes a) the exact and complete station name and number; b) rating table number--this is the same as the number on the rating curve (the ratings for each station are numbered in sequence and a number must never be repeated); and c) the exact period of use for the rating. The dates on which the use of a rating table is started and ended must be inserted. See Figures 55 and 56 of the sample station. More than one sheet of Form H112 may be necessary.
3. Enter the gauge height scale in the appropriate columns.
4. Pick values of discharge from the curve for equal increments of gauge height and enter on Form H112. For low stages, use increments of a tenth of a foot, for higher stages use half feet or feet. The values of discharge picked off should not be considered final but rather as preliminary figures to be smoothed arithmetically.

5. Form H112 has a column headed "difference." This is the difference between the discharge for each tenth foot in stage. In the "smoothing" process, these differences in discharge are adjusted to change smoothly. Usually these differences should increase. Differences that remain the same show that for that portion the rating is a straight line. If the differences grow smaller with an increase in stage, the rating has a reversal. A reversal in a rating is exceptional and should be examined very critically because the discharge measurements used to define the curve probably do not represent the same stage-discharge relation. The second differences, or the difference between the differences should vary smoothly. Examine the rating for the "Sample Station," Figures 55 and 56. Perfectly smooth variation in the second differences is usually impossible to achieve but wild jumps should be eliminated by careful construction of a rating table.

6. Compute the differences between the values picked off the curve in step 4 and carefully follow the remarks made in step 5. Enter these differences lightly in pencil in the proper column. For the portion of the rating in which the discharges were picked off for every half foot or foot, compute the total difference

and convert it to difference per tenth of a foot and enter it once near the edge of difference column. These values can now be used to compute a smooth rating table.

7. Compute the percent difference of all discharge measurements and list them on Form 110. The percent is always computed from the rating table discharge--not from a discharge value picked off the rating curve. Enter the rating table with the mean gauge height of the discharge measurement and obtain the corresponding rating table discharge. Round this discharge to the same number of significant figures used in the measurement discharge. Subtract algebraically the measured discharge from the rating table discharge and divide the difference by the rating table discharge, then convert this to percent. The percent is minus or plus, depending on whether the measured discharge is smaller or larger, respectively, than the rating table discharge. (All measurements that plot to left of the rating curve on Form H116 are minus, whereas all those to the right are plus). The rating discharge is always used as the base because the discharge measurements are considered as deviating from the average rating curve. Carry the percent to tenths of a percent as follows:

   +0.3, + 2.9, and -29.3 percent.

8. An example of the computation of percent difference follows:

On Form H110 for the Kafue River at Kasaka, Figure 50, locate discharge measurement No. 602.

The mean gauge height is 18.11 feet.

Enter the rating table No. 15, Form H112, for Kafue River at Kasaka, Figure 57, with this gauge height.

The rating discharge (computed to the hundredth of a foot) is 9480 + 23 = 9503 cusecs.

Since the measured discharge is carried to three significant figures, the rating discharge is also rounded off to the same number of places, or 9503 cusecs becomes 9500 cusecs.

The difference is 9500 - 9150 = 350 cusecs.

Converted to percent: $\frac{350}{9500} = 0.037$, or 3.7 percent.

The measured discharge is less than the rating discharge and the percent difference is minus, or -3.7 percent.

As a check, locate measurement No. 602 on the rating curve sheet. It is plotted reasonably correct and to the left of the curve, which confirms the minus sign.

9. The rating table may have to be reshaped once or twice by changing differences if some rating measurements deviate from the table by more than the acceptable percentage.

10. The rating table is the mathematical counterpart of the rating curve but, because of practical limitations in construction, the discharge values are generally entered on the table for each tenth of a foot gauge height. Consequently, if the table is used to hundredths, the discharge is obtained by interpolation. An examination of the rating tables in Figures 57 and 58 show that it is not always necessary to change the difference each tenth of a foot in gauge height throughout the entire range of the rating. This creates a rating made up by a series of straight lines which may or may not be the true rating. If the true rating is a curve and the table is a straight line, the difference in discharge is called an error. The size of this error must be known and limited or excessive errors in discharge will result from the use of the rating table. Rating tables must be computed on the basis of an allowable error in terms of percent.

The allowable error may be established by examining the definition of the rating curve which includes the number and quality of the discharge measurements and the range of stage covered by measurements. It also depends upon the shape and stability of the control. For the present conditions existing in Zambia, a 2 percent allowable error is recommended. This should be reduced to 1 percent for any station with a well defined rating and a weir control (this does not include stations where theoretical weir formula are used). For ratings that have a small curvature, little error will result from interpolating to hundredths between tenths but a spot check should be made at various points on the rating. For ratings with sharp curvature (usually at low stages), errors in percent of discharge may be greater than the allowable error and a curvilinear expansion to hundredths of a foot should be constructed on a form similar to the one shown in Figure 59. An estimated error for checking purposes can be obtained by converting the difference in discharge at the midpoint of the interpolated values to percent of the curve discharge. Since the curvature of a rating does not remain the same throughout the entire range in stage, one portion may require curvilinear expansion, another one difference per tenth, while the remainder of the table will give equally accurate results in percent by using a flat difference for portions ranging from two tenths to many feet in gauge height. Care should always be exercised to avoid a curve that is severely broken into a series of straight lines. Examine rating tables Figures 55-58.

11. There is no exact rule governing the use of significant figures in the rating table. However, the following can be used as guidelines:

a. Use the rating tables in Figures 55-58 as examples and guides.

b. The discharge in the rating table should always be the exact figures obtained from the addition of the differences.

c. Below 10 cusecs, the discharges can usually be carried to tenths except for ratings that have sharp curvature and are very well defined.

d. Between 10 and 99 cusecs, the discharges can be carried to either 2 or 3 significant figures. The choice depends upon the curvature and definition of the rating.

e. Between 100 and 999 cusecs, the discharges usually may be carried to 3 significant figures or to the nearest 5 or 10 cusecs where the rate of curvature permits, as the discharge approaches 1,000 cusecs.

f. At the above 1,000 cusecs, the rating can be carried to the nearest 5 or 10 cusecs, and as the curve approaches a straight line, much larger differences can be used. See the rating table for Kafue River at Kasaka, Figures 57 and 58.

12. Look over the percent column on Form H110 for the rating measurements and be sure the percent has been correctly entered for every measurement. Form H110 for Kafue River at Kasaka, Figures 48-51, is an example.

13. Plot the rating table discharges back on the rating curve sheet, Form H116, to see that the curve has not been greatly altered. If it is essentially the same as the original rating curve, both the table and curve are considered satisfactory and ready for checking. The table must be thoroughly checked before it is used to compute the discharge record.

14. Write the Rating paragraph of the Station Analysis.

SHIFTING CONTROL ADJUSTMENTS

General

The shift adjustment and percent difference columns on Form H110 were left blank during the initial listing of discharge measurements. Finally (except for checking) the percent difference was computed for all discharge measurements and listed on Form H110 after the rating table, Form H112, was completed. This completes Form H110 except for the shift adjustment column and the final percent difference for the discharge measurements used to define the shift adjustments.

The acceptable percent difference has been established (generally at 5 or 8 percent) and a decision has been made that the discharge measurements outside the limits of acceptability will either be 1) disregarded because of indeterminate errors in the basic data, or 2) used to define shift adjustments.

For convenience, a recommendation was made to use but 3 ratings per year. Some controls shift more often than this; in fact, some controls shift constantly and shift adjustments are used as a substitute for many new ratings. Discharge measurements that reflect temporary shifts in the control (stage-discharge relation) are used to define the adjustments that are applied to the gauge heights before entering a rating table.

A definite procedure should be followed in computing and applying the shift adjustments.

Preparation of shift adjustments

1. Review the section on "Controls," page 113.
2. Compute the shift adjustments for all the selected discharge measurements.
3. The measured discharge is always used as the base in the computation of shift adjustments.
4. Enter the rating table with the measured discharge and compute the equivalent gauge height to the nearest hundredth of a foot.
5. Subtract algebraically the equivalent gauge height from the measured gauge height. The difference is the shift adjustment.

6. The shift adjustment is plus or minus, depending upon whether the measured discharge is larger or smaller, respectively, than the rating discharge obtained by application of the mean gauge height of the discharge measurement to the rating table.

7. The percent difference is computed for the measurements which have been selected for defining the shift adjustments. The method of computation is the same as that used in calculating the percent difference for the rating measurements.

8. An example of the computation of a shift adjustment follows:

   Locate discharge measurement No. 601 on Form H110 for Kafue River at Kasaka, Figure 50.

   The mean gauge height is 18.25 feet.

   This measurement is 13.7 percent smaller than the rating (it plots 13.7 percent to the left of the rating curve) but it was considered a good measurement and should have been within 5 percent of the average rating No. 15. It was therefore selected to define a shift adjustment.

   The measured discharge is 8470 cusecs, which is equivalent to a gauge height of 17.66 feet.

   The shift adjustment is 18.25 - 17.66 = 0.59 feet.

   The rating discharge equivalent to 17.66 feet is 8,500 cusecs and the percent difference is

$$\frac{8500 - 8470}{8500} = \frac{30}{8500} = 0.004 \text{ or}$$

0.4 percent

Since the measured discharge is smaller than the rating table discharge, the percent is minus or -0.4 percent.

9. Some judgement must be used in computing the shift adjustment. In the example, 0.59 feet was calculated as the most suitable shift adjustment although the use of any shift adjustment from 0.59 to 0.62 feet would have been equally as close in percent as 0.59 feet. This adjustment was chosen because in the judgement of the hydrologist it gave a better overall shift adjustment distribution. Generally, use the adjustment that will bring the final percent closest to zero regardless of the rating given the discharge measurement.

Distribution of shift adjustments

The shift adjustment computed from the discharge measurement defines the shift in effect during the measurement but to be useful in computing the discharge record, it must be distributed over longer periods. It was explained previously that the shift adjustments are substitutes for temporary ratings and are used for the sake of accuracy and convenience in the computation of discharge records.

A means must be found to distribute the adjustments in accordance with shifts in the control because usually they vary with time or stage or a combination of these two. If the gauge height record indicates that the difference in adjustments occurred gradually between measurements, then they can be distributed according to time. If flashy changes in stage occur between the measurements, a larger proportion of the adjustment might be applied at the time of the rises. Remember that the ratings (including temporary ratings) usually do not change shape materially. However, the ratings affected by backwater may assume different shapes because of the very nature of the cause of backwater. For example, weed and brush growth on banks and islands will cause backwater at medium stages, floods on tributaries may cause backwater at high stages, and the collection of trees and debris on a bar may cause backwater only at low stages. It is of utmost importance to analyze the cause of the shift before distribution of the adjustments.

Frequently a series of measurements will define a temporary rating for a considerable range in stage but which occurs for such a short period of time that computing a new rating table is impractical. A temporary curve can be drawn to average the selected measurements and the daily shift adjustments are determined by measuring with a pair of dividers the difference between the temporary shift curve and base rating curve. The adjustment is measured from the temporary curve at a point corresponding to the gauge height. For example, the rating curve sheet for the Kafue River at Kasaka, Figure 60, shows two temporary shift curves which could have been used during the 1961 water year. The shift adjustments which were scaled off the rating curve sheet are shown on the computation form, Figure 61. (Daily mean discharge is not shown on the example). These were applied on the basis of stage with occasional slight changes to produce consistent streamflow records. The same shift adjustments would have been entered on Form H113, Figure 63, if the records were to be computed by automatic data processing. Except for three measurements which were disregarded because of obvious errors, all the measurements used to define the shift curves are within 5 percent of the curve.

If the measurements that define shift adjustments tend to scatter a shift diagram might be the best solution. An example is the diagram for Kafue River at Kasaka for the 1961 water year shown in Figure 62. The list of discharge measurements from which the diagram is constructed is on Form H110, Figure 64, and are a part of the group of measurements used to define the shift curve in Figure 60. In this case, the shift curve is the best solution and the diagram is only shown to illustrate the method of construction.

The discharge records computed with shift adjustments will be reduced in accuracy unless the measurements are dependable and made at a reasonable frequency. The frequency at which the measurements should be made depends upon the control conditions. Examine the list of discharge measurements for the 1968 Hydrological Year, Form H110, Figure 50, for Kafue River at Kasaka. Three measurements, Nos. 600, 601, and 604 plot more than 5 percent from the average rating. Nos. 600 and 601 are used to define shift adjustments and No. 604 is disregarded. Measurement No. 600 was made on 22 March, shift -0.33 foot, and No. 601 was made on 3 May, shift -0.59 foot. It appeared to the hydrologist that the shift from the base rating table No. 15 started about the 1st of January, but because of the small number of measurements, the shift might have started at some other time. If the shift had started around the middle of February instead of 7th January, the daily mean discharge may be in error by almost 10 percent. This lack of discharge measurements to define the adjustments and the distribution of adjustments is the cause of the "poor" accuracy rating for periods of shifting control in the "Remarks" paragraph of the Station Analysis for Kasaka.

Examination of the shift distribution on the discharge record form for Kafue River at Kasaka, Figure 70, shows that the adjustments are not necessarily varied by a 0.01 foot. One change was in a step of 0.09 foot while others are changed by lesser amounts. This pattern of distribution was used for two reasons, 1) it creates a reasonably smooth record of discharge, and 2) the change in daily mean discharge caused by the jump from one figure of adjustment to another was kept within 2 percent.

It is recommended that no shift adjustment be smaller than 0.01 foot and that wherever possible, flat adjustments be used for longer periods than one day in length, and also, except for low discharges, the change in daily mean discharge be within 2 percent when caused exclusively by an increase or decrease in the adjustment. And furthermore, the smoothness of the final discharge record should always be considered.

The discharge measurements Nos. 600 and 601 plot to the left of the rating curve in Figure 52. It was decided that the shift adjustments varied with both stage and time and that the temporary stage-discharge relation at the time of making No. 600 was essentially the same shape as rating curve No. 15 but was positioned to pass through the measurement No. 600. A similar condition existed for No. 601. The temporary curve through No. 600 progressively changed to the temporary curve through No. 601 and the adjustments were applied accordingly.

It was assumed that the initial shift in the control occurred about the 7th January. The adjustment started on that date and was distributed to 22nd March in a way to produce a good discharge record. Measurement No. 602 plotted on the rating curve No. 15 and the shift adjustments ended before 11th of June. Always keep in mind the general recommendations regarding the distribution of all shift adjustments.

The shift adjustments can be applied directly on the discharge computation form, Figure 70, for manual computation of discharge. For automatic data processing, the Form H113, Figure 65, is used to present the distribution of the adjustments. Write the DISCHARGE paragraph of the Station Analysis.

SUBDIVISION AND THE ALLOWABLE RANGE TABLE

General

The daily mean discharge may be in error if it is derived from the direct application of the daily mean gauge height to the rating table. The error is caused by both the curvature of the rating and is affected by the shape and range in stage of the daily stage hydrograph. Use of the daily mean gauge height will not cause an error if the rating is a straight line or the stage remains constant throughout the day.

Reference is made to "Subdivision" of the gauge height graph or recorder graph at discharge stations in the section on "Preparation of Gauge Height Record" and this should be reviewed. The exact daily mean discharge would be obtained by complete integration of the gauge height record which is accomplished by the use of digital recorder records and automatic data processing. The use of manual gauges and analog water-stage records precludes such a vast and tedious method for integration.

Complete integration can be by-passed using the simple technique of establishing a percent limit in the computation of the daily mean discharge and subdividing the day accordingly. This is accomplished by two practical methods of approach:

1. Use either the graph based on observer's gauge readings or a water-stage recorder graph. Pick out a few days and obtain the daily mean discharge by both subdivision and by use of the daily mean gauge height. Since the discharge obtained by subdivision is the correct figure, compute the percent error in the discharge computed from the daily mean gauge height. See the gauge height graphs, Figures 41, 42, 46, and 47. From a few subdivided days at different stages, a reasonable evaluation can be made as to how much change in stage at various gauge heights can be allowed and still keep the computed daily mean discharge within the desired percentage. This method is preferred if the computation is done by trained and competent personnel and only a few days are affected each year.
2. For untrained personnel, it is necessary to establish a more positive guideline for subdivision which is called an ALLOWABLE RANGE TABLE. The range table must be computed for each rating in use at stations that may have subdivided days. Streams that are slow to change can be ignored; examples are the lower Kafue River or the Zambezi River. Although the allowable range table is only applicable to a specific rating, it will be found that rating shapes change so little that seldom must a new range table be prepared for a gauging station. But do not take this for granted without a check.

Preparation of the allowable range table

The allowable range table simply lists the range in stage allowed before the daily stage hydrograph must be subdivided to keep the computed daily mean discharge less than the maximum percent error. Table 7 is an allowable range table computed from the sample station rating table shown on Figures 55 and 56 for a maximum error of 4 percent. It is recommended that the 4 percent maximum error be used in Zambia. This may seem excessive but seldom is the daily stage hydrograph of a shape that produces the maximum error. Choosing the maximum error is somewhat arbitrary but it must be remembered that its value is related to the curvature of the rating and the shape of the stage hydrograph for each gauging station.

The expanded section of the rating curve for the sample station is shown in Figure 66. This figure also contains a sample computation which is explanatory for the computation of the allowable range table. The allowable range table has been replotted in graphical form in Figure 67 to give a better illustration of the shape of the relationship for the sample station. It is not necessary to compute the allowable range for every tenth of a foot gauge height because the change is usually slow and the table can be easily interpolated.

It has been stated earlier the main reason for the need of subdivision (averaging discharge for intervals of the day) is because of the error introduced by the curvature of the rating table. But, in addition, it was noted that the shape of the daily stage hydrograph had some effect on the size of the percent error. Figure 68 shows this effect of the shape of the stage hydrograph at the sample station. The relationship will be different for each rating and for each range in stage and Figure 68 simply serves to show that the percent error is affected by the shape. For this particular rating between the gauge height of 3 feet and 4 feet, the computation shows that the maximum error in daily mean discharge would be 9 percent if it had been obtained directly from the application of the daily mean gauge height to the rating. And besides, this would have occurred when the gauge height remained at 4 feet for 35 percent of the day and at 3 feet for 65 percent of the day. Any other shape of the daily stage hydrograph ranging from 3 to 4 feet would cause a percent error of less than 9 percent according to the curve in Figure 68. This curve also illustrates another point that was mentioned earlier; that is, there is no need to subdivide if the stage remains constant throughout the day. Note that when both 3 and 4 feet occurs for 100 percent of the day, there is zero percent error.

HYDROLOGICAL SURVEY OF ZAMBIA

Computation of allowable range curve for Kawanda River near Chonta Rating table No 2

Gauge height	Q	2.08 x Q	Sum of Q's	Allowable Range in Feet
2.2	13.5	28.1	0.2 27.5	
			0.3 28.2	0.3
2.5	24.0	49.9	0.4 50.0	0.4
3.0	50.9	106	0.6 106	0.6
3.5	90.5	188	0.8 1.92	
			0.6 187	0.6
4.0	146	304	1.0 306	
			0.9 303	0.9
5.0	299	622	1.2 617	
			1.4 625	1.4
7.0	781	1,625	1.8 1674	
			1.6 1651	
			1.4 1630	1.4
9.0	1,720	3,580	2.0 3580	2.0
12.0	4,180	8,690	3.0 8,640	
			3.2 8700	3.2
14.0	6,570	13,660	4.0 13,890	
			3.2 13,680	3.2

SAMPLE

Example.- At a 5 foot stage, the daily mean gauge height can be used directly to obtain the daily mean discharge from rating No. 2 if the change in stage during the day is less than 1.4 feet and the maximum allowable error is set at 4 percent.

J E Bidwell

DISCHARGE COMPUTATION

General

The computation of the discharge record follows the preparation of the gauge height record and the rating. The time-honored method of manual computation involves the listing of the daily mean gauge heights in monthly columns on a convenient form, followed by the entry of daily mean discharges from the rating table. Figures 69 and 70 are forms used for the computation of the discharge record for Kafue River at Kasaka for the 1967 and 1968 hydrological years. The discharge record consists of both daily means (mean discharge for each calendar day of 24 hours) and extremes. These daily mean discharges are the basis for the computation of the monthly and yearly figures of discharge which are shown at the bottom of the discharge computation sheet.

Finally, every effort should be made to insure consistent records of discharge, i.e., the records of discharge for each gauging station should be consistent throughout the years, and the records of discharge throughout the basin or area should be in good agreement. Two methods are used to obtain these results: 1) graphical comparison, which entails the use of plotted hydrographs of daily mean discharge, and 2) mathematical comparison of the monthly and yearly discharges. Detailed descriptions of both methods are found in the following section.

The gauging station analysis, which includes all the preliminary steps previously described in the preparation of gauge heights and rating, is the most important portion of the preparation of the discharge records and must be done by qualified personnel. The preparation and computation methods require judgment gained from experience and the methods must be thoroughly understood by the hydrologist. Although in Zambia automatic data processing is used to compute the discharge records, an understanding of the computer program requires a good working knowledge of the manual method that is described in detail in the instructions. The specific instructions for automatic data processing will be issued separately.

Computation of daily mean discharge

The convenient form shown in both Figures 69 and 70 is recommended for use for all manual computation of discharge. This form is excellent for study, use, and illustration because space is provided for the consistent and systematic entry of all the relevant data. The following general notes are concerned with the use of the discharge record forms and should be carefully read:

1. The recommended form can be used for both English and metric units (the units of monthly and yearly computations are changed for the metric system).
2. All spaces at the top of the form should be filled in completely. Consistency is necessary in entering the correct station name, hydrological year, catchment

(drainage) area, observer, type of gauge height record, and rating table number.

3. When more than one rating table is used, the number of each must be entered in the upper right corner with the exact period of use, i.e.:

   Rating table No. 15 1st Oct. to 15th Dec.
   No. 16 16th Dec. to 21st June
   No. 17 22nd June to 30th Sept.

4. Marginal space is provided along the right side for the name of the person computing and checking the various processes. It is extremely important to insist that everyone must sign for the work that they have performed and insert the date of completion. This develops responsibility and pride in the work.

5. The daily mean gauge heights will usually be listed on this form after the preparation of the gauge height record. If this hasn't been done, the listing should be completed at this time. For days in which the daily mean gauge heights are obtained by subdivision, the symbol "S" should appear at the left of the gauge height, i.e., S12.34. A footnote at the left margin should briefly explain that the daily mean discharge was obtained by averaging discharge for intervals of the day and not by direct application of the daily mean gauge height to the rating table.

6. The number of each discharge measurement is entered in small figures in the space above the gauge height on the day that the measurement was made.

7. Insert the yearly maximum and minimum gauge heights, together with the time and date, where appropriate, in the space provided along the left margin.

8. The shift adjustments with the appropriate plus or minus signs are inserted in small figures along the left edge of the discharge column. If the gauge heights had been listed at the completion of the gauge height preparation, the shift adjustments should have been listed during the preparation of the "Discharge" paragraph. For subdivided days, the shift adjustments should be inserted to the right of each partial day gauge height on the graph based on the gauge readings or on the recorder chart, Figures 41, 42, 46, and 47. This flexibility in working on the discharge form must be under the guidance of the officer-in-charge of the computation of discharge and the Progress Sheet attached to the analysis file must always show the current status of the computations.

9. The daily mean discharges are computed from the current rating table using the listed daily mean gauge heights and shift corrections, if applicable. Draw a heavy horizontal line to separate the periods when different

rating tables have been used, although the heavy line is not used at the beginning or end of the year. In the example in step 3 above, the heavy lines would be used between 15th and 16th of December and the 21st and 22nd of June.

10. The discharge for subdivided days is computed by averaging discharge for intervals of a day. A review is recommended of the sections for Gauge Height Preparation, pp. 56-60, and Subdivision and the Allowable Range Table, pp. 77-79. Because they give a fairly complete description of the reasons for subdividing days and the methods that can be used, only a summary is given in this section.

    a. The daily mean discharge computed from the daily mean gauge height may be in error for days of substantial change in stage. To prevent this error or to keep it within allowable limits, the daily gauge height graph or recorder chart is subdivided into smaller parts of the day, as described in the section on page 58.

    b. Look over the chart for the Sample Station in Figure 46 and examine the computation for 6th December. The computation entails subdividing the 24 hours into a number of smaller intervals. In the example, the length of these partial days varies from 1 to 10 hours, depending upon the change in stage within the interval (it is not necessary in Zambia to use a time interval of less than one hour). These intervals are separated by a vertical pencil mark which is broken at the pen or pencil trace of gauge height.

c. The mean gauge height is computed for each interval by the plastic etched-line "scooter" and entered opposite the hourly interval.

d. All pen corrections and shift adjustments are then entered in the computation.

e. The mean discharge is obtained for each interval by application of mean gauge height to the rating after being properly adjusted by pen corrections and shifts.

f. The final computations includes weighting the partial discharges.

Large errors can result from not subdividing a daily stage hydrograph. In Figure 46, a 7 percent error occurs on 6th December and a 15 percent on 8th December. In Figure 41, which is a graph based on gauge readings, a 25 percent error occurs on 15th December. These percent differences were computed to show the importance of understanding this source of error. The allowable percent error can be changed to match the physical conditions and resultant basic data at a gauging station but a reasonable limit can be set only after the source of error is clearly understood.

The digital recorder and automatic data processing provides integration for each day of record. The computer program in preparation for use in Zambia will integrate days of change-in-stage but requires punched instructions for application of corrections and adjustments.

11. The rules to be followed in the computation of maximum, minimum and daily mean discharges are:

ENGLISH UNITS

Range of discharge (cusecs) From	To	Significant Figures
.01	0.09	1
(May be desired for station with small drainage area and artificial control)		
0.1	0.9	1
1.0	9.9	2
10	99	2
100	999	3
1000 and above		3

METRIC (SI) UNITS

Range of discharge (cumecs) From	To	Significant Figures
Below	0.0009	1
(May be desired for stations with small drainage area and artificial control)		
0.001	.009	1
0.010	.099	2
0.100	.999	3
1.00 and above		3

These rounding limits will be used for both manual computation and automatic data processing.

12. The extremes of discharge are entered on the left margin and if a shift adjustment is to be applied, it is inserted in small figures above the maximum or minimum gauge height. On some streams, the shift for the extremes may not be the same as for the daily mean gauge height. The maximum and minimum discharges are computed using the same rules for significant figures as those used in computing the daily mean discharge.

    The computed maximum discharge (or minimum) may occur more often than once a year because of the variation in shift adjustments, the method of computing the rating table, and the rules used in rounding off discharge figures. In any case, follow the example shown for the Kafue River at Kasaka in Figures 69 and 70.

Discharge hydrograph

A hydrograph is a graph, usually of stage or discharge of streamflow, plotted with respect to time. A recorder chart or a graph of observer's gauge readings are forms of stage hydrographs but in this section, we are dealing with the discharge hydrograph constructed of the plot of daily mean discharge in respect to the days of the water year. Because the hydrograph is a graphical representation of the discharge of a river it is used to make visual comparison of the streamflow at gauging stations on the same river or on rivers having similar regimens of flow. In this respect large errors in discharge can be spotted and periods identified that need additional analysis because the records do not compare logically with those from other gauging stations. See streamflow, Grover and Harrington, pp. 298-301 (5).

Manual plotting

The hydrograph is a most important part of the general procedure of converted basic streamflow records into accurate discharge records. However, it should be considered a worksheet in the preparation of streamflow records and there is rarely a necessity for elaborate "Gilding the Lily" type of drafting and inking. If one or two hydrographs are needed for illustrations in a publication, these should be specifically drafted for that purpose. Furthermore, it is recommended that each hydrograph should be on a separate sheet because it facilitates the comparison with other station hydrographs on a light table.

The most satisfactory discharge hydrograph is one plotted on a semilog paper with a vertical log scale for discharge and a horizontal arithmetic scale marked in days and months of a water year. For normal plotting, a 3-cycle paper about 24" long will be best for most gauging station records. If the range in daily discharge exceeds the 3-cycles, the scale can be broken and that portion exceeding the third cycle can be plotted at the bottom of the first cycle. Many streams in Zambia have periods of no flow and since zero flow cannot be plotted on the log paper, a practical solution is to use the log cycles for all flow periods and plot the no flow about 1/8 inch below the bottom of the first cycle.

Each day of record should be plotted in pencil free hand, except for jumps in discharge of about 1 inch or more in height, when a straight edge can be used to advantage. An example to follow is the discharge hydrograph for the Kafue River at Wusikili shown in Figure 71. Although the analysis of the hydrograph entails study of the rainfall records, the bar chart need not be plotted on the bottom of the form. In fact, a separate plotting of the rainfall is preferred because each plotted bar chart of rainfall can then be conveniently used with more than one discharge hydrograph. This will save much time in plotting. The bar chart should be plotted on a form with a vertical arithmetic scale and for convenience should have exactly the same horizontal time scale as on the discharge hydrograph.

Review the following items in the illustration in Figure 71:

1. Determine a discharge scale. Keep in mind that it is advantageous to have the whole year plotted on the 3 cycles with no broken scale. Place scale on both ends of sheet for convenience.
2. Enter station name, water year, catchment area, and symbols for discharge measurement, adjusted discharge,

and special readings in upper left corner. Always place these items in the same place on all sheets because this consistency helps to file and retrieve the hydrographs.

3. Plot free hand in pencil the daily mean discharge. The line should be a solid line, medium width, firm, clear-cut, and dark. Otherwise, the hydrograph cannot be used on the light table. A HB (or medium soft) drawing pencil is about right. Keep the lead well pointed with a sandpaper or coarse paper pad. A very fine lead mechanical pencil will work as a substitute.
4. Plot all discharge measurements and circle point. Enter number of discharge measurement and all pertinent notes.
5. Plot all extra readings, highwater marks, etc., converted to discharge and note with proper symbol.
6. Leave blank all days of no record.
7. The discharge measurement may not plot on the hydrograph of daily mean discharges. There are two reasons for this departure: 1) the rating curve averages the rating measurements and few of them are exactly zero percent difference from the rating. The percent difference, whether computed directly from the rating or by using a shift adjustment, shows up when the measurement is plotted on the hydrograph, and 2) the mean gauge height of the discharge measurement may not be identical to

the daily mean gauge height. The measurement will plot higher or lower than the hydrograph if the mean gauge height is greater or smaller, respectively, than the daily mean gauge height. In the first case, the measurement needs no correction, but in the second, an adjustment should be made. Measurement No. 75 on the hydrograph in Figure 71 was made at a much lower gauge height than the daily mean. The measurement plotted close to the rating curve but because of the change in stage during the day, it plotted below the hydrograph and is adjusted to the daily mean gauge height as follows:

$$Q_{Adj.} = \frac{Q \text{ meas x } Q \text{ daily}}{Q_{(\text{from meas. ght.})}}$$

Qmeas. = 1500 cusecs

Q daily = 1850 cusecs

Q (from meas. ght.) = 1460 cusecs

$$\therefore \; Q \text{ Adj.} = \frac{1500 \times 1850}{1460} = 1900 \text{ cusecs}$$

The Adjusted Q of 1900 cusecs is the plotted value on the hydrograph.

The same adjustment can be made directly on the hydrograph with a pair of dividers. Spread the points to a distance equal to the difference between the measured discharge and the discharge obtained from the mean gauge height of the measurement. Place one point of the dividers on the hydrograph and the other point will locate the position of the adjusted discharge. The adjusted point might be either above or below the hydrograph. If the measured discharge is larger than the discharge obtained from the mean gauge height of the measurement, the adjusted discharge plots above the hydrograph. The reverse holds if the measured discharge is smaller than the discharge computed from the mean gauge height of the measurement.

Computer program plotting

The Calcomp plotter at the Data Center will be used to plot the discharge hydrograph on a form similar to the one recommended for manual plotting. Although the notes, discharge measurements, and miscellaneous items will be plotted by hand, the machine plotting will save time and increase the accuracy of the hydrograph. This will promote greater use of the hydrographs in the final processing of the discharge records.

Use

The discharge hydrograph is an important tool in the computation of station records and the best method of use is to make visual comparisons on the light table. A comparison of the discharge per square mile (or sq km) can be made by marking the catchment areas on the log scale and superimpose the hydrographs by matching the catchment area marks. At the same time, examine the rainfall bar chart and all the notes and plotted items on the hydrograph.

Perhaps an examination of the gauge height record at this time will bring evidence to bear on questionable periods. This is the final examination of the daily mean discharge record and accuracy and consistency of the streamflow records may well depend upon the hydrograph analysis. The records that are filled in should always be shown by dashed lines. A few specific uses of the hydrograph follows:

1. Shifting control.

   Rivers with badly shifting control must be frequently measured to define the size and distribution of the shift adjustments. If there are few measurements, the daily discharge hydrograph can be compared with those from other stations and, if desirable, the shift adjustments are changed to make smoother transitions during rating changes and, in general, produce more consistent records. Large changes in the adjustments will show that more frequent measurements are necessary in future years. The accuracy of the records will be lowered until better field basic data is produced.

2. Periods of no record.

   These periods have been left blank on the hydrograph except for the plot of discharge measurements, miscellaneous gauge readings and notes, peak flow, range in stage, and similar information. These data, together with the rainfall record, are used to fill in the daily mean discharge by comparison with records from nearby stations. Usually records from stations on the same river make the best comparison but no station should be overlooked. Reconstruction of the gauge height record (described under preparation of the gauge height record) is the first choice but if this proves impossible, then the daily mean discharge is computed directly on the hydrograph. It must be remembered that spot discharges such as obtained by discharge measurements do not necessarily represent the mean for the day. In computing discharge for periods of no gauge height record, it is important to study the form of the recession for the gauging station. Since the yield at low flow may be different than those at medium or high flow, it is very important to understand the runoff characteristics of the river basins. A study of the record for previous years may shed light on the regimen of flow. This information is necessary before a reliable comparison of the hydrographs can be made.

3. Periods of backwater and doubtful gauge height record.

The hydrograph is excellent for identifying periods of backwater. The comparison is similar to that used for the periods of shifting control and no gauge height record. It is possible to identify faulty gauge height record that was assumed to be satisfactory during the preparation of the record. The gauge heights for Dec. 1-4 in Figure 71 were assumed to be in error after the hydrograph comparison. In this case, further comparison is called for before the daily mean discharges are revised.

Computation of monthly and yearly discharge

The monthly and yearly computations are entered at the bottom of the discharge computation form. The same summaries will be used for both the manual and machine computations but the units will vary between metric (SI) and English system. The following units are recommended:

	English	Metric (SI)
Total	cusec (ft^3/s)-day	m^3s-day
Mean discharge	cusec (ft^3/s)	m^3/s
Maximum daily mean discharge	cusec (ft^3/s)	m^3/s
Minimum daily mean discharge	cusec (ft^3/s)	m^3/s
Discharge per unit catchment area	cusec per square mile ($ft^3/s/m^2$)	$m^3/s/km^2$
Depth of runoff	inch	mm
Volume of runoff	acre-feet (ac-ft)	m^3

The following rounding-off limits are recommended for both monthly and yearly computations:

Totals

Units:
English - cusec-day
Metric - cumec-day

Rounding rule:
Exact total by addition; no rounding.

Mean discharge

Units:
English - cubic feet per second
Metric - cubic metre per second

Rounding rule:
Computed by dividing the totals by number of days and carried to:

English - Below 0.010 to 1 significant figure
0.010 to 0.99 to 2 significant figures
1.00 to 999 to 3 significant figures
1000 and above to 4 significant figures

Metric - Below 0.010 to 1 significant figure
0.010 to 0.099 to 2 significant figures
0.100 to 9.99 to 3 significant figures
10.00 and above to 4 significant figures

Maximum and minimum daily mean discharge

Units:
English - cubic feet per second
Metric - cubic metre per second

Rounding rules:
Are the same as maximum and minimum daily figures.

Discharge per unit catchment (drainage) area

Units:
English - cubic feet per square mile (CFSM)
Metric - cubic metre per second per square kilometre (CMSKM)

Rounding rule:
Computed by dividing the mean by the catchment area and carried to:
English - Below 0.10 to 1 significant figure
0.10 to 0.99 to 2 significant figures
1.00 and above to 3 significant figures

Metric - Below 0.0010 to 1 significant figure
0.0010 to 0.0099 to 2 significant figures
0.0100 and above to 3 significant figures

Depth of runoff

Units:
English - inches
Metric - millimetres

Rounding rule:
English - Computed by multiplying the total by 0.0372 and dividing by the catchment area and carried to:
Below 0.01 to 1 significant figure
0.01 and above to hundredths
Metric - Computed by multiplying the total by 86.4 and dividing by the catchment area and carried to:
Below 1.0 to 1 significant figure
1.0 to 9.9 to 2 significant figures
10 and above to units

Volume of runoff

Units:

English - acre-foot

Metric - cubic metre

Rounding rules:

English - Computed by multiplying the total cusec-by 1.9835:

Below 1 to 1 significant figure

1.0 to 99 to 2 significant figures

100 to 9990 to 3 significant figures

10,000 and above to 4 significant figures

Metric - Computed by multiplying the total cumec-days by 86,400:

Below 1,000 to 1 significant figure

1,000 to 99,000 to 2 significant figures

100,000 to 9,990,000 to 3 significant figures

10,000,000 and above to 4 significant figures.

Values will generally be given in millions of cubic metres.

Comparison of monthly and yearly mean discharge

Hydrographs of daily mean discharge are useful and necessary in comparing gauging station records. In addition, a quantitative, basinwide comparison can be made of the monthly and yearly means. This type of comparison might be used in the Kafue River basin, as shown in Figure 72. The monthly figures can be made more comparable if allowance is made for the travel time between stations, although on slow changing streams, this can sometimes be ignored. When the ungauged area between two gauging stations is a large percent of the total drainage area of the downstream station, the computation and comparison loses some of its value. A look at Figure 72, however, shows a very good comparison between Kafue River at Kipushi Road and at Ngosa Farm, irrespective of the large ungauged area. In summary, to be effective, an analysis of the basin streamflow requires a thorough study of all the basin characteristics in order to understand the quantitative results shown on the form. The computation may have little value without this analysis.

Sample discharge station analysis

Hydro Year 1967

Kafue River at Kasaka - KG 8

STATION ANALYSIS

Equipment.--Staff gauge in two sections, 12-21 ft. inside an open top circular concrete well and section 20-33 ft. attached to 6-inch diameter pipe standard, landward from well. Low to medium high discharge measurements made by boat from slack cableway 64 ft. upstream from gauge well.

Gauge-height record.--Twice daily gauge readings obtained by observer at 600 and 1800 hours. Gauge heights were also obtained when discharge measurements were made and at times of a few miscellaneous visits by an hydrographer. The observer's record is complete and satisfactory and agrees with the miscellaneous gauge readings by visitors.

Datum corrections.--Levels of 20th October, 1965, by C. R. Brickhill from B.M. I (elev. 23.84 ft., gauge datum) found the new staff gauge as follows:

Section 8-21	0.005 ft. low
Section 20-33	0.005 ft. low

These sections were established on 15th October, 1965, and no changes made to the gauge at time of levels. Water level found at 13.44 ft. by level and the gauge read 13.45 ft. at water level at same time.

Levels of 4th November, 1966, by an unknown technical assistant from B.M. 2 (elev. 25.43 ft., gauge datum) found staff gauge as follows:

Section 8-21	0.01 ft. low
Section 20-33	0.01 ft. low

Water level found at 12.93 ft. and gauge read 12.95 ft. at water level. No changes made to setting of gauges.

No datum corrections have been applied during the 1967 hydro. year.

No levels to the gauge sections have been run since those of 4th November, 1966, and consequently no datum corrections have been applied during the 1967 hydro year subsequent to these levels to either the observer's gauge readings or the gauge heights related to the discharge measurements.

Rating.--The channel has a smooth firm bottom with much grass growing at the edges. There are also scattered grass and reed covered bars and islands. The channel is straight in the vicinity of the gauge but gradually bends to the left about three quarters of a mile downstream. The right bank at the gauge will confine flow up to medium high water. The left bank will be overflowed at about a 17 ft. stage. The control is a section of channel below the gauge with some changes because of wash-out of grass and weed beds at high flow. Floating grass islands are prevalent on rising stages and cause great difficulties during discharge measurements. The Kafue Road bridge may have slight control effect at high stages.

Thirty-eight discharge measurements (Nos. 577-614) and 19 earlier measurements are available for this analysis. All the discharge measurements above 35,000 cusecs were plotted but lower measurements prior to No. 577 were not plotted because of shifts in the stage-discharge relationship.

Discharge measurements Nos. 537-547, 579-581, 585-599, 602, 603, 605, 606, 611-614 were used to define a new rating (No. 15). All of these measurements plot within 5 percent of rating No. 15 except Nos. 547, 579, and 613, which are +6.4, -5.7, and +6.6 percent, respectively, from the curve.

Measurements Nos. 582-584 plot to the right but are made within a few days of Nos. 580 and 581 and there is no reason for an increase in discharge as indicated by these three measurements. It is possible that these measurements were made by an unskilled observer and if each meter count had been in error by one extra count they could be corrected to within a reasonable percentage of the new rating (No. 15). Therefore, no shift corrections were computed on the basis of Nos. 582-584.

Discharge.--Rating No. 15 was used throughout the year. No shift corrections were applied. Since the rating No. 14, used in computing the 1966 records, differs by only 5 percent from rating No. 15 at the stage occurring at the end of 1966, no transitional shifts are used at the beginning of the 1967 hydro year.

Remarks.--Records good.

Written by L. E. Bidwell, 17/2/70

Checked by P. S. Lee, 22/4/70

Sample discharge station analysis

Hydro Year 1968

Kafue River at Kasaka KG 8

STATION ANALYSIS

Equipment.--Staff gauge in two sections, 12-21 feet inside an open top circular concrete well and 20-33 feet attached to a 6-inch diameter pipe standard, landward from well. Low and medium-high discharge measurements made by boat from slack cableway 64 feet upstream from gauge well.

Gauge-height record.--Twice daily gauge readings obtained by observer at 600 and 1800 hours complete and satisfactory. No days of missing record. Observer's readings compare favorably with those obtained during discharge measurements.

Datum corrections.--The last levels to the gauge were run 4th November, 1966.

No datum corrections have been applied throughout the year.

Rating.--The channel has a fairly smooth, firm bottom with grass growing along each bank. The grass is dense and no perceptible flow occurs through the grass at low and medium-low stages. The channel is straight in the vicinity of the gauge and bends slightly to the left about three quarters of a mile below. Some weed and grass covered bars and islands are below the gauge. The right bank will overflow at about a 23 ft. stage but the left bank starts to overflow at about 17 feet. The control at all stages is the channel below the gauge except the Kafue Road bridge may become slightly effective as a control at extremely high stages.

Seven discharge measurements (Nos. 599-605), made in the 1967 and 1968 hydro years and nine discharge measurements made in 1969 (Nos. 606-614) are available for this analysis. The low and medium stage measurements made in the 1969 hydro year are not used. The high stage measurements (Nos. 611-614) were used in the 1967 analysis to define last year's highwater portion of rating No. 15, which was used at the end of hydro year 1967.

Measurements Nos. 599, 602, 603, 605, and 606 plot within 5.1 percent of last year's rating No. 15 and it was continued in use throughout this year. Measurements Nos. 600 and 601, both at medium flow, plot considerably to the left of rating No. 15. Both of these measurements were made with too few sections and some doubt exists as to their accuracy but are used to define shift corrections. It is assumed that the shift to the left started on the rising stage during January 1968 and continued through June 10, 1968.

Discharge.--Rating No. 15, in use last year, was continued in use throughout this year. Shifting-control method was used January 7 to June 10 with the shift corrections defined by discharge measurements Nos. 600 and 601 and applied on the basis of time and stage. Measurements Nos. 602 and 603 plot to the left of the curve, rating No. 15, and could have defined shift corrections into August. Since they both plot within 3.7 percent of the rating, no shift corrections have been applied based on these two discharge measurements. No measurements were made June 1967 to March 1968 and the measurements Nos. 600-606 were all made with few sections so doubt is raised on the accuracy of the year's record.

Remarks.--Record fair except those during periods of shifting control (January 7 to June 10), which are poor.

Written by L. E. Bidwell, 20-2/70

Checked by P. S. Lee, 28/4/70

Sample stage station analysis

Hydro Year 196_

Kawanda River near Chonta

STATION ANALYSIS

Equipment.--Staff gauge on right bank in three sections, 0.5 feet, 4-9 feet and 8-13 feet.

Gauge-height record.--Thrice daily observer's gauge readings complete and satisfactory throughout the year. Hydrographer's gauge readings at time of the visit on Mar. 20, 196_ compares favorably with the observer's reading.

Datum corrections.--Levels of 15 October 196_, by J. H. Sommers from B.M. 2 (elevation 12.36 feet, gauge datum) found B.M. 1 at correct datum (8.12 feet) and the staff gauge as follows:

Section 0.5 feet reads correctly.
Section 4-9 feet reads correctly.
Section 8-13 feet reads 0.01 foot high.

The staff sections were not reset.

The water surface was found to be at 3.97 feet at hour 1500 and the staff gauge read 3.97 feet.

Levels of 22 April 196_, by J. Sekele from B.M. 2 (elevation 12,36 feet, gauge datum) found B.M. 1 at correct elevation and the staff gauge as follows:

Section 0-5 feet reads correctly.
Section 4-9 feet reads 0.03 foot low.
Section 8-13 feet reads 0.04 foot low.

The water surface elevation found at 4.64 feet and the staff gauge read 4.64 feet on the lower section at hour 1320.

The middle and upper sections were reset to correct elevation at hour 1345. The lower section was not reset.

No datum corrections necessary to the readings from the lower section but datum corrections necessary to middle and upper sections. Since no date of change is known, it is assumed that the gauges gradually changed between the first rise in stage on 3rd January and the date the levels were run on 22 April. The datum corrections therefore are as follows:

Section 4-9 feet

+0.01 foot -- 18 January to 18 February
+ .02 foot -- 19 February to 21 March
+ .03 foot -- 22 March to 22 April at 1345

Section 8-13 feet

+0.01 foot -- 17 January to 15 February
+ .02 foot -- 16 February to 12 March
+ .03 foot -- 13 March to 6 April
+ .04 foot -- 7-22 April at 1345

Written by L. E. Bidwell, 20/2/6_
Checked by J. H. Honaka, 28/3/6_

EXAMPLE

HYDROLOGICAL SURVEY OF ZAMBIA

Kafue River at Kasaka Catchment Area = 58,290 square miles

Year	Yearly Mean Disch.	Cumulative Mean Discharge	No. of Years	Average Discharge: Cusecs	Cumecs	Inches *	mm	Acre-feet ** in thousands	Cubic-Metres
1960	6,176	6,176	1						
61	11,520	17,696	2						
62	16,190	33,886	3	11,300		2.63		8,187	
63	33,460	67,772	4	16,940		3.95		12,270	
1964	9,961	77,733	5	15,550		3.62		11,270	
65	6,800	84,533	6	14,090		3.28		10,210	
66	7,200	91,733	7	13,100		3.05		9,491	
67	6,214	97,947	8	12,240		2.85		8,868	
68	5,183	103,130	9	11,460		2.67		8,303	

It is recommended that the average discharge for each streamflow station be computed by the method shown on this form. The calculation is made in pencil and filed in the station current file. Each year, upon completion of the yearly discharge records, the yearly mean discharge is entered as shown and the calculation is made. This computation sheet is easily recognized in the file if Form H114 is always used for the "Average discharge" computation.

Recommended rounding rules and computation method follows:

English Units

Cusecs - 3 significant figures below 1,000 and 4 significant figures 1,000 and above.
Inches - to hundredths.
Acre-feet - 3 significant figures below 10,000 and 4 significant figures 10,000 and above.
* Ave. yearly runoff in inches is computed by multiplying the average discharge in cubic feet per second by the factor 13.58 and dividing by the catchment area.
** Ave. yearly discharge in acre-feet is computed by multiplying the average discharge in cubic feet per second by the factor 724.5.

Metric Units

Use units that will give comparable percent accuracy to English units.

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A P P E N D I C E S

CONVERSION TABLES

Comparison of Units

Dimensions	English	Metric -S.I.
Length	Inch (in.) Foot (ft.) Mile (mi.)	Millimetre (mm) Centimetre (cm) Metre (m) Kilometre (km)
Area	Square foot (sq.ft.) Acre (ac) Square mile (sq. mi.)	Square metre (m^2) Square kilometre (km^2)
Volume	Cubic foot (cu.ft.) Acre foot (ac.ft.)	Cubic metre (m^3)
Time	Second (s)	Second (s)
Velocity	Feet per second (ft/sec)	Metre per second (m/s)

Conversion

Metric (S.I.) into English Units

To Convert	Into	Multiply by
Millimetres (mm)	Inches (in)	0.03937
Centimetres (cm)	Inches (in)	0.3937
Metres (m)	Feet (ft)	3.281
Kilometres (km)	Miles (mi)	0.6214
Square metres (m^2)	Square feet (ft^2)	10.76
Square kilometres (km^2)	Acres (ac)	247.1
Square kilometres (km^2)	Square miles (mi^2)	0.3861
Cubic metres (m^3)	Cubic feet (ft^3)	35.31
Metres per second (m/s)	Feet per second (ft/s)	3.281
Cubic metres per second (m^3/s) cumecs	Cubic feet per second (ft^3/s) cusecs	35.31
Cubic metres per second per square kilometre	Cubic feet per second per square mile	91.46

English into Metric (S.I.)

To Convert	Into	Multiply by
Inches (in.)	Millimetres (mm)	25.40
Feet (ft)	Metres (m)	0.3048
Miles (m)	Kilometres (km)	1.609
Square feet (ft^2)	Square metres (m^2)	0.09290
Acres (ac)	Square kilometres (km^2)	0.004047
Square miles (mi^2)	Square kilometres (km^2)	2.590
Cubic feet (ft^3)	Cubic metres (m^3)	0.02832
Acre feet (ac-ft)	Cubic metres (m^3)	1233
Cubic feet per second or cusec	Cubic metres per second cumecs (m^3/s)	0.02832
Cubic feet per second per square mile	Cubic metres per second per square kilometre	0.01093

GENERAL STREAM GAUGING TERMS

Artificial control.--A structure built in a stream channel to stabilize the stage-discharge relation.

Backwater.--Water backed up or retarded in its course as compared with its normal or natural condition of flow. In stream gauging, a rise in stage produced by a temporary obstruction such as weeds, fish traps, or tributary floods.

Bank.--The margins of a channel. See "Left (or Right) bank".

Bench mark.--A recognized permanent point of known elevation above a specified datum plane. Bronze tablets, bolts, chiseled marks are all examples of bench marks used at gauging stations in Zambia. It has been found expedient in the United States, where vertical control points and gauging stations are numerous, to separate the points of known elevation into three categories: 1) Bench marks; 2) Reference marks, and 3) Reference points. U.S.G.S. Water Supply Paper 888, pp. 210, 211 gives a detailed account of these points.

Channel (water course).--An open conduit either natural or artificial (canal) which periodically or continuously contains moving water, or which is a connecting link between two bodies of water.

Control.--A feature downstream from the gauge that determines the stage-discharge relation at the gauge. It can be either natural or artificial.

Cross-section.--The section across the stream, 90 degrees to the mean direction of flow, which is used in a discharge measurement to obtain the depth, width, and velocity of the water.

Datum of gauge.--The datum plane (either arbitrary or a recognized datum such as mean sea level) to which the zero of the gauge is referred. A permanent datum must be maintained by referring the zero of the gauge to a bench mark.

Discharge measurement.--The operation of measuring the discharge of a liquid in a conduit. In surface water hydrography, it is the determination of the discharge of water flowing in a stream, canal, or conduit. It is expressed as a rate of flow.

Error of Closure.--The difference between the initial elevation of the initial benchmark of a level circuit and the final elevation of the same benchmark obtained upon completion of the circuit.

Gauge height (water level).--The water-surface elevation referred to some arbitrary gauge datum. Gauge height is often used interchangeably with the more general term "stage", although gauge height is more appropriate when used with a reading on a gauge. In Zambia, the term "water level" is synonymous with gage height.

Gauging station.--A particular site on a stream, canal, lake, or reservoir where systematic observations of gauge height or discharge are obtained.

Horizontal angle.--The angle of current, or the difference between 90° and the angle made by the current with the discharge measurement cross-sections.

Left (or right) bank.--The stream bank to the left (or right) as viewed facing downstream.

Reach.--Generally, any length of a river or section of a river.

Reference point.--See "Bench mark".

River.--A natural stream of water of considerable flow, or a watercourse.

Sounding.--A determination of depth of water in a stream. In stream gauging, this is generally done during a discharge measurement at each vertical in the cross section prior to positioning the current meter for a velocity reading.

Stage.--The height of a water surface at a point along a stream, measured above an arbitrary datum. See "Gage height".

Stage-discharge relation.--The relation between gauge height (water level) and the amount of water flowing in a channel, expressed as volume per unit of time (discharge). At a discharge station this relationship is expressed in a rating curve or table.

Stream.--A general term for a body of flowing water. In hydrology, the term is generally applied to the water flowing in a natural channel, as distinct from a canal. In stream gauging, it is applied to the water flowing in any channel, natural or artificial.

Stream gauging.--The process and art of measuring the depths, areas, velocities, and rates of flow in natural or artificial channels.

Vertical.--One of the vertical lines which divide the cross section into smaller areas and in which the depth and velocity of the water is determined during a current meter discharge measurement.

Vertical angle.--The angle between the vertical and the sounding line when the current meter and sounding weight are dragged downstream by the water.

Water level.--See "Gauge height".

EQUIPMENT TERMS

Angle indicator (protractor).--An instrument attached to the outer end of the boom of a bridge crane, which measures the vertical angle during bridge discharge measurements. Similarly, another type is used on a cable car for the same purpose.

Bridge crane.--See "Crane".

Boat outfit.--It includes an adjustable telescopic boom used to extend the current meter and sounding weight beyond the bow of the boat, a crosspiece to attach the boom to the boat gunwales which holds the boat on the tag line, and a support and sheaves for a sounding reel and line. The boat outfit developed in Zambia consists of a boom attached to the boat seat and resting on the gunwale to extend the current meter and sounding weight over the side of the boat.

Cable car.--A car suspended on a cableway by sheaves (pulley) and designed to carry personnel and discharge measuring equipment across a river during a discharge measurement. The cable car is of two types, sit-down and stand-up.

Cableway.--A cable, spanning the stream, and supported and anchored on each bank, provides a track for a cable car which is used by the hydrographer in making a current meter discharge measurement.

Counterweight.--A cast iron (generally) weight used on the four-wheel truck base of a bridge crane to counter balance the sounding weight during a bridge discharge measurement.

Crane.--A machine consisting of a movable boom, 3 or 4-wheeled truck base, and support and sheaves for a sounding reel and line. It is used with a sounding reel to facilitate sounding with a heavy sounding weight in a bridge discharge measurement. The movable boom with current meter and sounding weight can be extended beyond the interfering bridge members.

Current meter.--An instrument used to measure the velocity of flowing water. They generally can be classified as those having vertical-axis rotors and those having horizontal-axis rotors.

Current meter rating.--The calibration of the current meter. It is usually a table expressing the relation between the revolutions of the bucket wheel (rotor) and the time, and expressed in velocity in feet per second or meters per second.

Float gauge.--A device inside a well which consists of a float which rides on the water surface attached to a counterweight by means of a stainless steel tape which passes over a suitable pulley and past an indicator pointer.

Handline.--An assembly of an upper rubber covered cable, hand reel, and lower steel single conductor cable to support the current meter and light sounding weights in discharge measurements of streams too deep to wade.

Hand reel.--A reel used to hold the steel cable of a handline and to connect the upper rubber-covered cable to the steel cable.

Inclined staff gauge.--See "Staff gauge".

Intake (Inlet).--The connection between the stilling well and stream through which water from the stream enters or leaves. It may be a length of pipe or a slot or hole through the wall of the stilling well.

Sounding cable.--The steel cable used to suspend the current meter and sounding weight when making a determination of depth and velocity in a stream. The cable is controlled either by a reel or by use of a handline.

Sounding reel.--The mechanism used to control the sounding cable. It has a drum for winding the cable and is used for raising and lowering the sounding weight and current meter and a mechanism for holding the cable at any desired position. A depth indicator is an integral part of the reel.

Sounding weight.--The weight suspended from the sounding cable below the current meter to keep it stationary in the water and to stablize the cable when making a sounding. The sounding weights are of various weights from 15 lbs. upward.

Staff gauge.--A fixed vertical or inclined scale, or staff, on which the height of the surface of water may be read. The vertical staff gauge consists of porcelain enamel iron sections attached to a stable support inside a stilling well or in the stream. The inclined staff gauge is built on the slope of a bank and graduated to indicate vertical heights.

Stilling well.--A chamber or well connected with the stream in such a way as to permit the measurement of the stream in relatively still conditions.

Tag line.--A small diameter galvanized steel aircraft cord with solder beads or brass tags at measured intervals and controlled by winding on a tag line reel. It is used in measuring the horizontal distances and widths in a wading or boat discharge measurement cross section.

Tag line reel.--A reel to hold and control a tag line. Various types and sizes are developed for use with various diameter and length tag lines.

Vertical staff gauge.--See "Staff gauge".

Wading rod.--A graduated rod used to suspend the current meter when making a measurement of depth and velocity of a shallow stream. The two types commonly used are top setting and the round rod.

Water-stage (level) recorder.--An instrument for producing a graphic or punched tape record of the rise and fall of a water surface with respect to time.

GENERAL HYDROLOGIC TERMS

Acre-foot (ac-ft, acre-ft.).--The quantity of water required to cover 1 acre to a depth of 1 foot.

Average discharge.--The mean rate of discharge that passes a given point over the period specified.

Basic hydrologic data.--Inventories of features of land and water that vary only from place to place (topographic and geologic maps), and records of processes that vary with both place and time (records of precipitation, streamflow, ground water, etc.).

Catchment area (Drainage area).--An area from which water drains to a single point; in a natural basin, the area contributing flow to a given place or a given point on a stream.

Cubic foot per second (cusecs, c.f.s.).--The rate of discharge representing a volume of 1 cubic foot passing a given point during 1 second.

Cubic meter per second (cumec).--The rate of discharge representing a volume of 1 cubic meter passing a given point during 1 second.

Discharge.--The volume of water (or total fluids) that passes a given point within a given period of time. Also, it is outflow or the flow of a stream, canal, aquifer, or pipe. Units of discharge commonly used in reference to streams are cubic foot per second (cusec) and cubic meter per second (cumec).

Downstream order.--The system of listing gauging stations in a downstream direction along the main stream and stations on tributaries are listed between stations on the main stream in the order in which those tributaries enter the main stream. Stations on tributaries to tributaries are listed in a similar manner.

Drainage area.--See "Catchment area".

Flood plain.--The lowland that borders a river, usually dry but subject to flooding.

Hydrograph.--A graph showing stage, flow, velocity, or other property of water with respect to time. In the Branch, the hydrograph usually refers to stage and discharge. That of discharge is used extensively in the final study of streamflow records.

Hydrologic year (water year).--The 12-month period 1st October to the 30th September. This division of the year usually is more suited to the study of rainfall-runoff than a calendar year, although in some areas the 12-month period may deviate from the months ordinarily considered. The hydrologic year is designated by the calendar year in which it ends. Thus, the year ending 30 September 1969 is called the 1969 hydrologic or water year.

Hydrology.--The science of the behavior of water in the atmosphere, on surface of the earth, and underground.

Ground water.--Water in the ground.

Runoff.--That part of the water yield that appears in streams. It is the same as streamflow unaffected by artificial diversions, storage, or other works of man in or on the stream channels.

Streamflow.--The actual flow in streams, whether or not subject to regulation or underflow.

Surface water.--Water on the surface of the earth.

Water year.--See "Hydrologic year".

Water yield (or yield).--The runoff from the catchment area or drainage basin including ground water outflow, that appears in the stream, plus ground-water outflow that bypasses the gauging station and leaves the basin underground. Water yield is the precipitation minus the evapotranspiration and therefore includes runoff plus underflow.

Valley.--An area drained by a river and its tributaries. An elongated depression of the earth's surface between ranges of hills.

FILING SYSTEM

A well designed, straighforward filing system is of prime importance in filing of hydrologic basic data and streamflow records. It should be mandatory that no files be left unattended on tops of desks or in desk drawers. It is the responsibility of the officer in charge to enforce this rule. The system must be designed for simplicity and accuracy. Complicated files that may serve admirably in an office under the control of a trained filing clerk will in most small hydrologic offices prove inefficient and a source of confusion. Elaborate numerical cross-indexed filing systems will only be a handicap.

For example: It is desired to analyze the basic data records for the 1969 water year (hydrologic year) for the Kafue River at Kasaka. Since all analyses are concerned with a particular gauging station, all filing should be identified by the gauging station name or number, that is, Kafue River at Kasaka, 5-0123. (The station number 5-0123 is only used as an illustration in this example as no actual station numbers have been assigned). Filing data by gauging station name and not by number is recommended for Zambia for two reasons: First, the amount of stations will remain fairly constant within the next few years, and second, the requests for data are almost always by river name and location. Also, data filed by gauging station name is easy to find because the request and the filing are similar in concept. These requests may be from outside sources or from an office hydrologist preparing a station analysis, but in either case, the station name is used.

In all stage and discharge station analyses, the basic streamflow data must be retrieved from a file, and using the Kafue River as an example, the following list contains the data ordinarily studied by the hydrologist in preparation of the 1969 records:

1. Gauge height record for 1969 water year.

    a. Recorder record.

    b. Gauge height readings.

2. Level notes obtained from gauge checks.

    a. 1968 water year notes.

    b. 1969 water year notes.

    c. 1970 water year notes, if available.

3. Discharge measurements.

    a. 1969 water year including last measurement in 1968 water year.

    b. Previous measurements may be necessary.

4. Miscellaneous field notes.

5. Analysis for 1968 water year.

6. List of discharge measurements for 1968.

7. Rating curve for 1968 water year.

8. Rating table for 1968 water year.

9. Field station description.

    a. Text.

    b. Site map and sketches.

    c. Photographs of gauge site, control and channel.

10. Miscellaneous office notes.

    a. Cross-section.

    b. Notes or letters pertaining to observer changes, etc.

This represents a large amount of different types of forms and data. Since they are used each year for the analysis of basic streamflow data for each gauging station, the process is repetitious by nature, that is, year after year for a large number of gauging stations.

The data can be merged for filing into four major groups for simplification as follows:

1. Gauge height record.

    a. Gauge readings (recommend 5" x 8" file).

    b. Recorder charts (recommend 8 1/2" x 11" file).

2. Basic streamflow data (5" x 8" file).

   a. Discharge measurement.

   b. Level notes (Form H102).

   c. Miscellaneous notes (Forms H100, H101).

3. Analysis of streamflow data and pertinent records (8 1/2" x 11" file).

   a. Analysis text.

   b. List of discharge measurements (Form H110).

   c. Current rating table (Form H112).

   d. Field station description.

      Text (Form 103)

      Photos

      Sketches (Form H105, H106)

      Cross-section

   e. Copy of daily mean discharge and gauge heights.

   f. Miscellaneous notes.

4. Current rating curve (map type of file).

Instead of searching through many office files and storage shelves, the hydrologist can with few exceptions retrieve the required data from the four following well-identified files:

1. Gauge height record.

2. Basic streamflow field data.

3. Analysis data (stage and discharge).

4. Current rating curve.

The data for each of the four groups will be filed with similar data from the other gauging stations in Zambia but will be separated and identified within the group by the gauging station name, in this example, Kafue River at Kasaka. One further division of the data is necessary; the files should be separated into "current" and "back" data. The current file will contain the data prior to analysis and computation of the records and the back file will contain the data after processing.

Further details regarding files are given in the following paragraphs:

Gauge height and basic streamflow field data

These should be separated into current and back data files. It is recommended that the Branch purchase two banks of 5" x 8" metal card file cabinets for the field data. An excellent type is one which is two drawers in width, six drawers in height, and mounted on an 8" x 10" base. These drawers should be constructed as an integral unit or interlocking for stability. A detailed description of the Field Data file is given on page 101.

Analysis data

These should be separated into current and back data files. The current file will contain the latest original copy of the following: station analysis, rating table, list of discharge measurements, field station description, miscellaneous notes, and computed streamflow records. It is recommended that these data be filed in a single folder. The analysis, rating table, list of discharge measurements should be enclosed (jacketed) by a folded copy of the sheet of yearly streamflow records, either the computer printout or form for manual computations. These jacketed items are bodily transferred to the back data file when the next hydrological year's records are inserted in the current file. The original copy of the field station description and any miscellaneous information will remain in the current file until they are superseded by a new or revised copy. It is further recommended that both the current and back data file folders be of the open type because the use of a wallet with a loose or tied flap is a hindrance to all users.

Rating curve sheets

The original copy of the current rating curve sheet should be kept flat in a map drawer type cabinet and filed in alphabetical order by station name. When a new sheet is prepared, the old original sheet should be folded and filed in the 8 1/2" x 11" back data file of streamflow records and data for that particular station.

It is recommended that at least two ozalid (black line) prints of the rating curve sheet be obtained each year after completion of the rating curve. One copy should be bound in a large loose-leaf binder and all current discharge measurements plotted as they are checked in the office. The second copy should be folded and placed in the Station Field File for use of the hydrographer in plotting discharge measurements in the field.

Field station data

This file contains information of importance to the hydrographer in the field. It is recommended that a brown paper envelope about 9" x 12" be used to contain the data. An envelope is prepared for each station and should be clearly marked FIELD FILE and followed by the station name. The contents are a copy of rating curve sheet, list of discharge measurements, level summary, field station description including maps, sketches, photos and any miscellaneous notes such as clock changes and maintenance notes. When time permits, a duplicate file should be prepared and kept in the office for other hydrographers to take in the field during floods or other hurried demands.

10m—G234 11-69

H 101

HYDROLOGICAL SURVEY OF ZAMBIA

Station No. ....

DESCRIPTION OF GAUGING STATION

On .... River at ....

Drainage basin ....

Province of .... Prepared by .... Date............, 19...

(Describe station fully, in accordance with outline on back of this form)

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Sheet No. .... of .... sheets. If insufficient space, use additional sheets.

OUTLINE OF DESCRIPTION OF GAUGING STATION

(Use headings as given below)

1. *Location*—(*a*) Relative to bridges, dams, falls, highways, islands, railroads, towns, tributaries, etc. Latitude and longitude. (*b*) How reached. Highway routes, including alternate routes during flood periods. Show complete information for auxiliary gauge if a slope station.

2. *Establishment*—Date and by whom. If a re-establishment so state, showing date and by whom.

3. *Drainage area*—Show how obtained, name of maps used (if known), or source (if furnished).

4. *Gauge*—(*a*) Description. If recorder, show make and type; elevations (bottom of well, intakes, sills of doors, reference point for tape gauge, and instrument shelf); description of inside, outside, and auxiliary gauges, intakes (including lengths), and flushing devices. Make special notes regarding operating conditions peculiar to station. (*b*) Observer's name, address, occupation, pay, distance to read gauge, refinement of readings, etc. (*c*) Elevation of zero of gauge above mean sea level or other datum. Give same information as above for auxiliary gauge if used to determine slope.

5. *History*—Brief description of other gauges operated nearby with dates of operation.

6. *Bench marks*—(*a*) Describe bench marks fully; make sketch showing principal features. Show elevation above zero of gauge, also above mean sea level or other datum, if available. (*b*) Describe fully bench mark used to determine elevation of zero of gauge above mean sea level or other datum; give location with respect to gauge.

7. *Channel and control*—Describe character of channel in vicinity of gauge and measuring section: (*a*) Character of bed of stream, as rock, gravel, sand, clean or vegetation covered, permanent or shifting; (*b*) character of banks at gauge and measuring section, as high, low, liable to overflow (stage of overflow), clean or vegetation covered; (*c*) condition of channel and flow above and below station and measuring section as straight or curved (give distances), flow smooth or turbulent, and approximate velocities at various stages; (*d*) number and location of channels at low and high water; if slope station, describe channel conditions in reach, inflow, breaks in bed, etc.

Describe controls for low and high stages: Location and character, as rock, gravel, sand, clean or vegetation covered, permanent or shifting, other special conditions.

8. *Discharge measurements*—(*a*) Location of low-, medium-, and high-water measuring sections. (*b*) Detailed description of measuring equipment, i.e., for cableway give heights of towers, type of anchorage, location of initial point for soundings, type of cable and cable car, length of span, unloaded sag, design load, etc. (*c*) Develop cross-section at measuring section to stage above high water. (*d*) Give special information, as maximum stage for wading, weights required for various stages, sections for slope-area, flow-over-dam, or contracted-opening computation, etc. (*e*) Probable accuracy (excellent, good, fair, or poor) with which measurements can be made.

9. *Floods*—Determine stages of major floods at station, referred to gauge datum. Show source and give reliability of data.

10. *Point of zero flow*—Give elevation referred to gauge datum, indicate probable accuracy in tenths of a foot. Note whether permanent or shifting.

11. *Regulation and diversion*—Location, description, and probable effect of dams, lakes, power plants, reservoirs, swamps, etc. above or just below station. Location and description of diversions above, at, or just below station, with probable amount of diversion and facilities for its determination.

12. *Accuracy*—State probable accuracy and reliability of data to be obtained at station, considering gauge-height record, control, and measuring conditions.

13. *Sketch*—Make sketch on cross-section paper, showing sufficient detail to enable one unfamiliar with the locality to reach the station with a minimum of effort. Show relative location of control, dams, diversions, gauge, highways, measuring sections, observer's house, railroads, bench marks, towns, tributaries, etc. (Make two sketches, detail and general, if necessary.) If available, include portion of topographic sheet covering area in which station is located (photostat of part of map is acceptable).

14. *Photographs*—If feasible, take photographs of the principal features at the station (close view of gauge and structure; general view of station showing control; measuring equipment, etc.).

Figure 1. Orderly and complete notes can be obtained by the consistent use of forms designed for detailed descriptions.

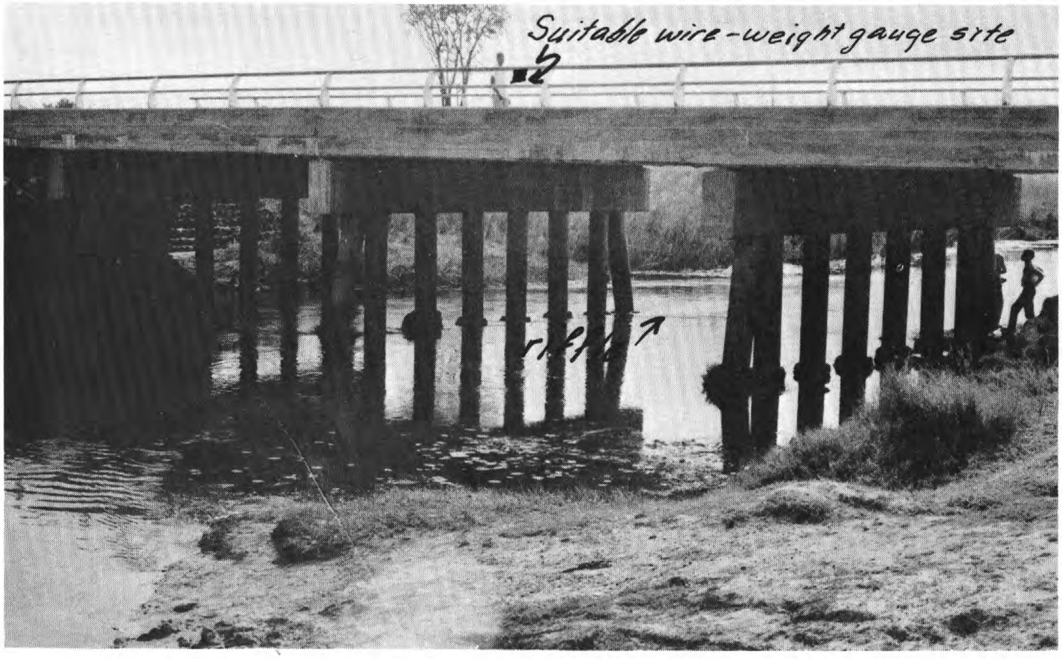


Figure 2. A stable concrete bridge with pipe rails is an ideal support for a Type A wire-weight gauge. At this gauging station, the present vertical staff gauge sections are 300 feet downstream with a very poor low-water control. The rocky riffle at the downstream side of the bridge makes a suitable low-water control for a wire-weight gauge on the upstream bridge rail.

Figure 3. The sheet of paper shows a good position for the installation of a Type A wire-weight gauge. The bridge provides a stable support and the gauge is easy to reach and read at all stages.

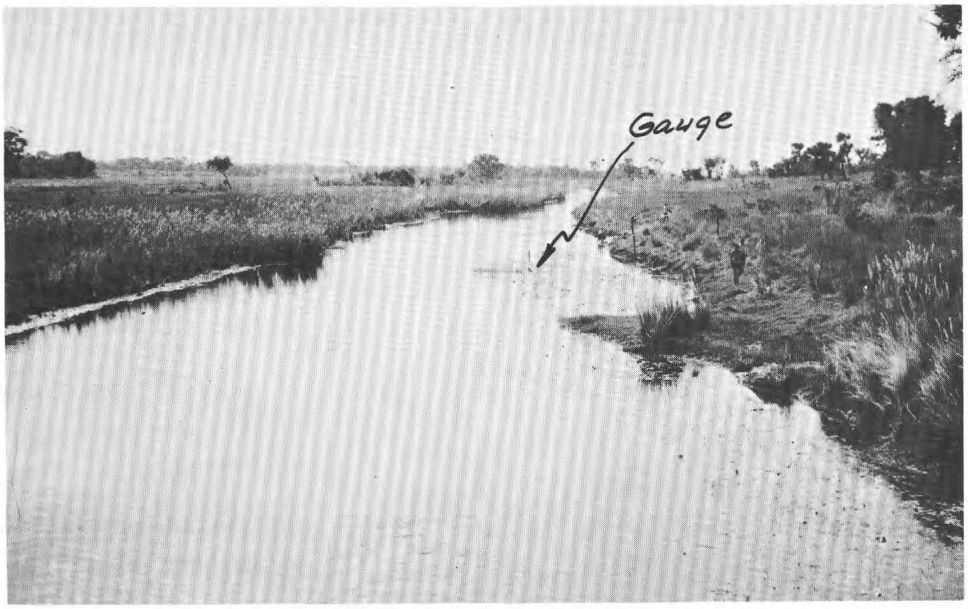


Figure 4. The long weedy channel with sluggish flow is a very poor control for the gauging station Luampa River at Luampa Road Bridge.

Figure 5. The low-water control for the telemetric gauging station on Luena River at Kasambemezi is a rocky riffle about 1/3 mile below the gauge. The clear-cut break in the water surface is characteristic of an effective control.

5m—G233 11-69 H100

HYDROLOGICAL SURVEY OF ZAMBIA

Date 26th Aug. , 196-

MISCELLANEOUS FIELD NOTES

Mutama River at Mutama Rapids

Ran levels to all outside staff sections and inside tape gauge. Reset bottom section. Tape OK.
Cleaned and oiled Stevens recorder.
Changed clocks - Removed No 312744 and replaced with No 442111 which was just back from repairman on 4th July 196-.
Cleaned intake with sewer rod - pumped out well with 1" power pump.
Painted door and cleaned house.
Marked gauge height scale on recorder. Hung new calendar in house.
Cut brush around well and cable section. Installed new roll of paper.

L.J. Johnson

Instructed observer to keep site clean etc.

L.J.

Steven recorder No 721,735

No. 1 of 1 sheets

Figure 6. Notes on all maintenance must be completed and sent to the designated office. Much time and effort will be saved by insisting that this type of report be written on Form H100.

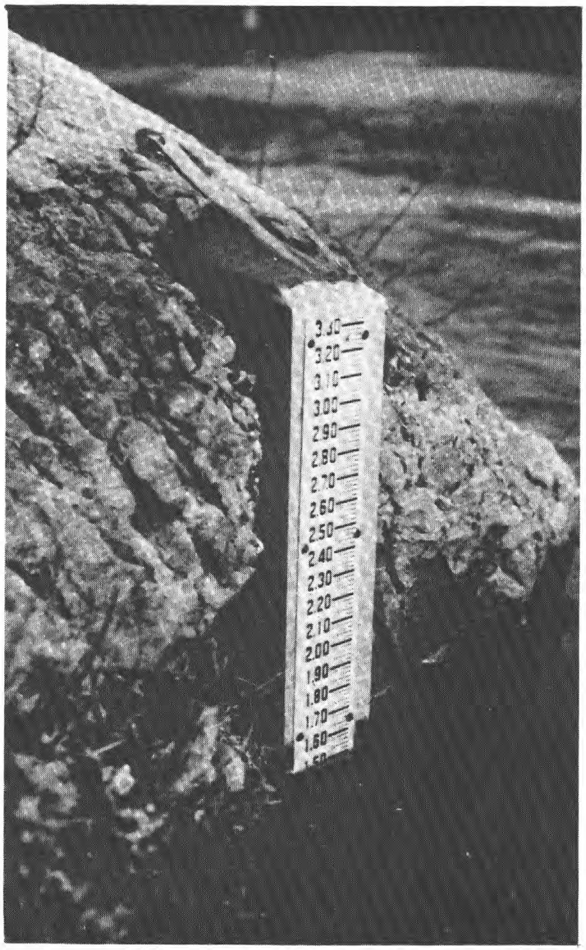


Figure 7. A vertical staff can be designed for easy and accurate reading.

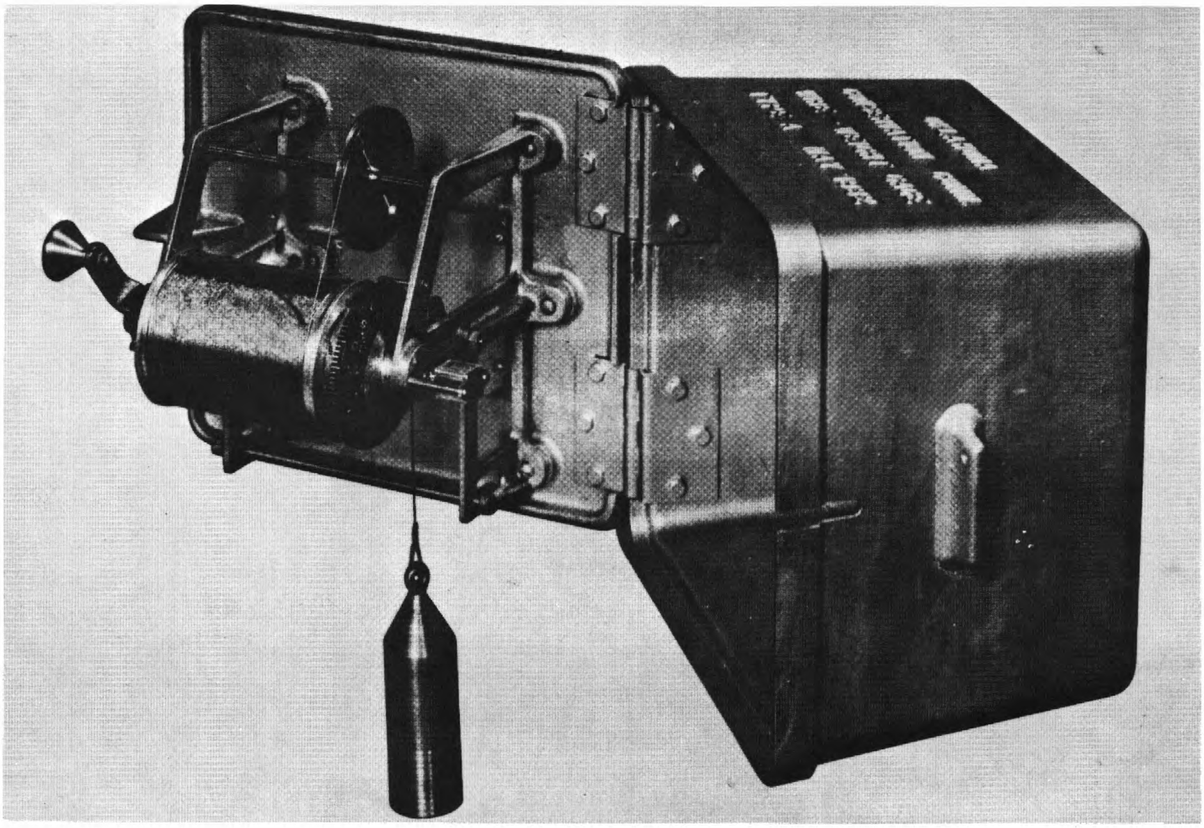


Figure 8. The Type A wire-weight gauge is an excellent non-recording gauge for installation on bridges.

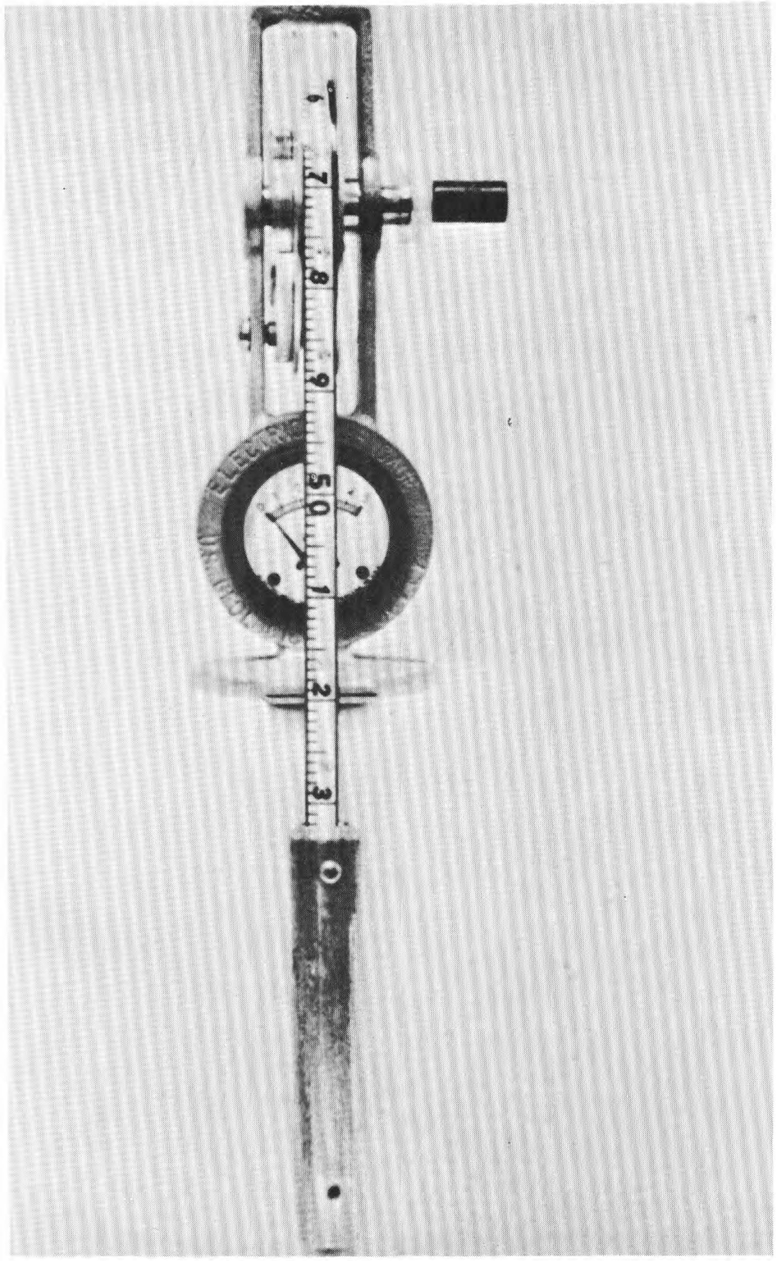


Figure 9. The electric tape gauge is designed for inside a well. Any low voltage battery will give long service.

Figure 10. The inside float tape gauge makes an ideal reference gauge for a recorder because it can be read simultaneously with setting of the recorder pen.

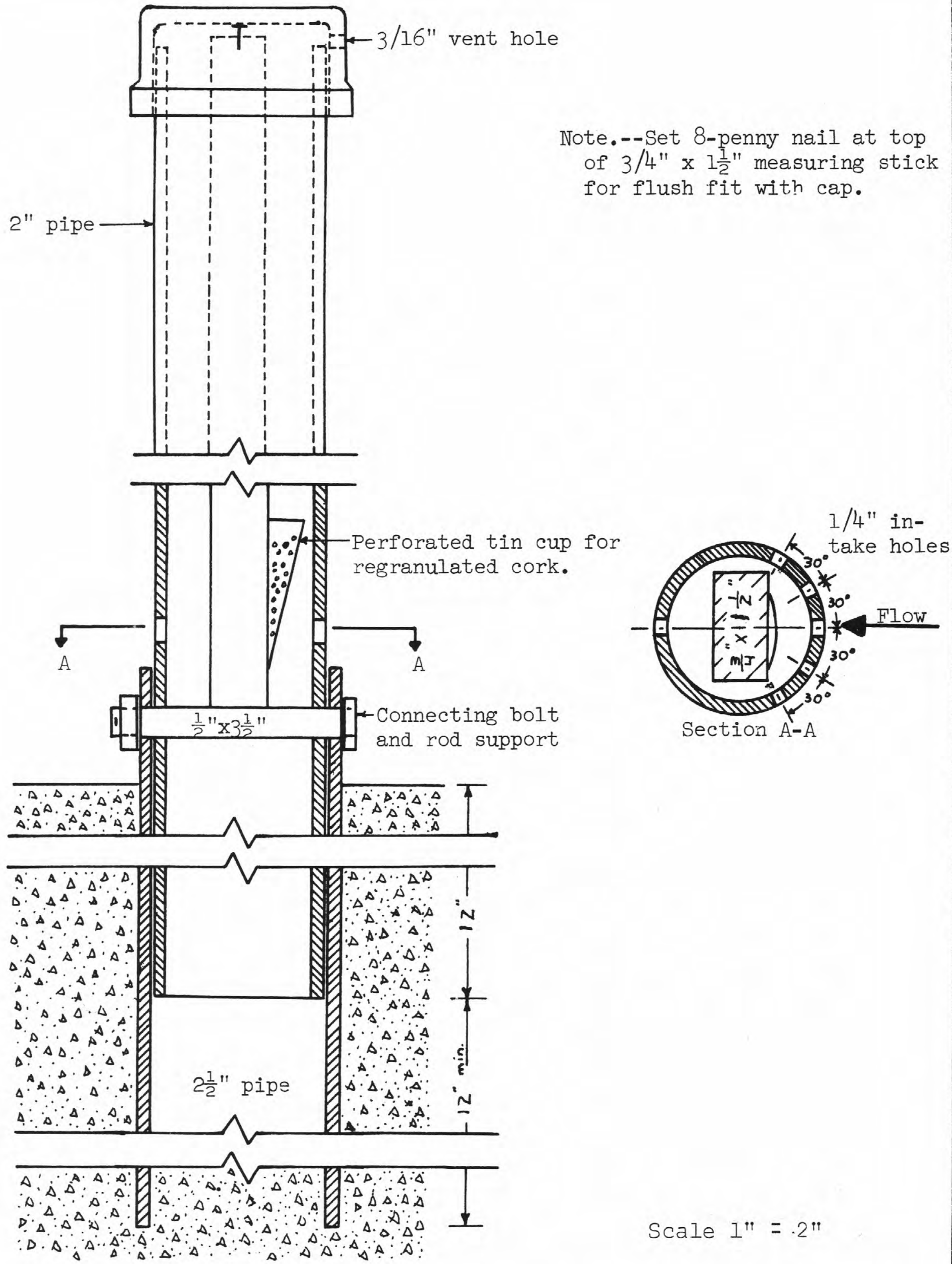


Figure 11. Design of intake holes and crest-stage gauge anchored in concrete.

Post type crest-stage gauge

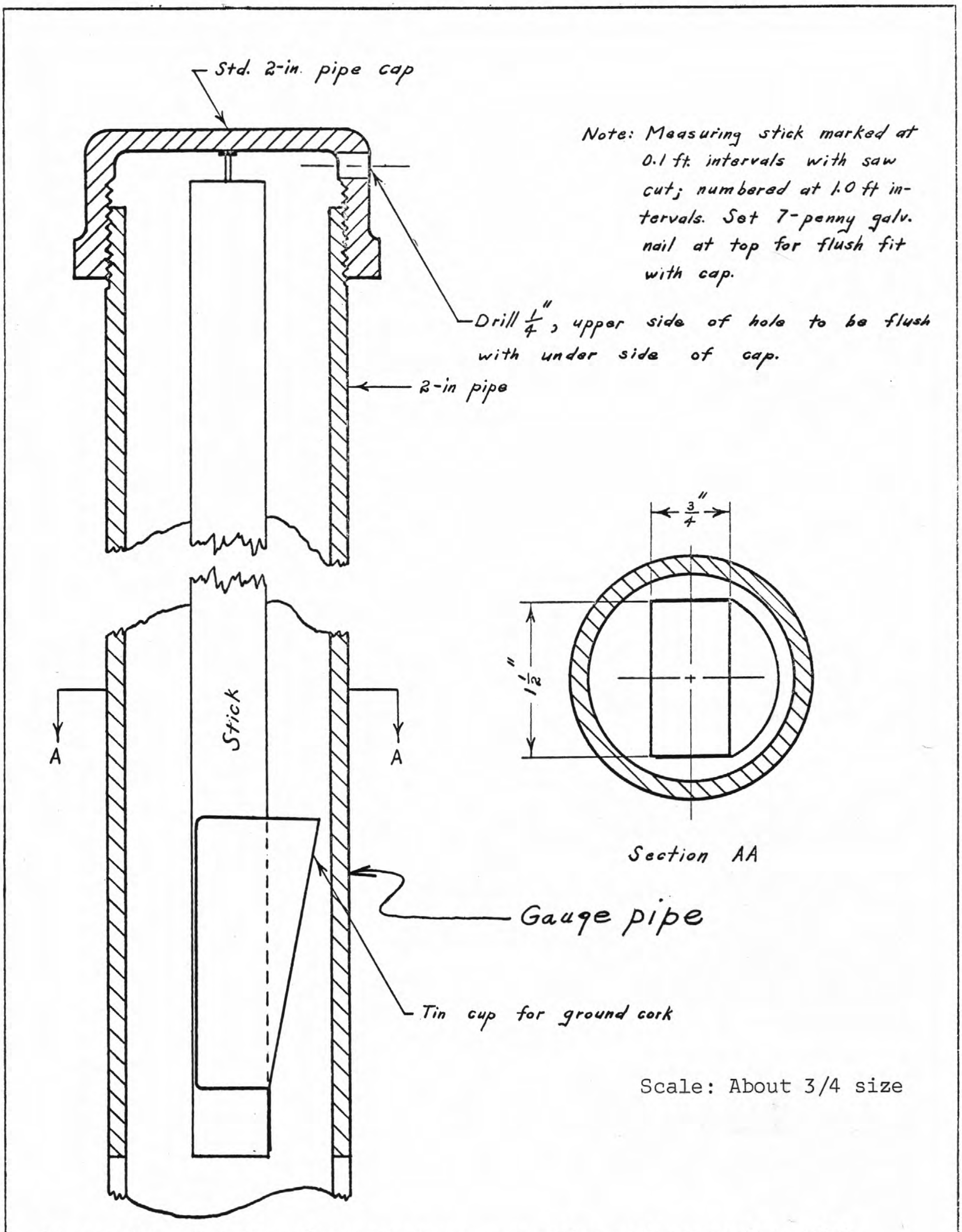


Figure 12. Details of crest-stage gauge pipe and measuring stick.

Post type crest-stage gauge

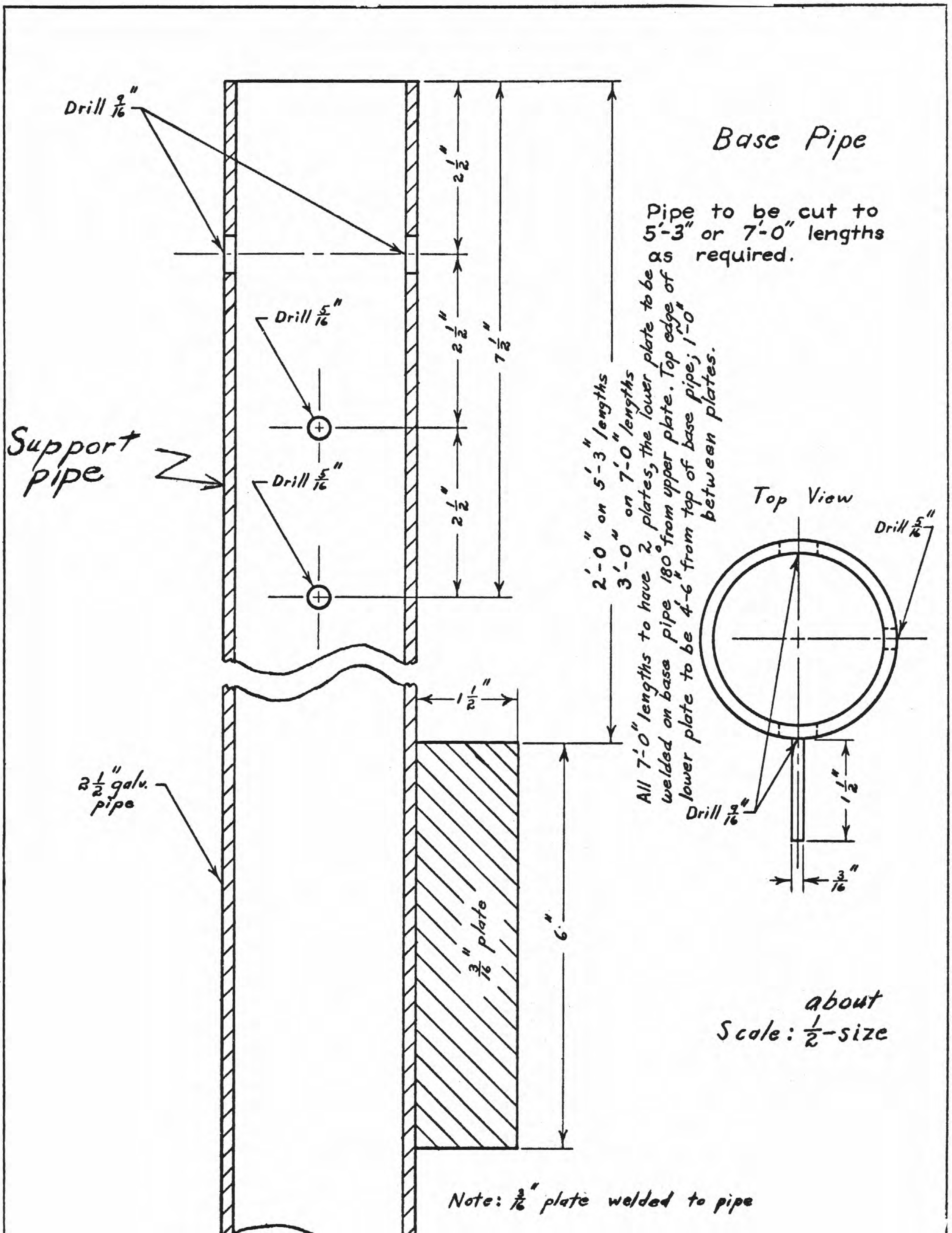


Figure 13. Details of support pipe of crest-stage gauge.

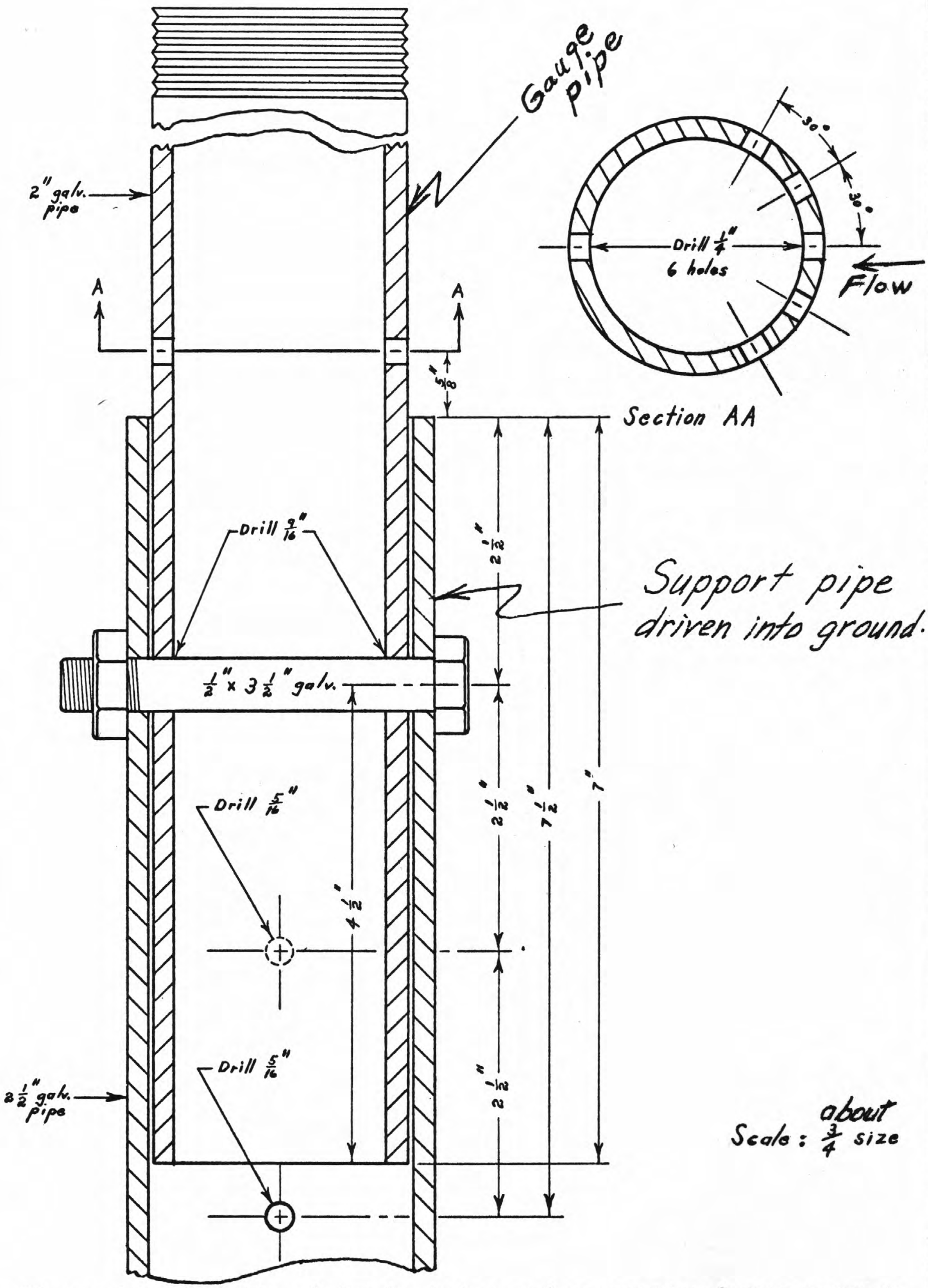


Figure 14. Details of intake holes and connection between crest-stage gauge and support pipe.

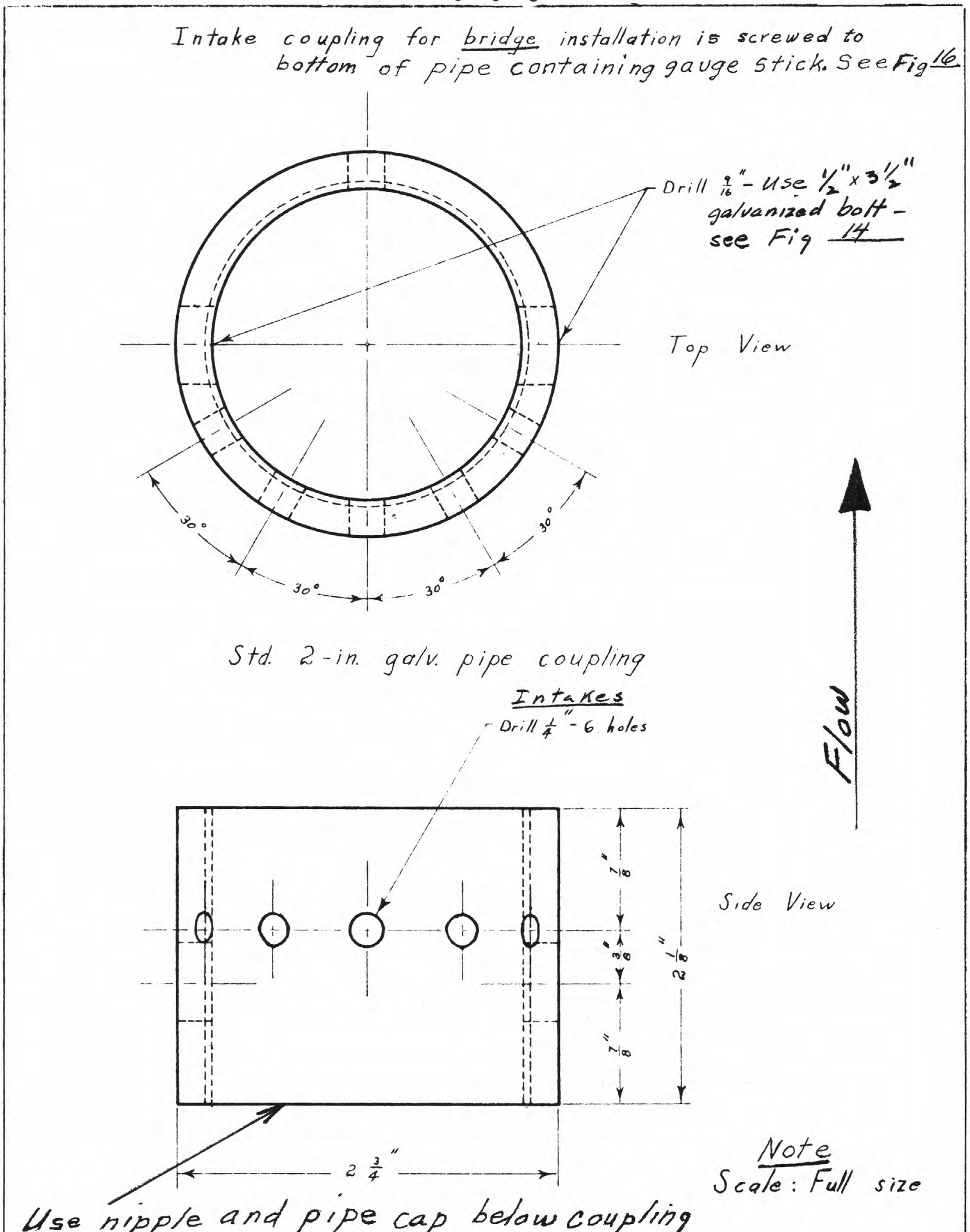


Figure 15. Details of intake coupling used at bridge installation of crest-stage gauge.

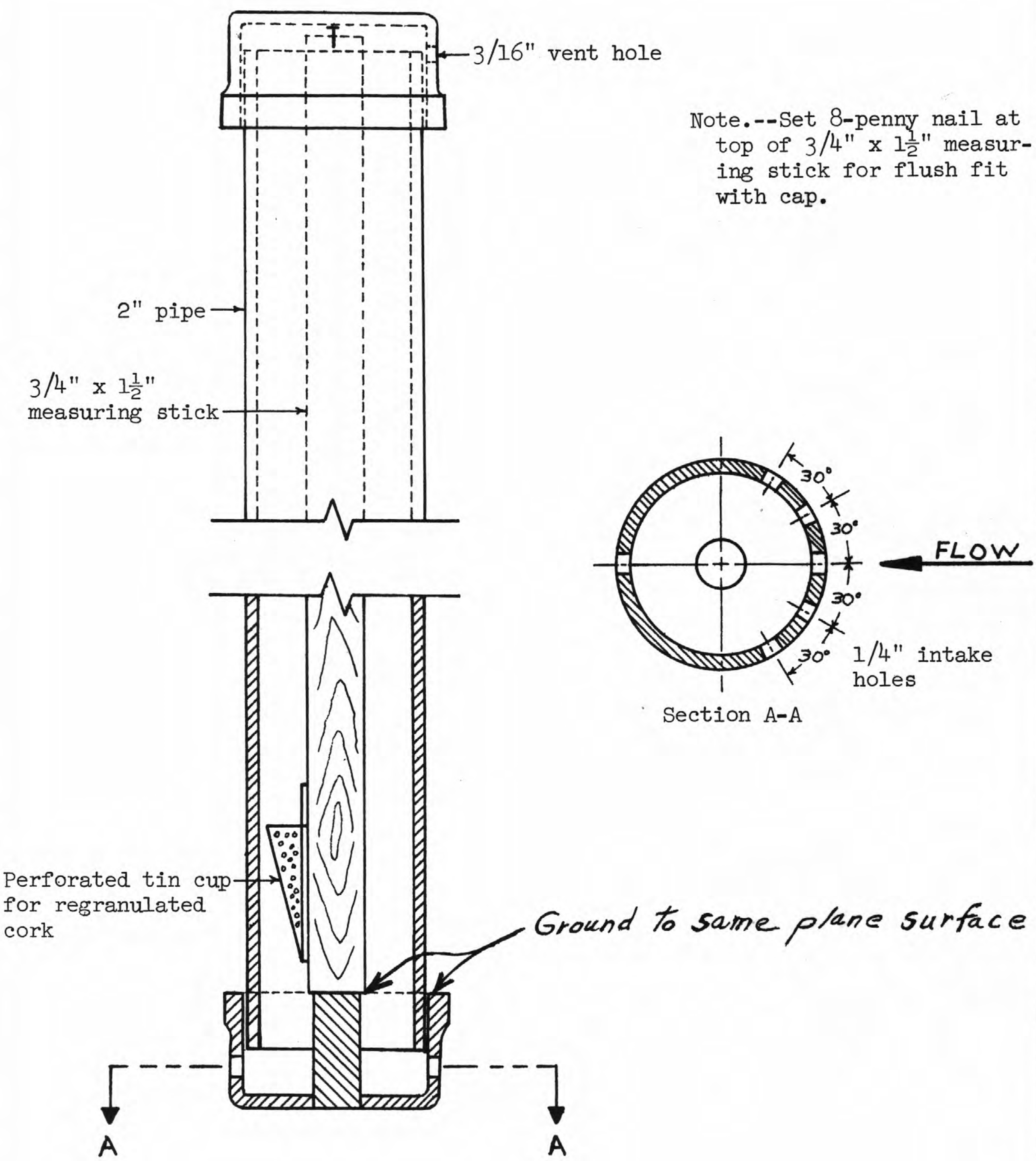


Figure 16. Design of crest-stage gauge.

5m—G246 12-69 H 114

HYDROLOGICAL SURVEY OF ZAMBIA

Kawanda River near Chonta - Level Summary

Date	Party	BM 1	BM 2	Closure	Outside staff gauge: Section	Correction: Found	Correction: Left
15 Oct 196-	J. Sommers ⊼	8.12	*12.36	0	0-5	0	0
	A. Jera ϕ				4-9	0	0
					8-13	-.01	reset 0
22 Apr. 196-	J. Sekele ⊼	8.12	*12.36	0	0-5	+.01	+.01
	A. Jera ϕ				4-9	-.03	reset 0
					8-13	-.04	reset 0

*Initial BM

Figure 17. A level check summary maintained for every gauging station should be carried in the Field Station File. This provides a history of gauge and bench mark changes and helps the level man make rational decisions during level checks at the gauging station.

5m—G235 1-70 H.102

HYDROLOGICAL SURVEY OF ZAMBIA

Sta. No. L63

LEVEL NOTES

Chibefwa River at MKushi Boma

Locality just upstr. from road bridge near Clinic

Party T. Manda, C. NKhoma Date 31st June, 1969

Station	B.S.	Rise + ~~Ht. Inst.~~ Fall −	F.S.	Elevation	Remarks
BM4				10.84	as given
BM3				10.96	as given
BM 4	1.52			10.84	Brass stud in concrete on Rt. bank near anthill
BM3		+0.12	1.40	10.96	Cross on upstr. bridge rail
staff gauge		−6.81	8.33	4.03	rod on 4.00 ft. section 4-9 ft
		the plate is bent and chipped.			
The 4-9 ft section lowered 0.03 ft at 1510 hours					
staff gauge		−6.84	8.36	4.00	rod on 4.00 ft. section 4-9 ft.
water surface		−11.27	9.75	1.09	at 1530 hours
staff gauge height = 1.07 at 1520 hours					
staff gauge		−5.84	7.36	5.00	rod on 4.99 ft which is top of section 0-5 ft.
BM4		0	1.52	10.84	
		no closure error			

Summary BM 3,4 satisfactory

Outside staff Gauge

Section 0-5 ft found 0.01 ft high - not reset

Section 4-9 ft found 0.03 ft high - reset - then OK

Error in staff gauge due to disturbance by people fetching water

No. 1 of 1 sheets Comp. by T. Manda Chk. by P. Slee

L.E. Bidwell

Figure 18. The rise and fall method can be used for computation of the results of level checks at gauging stations.

5m—G235 1-70 H.102

HYDROLOGICAL SURVEY OF ZAMBIA

SAMPLE

Sta. No. ....

LEVEL NOTES

Kawanda River near Chonta

Locality Gauging station

Party J. Sekele ⊼, A. Jero ⊕ Date 22 Apr. 196-

	Station	B.S.	Ht. Inst.	F.S.	Elevation	Remarks
Part I	B.M.1				8.12	as given
	B.M.2				12.36	as given
	B.M.2	2.20			12.36	Bronze tablet set in Top of concrete post
			14.56			
	outside staff gauge			1.52	13.04	rod on 13.00 ft Section 8-13 ft
	"			7.53	7.03	rod on 7.00 ft. Section 4-9 ft
	B.M.1			6.44	8.12	Top of bolt head in tree
	Reset level - check run					
Part II	B.M.2	2.31			12.36	
			14.67			
	B.M.1			6.56	8.11	
	O.St.G.			7.64	7.03	rod on 7.00 ft Section 4-9 ft
	O.St.G.			1.63	13.04	rod on 13.00 ft Section 8-13 ft.
Part III	B.M.1	1.73			8.12	
			9.85			
	Out St.G.			4.85	5.00	rod on 5.00 ft. Section 0-5 ft.
	water surface			5.20	4.65	at hour 1415 gauge read 4.64 ft.
	Reset level - check run					
Part IV	B.M.1	1.65			8.12	
			9.77			

No. 1 of 2 sheets Comp. by J. Sekele Chk. by JHH.

5m—G235 1-70 H.102

HYDROLOGICAL SURVEY OF ZAMBIA

SAMPLE

Sta. No. ....

LEVEL NOTES

Kawanda River nr. Chonta

Locality Gauging station

Party J. Sekele ⊼, A. Jero ⊕ Date 22 Apr. 196-

	Station	B.S.	Ht. Inst.	F.S.	Elevation	Remarks
Part IV			9.77			
	Out St.G			4.78	4.99	rod on 5.00 ft section 0-5 ft.
	water surface			5.13	4.64	At hour 1430 gauge read 4.64 ft.
	Lower section gauge satisfactory - Did not reset					
	Reset st. sections 4-9 ft and 8-13 ft at hour 1345					
Part V	B.M2	2.50			12.36	
			14.86			Gauge read 4.64 ft at 1350
	Outside Staff gauge			7.86	7.00	rod on 7.00 ft Section 4-9 ft.
	Out St.G.			1.86	13.00	rod on 13.00 ft Section 8-13 ft.
	B.M2			2.50	12.36	Closure OK

Part VI

Summary

B.M.'s 1 and 2 satisfactory

Outside Staff Gauge

Section 0-5 ft found 0.01 ft. low - not reset

Section 4-9 ft found 0.03 ft. high - reset

Section 8-13 ft. found 0.04 ft. high - reset

Since the gauges are high the gauge readings are too low.

The upper two staff gauges probably raised gradually over wet season. This started near the 1st January at the gauge.

No. 2 of 2 sheets Comp. by J.S. Chk. by JHH.

Figure 19. Level checks of gauges can be run effectively and with a saving in time by using the method of resetting the level shown in the sample notes.

Figure 20. All level checks must be accurate and complete and the results clearly shown in the level notes.

5m—G235 1-70 H.102

SAMPLE

HYDROLOGICAL SURVEY OF ZAMBIA
LEVEL NOTES

Stream Kafue River at Nambula
Locality at old road bridge
Party J. Ngona ⊼, J Sekele ⌀ Date 25th Sept , 1967

STATION	B. S.	HT. INST.	F. S.	ELEVATION	REMARKS
BM 1				19.93	as given
BM2				17.62	as given
BM3				6.27	as given
RP1				23.43	as given
RP2				20.01	as given
Check Bar - wire weight gauge				23.10	as given
BM 2	7.68	25.30		17.62	Chisel □ on left downstr. bridge wingwall
BM1			5.38	19.92	Chisel □ on top of right d/str. bridge abutment.
RP.2			5.29	20.01	Top of brass screw in trapdoor sill in house.
RP.1			1.88	23.42	File notch in top of br. rail 2ft rt. of w. wt.
CK. Bar			2.20	23.10	wire wt. Gauge ck bar.
Reset level - Check run					
BM2	7.52	25.14		17.62	
BM1			5.22	19.92	
RP2			5.13	20.01	
RP1			1.72	23.42	
CK Bar			2.04	23.10	
		Levels To w. wt. Gauge			
RP1	Tape down -16.17	7.25		23.42	
BM3			0.98	6.27	
Water Surface			5.14	2.11	Bottom of level rod on water surface in river

No. 1 of 3 sheets Comp. by J. Ngona Chk. by LEB

5m—G235 1-70 H.102

SAMPLE

HYDROLOGICAL SURVEY OF ZAMBIA
LEVEL NOTES

Stream Kafue River at Nambula
Locality at old road bridge
Party J. Ngona ⊼, J Sekele ⌀ Date 25th Sept , 1967

STATION	B. S.	HT. INST.	F. S.	ELEVATION	REMARKS
Bottom of gauge wt. on		7.25 H.I.		7.25	wire weight gauge reads 7.27
wire wt Gauge reads 2.13 ft at water surface at 0840 hours					
With weight of gauge on ck bar the gauge reads 23.12 ft.					
Reset gauge to read 23.10 on ck bar at 0850 hours					
Bottom of weight on		H.I		7.25	W. wt. gauge reads 7.25 This satisfactory
Reset level - Check run.					
RP1	Tape down -16.44	6.98		23.42	
BM3			0.71	6.27	
Bottom of gauge wt. on		H.I.		6.98	w. wt. gauge reads 6.98
wire weight gauge reads 2.11 at 0900 hours - OK					
	Levels to Inside Staff and Float Tape				
R.P2				20.01	Check 20.01
Tape down to water S. in well				-17.90	-17.90
Elevation of water surface				2.11	2.11
Inside Tape gauge reads				2.10	2.10
Inside Staff gauge reads				2.10	2.10
Changed Float tape index to read 2.11					
Did not change Inside staff - All sections of inside staff gauge checks within 0.01 ft by steel tape. (range 0 - 20.5 ft)					
Wire wt = 2.12, Float Tape = 2.12, In. St. = 2.11, Pen 2.12 at 0930 hours					

No. 2 of 3 sheets Comp. by J. Ngona Chk. by LEB.

5m—G235 1-70 SAMPLE STATION H.102

HYDROLOGICAL SURVEY OF ZAMBIA

Crest-Stage Gauge Sta. No. 124

LEVEL NOTES

Kawanda River at Kato

Locality 300 feet above culvert

Party L.W. Goma T., E. SeKola Date 8th October 1968

Station	B.S.	Ht. Inst.	F.S.	Elevation	Remarks
Crest-Stage Gauge					
BM.1				20.00	as given
B.M.2				14.45	as given
Index				15.38	as given
BM1	2.10			20.00	Chiseled □ on top of rt. upstr. wingwall of culvert.
Index		22.10	6.72	15.38	Threaded end of bolt - zero of gauge.
BM2			7.65	14.45	Top of bronze tablet 20ft. d/str. from gauge
T.P.1			6.23	15.87	Rock
	5.80	21.67			
Index			6.29	15.38	
B.M.2			7.22	14.45	
BM1			1.67	20.00	

Gauge stick reading 0-4.88 feet
Error of closure is zero

All B.M.'s and Index of gauge are found at correct elevation.

L.E. Bidwell

No. 1 of 1 sheets Comp. by L.W. Goma Chk. by J.C. Sekola

Figure 21. Level checks and notes at crest stage gauges must be accurate and complete whether it is installed alone as a base gauge or is used as auxillary gauge at a continuous gauging station.

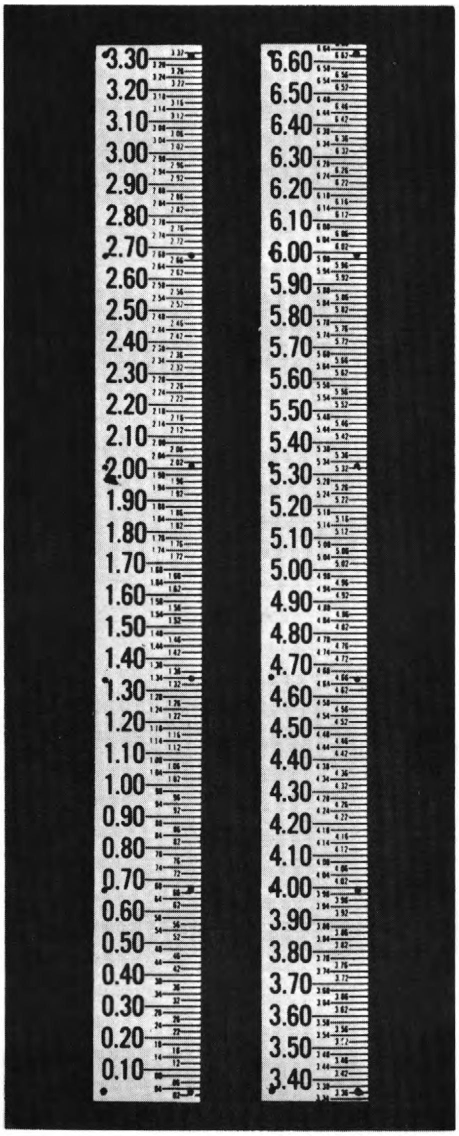


Figure 22. Estimation of gauge heights should not be necessary with a well designed staff gauge.

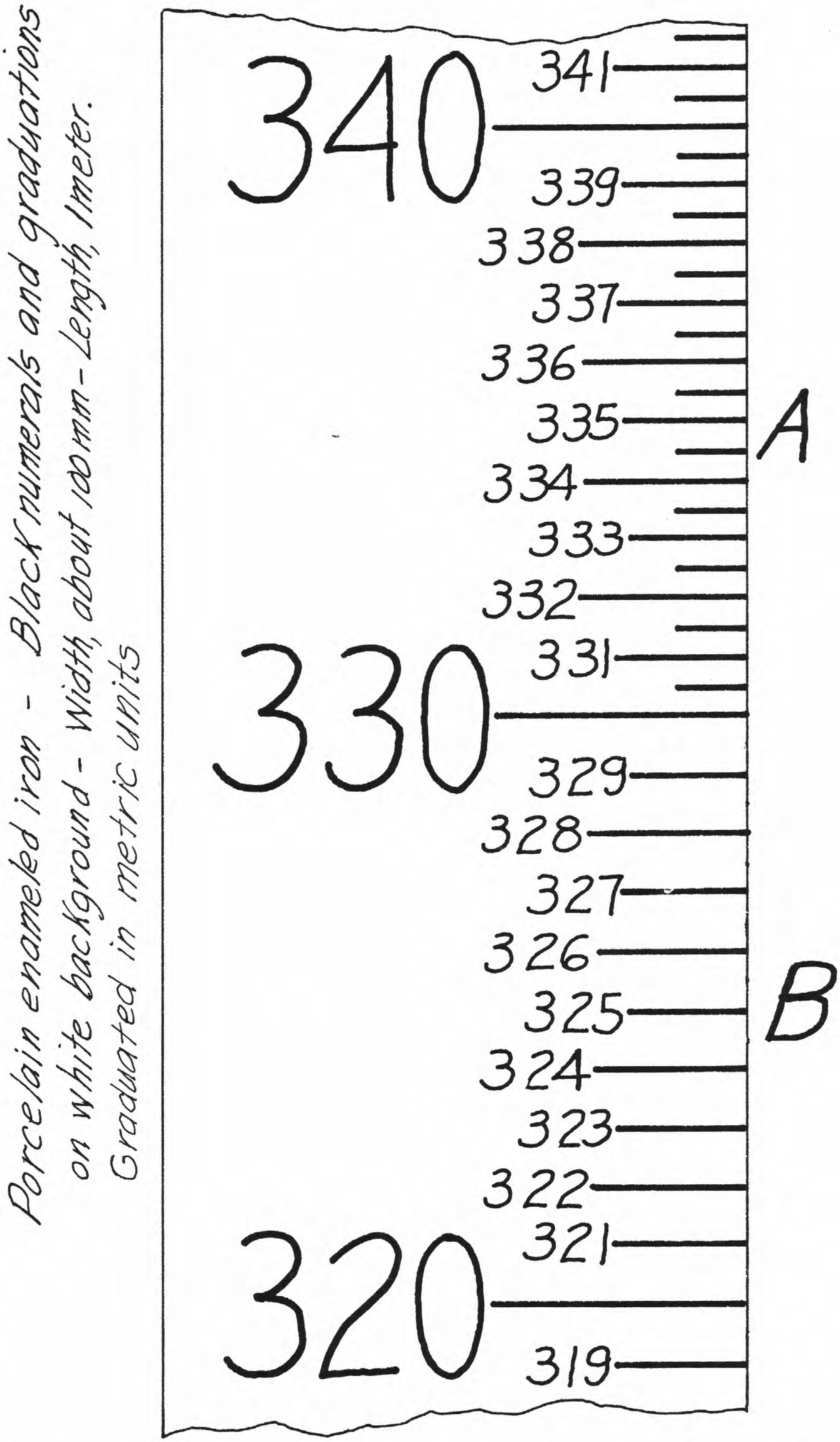


Figure 23. Observers with minimum education and training need a well designed staff gauge to obtain accurate gauge readings.

HYDROLOGICAL SURVEY OF ZAMBIA
DATA FOR STATION DESCRIPTION

H122a
5m—K463 11-70

On Kafue River at/near* Kasaka above/below* —
Date obtained by Jerome R. Sekele Date 12th Dec. 196–

LOCATION: Describe how reached. Obtain specific information so a hydrographer unacquainted with location can go directly to the gauge. Use speedometer mileage for distances wherever practical; maps may also be used. Refer gauge to tributaries, dams, falls or other hydrological features. Refer gauge to towns, roads, railways, bridges, pontoons or other prominent landmarks. If there is an auxiliary gauge give necessary additional access information:

From Lusaka drive south on Great North Road (main highway) from south end of Cairo Road 26.7 miles to Kafue. Continue south from Kafue 4.8 miles to dirt road and "Hydro. Station" sign. Turn right at sign and follow road 1.0 mile to river and gauge. Main highway is black top. Dirt road is muddy but passable during rains. Gauge is 1½ miles upstream from Nansenga River and 4 miles below The Kafue railway bridge.

MAP REFERENCE: Was this checked?—yes/no* Latitude 15° 50' South, Longitude 28° 13' East.
MAIN GAUGE: On right/left* bank .... ft/metres* at/above/below bridge/pontoon* or 1¾ miles above Kafue road bridge.
OUTSIDE GAUGE: Vertical/inclined* staff/gauge. Describe sections and how mounted:
Range 20.0 - 33.0 ft/metres* mounted on 6" dia pipe, remarks in concrete
Range .... ft/metres* mounted on ...., remarks ....
Range .... ft/metres* mounted on ...., remarks ....
Range .... ft/metres* mounted on ...., remarks ....
Range .... ft/metres* mounted on ...., remarks ....
Range .... ft/metres* mounted on ...., remarks ....
Describe special problems in reading outside gauge due to waves, distance from bank etc. At medium high stages inside gauge read by wading or boat - Outside seen from bank.
Wire Weight gauge mounted on —
.... Dial reads .... with weight on check bar, elevation of check bar ....
INSIDE GAUGE: at ~~ft/metres* upstream/downstream*~~ of outside gauge
Non recording gauge: float tape/electric tape/staff* (range of staff gauge 12.0 - 21.0 ft/metres*).
Recorder: Drum/Strip Chart/Digital. Make none, recorder serial No. ....,
ght ratio ...., range in stage – ft/metres*, time scale ...., clock serial No. ....
Well Concrete/brick/metal*, size 48" dia. pipe (inside), elevation of top 21.38 ft., of bottom 11.0 ft.
Clean-out door size None, elevation of sill —
Intake: Pipe/opening*, number 4 slots Intake diam. or size ? lengths of pipe ....
elevations of inverts will obtain at low water
Flushing Equipment: None
Recorder house: Walk in/reach in/concrete/brick/wood/metal*, size None (inside), elevation of shelf ....
ventilation poor/fair/good*
AUXILIARY GAUGE describe as above: None. A staff gauge exists at both The Kafue road bridge and at The Kafue railway bridge

OBSERVER full time/part time* Name N. Kamboyi, E. Mulenga
Address Kafue Lives at gauge
Distance from gauge at ~~miles/km~~* Frequency of visits 2 daily Education Standard — Reliability good
BENCH MARKS: Describe type, and exact location in relation to gauge and other permanent features.
Will obtain next trip

Figure 24

*circle relevant word

Data for Station Description—*Continued:*

CHANNEL: describe both above and below gauge and discharge measuring section and auxiliary gauges. Give number and location of channels at various stages. Describe character of bed and banks (rock, sand, mud, vegetation, stability). Describe flood plain and measure width. Give distances to bends, islands, etc. and describe condition of flow at various stages. Describe reach between auxiliary gauge and main gauge (inflow, breaks in bed, etc.)

Left bank overflows at about 20' ght. Right bank overflows at about 23 ft ght. Channel straight 1 mi. above to 3/4 mile below gauge where it bends slightly to the left. Weeds and grass along each bank. At gauge the low and medium water channel has 250 ft. of thick weeds along right bank (little if any flow). Left bank at gauge has less weeds which are cleared at gauge and boat cable site. Some brush and trees along high water banks. Bed firm and fairly smooth but with some bars and islands above and below gauge. Weeds and grass on islands. This has some effect on velocity distribution at low stages. Many large clumps of weeds break loose at high stages.

CONTROL: Give distance from gauge of each control (low, medium and high water). Describe character (rock, gravel, vegetation, stability, shifts due to debris or human or animal interference). Describe any variable slope conditions.

At medium to high stages channel is control. At extremely high stages Kafue road bridge serves as partial control. Low stages probably channel control. (will examine at low flow). The channel will shift at low amd medium stages because of weeds breaking loose at high stages. Bottom is fairly stable. Probably magnitude of shifts will remain the same year after year.

DISCHARGE MEASUREMENTS: Describe best measuring sections for low, medium and high stage, give distances from gauge and access directions. Describe flow conditions, e.g. turbulent, smooth, fast, sluggish, horizontal angles, dead water. Estimate probable accuracy. Describe measurement methods, e.g. wading, cableway, bridge, boat, pontoon. Detail special equipment necessary, e.g. sounding weights for various stages, tag lines, handline, bridge crane, equipment stored at gauge. Special cautions, e.g. crocodiles, floating islands, bridge traffic, piers, boat traffic.

Maximum Wading Stage none ft/metres* (1) All stages measured by boat at cableway 64 ft above gauge. Flow smooth with no angles at any stage. Velocities high enough to measure. Dead water in weeds on right bank. Cable is in water (slack) and is broken repeatedly by floating islands. Cable is not marked and must be taped each time used or boat positioned by sextant. This is poor arrangement. (2) Good meas. made at Kafue road bridge 1 3/4 miles downstream. Max. vel. at high stage will be 5 to 8 ft/sec. A 100 to 150 lb weight should be used. Downst. or upstr. side bridge can be used. Examine at each meas. Watch for floating islands - very dangerous! Get permission to use bridge from Kafue Police station at each meas.

POINT OF ZERO FLOW: not determined ght stable/unstable*
SKETCH: Use back of sheets to make a dimensioned sketch of the site
REMARKS: Use rest of sheets for any additional information

The physical features above low water banks vary along the river. At the gauge the left bank will not overflow very much (100 ft) because of sloping bank. On right bank water tops bank at about 23 ft ght. River widens below gauge but all flow confined at bridge meas. site.

Figure 25

*circle relevant word

HYDROLOGICAL SURVEY OF ZAMBIA

Sample

Description Prepared 12th December, 1962
(Date)

by F. T. MUMBWA

Description of Gauging Station on KAWANDA RIVER NEAR CHONTA, ZAMBIA

Location.- Lat. 12°52', long. 26°02', on right bank 200 feet downstream from bridge on the Kasempa-Solwezi road, 2 miles downstream from Luba River, 6½ miles north of Chonta, and 40 miles northeast of Kasempa.

To visit station drive 40 miles north from Kasempa on Kasempa-Solwezi road to Chonta, then continue 6½ miles north to bridge and gauge.

Established.- 4th December, 1962, by Mr. J. P. Oswald.

Gauge.- Vertical staff gauge in three sections; lower two sections of gauge are enamel gauge plates bolted to slotted 2" angle iron posts driven into stream bed near right bank and the higher section is on 6" dia. pipe post anchored in concrete on right bank 20 feet landward from edge of low water channel.

Range in gauges:

Lower section 0-5 feet, gauge datum
Middle section 4-9 feet, gauge datum
Upper section 8-13 feet, gauge datum

(THE FOLLOWING FORM IS USED FOR RECORDER INSTALLATIONS)

Stevens A-35 continuous water stage recorder in 4 feet x 4 feet walk-in-type metal shelter on a 4 foot diameter concrete pipe well.

Time scale is 2.4 inches per day, gauge height scale 1:6. Recorder paper actuated by a weight and clock, gauge height pen actuated by perforated tape, and 10" diameter float.

The following elevations are referred to gauge datum:

Top of instrument shelf	21.2 feet
House door sill	18.7 feet
Top of house floor	18.5 feet
Well door sill (2½ feet x 3 feet)	11.8 feet
Invert of upper 3" dia. 18 ft. long intake pipe	2.5 feet
Invert of lower 3" dia. 30 feet long intake pipe	1.5 feet
Bottom of well	0.5 feet

Both intake pipes attached to flush tank through gate valves. Recorder will record from 6.5 to 20.5 feet gauge heights.

Figure 26

Base gauge is enamel section staff gauge, range 1.0 to 21.0 feet, attached to inside of well.

Outside reference gauge is vertical staff gauge in three sections (0.5 feet and 4-9 feet) near right bank 20 feet downstream from well and one upper section (8-21 feet) attached to downstream side of well and house.

Control.- Low and medium stages controlled by rock ledge 400 feet below gauge and just above remains of abandoned bridge. High stages controlled by rock ledge and remains of old bridge piers and abutments about 400 feet below gauge. Brush and vegetation on rock ledge and channel banks cause variable backwater at low and medium stages, otherwise control is very stable.

Point of zero flow 1.7 feet ±0.2 feet, determined 11th November, 1962.

Discharge measurements.- Low stages below 4.5 feet measured by wading at sections a quarter of a mile below gauge and about 1000 feet below abandoned road bridge. Site of wading section will change as the stage changes but will remain in the general locality.

Medium and high stages are measured from car on cableway 50 feet below gauge. Car kept at right tower.

Extreme high stages are measured from downstream side of road bridge 200 feet above gauge.

History.- Gauging station established in 1962. Maximum stage known about 16 feet gauge datum in 1958, from local inhabitant.

Remarks.- Discharge records will probably be fair to good. Station established to increase the hydrologic coverage of Zambia. The basin upstream has little water use development and no major development is likely.

Bench marks.- B.M. No. 2 is top of bolt head 1 ft. above ground in streamward side of 18" dia. tree 20 ft. landward from right bank and 40 ft. downstream from cableway. Elevation, 8.12 feet, gauge datum.

B.M. No. 2 is top of brass tablet 6 inches above ground surface set in concrete post on right bank 200 feet downstream from bridge, 50 feet landward from right bank of river, and 10 feet upstream from right anchor of cableway. Elevation, 12.36 feet, gauge datum.

Observer.- J. Nkonola hired as observer and issued record book. He lives first house on downstream side of bridge on Kasempa-Solwezi road. House is about 600 feet from right bank of river, and 500 feet from road. He will make three gauge readings per day at 0600, 1200, and 1800 hours.

Figure 27

SAMPLE

Preliminary Station Description

ZAMBEZI RIVER BASIN

Kawanda River near Chonta

Established 4th December, 1962

Location.- Staff gauge in 3 sections (0-5 ft, 4-9 ft, and 8-13 ft). Lat. 13°24', long 25°24', on right bank 200 ft. downstream from bridge on the Kasempa-Mankoya road, 2 miles downstream from Lubo River, 6 1/2 miles west of Chonta and 31 miles southwest of Kasempa.

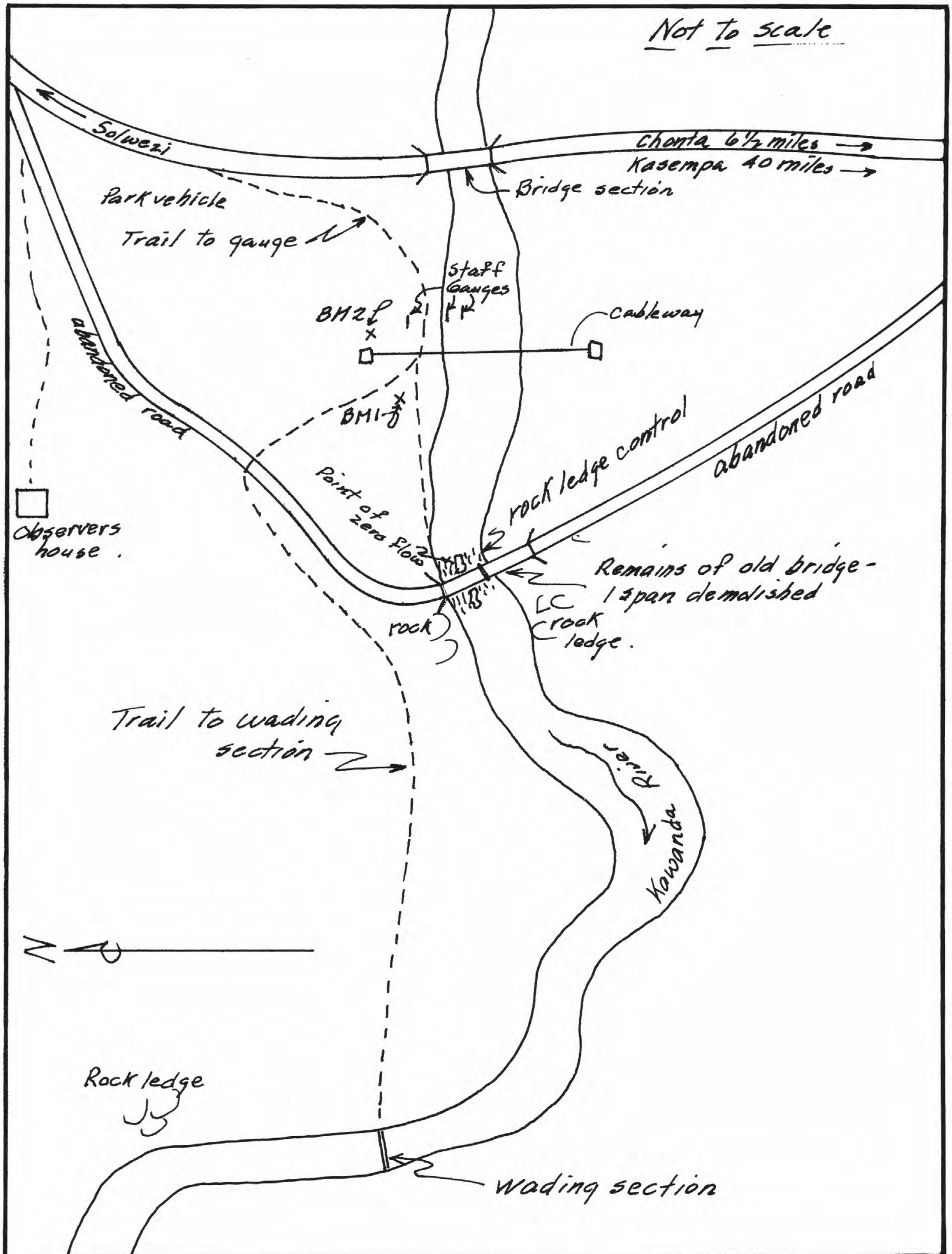
Remarks.- The records will not be equivalent to those obtained in 1958-59 at site 3 miles upstream because of inflow from Luba River.

Signed ______________________
J. P. Oswald

Figure 28

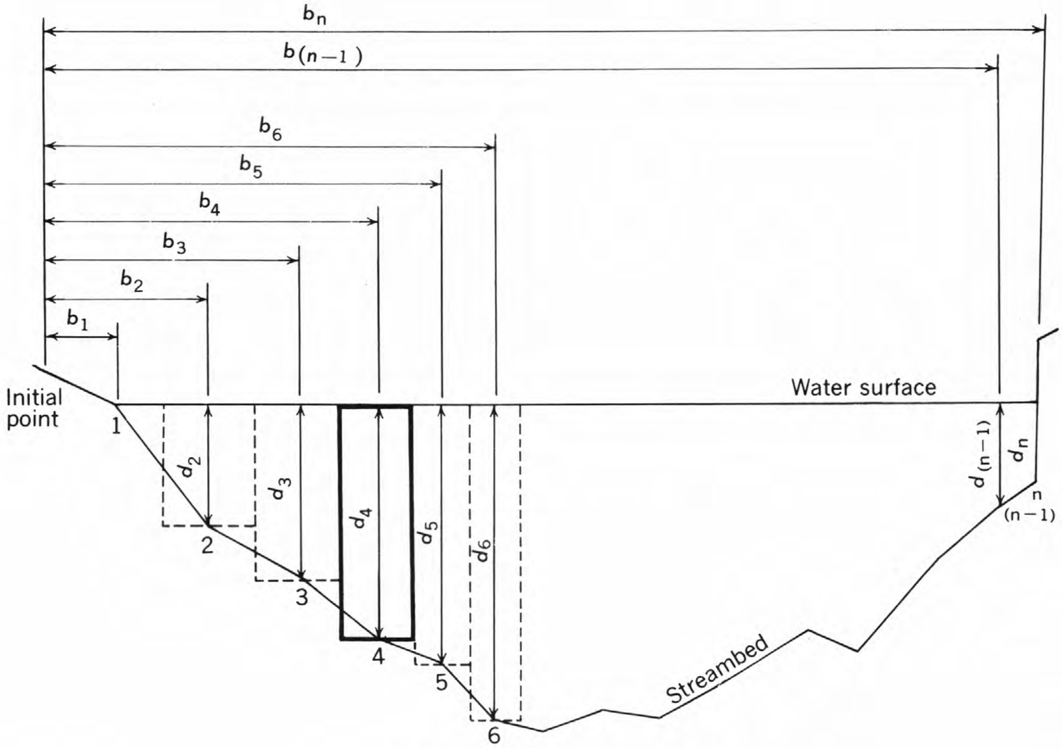
HYDROLOGICAL SURVEY OF ZAMBIA

Kawanda River near Chonta



Sheet No. 3 of 3 Sheets. Prepared by [illegible] Date 12-12-62 Checked by J.H.A. Date [illegible]

Figure 29. A sketch of the station site is an important part of the Station Field Description.



EXPLANATION

1, 2, 3, ... n	Observation points
$b_1, b_2, b_3, \ldots\ldots b_n$	Distance, in feet, from the initial point to the observation point
$d_1, d_2, d_3, \ldots\ldots d_n$	Depth of water, in feet, at the observation point
Dashed lines	Boundary of partial sections; one heavily outlined discussed in text

Figure 30. A current-meter measurement is the summation of the partial discharges of the cross-section of the stream. In the midsection method shown in the sketch, it is assumed that the velocity and depth at each vertical represents the mean velocity and depth in a partial rectangular area.

H108

HYDROLOGICAL SURVEY OF ZAMBIA

DISCHARGE MEASUREMENT NOTES

SAMPLE

Date 4 April, 196-

Kawanda River near Chonta

Angle coefficient	Dist. from initial point	Width	Depth	Observation depth	Revolutions	Time in seconds	Velocity: At point	Velocity: Mean in vertical	Adjusted for hor. angle or	Area	Discharge
0.5 t. g -3.11 @ 0805 - R.G @ 0810											
	5	2.5	0	—	—	—			0	0	0
	10	4.5	2.00	.6	7	52		.33	.33	9.00	2.97
	14	3.5	2.33	.6	7	40		.42	.42	8.05	3.36
	17	3	2.40	.6	10	55		.44	.44	7.20	3.17
⊙	20	2.5	2.40	.6	15	55		.64	.64	6.00	3.84
	22	2	2.40	.6	15	50		.70	.70	4.80	3.36 16.70
0830 - ght = 3.35 @ 0830											
	24	2	3.00	.2	15	45	.78	.63	.63	6.00	3.78
				.8	10	50	.48				
	26	2	3.00	.2	15	45	.78	.64	.64	6.00	3.84
				.8	10	48	.50				
	28	2	3.00	.2	15	43	.82	.67	.67	6.00	4.02
				.8	10	46	.52				
	30	2	2.80	.2	20	52	.90	.74	.74	5.60	4.14
				.8	10	40	.59				
	32	2	2.70	.2	20	50	.93	.75	.75	5.40	4.05
				.8	10	42	.57				
	34	2	2.85	.2	20	48	.97	.74	.74	5.70	4.22
				.8	10	46	.52				24.05
0900										69.75	40.75

No. 2 of 3 Sheets. Comp. by A.S Chk. by JHH

H108

HYDROLOGICAL SURVEY OF ZAMBIA

DISCHARGE MEASUREMENT NOTES

Date 4 April, 196-

Kawanda River near Chonta

Angle coefficient	Dist. from initial point	Width	Depth	Observation depth	Revolutions	Time in seconds	Velocity: At point	Velocity: Mean in vertical	Adjusted for hor. angle or	Area	Discharge
	ght - 3.50 @ 0910									69.75	
	36	2	2.60	.2	20	52	0.90	0.77	0.77	5.20	4.00
				.8	15	55	.64				
	38	2	3.10	.2	15	42	.83	.68	.68	6.20	4.22
				.8	10	46	.52				
	40	2	3.00	.2	15	48	.73	.60	.60	6.00	3.60
				.8	10	50	.48				
	42	2	3.00	.2	15	52	.68	.55	.55	6.00	3.30
				.8	7	40	.42				
⊙	44	2.5	2.40	.6	10	45		.53	.53	6.00	3.18
	47	3	2.40	.6	10	45		.53	.53	7.20	3.82
0940 ght = 3.56 @ 0940											22.12 62.87
	50	3	2.40	.6	10	45		.53	.53	7.20	3.82
	53	3	2.20	.6	10	46		.52	.52	6.60	3.43
	56	3	2.20	.6	10	50		.48	.48	6.60	3.17
.99	59	3.5	2.20	.6	7	40		.42	.42	7.70	3.23
.99	63	4	2.00	.6	7	45		.38	.38	8.00	3.04
.98	67	4.5	1.20	.6	10	56		.43	.42	5.40	2.27
	72	2.5	0	—	—	—		0	0	0	0 18.96
	L.B @ 1015 - os Gauge = 3.48 @ 1020									147.85	81.83

No. 3 of 3 Sheets. Comp. by A.S Chk. by JHH

Figure 31. Recorded time of start, end, and intermediate points of a discharge measurement is necessary for the calculation of weighted mean gauge height.

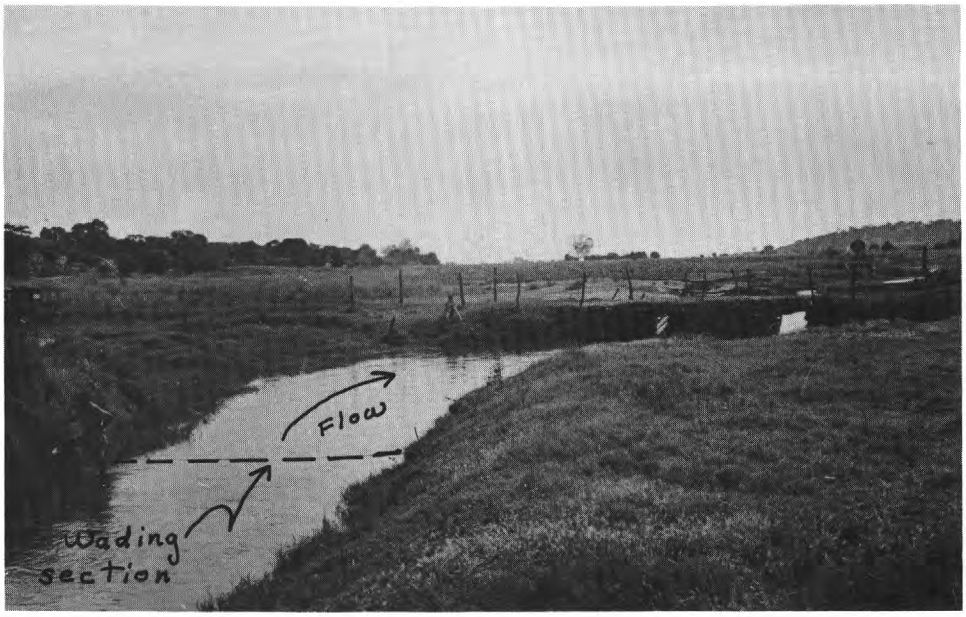


Figure 32. The wading section at Namitome River at Namitome is very good. It is characterized by a smooth solid bottom, straight approach section, evenly distributed flow of about one foot per second velocity, and a one foot depth in most verticals.

Figure 33. Suitable wading sections can generally be found in areas of rock ledges and boulders by a thorough reconnaissance of the river. The wading section for the Chongwe River at Chongwe Road Bridge is a quarter of a mile below the gauge and has a ledge rock location with good velocity distribution.

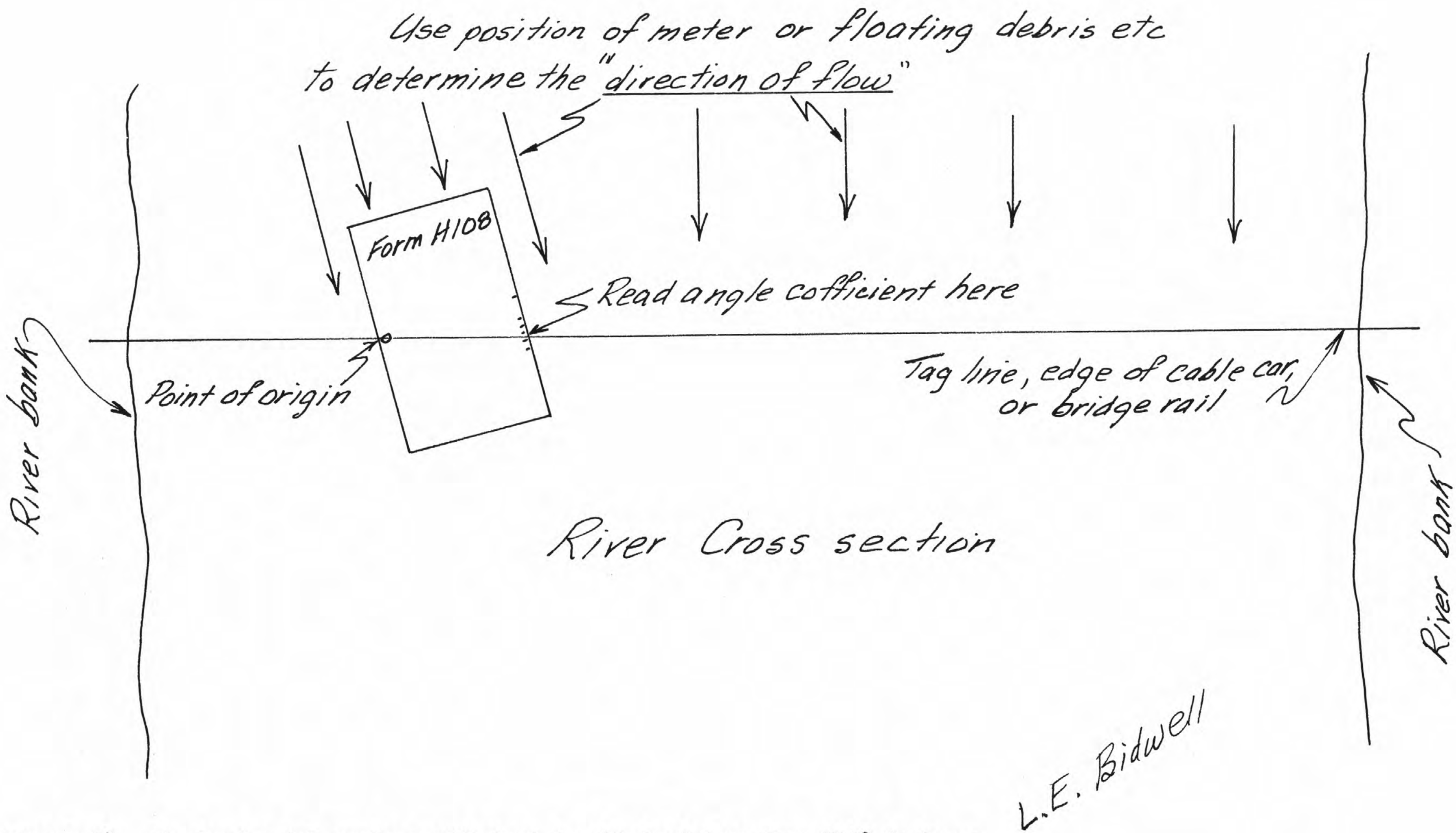


Figure 34. The horizontal angle coefficient is obtained from Form H108 during a discharge measurement.

H 109
2m—OL160 3-70

HYDROLOGICAL SURVEY OF ZAMBIA

DISCHARGE MEASUREMENT NOTES—TWO TABLE METHOD

Date 26 March 196

Luangwa River at Luangwa Bridge STA. No. 4-

Distance from initial point	Distance above water surface	Vertical angle °	Observed depth	Air correction	Wetline depth	Water correction	Vertical depth	Depth of observation	Revolutions	Time in seconds	VELOCITY At point	Mean in vertical	Adjusted for hor. angle	Area	Mean depth	Width	Discharge
			1330 Hour														
305	79	9	15.9	1.0	14.9	0.1	14.8	.2	150	45	7.50	7.76		296	14.8	20	2300
								.8	150	42	8.03						
325	79	11	18.5	1.5	17.0	0.1	16.9	.2	150	41	8.22	7.70		296	16.9	17.5	2,280
								.8	150	47	7.18						
340	79	13	18.9	2.1	16.8	0.1	16.7	.2	200	52	8.65	7.33		250	16.7	15	1,830
								.8	150	56	6.02						
355	79	8	17.3	0.8	16.5	0.1	16.4	.2	150	52	6.49	4.82		246	16.4	15	1,190
								.8	60	43	3.14						
370	79	–	12.9	–	–	–	12.9	.2	80	44	4.09	2.57		194	12.9	15	500
								.8	20	43	1.05						
385	79	8	21.6	0.8	20.8	0.1	20.7	.2	200	46	9.77	7.14		310	20.7	15	2,210
								.8	80	40	4.50						
400	79	16	27.6	3.2	24.4	0.3	24.1	.2	150	42	8.03	5.70		362	24.1	15	2,060
								.8	60	40	3.37						
415	79	20	33.8	5.1	28.7	0.6	28.1	.2	200	44	10.24	9.44		422	28.1	15	3,980
								.8	200	52	8.65						
430	79	28	37.4	10.4	27.0	1.1	25.9	.2	150	44	7.66	8.42		388	25.9	15	3,270
								.8	200	49	9.17						
445	79	28	45.1	10.4	34.7	1.4	33.3	.2	150	44	7.66	7.58		500	33.3	15	3,790
								.8	150	45	7.50						
460	79	26	46.1	9.0	37.1	1.3	35.8	.2	150	42	8.03	7.14		626	35.8	17.5	4,470
Hour 1500								.8	150	54	6.25						
480	80	24	40.2	7.6	32.6	1.0	31.6	.2	150	41	8.22	8.27		553	31.6	17.5	4,570
								.8	200	54	8.32						
495	80	30	43.2	12.4	30.8	1.5	29.3	.2	200	54	8.81	8.81		586	29.3	20	5,160
								.8	200	54	8.81						
520	80	14	33.6	2.5	31.1	0.3	30.8	.2	200	51	7.66	5.98		847	30.8	27.5	5,060
								.8	200	51	4.31						
550	80	12	23.8	1.8	22.0	0.2	21.8	.2	150	44	9.56	6.82		545	21.8	25	3,720
								.8	90	47	4.09						

Computed by M.M.P. Checked by M.M.H. No. 3 of 4 Sheets

Figure 35. Corrections for vertical angles are applied to the depth during discharge measurements made at high velocities and great depth if the current meter and sounding weight is carried downstream. Corrections are tabulated in Tables 3, 4 and 5. It may also be necessary to apply horizontal angle coefficients to the same measurement.

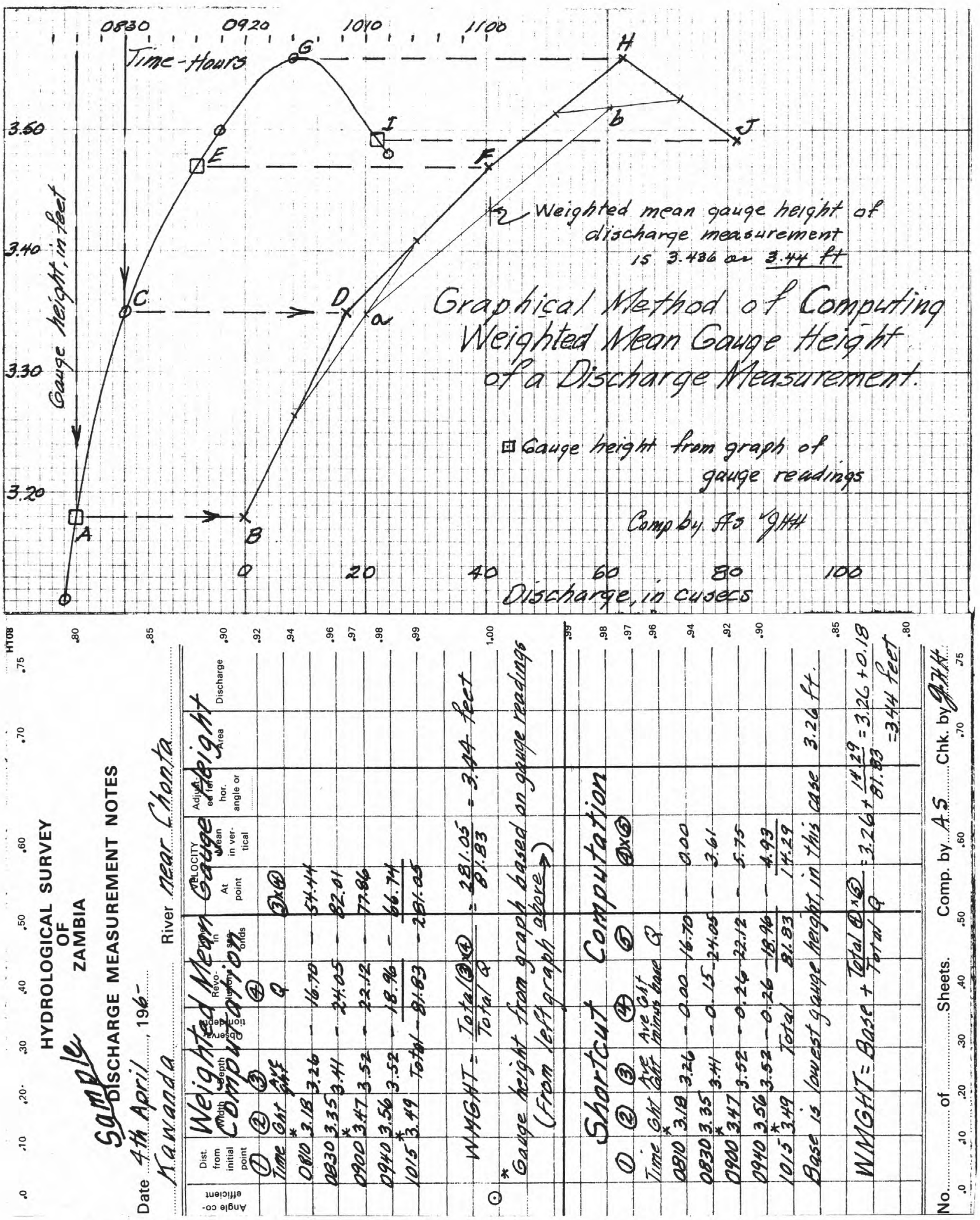


Figure 36. The mean gauge height of a discharge measurement made during a rapid change in stage is obtained by graphical or arithmetical weighting.

Figure 37. The time of travel adjustment is used to obtain the mean gauge height of a discharge measurement made during a change in stage at a section some distance from the gauge and control.

SAMPLE

10m—G240 12-69

HYDROLOGICAL SURVEY OF ZAMBIA

H 107

Meas. No. 267
Comp. by as
Checked by JHH

DISCHARGE MEASUREMENT NOTES

Sta. No. ....

Kawanda River at Chonta

Date 4 March, 196– Party A. Sekele, J.H. Henry

Width 200 Area 1030 Vel. 4.06 G.H. 12.05 Disch. 4180 +82 4260

Method 2-.8 No. secs. 26 G. H. change 0.46 in 1.15

Method coef. – Hor. angle coef. Varies Susp. coef. 1.00 Meter No. 7289

GAUGE READINGS			Adj's Travel time	Start Outside
Time		Recorder	Inside	Outside
10:45			11.36	11.50
11:10	by observer Start		11.61	11.72
1220	by observer finish		12.10	12.18
1240			12.27	12.32
Weighted M. G. H.				
G. H. correction				
Correct M. G. H.				

Date rated 12-2-65

Suspension: ~~rod~~, weight 100C 1.0 lb.

Meter 1.0 above bottom of wt.

Spin before meas. 2:30 after 2:25

Meas. plots – % diff. from – rating

Wading, cable, ice, boat, upstream, downstream, side bridge 0.8 feet, mile, above, below gauge (road bridge)

Levels obtained No

Temperature: Air 79 °C @ 1045

Water 66 °C @ 1050

Weather Humid, showers, breeze

Measurement rated excellent (2%), good (5%), fair (8%), poor (over 8%), based on following conditions: Cross section Fairly even, some boulders, mostly gravel

Flow Good distribution, some debris flowing

Other Cleared grass off meter at sections 120 and 135

Gauge OK

Record removed – Intake flushed U – L –

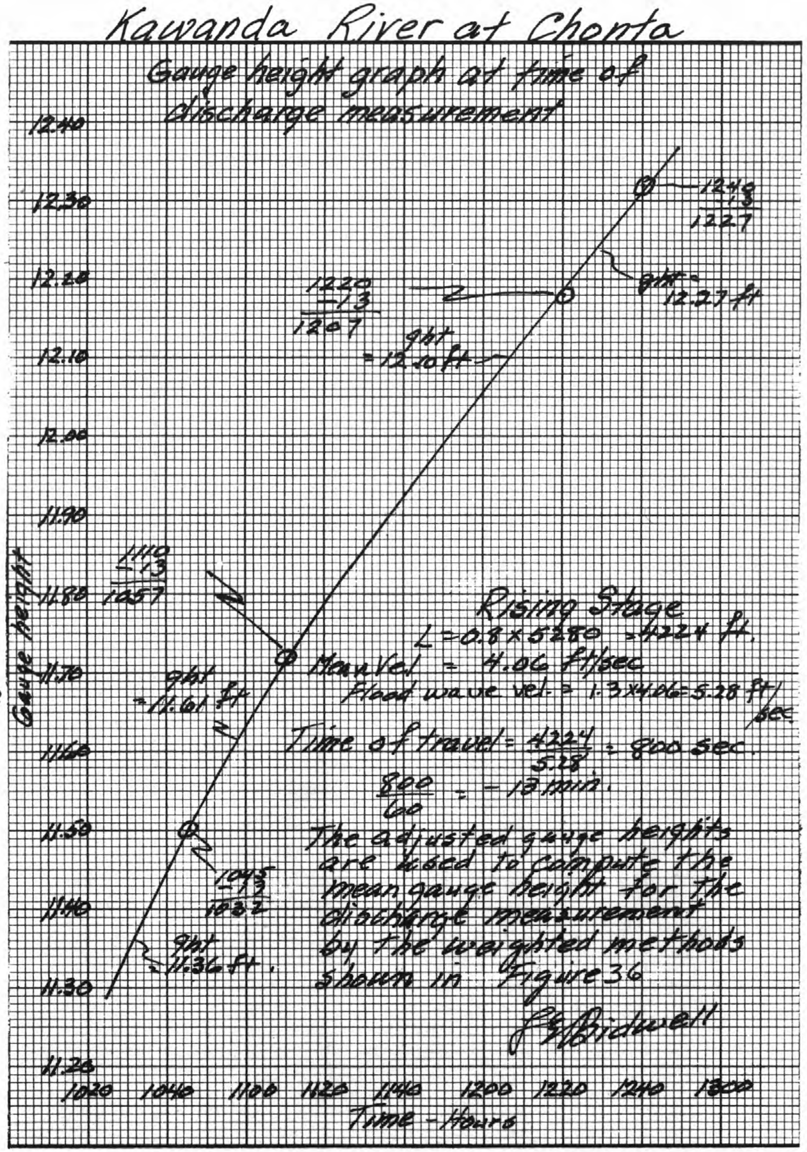
Observer Saw – examined book.

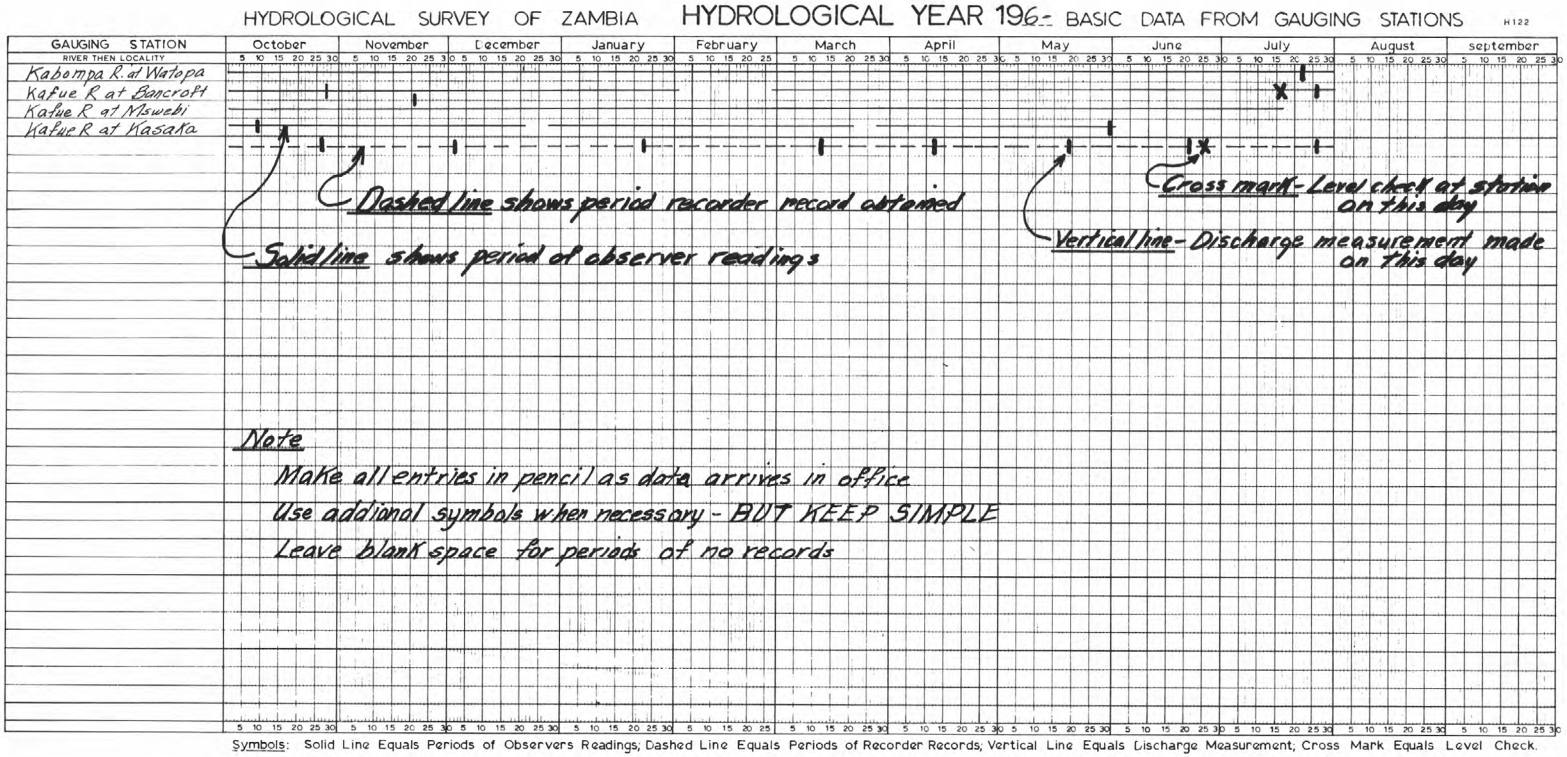
Control Constriction channel 300 ft. below gauge. Clear. No change from 31-January. No b.w.

Remarks Discharge adjustment for channel storage effect +82 cusecs – See page 5.
Ref. pt. to W.S. – 18.13 ft at 1110 and 18.49 ft at 1220 at measuring section.

G. H. of zero flow .... ft. LEBidwell

1 of 5 sheets.




HYDROLOGICAL SURVEY OF ZAMBIA
HYDROLOGICAL YEAR 196-
BASIC DATA FROM GAUGING STATIONS
H122
GAUGING STATION
RIVER THEN LOCALITY
October
November
December
January
February
March
April
May
June
July
August
september
Kabompa R. at Watopa
Kafue R at Bancroft
Kafue R at Mswebi
Kafue R at Kasaka
Dashed line shows period recorder record obtained
Solid line shows period of observer readings
Cross mark - Level check at station on this day
Vertical line - Discharge measurement made on this day
Note
Make all entries in pencil as data arrives in office
Use addional symbols when necessary - BUT KEEP SIMPLE
Leave blank space for periods of no records
Symbols: Solid Line Equals Periods of Observers Readings; Dashed Line Equals Periods of Recorder Records; Vertical Line Equals Discharge Measurement; Cross Mark Equals Level Check.

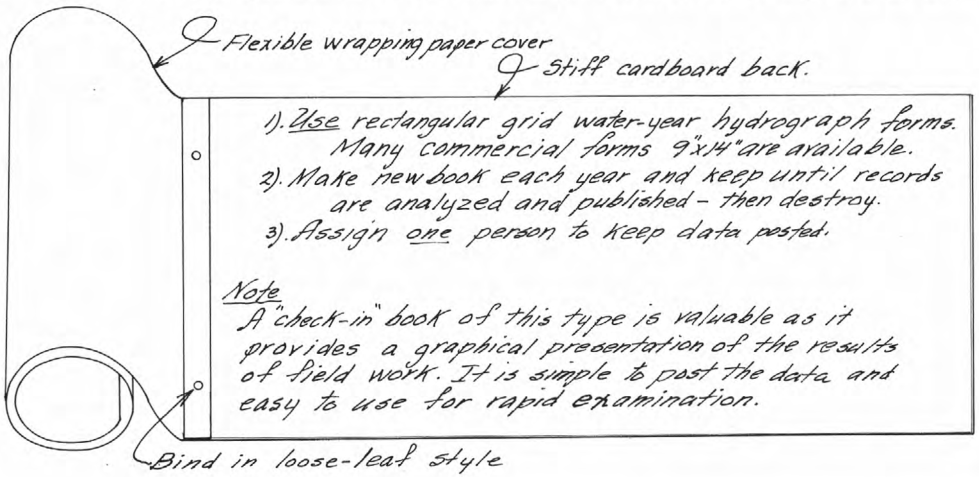

Flexible wrapping paper cover
Stiff cardboard back.
1). Use rectangular grid water-year hydrograph forms. Many commercial forms 9"x14" are available.
2). Make new book each year and keep until records are analyzed and published - then destroy.
3). Assign one person to keep data posted.
Note
A "check-in" book of this type is valuable as it provides a graphical presentation of the results of field work. It is simple to post the data and easy to use for rapid examination.
Bind in loose-leaf style

Figure 38

DISCHARGE STATION PROGRESS REPORT - HYDRO YEAR ________

________ River at / near ________

Date and enter name in each item in box	Prepared	Checked
EQUIPMENT		
1. Write "Equipment" paragraph		
GAUGE-HEIGHT RECORD - NON-RECORDING		
1. Enter ghts.* by hydrographers on ght. record sheets		
2. Plot graph of ghts. for days of rapid change in stage		
3. Compute means from ghts. - list on record sheets		
4. Compute ghts. from graph plotted in 2		
5. Find max., min., peaks - list ght., date, time on H114		
6. Write "Gauge height record" paragraph		
GAUGE-HEIGHT RECORD - RECORDING		
1. Enter readings by hydrographers on charts		
2. Compute and apply time corrections on charts		
3. Enter dates on all charts		
4. Compute daily mean ghts. on charts		
5. Compute and apply pen corrections on charts		
6. Compute ghts. for days of rapid change in stage on charts		
7. Find max., min., peaks - list ght., date, time on H114		
8. Write "Gauge height record" paragraph		
DATUM CORRECTION		
1. Check all applicable level notes		
2. Determine datum corrections - list on H113		
3. Write "Datum correction" paragraph		
4. Punch ght. cards from means on original ght. record sheets		
5. Punch datum correction cards from H113		
6. Run ght. computer program		
7. Scan ght. printout and stage hydrograph		
8. Punch revised cards, if necessary		
RATING		
1. Examine measurements, apply datum corrections - list on H110		
2. Plot measurements on curve graph sheet H116		
3. Draw curve in pencil		
4. Compute rating table on H112		
5. Compute percentage and shifts on H110		
6. Distribute shift corrections on H113		
7. Write "Rating" paragraph		
8. Punch rating table cards from H112		
9. Punch shift cards from H113		
DISCHARGE		
1. Compute discharge for days of rapid change in stage		
2. Punch discharge cards for days of rapid change in stage		
3. Run discharge computer program		
4. Examine printout and hydrograph		
5. Compute Q. for missing ghts. - list on H113		
6. Determine max., min., peak discharge on ght. - list on H114		
7. Punch revise cards and re-run program for manuscript printout		
8. Write "Discharge" paragraph		
9. Write "Remarks" paragraph		
MANUSCRIPT		
1. Compute average discharge for period of record		
2. Write station description - use last year's copy		

Figure 39

* Ght. - gauge height.

STAGE STATION PROGRESS REPORT - HYDRO YEAR________

______________________________River at/near ______________________________

Date and enter name in each item in box	Prepared	Checked
EQUIPMENT		
1. Write "Equipment" paragraph		
GAUGE-HEIGHT RECORD - NON-RECORDING		
1. Enter ghts.* by hydrographers on ght. record sheets		
2. Plot graph of ghts. for days of rapid change in stage		
3. Compute means from ghts. - list on record sheets		
4. Compute ghts. from graph plotted in 2		
5. Find max., min., peaks - list ght., date, time on H114		
6. Write "Gauge-height record" paragraph		
GAUGE-HEIGHT RECORD - RECORDING		
1. Enter hydrographer's readings on charts		
2. Compute and apply time corrections on charts		
3. Enter dates on all charts		
4. Compute daily mean ghts. on charts		
5. Compute and apply pen corrections on charts		
6. Compute ghts. for days of rapid change in stage on charts		
7. Find max., min., peaks - list ght., date, time on H114		
8. Write "Gauge-height record" paragraph		
DATUM CORRECTION		
1. Check all applicable level notes		
2. Determine datum corrections - list on H113		
3. Write "Datum correction" paragraph		
4. Punch ght. cards from means on original ght. record sheets		
5. Punch datum correction cards from H113		
6. Run ght. computer program		
7. Scan ght. printout and stage hydrograph		
8. Punch revised cards, if necessary		
9. Re-run program for manuscript printout		
10. Write "Remarks" paragraph		
MANUSCRIPT		
1. Write Station Description - use last year's copy		

* Ght. - gauge height.

Figure 40

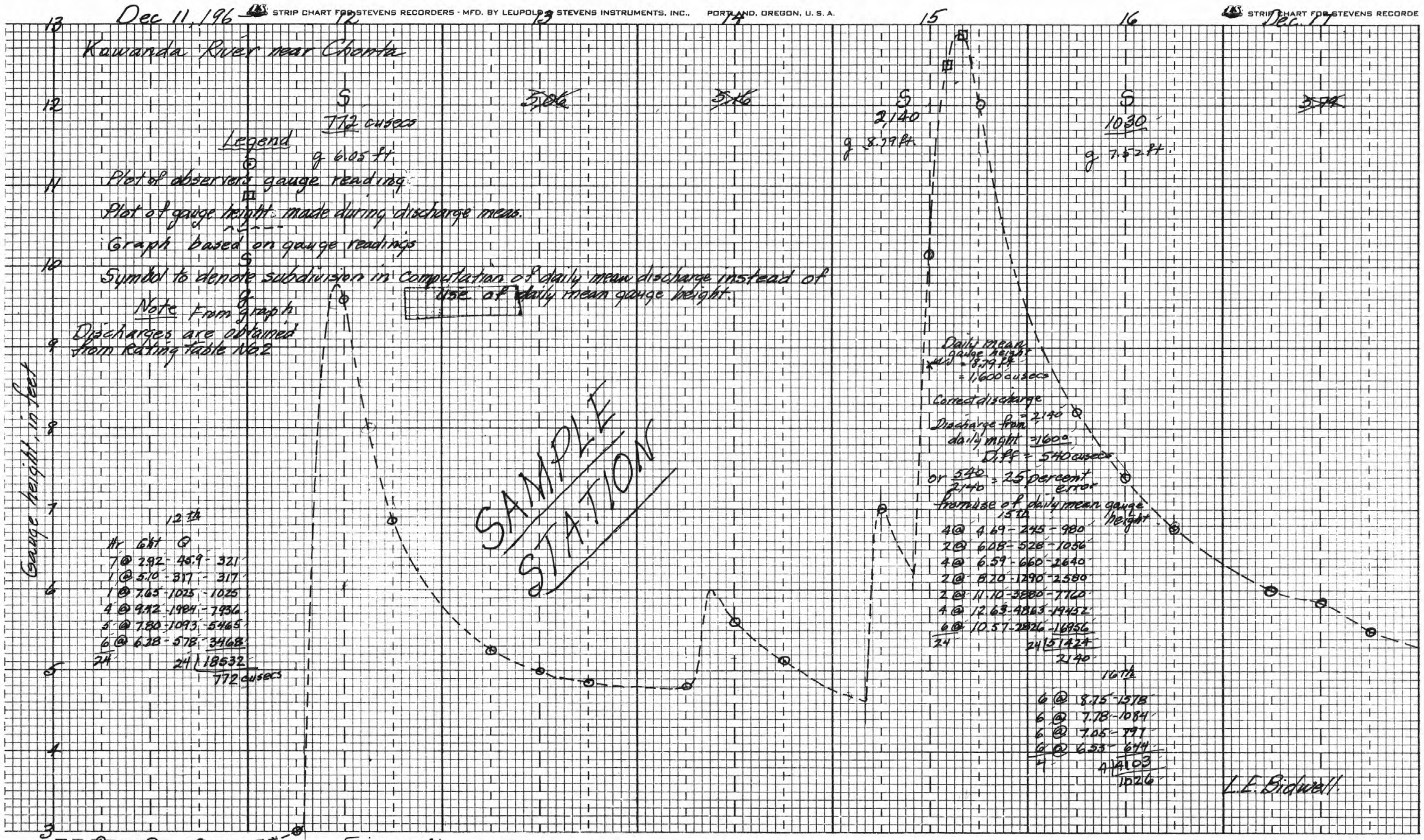

Dec 11, 196
STRIP CHART FOR STEVENS RECORDERS - MFD. BY LEUPOLD & STEVENS INSTRUMENTS, INC., PORTLAND, OREGON, U. S. A.
Dec. 17
Kowanda River near Chonta
Gauge height, in feet
Legend
Plot of observer's gauge reading
Plot of gauge height made during discharge meas.
Graph based on gauge readings
Symbol to denote subdivision in computation of daily mean discharge instead of use of daily mean gauge height.
Note From graph
Discharges are obtained from Rating Table No.2
S
772 cusecs
g 6.05 ft
S
2,140
g 8.79 ft
S
1030
g 7.52 ft
SAMPLE STATION
12th
Hr Ght Q
7 @ 2.92 - 45.9 - 321
1 @ 5.10 - 317 - 317
1 @ 7.65 - 1025 - 1025
4 @ 9.92 - 1984 - 7936
5 @ 7.80 - 1093 - 5465
6 @ 6.38 - 578 - 3468
24 24 | 18532
772 cusecs
Daily mean gauge height = 8.79 ft = 1,600 cusecs
Correct discharge = 2140
Discharge from daily mght = 1600
Diff = 540 cusecs
or 540/2140 = 25 percent error from use of daily mean gauge height
15th
4 @ 4.69 - 245 - 980
2 @ 6.08 - 528 - 1056
4 @ 6.59 - 660 - 2640
2 @ 8.20 - 1290 - 2580
2 @ 11.10 - 3880 - 7760
4 @ 12.63 - 4863 - 19452
6 @ 10.57 - 2826 - 16956
24 24 | 51424
2140
16th
6 @ 8.75 - 1578
6 @ 7.78 - 1084
6 @ 7.05 - 797
6 @ 6.53 - 644
4 4 | 4103
1026
L.E. Bidwell

Figure 41

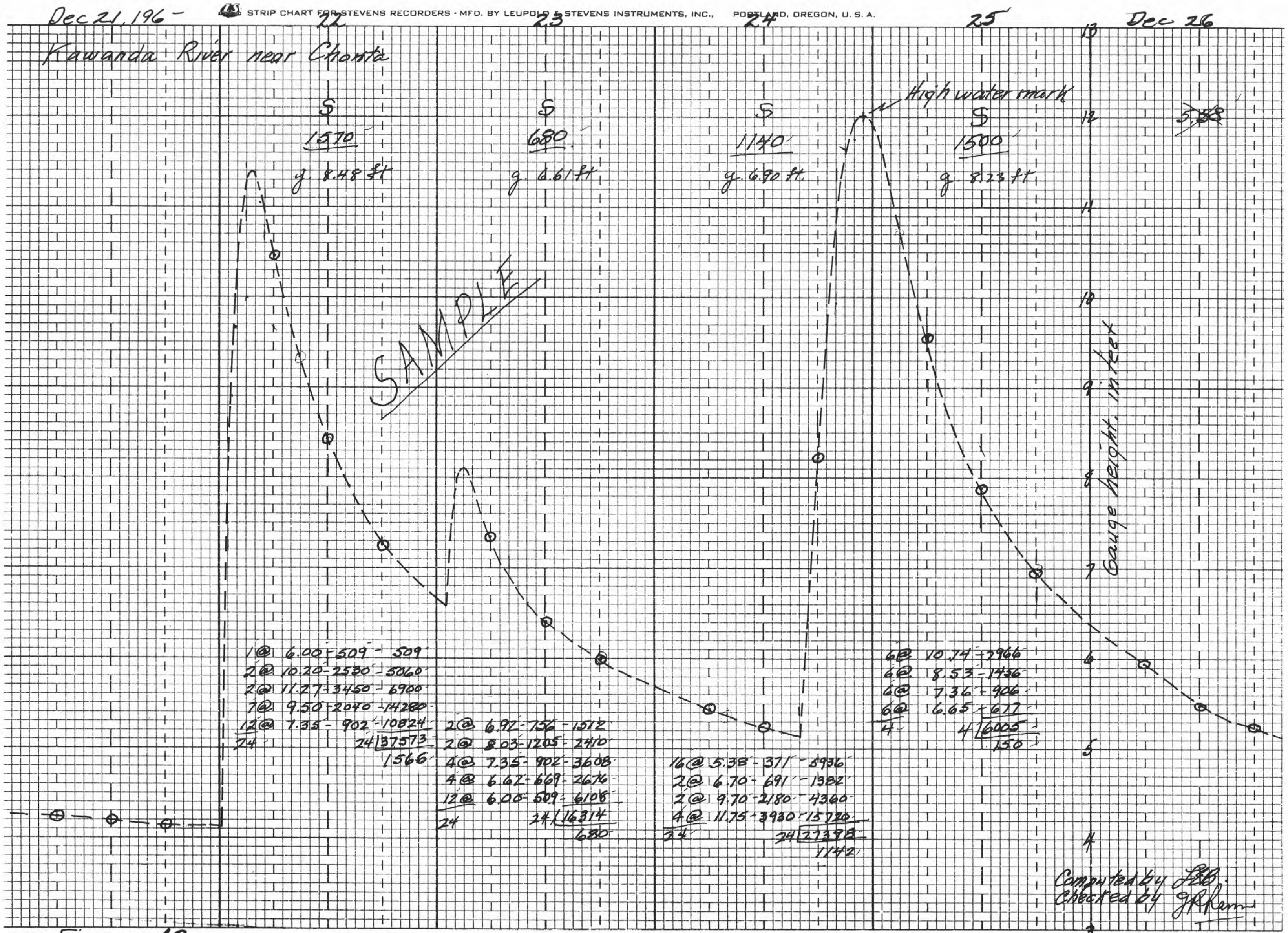
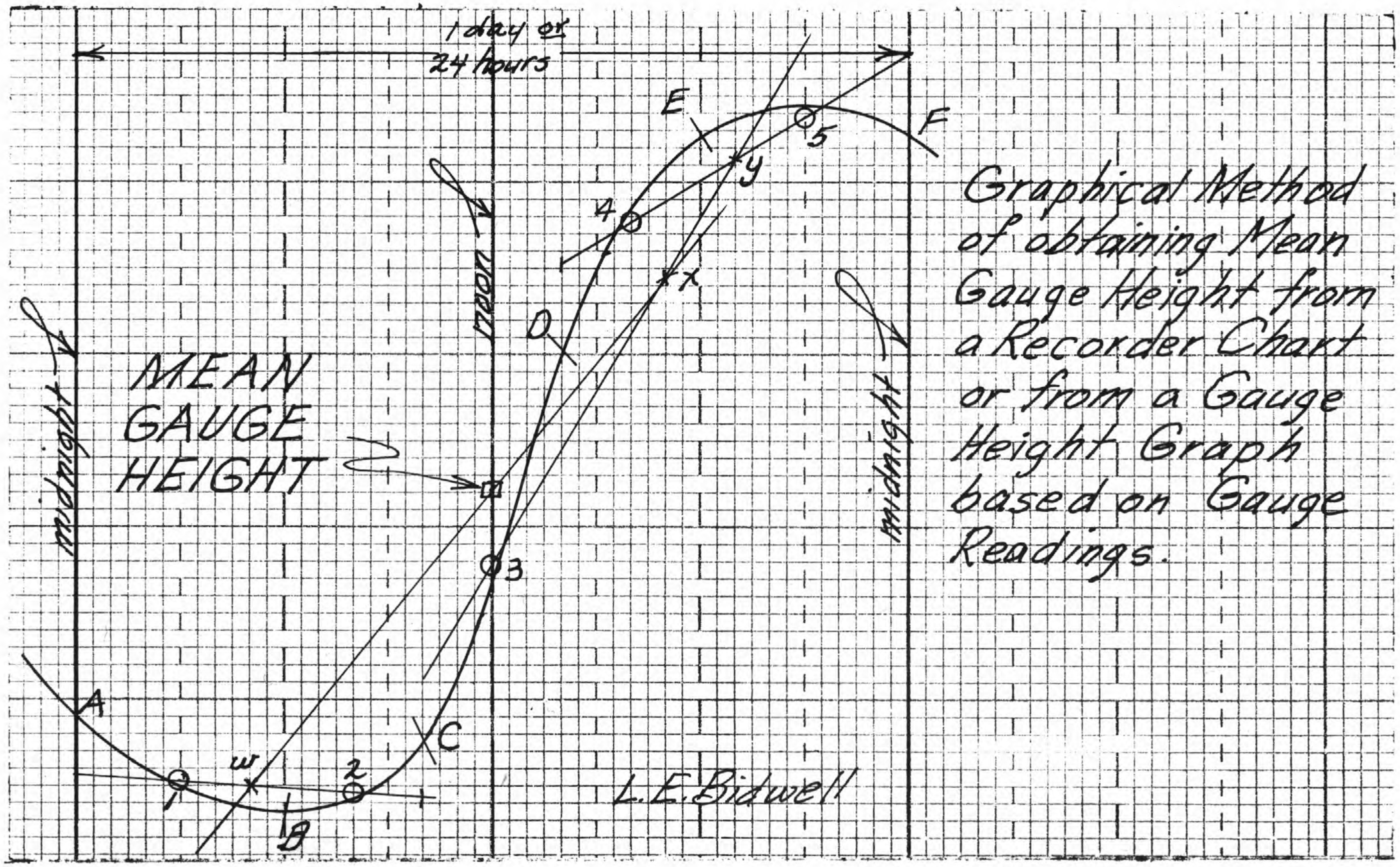

Dec 21, 196-
STRIP CHART FOR STEVENS RECORDERS - MFD. BY LEUPOLD & STEVENS INSTRUMENTS, INC., PORTLAND, OREGON, U. S. A.
22
23
24
25
Dec 26
Kawanda River near Chonta
S
1570
g. 8.48 ft
S
680
g. 6.61 ft
S
1140
g. 6.90 ft.
High water mark
S
1500
g. 8.23 ft
~~5.38~~
SAMPLE
Gauge height in feet
13
12
11
10
9
8
7
6
5
4
3
1@ 6.00 - 509 - 509
2@ 10.20 - 2530 - 5060
2@ 11.27 - 3450 - 6900
7@ 9.50 - 2040 - 14280
12@ 7.35 - 902 - 10824
24
24 | 37573
1566
2@ 6.92 - 756 - 1512
2@ 8.03 - 1205 - 2410
4@ 7.35 - 902 - 3608
4@ 6.62 - 669 - 2676
12@ 6.00 - 509 - 6108
24
24 | 16314
680
16@ 5.38 - 371 - 5936
2@ 6.70 - 691 - 1382
2@ 9.70 - 2180 - 4360
4@ 11.75 - 3930 - 15720
24
24 | 27398
1142
6@ 10.74 - 2966
6@ 8.53 - 1436
6@ 7.36 - 906
6@ 6.65 - 677
4
4 | 6005
1500
Computed by LBB.
Checked by JRKam
Figure 42

Figure 43



The figure shows a stage graph for a 24-hour period. A convenient tool for the graphical analysis is a small piece of plastic with a scratched line on one side having a length equal to the 24 hour period on the chart and the midpoint marked by a small hole for pencil marking on the chart. The scratch line is placed along the graph and the areas between the line and the graph above the line are balanced with similiar areas below the line. Since the areas are balanced by eye the accuracy is dependent upon the size and number of the areas to be balanced. With a large change in stage during a day it is necessary to separate the gauge height graph into smaller segments or periods of time.

The graph is divided into 5 segments with ends at A, B, C, D, E and F. These periods were chosen to keep the balanced areas reasonably small. The mean gauge height for each period is marked at the midpoints 1, 2, 3, 4 and 5. The midpoints 1 and 2 are connected and 4 and 5 are connected by straight lines and the respective midpoints of the combined periods A to C and D to F are marked on their respective lines. This is a successive process and midpoints 3 and y are joined and finally midpoint w to x. The midpoint at noon is then plotted on the line w to x which locates the daily mean gauge height.

ORIGINAL

W.A. Form 111
300bks—T712 8-67 S 2A

REPUBLIC OF ZAMBIA

Ministry of Natural
Resources and Tourism
Hydrological Branch

SAMPLE STATION

№ 18976 C

WATER LEVELS

RIVER AND STATION Kawanda River near Chonta FOR THE MONTH OF Dec. 196-

Date	Mean	6 a.m.	1200	1800	REMARKS
1	3.00	3.00	3.00	3.00	
2	2.98	3.00	3.00	2.95	
3	2.87	2.88	2.88	2.85	
4	2.90	2.86	2.89	2.95	
5	3.14	3.10	3.15	3.16	
6	3.22	3.20	3.22	3.25	
7	3.11	3.20	3.08	3.05	
8	2.94	2.99	2.95	2.88	
9	2.92	2.85	2.95	2.95	
10	2.86	2.89	2.85	2.85	
11	2.85	2.85	2.85	2.85	
12	96.05	3.00	9.60	6.85	
13	5.03	5.25	5.00	4.85	
14	5.17	4.80	5.60	5.12	Discharge measurement
15	98.79	7.00	10.15	12.00	Ght {12.48 @ 2pm {12.87 @ 4:10 pm JHK
16	97.52	8.20	7.40	6.75	
17	5.78	6.00	5.85	5.50	
18	5.01	5.15	5.02	4.85	
19	4.61	4.64	4.62	4.58	
20	4.35	4.40	4.35	4.30	
21	4.20	4.25	4.20	4.15	
22	98.48	10.46	8.42	7.26	
23	96.61	7.35	6.40	5.98	
24	96.90	5.42	5.25	8.22	
25	98.23	9.55	7.88	6.95	Flood last night, about 12 ft by mark on gauge.
26	5.56	5.95	5.48	5.24	
27	4.89	5.00	4.85	4.82	
28	4.64	4.70	4.63	4.58	
29	4.41	4.44	4.40	4.38	
30	4.24	4.28	4.25	4.18	
31	4.09	4.13	4.10	4.05	

L. E. Bidwell - USGS

Water levels to be read at 6 a.m. (and other hours as directed) and entered against to-day's date.

J. Nkomela
Gauge Reader.

Figure 44

H 113
2m—G245 12-69

HYDROLOGICAL SURVEY OF ZAMBIA

3. Shift
4. Datum
5. Aux. Datum

6. Discharge
7. Gauge Height

SAMPLE

Sta. No. 123

Corrections for Kawanda River nr. Chonta for year ending September 30, 196-

Day	October (10)	November (11)	December (12)	January (01)	February (02)	March (03)	Day	April (04)	May (05)	June (06)	July (07)	August (08)	September (09)	Day
1					+.01	+.02	1	+.03						1
2							2							2
3							3							3
4							4							4
5							5							5
6							6	+.03						6
7							7	+.04						7
8							8							8
9							9							9
10							10							10
11							11							11
12						+.02	12							12
13						+.03	13							13
14							14							14
15					+.01		15							15
16				0	+.02		16							16
17				+.01			17							17
18							18							18
19							19							19
20							20							20
21							21	+.04						21
22							22	+.02						22
23							23	0						23
24							24							24
25							25							25
26							26							26
27							27							27
28							28							28
29					+.02		29							29
30							30							30
31				+.01		+.03	31							31

Remarks: The distribution of the datum corrections is dependent upon both time and stage because the datum correction for the middle gauge section differs from that of the upper section.

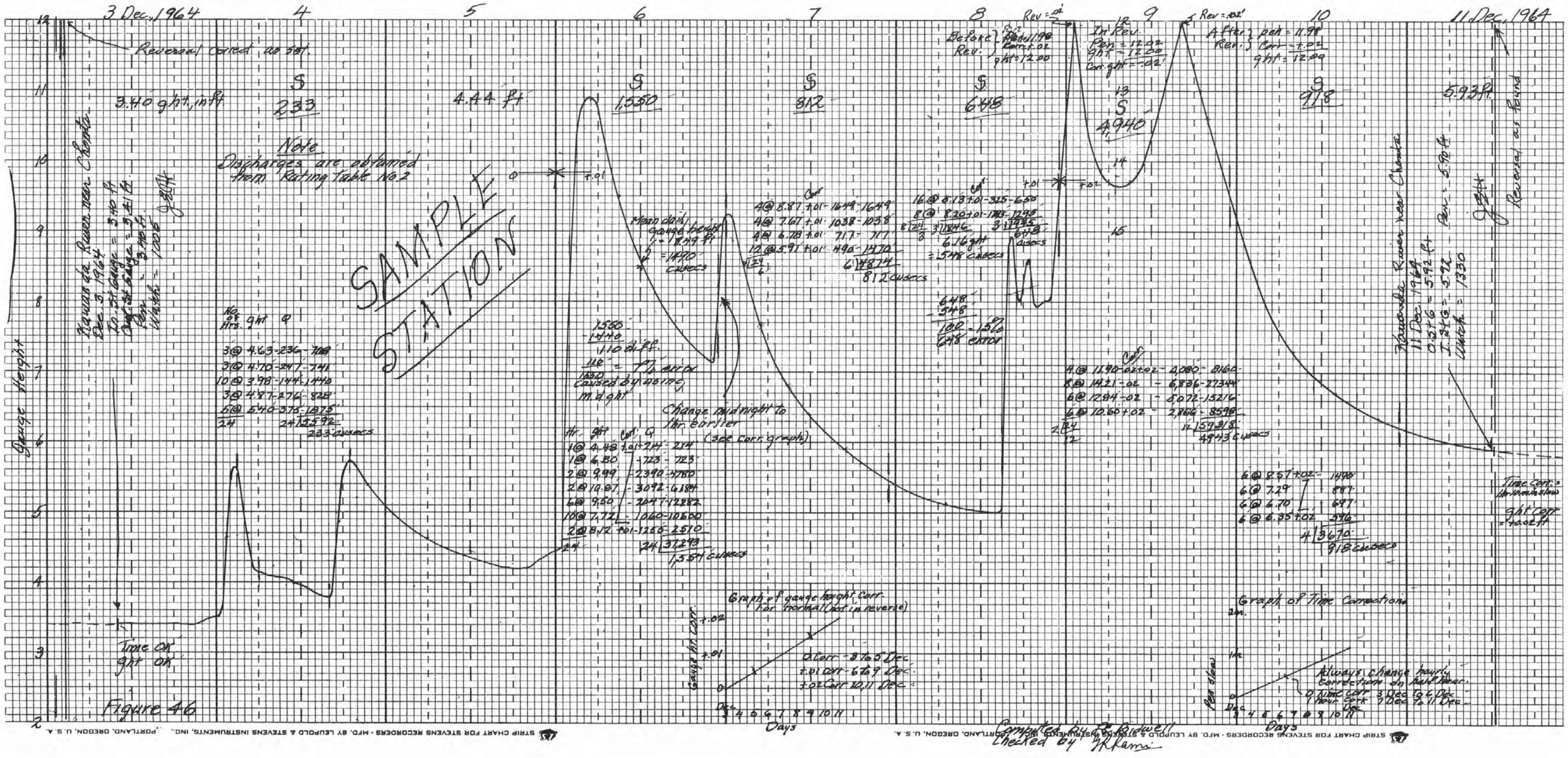
Figure 45

Max. Daily

Min. Daily

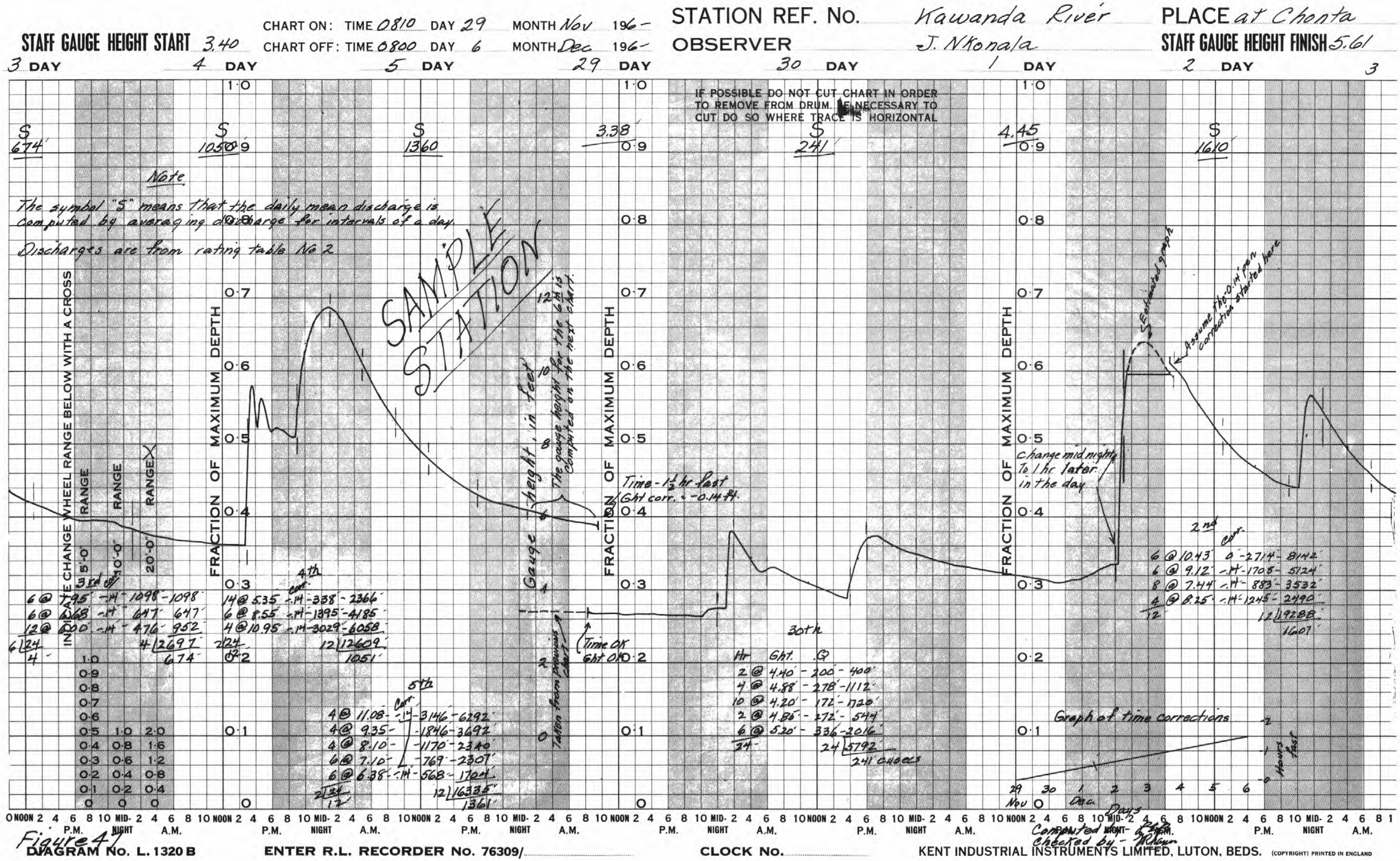
CFS—Day Total

J. E. Birdwell



3 Dec. 1964
11 Dec. 1964
Reversal cored as set.
Note
Discharges are obtained from Rating Table No. 2
SAMPLE STATION
Gauge Height
Mean daily gauge height
Change midnight to 1hr. earlier (see corr. graph)
Time OK
ght OK
Graph of gauge height corr. for normal (not in reverse)
Gauge ht. corr.
Days
Graph of Time Corrections
Always change hourly correction on half hour.
Reversal as found
Computed by R. E. Bidwell
Checked by
STRIP CHART FOR STEVENS RECORDERS - MFD. BY LEUPOLD & STEVENS INSTRUMENTS, INC., PORTLAND, OREGON, U. S. A.

Figure 46



STAFF GAUGE HEIGHT START 3.40
CHART ON: TIME 0810 DAY 29 MONTH Nov 196-
CHART OFF: TIME 0800 DAY 6 MONTH Dec 196-
STATION REF. No. Kawanda River
OBSERVER J. NKonala
PLACE at Chonta
STAFF GAUGE HEIGHT FINISH 5.61
3 DAY 4 DAY 5 DAY 29 DAY 30 DAY 1 DAY 2 DAY 3
IF POSSIBLE DO NOT CUT CHART IN ORDER TO REMOVE FROM DRUM. IF NECESSARY TO CUT DO SO WHERE TRACE IS HORIZONTAL
S 674
S 1050
S 1360
S 241
S 1610
3.38
4.45
Note
The symbol "S" means that the daily mean discharge is computed by averaging discharge for intervals of a day.
Discharges are from rating table No 2
SAMPLE STATION
INDICATE CHANGE WHEEL RANGE BELOW WITH A CROSS
RANGE 5'-0 RANGE 10'-0 RANGE 20'-0
FRACTION OF MAXIMUM DEPTH
Gauge height, in feet
The gauge height for the 6th is computed on the next chart.
Time-1½ hr fast
Ght corr. = -0.14 ft.
Taken from previous chart
Time OK Ght OK
Change mid night to 1 hr later in the day
Estimated graph
Assume the -0.14 pen correction started here
Graph of time corrections
Hours fast
29 Nov 30 1 Dec. 2 3 4 5 6 Days
3rd corr.
6@ 7.95 -.14 1098 1098
6@ 6.68 -.14 647 647
12@ 6.00 -.14 476 952
4|2697
674
4th corr.
14@ 5.35 -.14 338 2366
6@ 8.55 -.14 1395 4185
4@ 10.95 -.14 3029 6058
12|12609
1051
5th corr.
4@ 11.08 -.14 3146 6292
4@ 9.35 1846 3692
4@ 8.10 1170 2340
6@ 7.10 769 2307
6@ 6.38 -.14 568 1704
12|16335
1361
30th
Hr Ght. Q
2@ 4.40 200 400
4@ 4.88 278 1112
10@ 4.20 172 1720
2@ 4.86 272 544
6@ 5.20 336 2016
24 24|5792
241 checks
2nd corr.
6@ 10.43 0 2714 8142
6@ 9.12 -.14 1708 5124
8@ 7.44 -.14 883 3532
4@ 8.25 -.14 1245 2490
12|19288
1607
NOON MID-NIGHT P.M. A.M.
Computed by
Checked by
DIAGRAM No. L. 1320 B
ENTER R.L. RECORDER No. 76309/
CLOCK No.
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Figure 47

HYDROLOGICAL SURVEY OF ZAMBIA

Station No. K68

Discharge measurements of Kafue River at Kasaka during the year ending September 30, 1967

No.	Date	Made by	Width (ft)	Area (sq. ft)	Mean velocity (ft/sec)	Gauge height (ft)	Discharge (cusec)	Rating No. 15 Shift adj. (ft)	Per cent diff.	Method	Number meas. sections	Gauge height change (ft)	Time (hr)	Meas. rated		Sections in flow	REMARKS
	1966																
577	24-8	Brickbill	786	4,340	0.77	15.13	3,330		-4.3	0.6	20	-.03	3.5			15	
578	17-11	Y. Mukwamataba	620	2,600	.28	12.71	732		-8.5	.6	22	+.01	2.3			18	
579	21-11	"	628	2,630	.30	12.77	796		-5.7	.6	22	+.02	2.7			16	simultaneous
580	21-11	P. Lee	622	2,640	.34	12.77	886		+5.0	.6	22	0	2.6			18	Q meas.
581	25-11	P. Lee	606	2,450	.29	12.59	717		+0.1	.6	21	-.01	2.3			18	
582	28-11		620	2,570	.38	12.65	981		+29.4	.6	23	-.01	2.7			20	Do not use
583	3-12		630	2,500	.36	12.61	898		+23.0	.6	23	+.02	3.2			19	Do not use
584	6-12		630	2,530	.36	12.68	905		+16.2	.6	23	+.05	2.5			21	Do not use
585	12-12		780	2,960	.38	13.13	1,120		-0.9	.6	28	+.15	2.2			19	
586	16-12		780	2,890	.34	13.01	997		-3.0	.6	26	-.07	2.3			18	
	1967																
587	16-1		794	4,160	.71	14.69	2,940		+3.5	.6	28	-.01	2.1			19	
588	20-1		792	4,630	.81	15.19	3,730		+4.5	.6	27	+.01	3.5			20	
589	1-2		815	5,200	.97	16.17	5,060		-4.9	.6	28	0	3.2			19	
590	10-2		879	6,190	1.08	16.83	6,650		-0.4	.6	30	+.02	2.9			20	
591	17-2		886	6,520	1.18	17.13	7,710		+5.0	.6	30	-.03	3.8			20	
592	23-2		887	6,690	1.15	17.35	7,700		-1.5	.6	31	0	3.0			20	
593	1-4		820	6,620	1.37	17.92	9,100		+0.3	.6	28	0	4.3			20	
594	10-4		829	6,700	1.41	17.98	9,410		+2.2	.6	28	0	5.2			21	
595	17-5		829	6,910	1.49	18.51	10,300		-1.0	.6	28	-.01	3.5			19	

Copied by L.E. Bidwell Computed by L.E. Bidwell Checked by M.M. Mulipukwa

sheet 1 of 2

Figure 48

5m—G243 12-69

HYDROLOGICAL SURVEY OF ZAMBIA

Station No. KG 8

Discharge measurements of Kafue River at Kasaka during the year ending September 30, 1967

No.	Date	Made by	Width	Area	Mean velocity	Gauge height	Discharge	Rating No. 15 Shift adj.	Per cent diff.	Method	Number meas. sections	Gauge height change	Time	Meas. rated		Sections in flow	REMARKS
	1967																
596	23-5		832	7,060	1.50	18.62	10,600		-0.9	0.6	28	0	3.6			21	
597	2-6		834	7,050	1.58	18.78	11,100		0	.6	28	0	3.6			21	
598	10-6		837	7,110	1.57	18.89	11,200		-0.9	.6	28	+.01	4.8			22	
599	19-6		841	7,170	1.58	18.96	11,300		-1.7	.6	29	0	4.8			22	
	1968																
600	22-3		822	6,410	1.17	17.54	7,510	-.33		.6	21	+.02	4.2			15	Each of 5 sections had over 10% of Total Q. Channel shifted

Copied by J.E. Bidwell   Computed by J.E. Bidwell   Checked by M. M. Mulipukwa

Sheet 2 of 2

Figure.- 49

5m—G243 12-69

HYDROLOGICAL SURVEY OF ZAMBIA

Station No. K68

Discharge measurements of Kafue River at Kasaka during the year ending September 30, 1968

No.	Date	Made by	Width	Area	Mean velocity	Gauge height	Discharge	Rating No 15: Shift adj.	Rating No 15: Per cent diff.	Method	Number meas. sections	Gauge height change	Time	Meas. rated		Section in flow	REMARKS
	1967																
599	19-6		841	7,170	1.58	18.96	11,300		-1.7	0.6	29	0	4.8			22	
	1968																
600	22-3		822	6,410	1.17	17.54	7,510	-.33	0	.6	21	+.02	4.2			15	Each of 5 sections had over 10% of Total Q
601	3-5		821	6,910	1.22	18.25	8,470	-.59	-0.4	.6	21	+.01	2.5			12	Sections poorly spaced
602	11-6		832	6,920	1.32	18.11	9,150		-3.7	.6	21	0	3.0			14	" " "
603	23-8		734	3,970	.69	14.71	2,760		-3.5	.6	19	-.03	4.2			16	" " "
604	30-8		750	4,100	.73	14.51	2,980	Ignore +.28		.6	18	-.01	3.0			17	" " "
605	23-9		740	3,360	.61	13.94	2,050		+5.1	.6	16	-.04	2.2			15	One section had 26% of total flow
606	3-12		680	3,240	.52	13.64	1,700		+4.3	.6	17	0	3.1			14	Sections poorly spaced

Copied by L.E. Bidwell Computed by L.E. Bidwell Checked by M.M. Mulipukwa

Figure.-50

5m—G243 12-69

HYDROLOGICAL SURVEY OF ZAMBIA

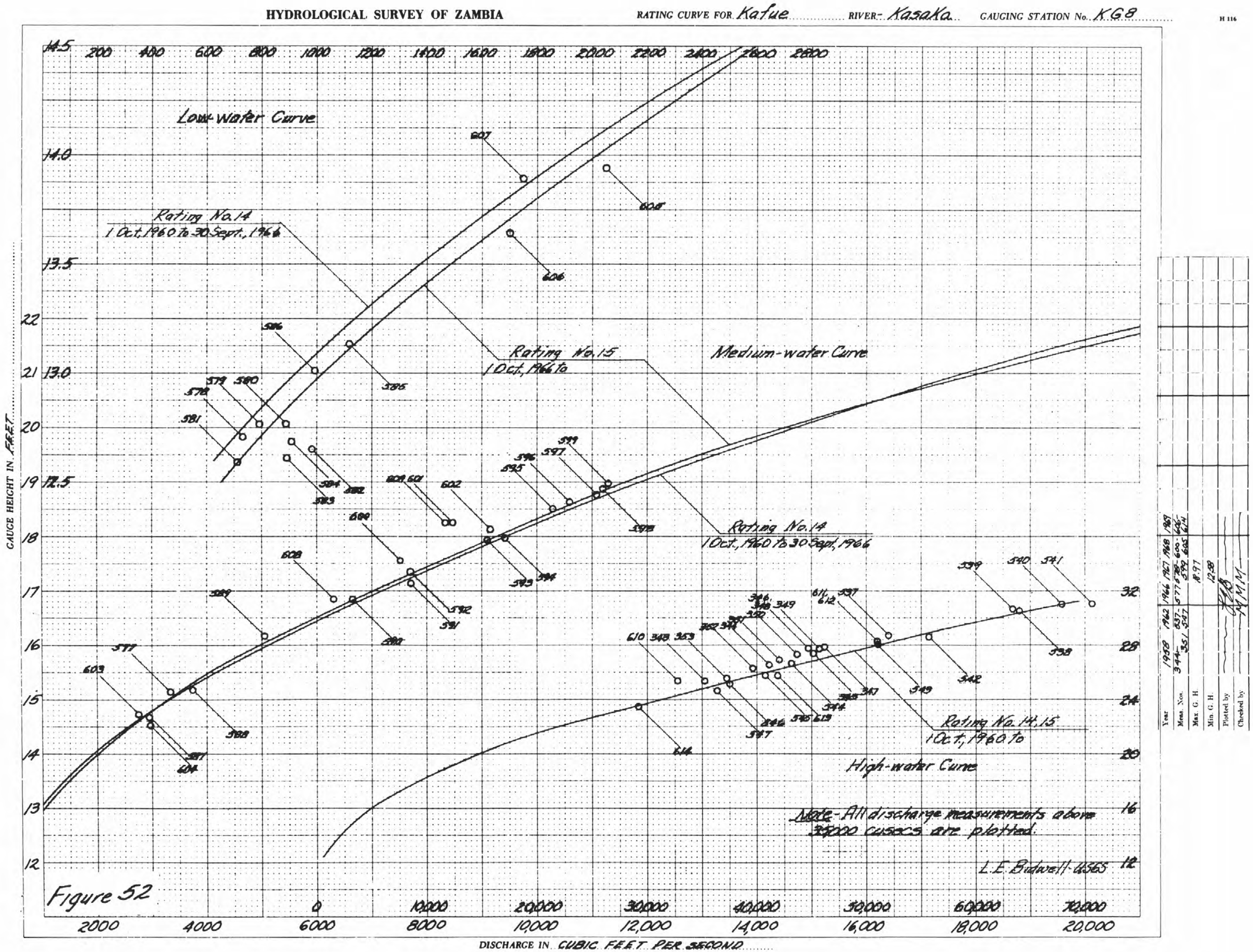
Station No. K68

Discharge measurements of Kafue River at Kasaka during the year ending September 30, 1969

No.	Date	Made by	Width	Area	Mean velocity	Gauge height	Discharge	Rating No.15		Method	Number meas. sections	Gauge height change	Time	Meas. rated		Sections in flow	REMARKS
								Shift adj.	Per cent diff.								
	1968																
605	23-9		740	3,360	0.61	13.94	2,050		+5.1	0.6	16	-.04	2.2			15	One section had 26% of total flow
606	3-12		680	3,240	.52	13.64	1,700		+4.3	.6	17	0	3.1			14	Sections poorly spaced
607	6-12		750	3,500	.50	13.89	1,750	Not for and	used 1967 1968	.6	17	+.02	?			15	" " Velocity looks low
	1969																
608	3-1		864	6,300	1.00	16.85	6,320	"	"	.6	22	+.01	2.1			14	Sections poorly spaced
609	23-1		843	7,080	1.18	18.26	8,350	"	"	.6	21	0	2.6			14	" " "
610	18-4	T. Nguira, M Patel L.E Bidwell	405	7,520	4.36	25.28	32,800	"	"	.2-.8	35	+.11	5.2	G		35	Training meas. at bridge.
611	9-5	T. Nguira, M. Patel	416	8,820	5.78	28.21	51,000		-2.3	.2-.8	41	0	3.9	?		41	Meas. not given a rating - From Bridge
612	13-5	M. Patel. T. Nguira	414.5	8,570	5.95	28.20	51,000		-2.1	.2-.8	42	-.02	4.2	?		42	Meas. not given a rating - " Bridge
613	4-17	M. Patel, T. Nguira	411	8,390	5.00	25.66	41,900		+6.3	.2-.8	40	-.01	3.0	G		40	Bridge meas.
614	7-8	M. Patel, T. Nguira	409	7,011	4.17	23.54	29,300		+1.4	.2-.8	35	-.02	3.2	F		35	" "

Copied by L. E. Bidwell Computed by L. E. Bidwell Checked by M. M. Mulipukwa

Figure:-51



HYDROLOGICAL SURVEY OF ZAMBIA
RATING CURVE FOR Kafue RIVER- Kasaka GAUGING STATION No. KG8
H 116
Low-water Curve
Rating No. 14
1 Oct. 1960 To 30 Sept. 1966
Rating No. 15
1 Oct. 1966 To
Medium-water Curve
Rating No. 14
1 Oct. 1960 To 30 Sept. 1966
Rating No. 14, 15
1 Oct. 1960 To
High-water Curve
Note- All discharge measurements above 35000 cusecs are plotted.
L.E. Bidwell-4565
Figure 52
GAUGE HEIGHT IN FEET
DISCHARGE IN CUBIC FEET PER SECOND
Year
Meas. Nos.
Max. G. H.
Min. G. H.
Plotted by
Checked by

H 112
2m—G360 12-69 S

HYDROLOGICAL SURVEY OF ZAMBIA

Station No. ....

Table No. ....

RATING TABLE FOR Suggested Metric Table ....

Begin .... Year .... Month .... Day .... Hour

From .... to ...., from .... to ...., from .... to ....

Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference
Metre	Cumec	Cumec																		
.00			.00			.00			.00			.00			.00			.00		
.05			.05			.05			.05			.05			.05			.05		
.10			.10			.10			.10			.10			.10			.10		
.15			.15			.15			.15			.15			.15			.15		
.20			.20			.20			.20			.20			.20			.20		
.25			.25			.25			.25			.25			.25			.25		
.30			.30			.30			.30			.30			.30			.30		
.35			.35			.35			.35			.35			.35			.35		
.40			.40			.40			.40			.40			.40			.40		
.45			.45			.45			.45			.45			.45			.45		
.50			.50			.50			.50			.50			.50			.50		
.55			.55			.55			.55			.55			.55			.55		
.60			.60			.60			.60			.60			.60			.60		
.65			.65			.65			.65			.65			.65			.65		
.70			.70			.70			.70			.70			.70			.70		
.75			.75			.75			.75			.75			.75			.75		
.80			.80			.80			.80			.80			.80			.80		
.85			.85			.85			.85			.85			.85			.85		
.90			.90			.90			.90			.90			.90			.90		
.95			.95			.95			.95			.95			.95			.95		

This table is applicable for open-channel conditions. It is based on ———— discharge measurements made during ....

and is .... well defined between .... and ....

....

Sheet .... of ....

Figure-53

J.E. Bidwell

Compiled by .... date ....

Checked by .... date ....

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2m—G360 12-69 S

HYDROLOGICAL SURVEY OF ZAMBIA

Station No...

Table No..................

RATING TABLE FOR Suggested Metric table Curvilinear expansion

Begin ....
Year Month Day Hour

From............................ to............................, from............................ to............................, from............................ to............................

Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge
Metre	Cumec																		
.000		.100																	
.005		.105																	
.010		.110																	
.015		.115																	
.020																			
.025																			
.030																			
.035																			
.040																			
.045																			
.050																			
.055																			
.060																			
.065																			
.070																			
.075																			
.080																			
.085																			
.090																			
.095																			

This table is applicable for open-channel conditions. It is based on .... discharge measurements made during ....

.... and is .... well defined between .... and ....

Comp by...... date.......

Ckd by...... date.......

Figure-54

GPO : 1967 OF—249-764

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HYDROLOGICAL SURVEY OF ZAMBIA

Station No. 123

Table No. 2

RATING TABLE FOR KAWANDA RIVER NEAR CHONTA

Begin 196– (Year) JUNE, (Month) 15TH (Day) .... (Hour)

From 15 June, 196– to 30 Sept. 196–, from .... to ...., from .... to ....

Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference
.00			3.00	50.9	6.7	5.00	299	18	7.00	781	32	9.00	1720	60	11.00	3200	90	13.00	5270	120
.10			.10	57.6	7.2	.10	317	19	.10	813	34	.10	1780		.10	3290	90	.10	5390	
.20			.20	64.8	7.8	.20	336	19	.20	847	36	.20	1840		.20	3380	100	.20	5510	
.30			.30	72.6	8.6	.30	355	20	.30	883	38	.30	1900	60	.30	3480		.30	5630	
.40			.40	81.2	9.3	.40	375	20	.40	921	40	.40	1970	70	.40	3580		.40	5750	120
.50			.50	90.5	9.9	.50	395	22	.50	961	42	.50	2040		.50	3680		.50	5870	140
.60			.60	100.4	10.5	.60	417	22	.60	1003	44	.60	2110		.60	3780		.60	6010	
.70			.70	110.9	11.2	.70	439	23	.70	1047	46	.70	2180		.70	3880		.70	6150	
.80			.80	122.1	11.9	.80	462	23	.80	1093	48	.80	2250		.80	3980		.80	6290	
.90			.90	134.0	12.0	.90	485	24	.90	1141	49	.90	2320		.90	4080		.90	6430	
2.00	9.0	2.0	4.00	146	13	6.00	509	24	8.00	1190	50	10.00	2390		12.00	4180	100	14.00	6570	
.10	11.0	2.5	.10	159	13	.10	533	25	.10	1240		.10	2460	70	.10	4280	110	.10	6710	
.20	13.5	3.0	.20	172	14	.20	558	25	.20	1290		.20	2530	80	.20	4390		.20	6850	140
.30	16.5	3.5	.30	186	14	.30	583	26	.30	1340		.30	2610		.30	4500		.30	6990	160
.40	20.0	4.0	.40	200	15	.40	609	27	.40	1390	50	.40	2690		.40	4610		.40	7150	
.50	24.0	4.5	.50	215	16	.50	636	27	.50	1440	55	.50	2770		.50	4720		.50	7310	
.60	28.5	5.0	.60	231	16	.60	663	28	.60	1495		.60	2850	80	.60	4830		.60	7470	
.70	33.5	5.4	.70	247	17	.70	691	29	.70	1550		.70	2930	90	.70	4940		.70	7630	
.80	38.9	5.8	.80	264	17	.80	720	30	.80	1605	55	.80	3020		.80	5050		.80	7790	
.90	44.7	6.2	.90	281	18	.90	750	31	.90	1660	60	.90	3110	90	.90	5160	110	.90	7950	160

This table is applicable for open-channel conditions. It is based on 15 discharge measurements made during 1965 AND SHAPE OF PREVIOUS CURVE (NO 1)

and is FAIRLY well defined between 50 cfs and 5000 cfs.

This rating is same as rating No1 above 11.2 ft.

Compiled by L.E.B. date 8/4/6–

Checked by J.H.H. date 10/4/6–

Sheet 1 of 2

Figure-55

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2m—G360 12-69 S

HYDROLOGICAL SURVEY OF ZAMBIA

Station No. 123

Table No. 2

RATING TABLE FOR KAWANDA RIVER NEAR CHONTA

Begin 196- JUNE, 15TH
Year Month Day Hour

From 15 June 196- to 30 Sept. 196-, from .... to ...., from .... to ....

Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference
15 .00	8110	160	.00			.00			.00			.00			.00			.00		
.10	8270		.10			.10			.10			.10			.10			.10		
.20	8430		.20			.20			.20			.20			.20			.20		
.30	8590		.30			.30			.30			.30			.30			.30		
.40	8750		.40			.40			.40			.40			.40			.40		
.50	8910		.50			.50			.50			.50			.50			.50		
.60	9070		.60			.60			.60			.60			.60			.60		
70	9230		.70			.70			.70			.70			.70			.70		
.80	9390		.80			.80			.80			.80			.80			.80		
.90	9550	160	.90			.90			.90			.90			.90			.90		
16 .00	9710		.00			.00			.00			.00			.00			.00		
.10			.10			.10			.10			.10			.10			.10		
.20			.20			.20			.20			.20			.20			.20		
.30			.30			.30			.30			.30			.30			.30		
.40			.40			.40			.40			.40			.40			.40		
.50			.50			.50			.50			.50			.50			.50		
.60			.60			.60			.60			.60			.60			.60		
.70			.70			.70			.70			.70			.70			.70		
.80			.80			.80			.80			.80			.80			.80		
.90			.90			.90			.90			.90			.90			.90		

This table is applicable for open-channel conditions. It is based on 15 discharge measurements made during 1965 AND SHAPE OF PREVIOUS CURVE (NO 1.)

and is FAIRLY well defined between 50 cfs and 5,000 cfs.

Compiled by L.E.B. date 8/4/6-

Checked by J.H.H. date 10/4/6-

Sheet 2 of 2

Figure-56

H 112
2m—G360 12-69 S

HYDROLOGICAL SURVEY OF ZAMBIA

Station No. KG 8

Table No. 15

RATING TABLE FOR KAFUE RIVER AT KASAKA

Begin 1966 OCTOBER 1 1
Year Month Day Hour

From 1st OCTOBER, 1966 to ...., from .... to ...., from .... to ....

Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference
12 .00			14.00	2020	110	16.00	4990	190	18.00	9250	230	20.00	14500	350	22.00	22000	450	24.00	31100	500
.10			.10	2130		.10	5180	200	.10	9480		.10	14850		.10	22450		.10	31600	
.20			.20	2240	110	.20	5380		.20	9710		.20	15200		.20	22900		.20	32100	
.30			.30	2350	120	.30	5580	200	.30	9940		.30	15550		.30	23350		.30	32600	
.40			.40	2470	120	.40	5780	210	.40	10170		.40	15900		.40	23800		.40	33100	
.50	656	67	.50	2590	130	.50	5990		.50	10400		.50	16250		.50	24250		.50	33600	
.60	723	70	.60	2720	130	.60	6200		.60	10630	230	.60	16600		.60	27700		.60	34100	
70	793	73	.70	2850	140	.70	6410		.70	10860	250	.70	16950		.70	25150		.70	34600	
.80	866	75	.80	2990	140	.80	6620	210	.80	11110		.80	17300		.80	25600		.80	35100	
.90	941	79	.90	3130	150	.90	6830	220	.90	11360		.90	17650	350	.90	26050		.90	35600	
13 .00	1,020	85	15.00	3280	150	17.00	7050		19.00	11610		21.00	18000	400	23.00	26500		25.00	36100	
.10	1105	90	.10	3430	160	.10	7270		.10	11860	250	.10	18400		.10	26950		.10	36600	
.20	1195	95	.20	3590		.20	7490		.20	12110	290	.20	18800		.20	27400		.20	37100	
.30	1,290	95	.30	3750	160	.30	7710		.30	12400	300	.30	19200		.30	27850		.30	37600	
.40	1,385	100	.40	3910	170	.40	7930		.40	12700		.40	19600		.40	28300		.40	38100	
.50	1485	100	.50	4080	170	.50	8150		.50	13000		50	20000		.50	28750		.50	38600	
.60	1,585	105	.60	4250	180	.60	8370		.60	13300		.60	20400		.60	29200		.60	39100	
.70	1690	110	.70	4430	180	.70	8590		.70	13600		.70	20800		.70	29650	450	.70	39600	
.80	1,800		.80	4610	190	.80	8810		.80	13900		.80	21200		.80	30100	500	.80	40100	
.90	1,910	110	.90	4800	190	.90	9030	220	.90	14200	300	.90	21600	400	.90	30600	500	.90	40600	500

This table is applicable for open-channel conditions. It is based on 19 discharge measurements made during 1966 AND 1967 AND ALL HIGH WATER DISCHARGE MEASUREMENTS ABOVE 35,000 cusecs.

Compiled by LEB date 17-2-70

and is .... well defined between 700 cfs and 69,000 cfs.

Checked by M.M.T.M. date 20-3-70

SHAPE OF PREVIOUS RATING.

Sheet 1 of 2

Figure-57

Re-copied: M.S.C. Mackenzie

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2m—G360 12-69 S

HYDROLOGICAL SURVEY OF ZAMBIA

Station No. KG8

Table No. 15

RATING TABLE FOR KAFUE RIVER AT KASAKA

Begin 1966 OCTOBER 1 1
Year Month Day Hour

From 1st OCTOBER 1966 to ...., from .... to ...., from .... to ....

Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference	Gauge height	Discharge	Difference
26 .00	41100	500	28.00	51100	500	30.00	62100	600	.00			.00			.00			.00		
.10	41600		.10	51600		.10	62700		.10			.10			.10			.10		
.20	42100		.20	52100		.20	63300		.20			.20			.20			.20		
.30	42600		.30	52600		.30	63900		.30			.30			.30			.30		
.40	43100		.40	53100		.40	64500		.40			.40			.40			.40		
.50	43600		.50	53600		.50	65100		.50			.50			.50			.50		
.60	44100		.60	54100		.60	65700		.60			.60			.60			.60		
70	44600		.70	54600		.70	66300		.70			.70			.70			.70		
.80	45100		.80	55100		.80	66900		.80			.80			.80			.80		
.90	45600		.90	55600	500	.90	67500		.90			.90			.90			.90		
27 .00	46100		29.00	56100	600	31.00	68100		.00			.00			.00			.00		
.10	46600		.10	56700		.10	68700	600	.10			.10			.10			.10		
.20	47100		.20	57300		.20	69300		.20			.20			.20			.20		
.30	47600		.30	57900		.30			.30			.30			.30			.30		
.40	48100		.40	58500		.40			.40			.40			.40			.40		
.50	48600		.50	59100		.50			.50			.50			.50			.50		
.60	49100		.60	59700		.60			.60			.60			.60			.60		
.70	49600		.70	60300		.70			.70			.70			.70			.70		
.80	50100		.80	60900		.80			.80			.80			.80			.80		
.90	50600	500	.90	61500	600	.90			.90			.90			.90			.90		

This table is applicable for open-channel conditions. It is based on 19 discharge measurements made during 1966 AND 1967 AND ALL HIGH WATER DISCHARGE MEASUREMENTS ABOVE 35,000 cusecs

and is .... well defined between 700 cfs and 69000 cfs.

SHAPE OF PREVIOUS RATING.

Sheet 2 of 2

Figure 58

Compiled by LEB date 17.2.70

Checked by M.M.T.M. date 20.3.70

Re-copied: M.S.C. Mackenzie.

5m—K675 9-70 S

HYDROLOGICAL SURVEY OF ZAMBIA

Sta. No. _ _ _ . _ _ _

Table No. _ _

Begin _ _ YR _ _ MO _ _ D _ _ HR

Rating table for ....

from .... *to* ...., *from* .... *to* ...., *from* .... *to* ....

Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge
Feet	Cfs	Feet	Cfs	Feet	Cfs	Feet	Cfs	Feet	Cfs	Feet	Cfs	Feet	Cfs	Feet	Cfs	Feet	Cfs	Feet	Cfs
.00		.20		.40		.60		.80		.00		.20		.40		.60		.80	
.01		.21		.41		.61		.81		.01		.21		.41		.61		.81	
.02		.22		.42		.62		.82		.02		.22		.42		.62		.82	
.03		.23		.43		.63		.83		.03		.23		.43		.63		.83	
.04		.24		.44		.64		.84		.04		.24		.44		.64		.84	
.05		.25		.45		.65		.85		.05		.25		.45		.65		.85	
.06		.26		.46		.66		.86		.06		.26		.46		.66		.86	
.07		.27		.47		.67		.87		.07		.27		.47		.67		.87	
.08		.28		.48		.68		.88		.08		.28		.48		.68		.88	
.09		.29		.49		.69		.89		.09		.29		.49		.69		.89	
.10		.30		.50		.70		.90		.10		.30		.50		.70		.90	
.11		.31		.51		.71		.91		.11		.31		.51		.71		.91	
.12		.32		.52		.72		.92		.12		.32		.52		.72		.92	
.13		.33		.53		.73		.93		.13		.33		.53		.73		.93	
.14		.34		.54		.74		.94		.14		.34		.54		.74		.94	
.15		.35		.55		.75		.95		.15		.35		.55		.75		.95	
.16		.36		.56		.76		.96		.16		.36		.56		.76		.96	
.17		.37		.57		.77		.97		.17		.37		.57		.77		.97	
.18		.38		.58		.78		.98		.18		.38		.58		.78		.98	
.19		.39		.59		.79		.99		.19		.39		.59		.79		.99	

This table is applicable for open-channel conditions. It is based on .... discharge measurements made during ....

.... and is .... well defined between .... cfs and .... cfs.

Comp by...... date......

Ckd by...... date......

Figure- 59

HYDROLOGICAL SURVEY OF ZAMBIA — RATING CURVE FOR Kafue RIVER at Kasaka GAUGING STATION No. — H 116

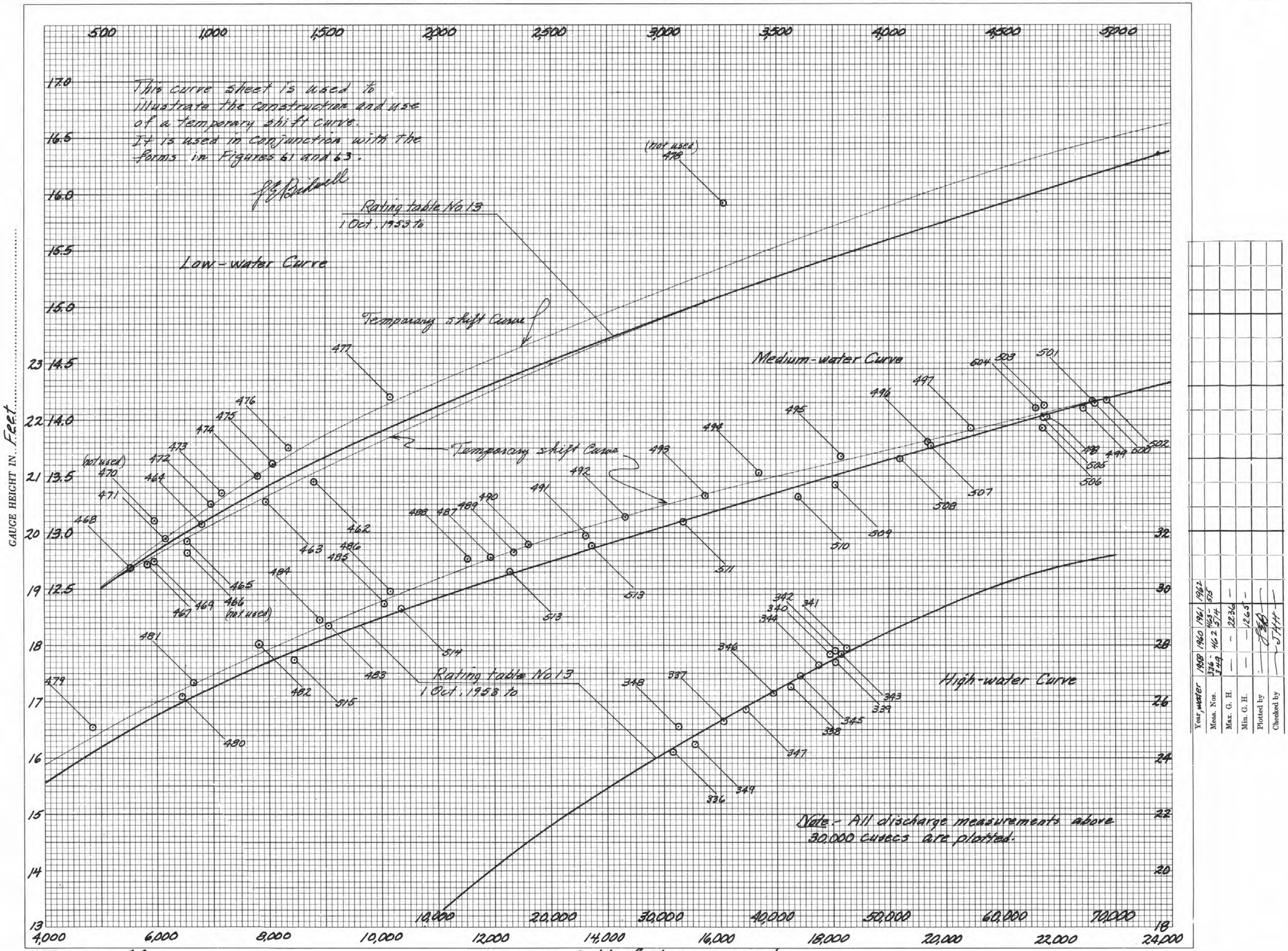

Figure 60

Daily Gauge Height, in Feet, and Discharge, in cusecs of *Kafue* River

At ~~Near~~ *Kasaka* for the Year Ending September 30, 19*61*

Drainage Area *58,290* Square Miles. Water-Stage Recorder ——— Ratio ......

Gauge Read to *hundredths* ~~Once~~ Twice a Day by ......

HYDROLOGICAL SURVEY OF ZAMBIA

Used rating table No. ......

Day	October Gauge height	October Discharge	November Gauge height	November Discharge	December Gauge height	December Discharge	January Gauge height	January Discharge	February Gauge height	February Discharge	March Gauge height	March Discharge
1	13.40	+.18	12.75		12.95	-.05	13.70	-.17	17.05	-.25	18.45	-.25
2	13.40	+.17	12.75		13.00	-.05	13.65		17.10		18.45	
3	13.35	+.16	12.75		13.05	-.10	13.70		17.10		18.42	
4	13.35	+.15	12.70		13.05		13.70	-.17	17.10		18.50	
5	13.30	+.13	12.70		13.05		13.75	-.18	17.20		18.55	
6	13.28	+.12	12.70		13.10		13.75		17.20		18.58	-.25
7	13.25	+.11	12.65		13.20		13.75		17.22		18.78	-.30
8	13.25	+.10	12.70		13.25		13.75		17.28		18.72	
9	13.20	+.08	12.70		13.26		13.85		17.32		18.72	
10	13.20	+.06	12.70	0	13.30		13.95	-.18	17.38		18.10	
11	13.15	+.03	12.70	+.01	13.30	-.10	14.05	-.20	17.72		18.75	
12	13.08	0	12.70	+.02	13.36	-.12	14.20		17.72		18.85	
13	13.05		12.70	+.03	13.36		14.30		17.82		18.88	
14	13.05		12.75	+.07	13.35		14.40	-.20	17.85		18.90	
15	13.05		12.75		13.40		14.50	-.22	17.95		18.95	
16	13.00		12.70		13.40	-.12	14.65		18.02		19.02	
17	13.00		12.75	+.07	13.45	-.15	14.90	-.22	18.12		19.08	
18	13.00		12.70	+.03	13.45		15.40	-.25	18.20		19.10	-.30
19	12.95		12.70		13.45		15.80		18.30		19.25	-.35
20	12.95		12.70	+.03	13.45		15.60	-.25	18.30		19.35	-.40
21	12.95		12.80	0	13.50		16.55	-.30	18.35		19.42	
22	12.95		12.80		13.55		16.50		18.35		19.52	
23	12.95		13.03		13.55		16.48		18.35		19.58	
24	12.95		12.80		13.55		16.45		18.35		19.58	
25	12.90		12.80		13.50		16.50		18.40		19.58	
26	12.90		12.90		13.50	-.15	16.56		18.40		19.55	
27	12.83		12.90	0	13.55	-.17	16.70		18.40		19.52	
28	12.80		12.95	-.05	13.60		16.88	-.30	18.40	-.25	19.55	
29	12.80		12.95		13.60		16.98	-.25			19.52	
30	12.75		12.95	-.05	13.70		17.00				19.65	
31	12.75				13.80	-.17	17.02	-.25			19.55	-.40
Total												

Day	April Gauge height	April Discharge	May Gauge height	May Discharge	June Gauge height	June Discharge	July Gauge height	July Discharge	August Gauge height	August Discharge	September Gauge height	September Discharge
1	19.55	-.40	20.66	-.35	21.90	-.10	22.35		21.85		20.48	
2	19.55		20.70		21.90	-.10	22.35		21.82		20.42	
3	19.60		20.75		21.95	-.05	22.35		21.80		20.32	
4	19.60		20.80		22.00	-.05	22.36		21.78		20.25	
5	19.65		20.85	-.35	22.00	0	22.35		21.75		20.20	
6	19.65		20.92	-.30	22.05		22.35		21.68		20.15	
7	19.68		21.05		22.05		22.30		21.65		21.10	
8	19.72		21.08		22.10		22.30		21.55		20.02	
9	19.72		21.05		22.10		22.30		21.52		19.95	
10	19.72		20.80		22.12		22.30		21.50		19.90	
11	19.74		21.10		22.15		22.30		21.45		19.82	
12	19.75		21.12	-.30	22.20		22.28		21.42		19.76	
13	19.78		21.22	-.25	22.20		22.25		21.38		19.72	
14	19.78		21.28	-.20	22.20		22.28		21.35		19.68	
15	19.82		21.30		22.22		22.25		21.30		19.62	
16	19.89		21.33		22.25		22.25		21.25		19.52	
17	19.92		21.38	-.20	22.25		22.22		21.25		19.44	
18	19.95		21.45	-.15	22.30		22.20		21.20		19.35	
19	20.02		21.45		22.30		22.18		21.12		19.26	
20	20.10		21.52		22.30		22.15		21.08		19.18	
21	20.12		21.55		22.35		22.15		21.08		19.10	
22	20.15		21.55		22.35		22.12		20.92		19.02	
23	20.20		21.60		22.35		22.10		20.95		18.92	
24	20.22		21.65		22.35		22.10		20.90		18.82	
25	20.20		21.65	-.15	22.35		22.05		20.85		18.72	
26	20.35		21.70	-.10	22.35		22.05		20.80		18.60	
27	20.40		21.72		22.36		22.00		20.75		18.48	
28	20.45		21.75		22.35		21.98		20.68		18.38	
29	20.62		21.80		22.35		21.95		20.63		18.24	
30	20.60	-.40	21.82		22.35		21.90		20.58		18.10	
31			21.85	-.10			21.90		20.52			
Total												

Max. G. H. ...... ft. at ...... on ......

Min. G. H. ...... ft. on ......

Max Disch. ...... cusecs at ...... (G. H. ...... ft.), on ......

Min. Disch. ...... cusecs on ...... (G. H. ...... ft.), ...

Calendar Year

Mean cusecs

cusecs per square mile

Run-off in inches

Run-off in acre-feet

Maximum

Minimum

Period Year

Quarter: Fourth, Third, Second, First — Computed, Checked, Date

Quarter: Fourth, Third, Second, First — Disch. applied, Disch. checked, Date

Quarter: Fourth, Third, Second, First — G. H. copied, G. H. checked, Date

Not checked

Figure 61. The shift adjustments applied on this form are from the curves in Figure 60. The adjustments are the measured differences between the temporary shift curve and the base rating with the daily mean gauge height as the initial point on the shift curve. The final distribution has been arranged to give a smooth discharge hydrograph.

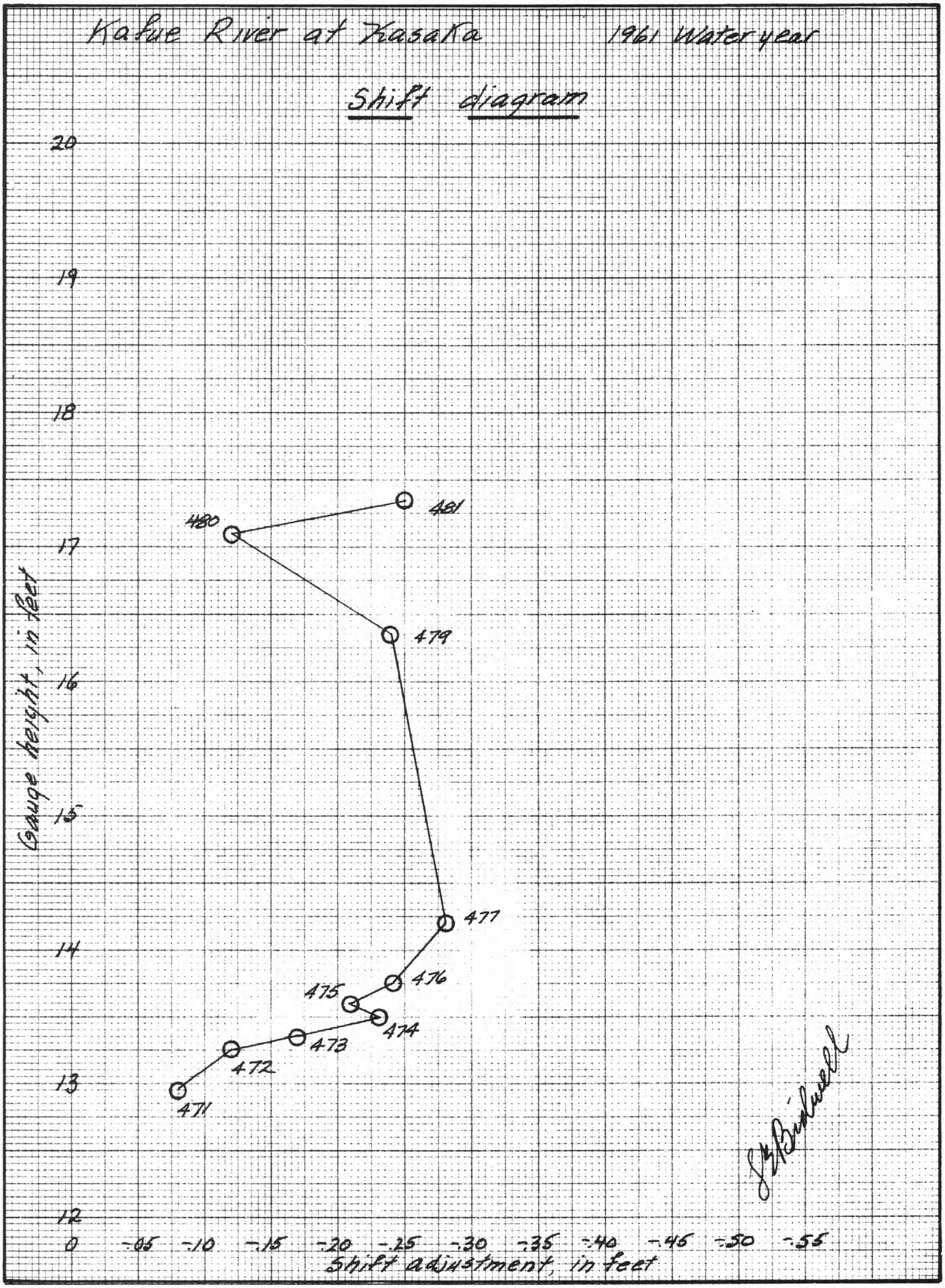

Figure 62. A shift adjustment diagram is helpful in the distribution of the adjustments.

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HYDROLOGICAL SURVEY OF ZAMBIA

3. Shift
4. Datum
5. Aux. Datum
6. Discharge
7. Gauge Height

Sta. No. ....

Corrections for Kafue River at Kasaka .... for year ending September 30, 1961

Day	October (10)	November (11)	December (12)	January (01)	February (02)	March (03)	Day	April (04)	May (05)	June (06)	July (07)	August (08)	September (09)	Day
1	+0.18		-0.05	-0.17	-0.25	-0.25	1	-0.40	-0.35	-0.10				1
2	+ .17		-.05				2			-.10				2
3	+ .16		-.10				3			-.05				3
4	+ .15			-.17			4			-.05				4
5	+ .13			-.18			5		-.35	0				5
6	+ .12					-.25	6		-.30					6
7	+ .11					-.30	7							7
8	+ .10						8							8
9	+ .08						9							9
10	+ .06	0		-.18			10							10
11	+ .03	+0.01	-.10	-.20			11							11
12	0	+ .02	-.12				12		-.30					12
13		+ .03					13		-.25					13
14		+ .07		-.20			14		-.20					14
15				-.22			15							15
16			-.12				16							16
17		+ .07	-.15	-.22			17		-.20					17
18		+ .03		-.25		-.30	18		-.15					18
19		+ .03				-.35	19							19
20		+ .03		-.25		-.40	20							20
21		0		-.30			21							21
22							22							22
23							23							23
24							24							24
25							25		-.15					25
26			-.15				26		-.10					26
27		0	-.17				27							27
28		-.05		-.30	-.25		28							28
29		-.05		-.25			29							29
30		-.05					30	-.40						30
31			-.17	-.25		-.40	31		-.10					31

Remarks: These are shift adjustments picked off the temporary curves in Figure 60. These values are the difference in gauge height between rating No 13 and the temporary shift curves starting with the daily mean gauge height as a point on the shift curve.

Max. Daily ....
Min. Daily ....
CFS—Day Total ....

Figure-63

HYDROLOGICAL SURVEY OF ZAMBIA

Station No.........

Discharge measurements of Kafue River at Kasaka during the year ending September 30, 1961

No.	Date	Made by	Width	Area	Mean velocity	Gauge height	Discharge	Rating No 13 Shift adj.	Rating No 13 Per cent diff.	Method	Number meas. sections	Gauge height change	Time	Meas. rated			REMARKS
	1960																
463	6 Oct			3160	0.39	13.28	1,240	+0.12	0								
464	12 Oct			3020	.31	13.08	946	0	-0.4								
465	20 Oct			2900	.30	12.95	882	0	+4.5								
466	27 Oct			2800	.32	12.82	892	0	+20.1								Disregard
467	3 Nov.			2740	.26	12.73	708	0	+4.9								
468	10 Nov.			2750	.23	12.70	636	0	-2.5								
469	17 Nov			2760	.27	12.75	740	+0.07	-0.4								
470	23 Nov			3010	.25	13.10	748	-.27	-0.4								Disregard
471	29 Nov			2940	.27	12.95	781	-.08	0								
472	8 Dec			3220	.31	13.25	991	-.12	-0.6								
473	14 Dec			3220	.32	13.35	1040	-.17	0								
474	21 Dec			3400	.35	13.50	1120	-.23	0								
475	29 Dec			3380	.36	13.6	1230	-.21	0								
	1961																
476	5 Jan			3540	.38	13.75	1340	-.24	0								
477	12 Jan			3850	.46	14.20	1780	-.28	0								
478	19 Jan			5200	.63	15.91	3260	-.83	0								Disregard
479	26 Jan			5690	.86	16.37	4890	-.24	0								
480	2 Feb			6280	1.02	17.1	6430	-.12	-0.2								
481	9 Feb			6480	1.03	17.34	6670	-.25	-0.1								

Copied by L. E. Bidwell Computed by L. E. Bidwell Checked by M. P. Machiri

Figure - 64

H 113
2m—G245 12-69

HYDROLOGICAL SURVEY OF ZAMBIA

Sta. No. KG8

3. Shift
4. Datum
5. Aux. Datum
6. Discharge
7. Gauge Height

Corrections for Kafue River at Kasaka for year ending September 30, 19 68

Day	October (10)	November (11)	December (12)	January (01)	February (02)	March (03)	Day	April (04)	May (05)	June (06)	July (07)	August (08)	September (09)	Day
1					-.15	-.30	1	-.35	-.59	-.14				1
2							2	-.40		-.12				2
3							3			-.10				3
4							4		-.59	-.08				4
5					-.15		5		-.55	-.08				5
6				0	-.20		6		-.50	-.06				6
7				-.05			7	-.40	-.45	-.06				7
8							8	-.45	-.45	-.04				8
9				-.05			9		-.40	-.04				9
10				-.10			10		-.40	-.02				10
11							11		-.35	0				11
12							12		-.35					12
13							13		-.30					13
14							14							14
15					-.20	-.30	15							15
16					-.25	-.33	16							16
17							17		-.30					17
18							18	-.45	-.25					18
19							19	-.50	-.25					19
20				-.10			20		-.20					20
21				-.15			21							21
22							22							22
23							23							23
24					-.25		24		-.20					24
25					-.30		25	-.50	-.18					25
26							26	-.59	-.15					26
27							27							27
28							28							28
29					-.30		29							29
30							30	-.59						30
31				-.15		-.33	31		-.15					31

Remarks: The shift adjustments are tabulated on this form when the records are computed by automatic data processing.

F.E. Bidwell

Figure 65

Max. Daily

Min. Daily

CFS—Day Total

HYDROLOGICAL SURVEY OF ZAMBIA

Kawanda River near Chonta — Sample

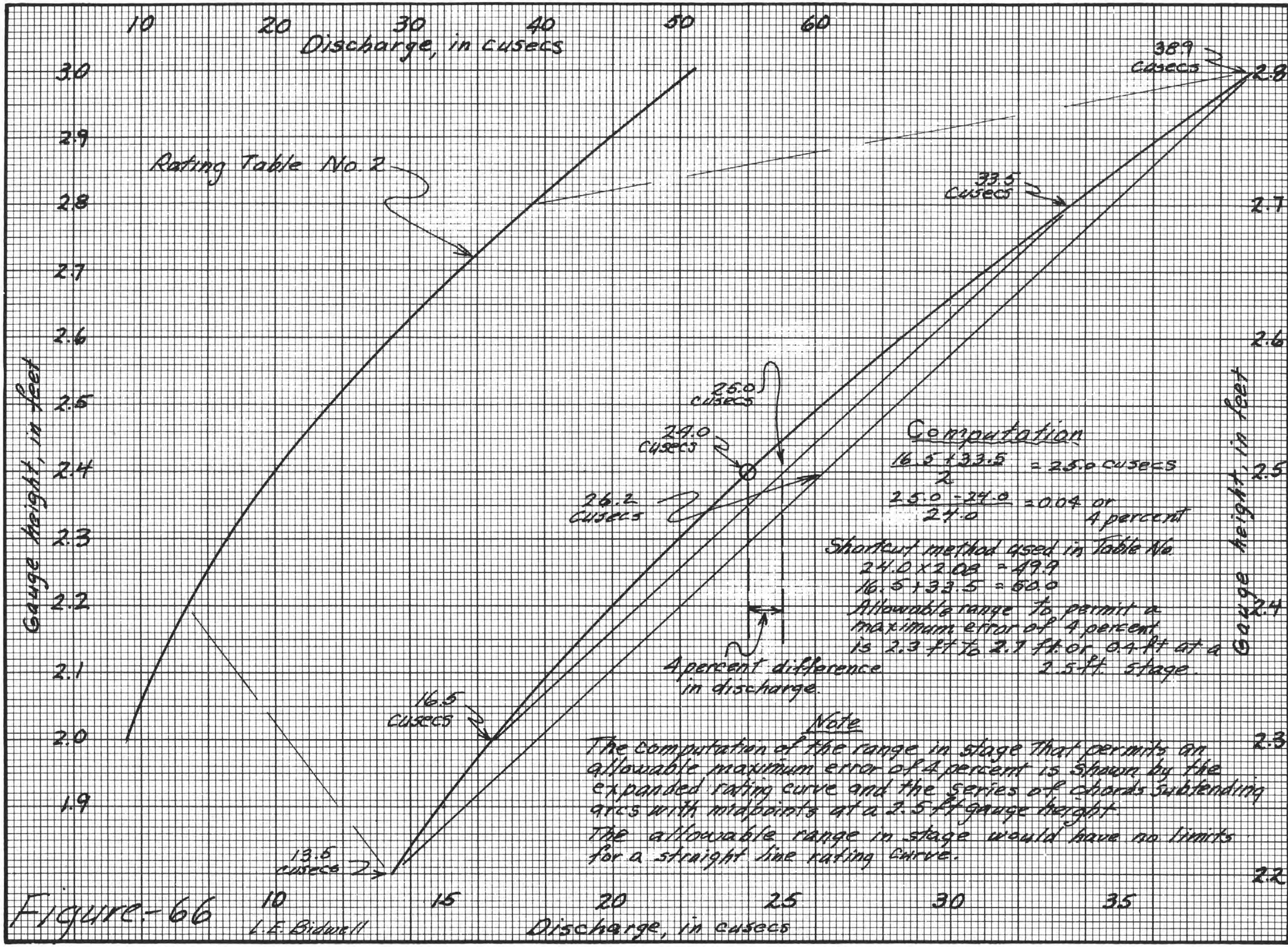

Figure-66

HYDROLOGICAL SURVEY OF ZAMBIA

Kawanda River near Chonta

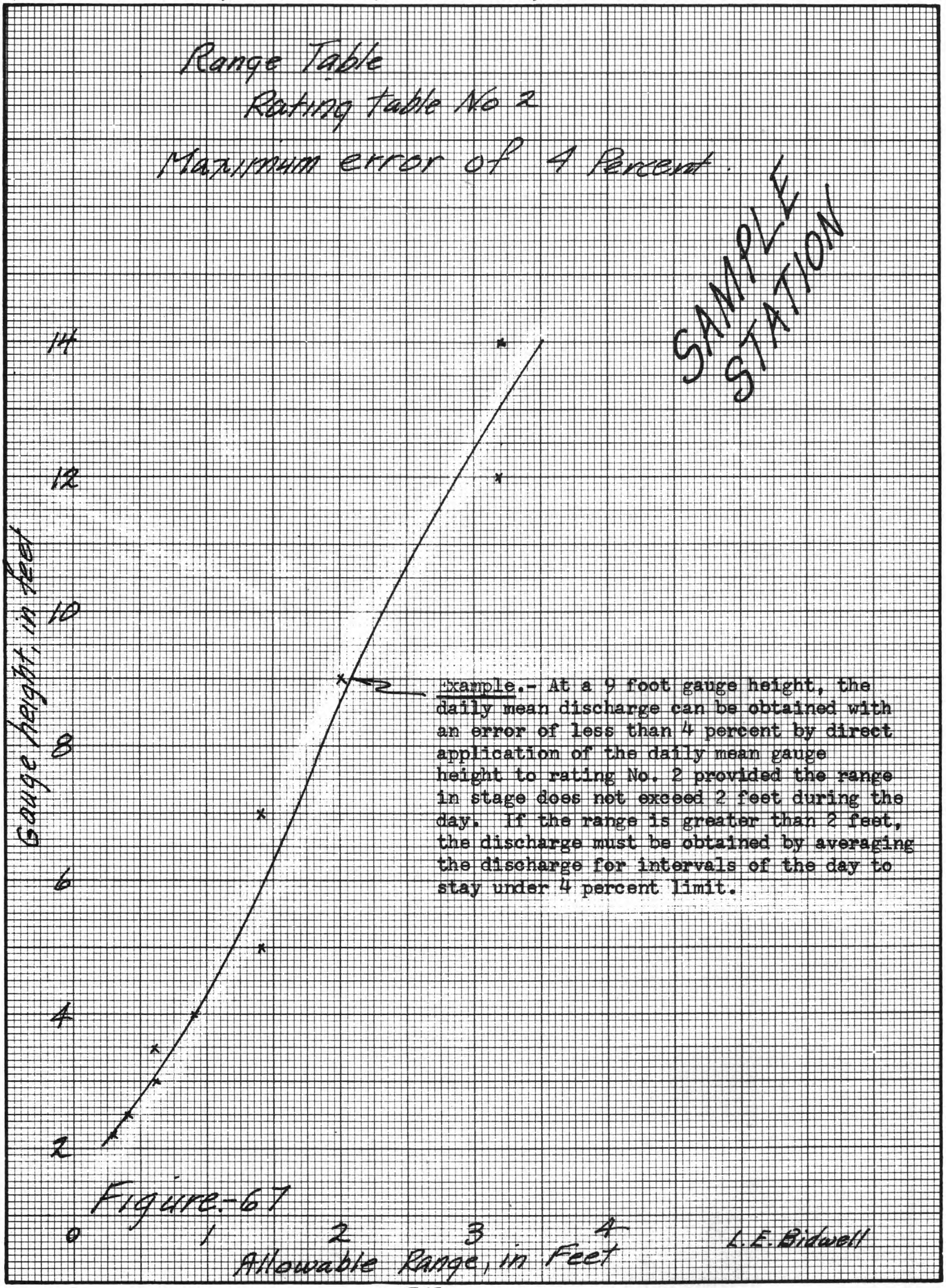

Figure.-67

Prepared by LEB Date 204-70

Kawanda River near Chonta (SAMPLE STATION)

The shape of the daily gauge height graph affects the percent error caused by use of daily mean gauge height to compute the daily mean discharge. The percent error will change with a change in the curvature of the rating table, a straight line rating will produce no error.

EXAMPLE

"A" - 20 hours at a 3 ft stage and 4 hours at a 4 ft stage.

"B" - 12 hours at a 3 ft stage and 12 hours at a 4 ft stage.

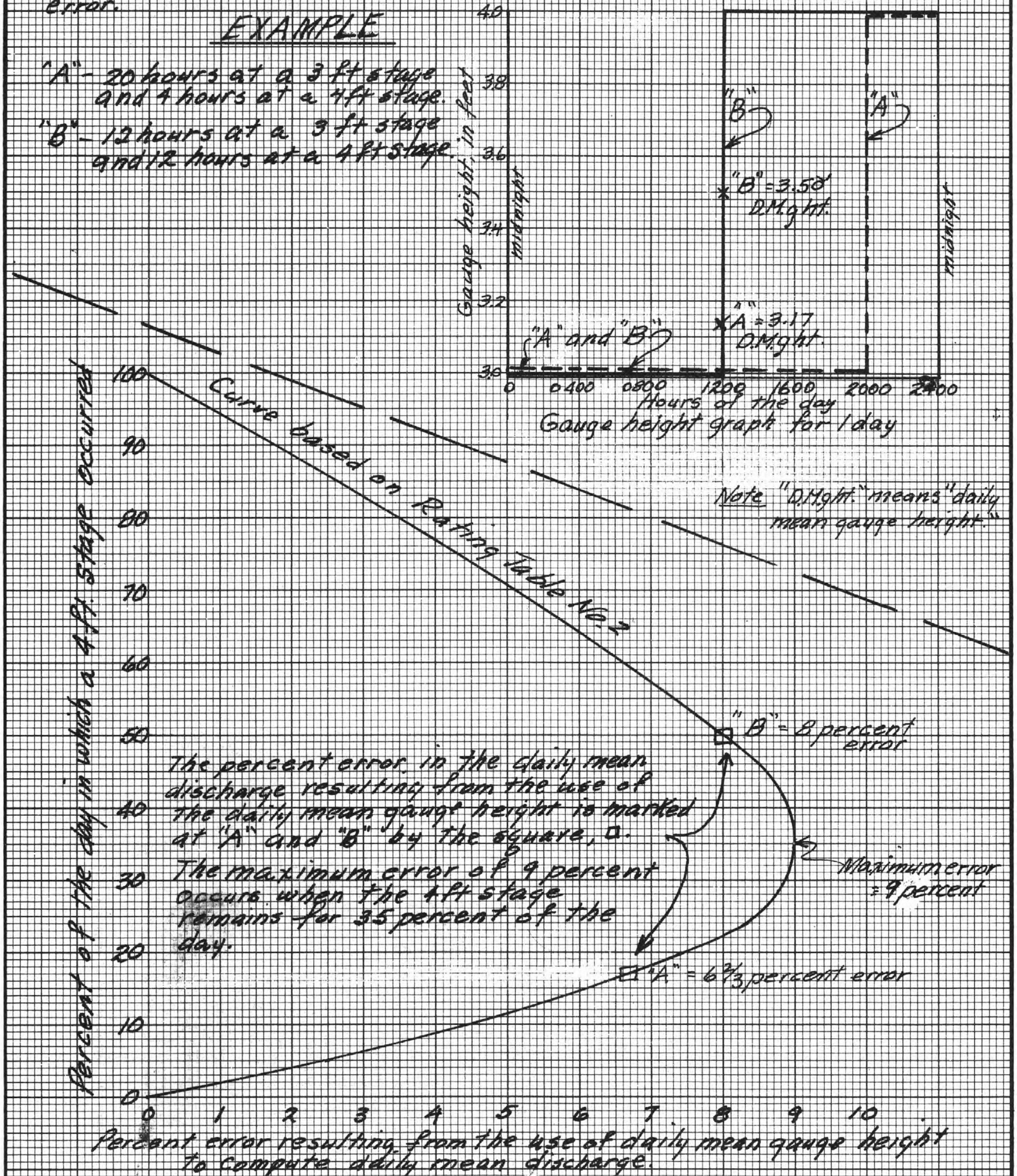

Figure-68

F.E. Bidwell Date 28-4-70

Daily Gauge Height, in Feet, and Discharge, in cusecs of KAFUE River

HYDROLOGICAL SURVEY OF ZAMBIA

At KASAKA for the Year Ending September 30, 1967

Drainage Area 58,290 Square Miles. Water-Stage Recorder — Ratio — : —

Gauge Read to hundredths Once/Twice a Day by E. MULENGA, S. NTHOBOLO, N. KAM BOYI

Used rating table No. 15

Max. Disch. 11,500 cusecs. at * on 17/9-30 June (G.H. — ft.). Max. G.H. 18.97 ft. at — on 21-23 June (observed)

Min. Disch. 710 cusecs. on 2,3,8 Dec (G.H. 12.58 ft.). Min. G.H. 12.58 ft. on 2,3,8 Dec (observed)

* From graph based on gauge readings

Day	October Gauge height	October Discharge	November Gauge height	November Discharge	December Gauge height	December Discharge	January Gauge height	January Discharge	February Gauge height	February Discharge	March Gauge height	March Discharge
1	13.46	1,440	12.98	1,000	12.62	737	14.05	2,080	16.18	5,340	17.76	8,720
2	13.55	1,540	12.91	949	12.59	716	14.08	2,110	16.23	5,440	17.73	8,660
3	13.52	1,500	12.94	973	12.60	723	14.14	2,170	16.29	5,560	17.63	8,440
4	13.52	1,500	12.92	957	12.62	737	14.61	2,730	16.31	5,600	17.62	8,410
5	13.47	1,460	12.90	941	12.61	730	14.54	2,640	16.41	5,800	17.64	8,460
6	13.40	1,380	12.89	934	12.64	751	14.52	2,620	16.58	6,160	17.65	8,480
7	13.29	1,280	12.90	941	12.63	744	14.72	2,880	16.67	6,350	17.65	8,480
8	13.40	1,380	12.85	904	12.59	716	14.63	2,760	16.77	6,560	17.65	8,480
9	13.39	1,380	12.81	874	12.75	830	14.58	2,690	16.80	6,620	17.68	8,550
10	13.39	1,380	12.81	874	12.67	772	14.48	2,570	16.86	6,750	17.69	8,570
11	13.39	1,380	12.74	822	12.67	772	14.53	2,630	16.91	6,850	17.70	8,590
12	13.34	1,330	12.73	815	13.04	1,050	14.60	2,720	16.97	6,980	17.71	8,610
13	13.30	1,290	12.80	866	12.97	996	14.62	2,750	17.00	7,050	17.73	8,660
14	13.28	1,270	12.77	844	12.91	949	14.63	2,760	17.02	7,090	17.73	8,660
15	13.28	1,270	12.74	822	13.08	1,090	14.68	2,820	17.04	7,140	17.74	8,680
16	13.16	1,160	12.74	822	13.00	1,020	14.69	2,840	17.14	7,360	17.74	8,680
17	13.15	1,150	12.70	793	12.99	1,010	15.15	3,510	17.12	7,310	17.76	8,720
18	13.18	1,180	12.69	786	13.20	1,200	15.25	3,670	17.17	7,420	17.77	8,740
19	13.13	1,130	12.71	800	13.30	1,290	15.20	3,590	17.15	7,380	17.76	8,720
20	13.14	1,140	12.86	911	14.48	2,570	15.19	3,570	17.15	7,380	17.76	8,720
21	13.15	1,150	12.78	851	14.37	2,430	15.14	3,490	17.20	7,490	17.74	8,680
22	13.16	1,160	12.74	822	14.23	2,270	15.88	4,760	17.24	7,580	17.75	8,700
23	13.13	1,130	12.71	800	14.22	2,260	15.72	4,470	17.35	7,820	17.74	8,680
24	13.01	1,030	12.72	808	14.03	2,050	15.65	4,340	17.38	7,890	17.77	8,740
25	13.08	1,090	12.63	744	14.02	2,040	15.57	4,200	17.38	7,890	17.77	8,740
26	13.03	1,050	12.66	765	13.94	1,950	15.59	4,230	17.42	7,970	17.83	8,880
27	13.01	1,030	12.78	851	14.07	2,100	15.62	4,290	17.42	7,970	17.87	8,960
28	13.04	1,050	12.64	751	14.05	2,080	15.77	4,560	17.59	8,350	17.91	9,050
29	13.03	1,050	12.65	758	14.00	2,020	15.86	4,720			17.92	9,070
30	13.00	1,020	12.64	751	14.01	2,030	16.06	5,100			17.91	9,050
31	12.98	1,000			14.05	2,080	16.11	5,200			17.92	9,070
Total		38,306		25,629		42,713		105,470		195,100		269,650
Mean		1,236		854		1,378		3,402		6,968		8,698
cusecs per square mile		0.02		0.01		0.02		0.06		0.12		0.15
Run-off in inches		0.02		0.02		0.03		0.07		0.12		0.17
Run-off in acre-feet		75,980		50,830		84,720		209,200		387,000		534,900
Maximum		1,540		1,000		2,570		5,200		8,350		9,070
Minimum		1,000		744		716		2,080		5,340		8,410

Day	April Gauge height	April Discharge	May Gauge height	May Discharge	June Gauge height	June Discharge	July Gauge height	July Discharge	August Gauge height	August Discharge	September Gauge height	September Discharge	Period Year 1966-67
1	17.91	9,050	18.34	10,000	18.77	11,000	18.92	11,400	18.01	9,270	16.02	5,030	
2	17.91	9,050	18.33	10,000	18.79	11,100	18.91	11,400	17.94	9,120	15.94	4,880	
3	17.89	9,010	18.36	10,100	18.79	11,100	18.90	11,400	17.88	8,990	15.87	4,740	
4	17.89	9,010	18.35	10,100	18.80	11,100	18.89	11,300	17.82	8,850	15.76	4,540	
5	17.91	9,050	18.37	10,100	18.85	11,200	18.86	11,300	17.76	8,720	15.69	4,410	
6	17.91	9,050	18.37	10,100	18.84	11,200	18.83	11,200	17.71	8,610	15.57	4,200	
7	17.94	9,120	18.37	10,100	18.85	11,200	18.84	11,200	17.65	8,480	15.46	4,010	
8	17.94	9,120	18.38	10,100	18.86	11,300	18.83	11,200	17.58	8,330	15.38	3,880	
9	17.95	9,140	18.38	10,100	18.87	11,300	18.79	11,100	17.53	8,220	15.27	3,700	
10	17.98	9,210	18.39	10,200	18.90	11,400	18.77	11,000	17.48	8,110	15.16	3,530	
11	17.98	9,210	18.41	10,200	18.90	11,400	18.75	11,000	17.40	7,930	15.10	3,430	
12	18.00	9,250	18.45	10,300	18.90	11,400	18.75	11,000	17.34	7,800	15.01	3,300	
13	17.91	9,050	18.46	10,300	18.92	11,400	18.73	10,900	17.29	7,690	14.94	3,190	
14	17.96	9,160	18.47	10,300	18.91	11,400	18.71	10,900	17.23	7,560	14.82	3,020	
15	18.03	9,320	18.48	10,400	18.93	11,400	18.68	10,800	17.16	7,400	14.77	2,950	
16	18.07	9,410	18.49	10,400	18.93	11,400	18.62	10,700	17.10	7,270	14.68	2,820	
17	18.08	9,430	18.52	10,400	18.95	11,500	18.61	10,600	17.06	7,180	14.58	2,690	
18	18.07	9,410	18.54	10,500	18.93	11,400	18.58	10,600	16.98	7,010	14.53	2,630	
19	18.09	9,460	18.55	10,500	18.95	11,500	18.55	10,500	16.90	6,830	14.38	2,450	
20	18.09	9,460	18.59	10,600	18.96	11,500	18.52	10,400	16.78	6,580	14.36	2,420	
21	18.12	9,530	18.60	10,600	18.97	11,500	18.49	10,400	16.73	6,470	14.30	2,350	
22	18.12	9,530	18.60	10,600	18.94	11,500	18.43	10,200	16.69	6,390	14.27	2,320	
23	18.13	9,550	18.61	10,600	18.96	11,500	18.39	10,200	16.62	6,240	14.21	2,250	
24	18.14	9,570	18.64	10,700	18.96	11,500	18.37	10,100	16.56	6,120	14.17	2,210	
25	18.16	9,620	18.64	10,700	18.95	11,500	18.33	10,000	16.48	5,950	14.16	2,200	
26	18.18	9,660	18.66	10,800	18.94	11,500	18.25	9,820	16.42	5,820	14.15	2,190	
27	18.20	9,710	18.66	10,800	18.95	11,500	18.22	9,760	16.37	5,720	14.09	2,120	
28	18.20	9,710	18.70	10,900	18.95	11,500	18.18	9,660	16.30	5,580	14.05	2,080	
29	18.22	9,760	18.70	10,900	18.96	11,500	18.15	9,600	16.22	5,420	14.00	2,020	
30	18.33	10,000	18.72	10,900	18.95	11,500	18.11	9,500	16.15	5,280	13.96	1,980	
31			18.75	11,000			18.06	9,390	16.08	5,140			
Total		280,610		323,300		341,200		328,530		224,080		93,540	2,268,128
Mean		9,354		10,430		11,370		10,600		7,228		3,118	6,214
cusecs per square mile		0.16		0.18		0.20		0.18		0.12		0.05	0.11
Run-off in inches		0.18		0.21		0.22		0.21		0.14		0.06	1.45
Run-off in acre-feet		556,600		641,300		676,800		651,600		444,500		185,500	4,499,000
Maximum		10,000		11,000		11,500		11,400		9,270		5,030	11,500
Minimum		9,010		10,000		11,000		9,390		5,140		1,980	716

First Quarter / Second / Third / Fourth — Computed [illegible] Checked [illegible] Date 5/5/70

Disch. applied [illegible] Disch. checked [illegible] Date 4/5/70

G.H. copied [illegible] G.H. checked [illegible] Date 1/5/70

L. E. Bidwell

Figure 69. Manual method of computation of streamflow records for Kafue River at Kasaka for the 1967 hydrological year.

Daily Gauge Height, in Feet, and Discharge, in cusecs of KAFUE River

HYDROLOGICAL SURVEY OF ZAMBIA

At KASAKA for the Year Ending September 30, 1968

Used rating table No. 15

Drainage Area 58,290 Square Miles. Water-Stage Recorder —— Ratio —:—

Gauge Read to HUNDREDTHS Twice a Day by E. MULENGA, S. NTHOBOLO, N. KAMBAYI

Max. G. H. 18.29 ft. at — on 28 May; Min. G. H. 13.34 ft. on 14 Nov.

Max Disch. 9,570 cusecs at — on 28 May, 8,9 June; Min. Disch. 1,330 cusecs on 14 Nov. (G. H. 13.34 ft.)

Day	October Gauge height	October Discharge	November Gauge height	November Discharge	December Gauge height	December Discharge	January Gauge height	January Discharge	February Gauge height	February Discharge	March Gauge height	March Discharge
1	13.98	2,000	13.44	1420	13.94	1,950	15.18	3560	16.22	5120	17.12	6660
2	13.92	1,930	13.49	1,480	13.96	1,980	15.25	3,670	16.25	5180	17.13	6680
3	13.89	1,900	13.42	1,400	13.97	1,990	15.30	3750	16.28	5240	17.14	6,700
4	13.86	1,870	13.39	1,380	14.05	2080	15.37	3860	16.30	5280	17.20	6,830
5	13.87	1880	13.44	1,420	14.31	2360	15.41	3930	16.31	5300	17.21	6,850
6	13.86	1,870	13.47	1460	14.15	2180	15.45	4000	16.42	5420	17.22	6,870
7	13.86	1,870	13.44	1420	14.15	2180	15.50	4000	16.42	5420	17.24	6,920
8	13.75	1,740	13.43	1,420	14.17	2210	15.52	4030	16.48	5540	17.26	6960
9	13.65	1,640	13.42	1400	14.19	2,230	15.53	4,050	16.52	5620	17.28	7010
10	13.62	1610	13.40	1,380	14.23	2270	15.59	4060	16.68	5950	17.31	7070
11	13.63	1,620	13.39	1,380	14.23	2270	15.61	4,100	16.73	6,050	17.32	7,090
12	13.62	1,610	13.39	1,380	14.24	2280	15.69	4,230	16.77	6,140	17.36	7,180
13	13.58	1,560	13.39	1,380	14.28	2,330	15.67	4200	16.91	6,430	17.40	7,270
14	13.51	1,500	13.36	1,350	14.37	2,430	15.69	4,230	17.11	6,850	17.40	7,270
15	13.57	1,560	13.36	1,350	14.40	2,470	15.68	4220	16.99	6600	17.42	7,310
16	13.52	1,500	13.36	1,350	14.44	2520	15.71	4270	17.47	7,530	17.44	7,290
17	13.51	1,500	13.35	1,340	14.46	2,540	15.78	4,390	17.82	8,300	17.48	7,380
18	13.48	1,460	13.38	1,370	14.51	2600	15.80	4430	17.15	6,830	17.50	7,420
19	13.45	1440	13.51	1500	14.54	2,640	15.81	4,450	17.05	6620	17.50	7,420
20	13.45	1440	13.48	1460	14.56	2,670	15.85	4520	17.02	6,560	17.51	7450
21	13.43	1,420	13.50	1,480	14.60	2720	15.90	4520	17.01	6,540	17.51	7,450
22	13.44	1,420	13.42	1,400	14.64	2,770	15.93	4,570	16.85	6,200	17.53	7,490
23	13.46	1,440	13.54	1,520	14.74	2900	15.94	4,590	16.68	5,840	17.58	7600
24	13.41	1,400	13.65	1,640	14.73	2,890	15.98	4,670	16.84	6,180	17.61	7,670
25	13.44	1,420	13.69	1,680	14.82	3020	16.00	4,700	17.01	6,430	17.62	7,690
26	13.43	1,420	13.68	1,670	14.91	3,140	16.03	4,760	17.01	6,430	17.65	7,750
27	13.40	1,380	13.68	1,670	14.92	3,160	16.07	4,840	17.04	6,490	17.66	7,780
28	13.54	1,520	13.72	1710	14.98	3,250	16.10	4,900	17.06	6,540	17.67	7,800
29	13.47	1,460	13.75	1,740	15.06	3,370	16.16	5010	17.09	6,600	17.69	7,840
30	13.46	1,440	13.85	1,860	15.14	3,490	16.18	5,050			17.70	7,860
31	13.45	1440			15.18	3,560	16.19	5,070			17.71	7,890

Day	April Gauge height	April Discharge	May Gauge height	May Discharge	June Gauge height	June Discharge	July Gauge height	July Discharge	August Gauge height	August Discharge	September Gauge height	September Discharge
1	17.75	7930	18.21	8410	18.26	9530	17.51	8,170	16.01	5,010	14.43	2,510
2	17.79	7,910	18.22	8440	18.25	9550	17.50	8,150	15.93	4,860	14.49	2,580
3	17.81	7,950	18.23	8460	18.23	9550	17.44	8,020	15.87	4,740	14.40	2,470
4	17.83	8,000	18.23	8,460	18.20	9,530	17.39	7,910	15.83	4,670	14.33	2,390
5	17.84	8020	18.23	8550	18.20	9530	17.37	7860	15.80	4610	14.21	2,250
6	17.87	8080	18.26	8720	18.19	9,550	17.29	7,690	15.68	4,390	14.26	2,310
7	17.87	8,080	18.24	8,790	18.19	9,550	17.23	7,560	15.64	4,320	14.24	2,280
8	17.90	8,040	18.24	8,790	18.18	9,570	17.20	7,490	15.60	4,250	14.21	2,250
9	17.92	8,080	18.25	8,920	18.18	9,570	17.17	7,420	15.53	4,130	14.15	2,180
10	17.93	8110	18.25	8,920	18.14	9530	17.09	7,250	15.49	4,060	14.14	2,170
11	17.96	8150	18.27	9,070	18.11	9,500	17.00	7,050	15.35	3,830	14.16	2,200
12	17.98	8220	18.27	9,070	18.11	9,500	16.99	7,030	15.33	3,800	14.20	2,240
13	17.95	8,150	18.25	9,140	18.11	9,500	16.97	6,980	15.27	3,700	14.15	2,180
14	17.98	8,220	18.24	9,120	18.05	9,360	16.94	6,920	15.16	3,530	14.09	2,120
15	17.99	8,240	18.23	9,100	18.02	9,300	16.88	6,790	15.13	3,480	14.06	2,090
16	18.00	8,260	18.22	9,070	18.00	9,250	16.83	6,680	15.06	3,370	14.05	2,080
17	18.01	8,280	18.23	9,100	17.95	9,140	16.79	6,600	14.99	3,260	14.05	2,080
18	18.03	8,330	18.27	9,300	17.81	8,830	16.74	6,490	14.88	3,100	14.03	2,050
19	18.12	8,410	18.27	9,300	17.91	9,050	16.69	6,390	14.85	3,060	14.02	2,040
20	18.18	8,550	18.24	9,340	17.90	9,030	16.63	6,260	14.83	3,030	13.98	2,000
21	18.18	8,550	18.24	9,340	17.87	8,960	16.56	6,120	14.80	2,990	13.92	1,930
22	18.17	8,520	18.24	9,340	17.81	8,830	16.49	5,970	14.76	2,930	13.96	1,980
23	18.18	8,550	18.24	9,340	17.80	8,810	16.45	5,880	14.71	2,860	13.96	1,980
24	18.19	8,570	18.24	9,340	17.75	8,700	16.42	5,820	14.68	2,820	13.94	1,950
25	18.15	8,480	18.23	9,360	17.71	8,610	16.39	5,760	14.66	2,800	13.87	1,880
26	18.23	8,460	18.27	9,530	17.70	8,590	16.35	5,680	14.60	2,720	13.78	1,780
27	18.18	8,350	18.28	9,550	17.67	8,520	16.29	5,560	14.59	2,710	13.69	1,680
28	18.21	8,410	18.27	9,530	17.63	8,440	16.22	5,420	14.55	2,660	13.70	1,690
29	18.21	8,410	18.27	9,530	17.59	8,350	16.18	5,340	14.52	2,620	13.85	1,860
30	18.21	8,410	18.27	9,530	17.59	8,350	16.11	5,200	14.49	2,580	13.75	1,740
31			18.27	9,530			16.05	5,080	14.43	2,510		

	October	November	December	January	February	March	April	May	June	July	August	September	Year 1967-68
Total	49,260	44,410	80,450	134,630	179,230	226,450	247,720	281,990	274,080	206,540	109,400	62,940	1,897,100
Mean	1,589	1,480	2,595	4,343	6,180	7,305	8,257	9,096	9,136	6,663	3,529	2,098	5,183
cusecs per square mile	0.03	0.03	0.04	0.07	0.11	0.13	0.14	0.16	0.16	0.11	0.06	0.04	0.09
Run-off in inches	0.03	0.03	0.05	0.09	0.11	0.14	0.16	0.18	0.17	0.13	0.07	0.04	1.21
Run-off in acre-feet	97,700	88,090	159,600	267,000	355,500	449,200	491,400	559,300	543,600	409,700	217,000	124,800	3,763,900
Maximum	2,000	1,860	3,560	5,070	8,300	7,890	8,570	9,550	9,570	8,170	5,010	2,580	9,570
Minimum	1,380	1,340	1,950	3,560	5,120	6,660	7,910	8,410	8,350	5,080	2,510	1,740	1,340

Quarter: Computed, Checked, Date 6/5/70; Disch. applied, Disch. checked, Date 5/5/70; G.H. copied, G.H. checked, Date 5/5/70

L. E. Bidwell

Figure 70. Manual method of computation of streamflow records for Kafue River at Kasaka for the 1968 hydrological year.

HYDROLOGICAL SURVEY OF ZAMBIA

HYDROGRAPH FOR

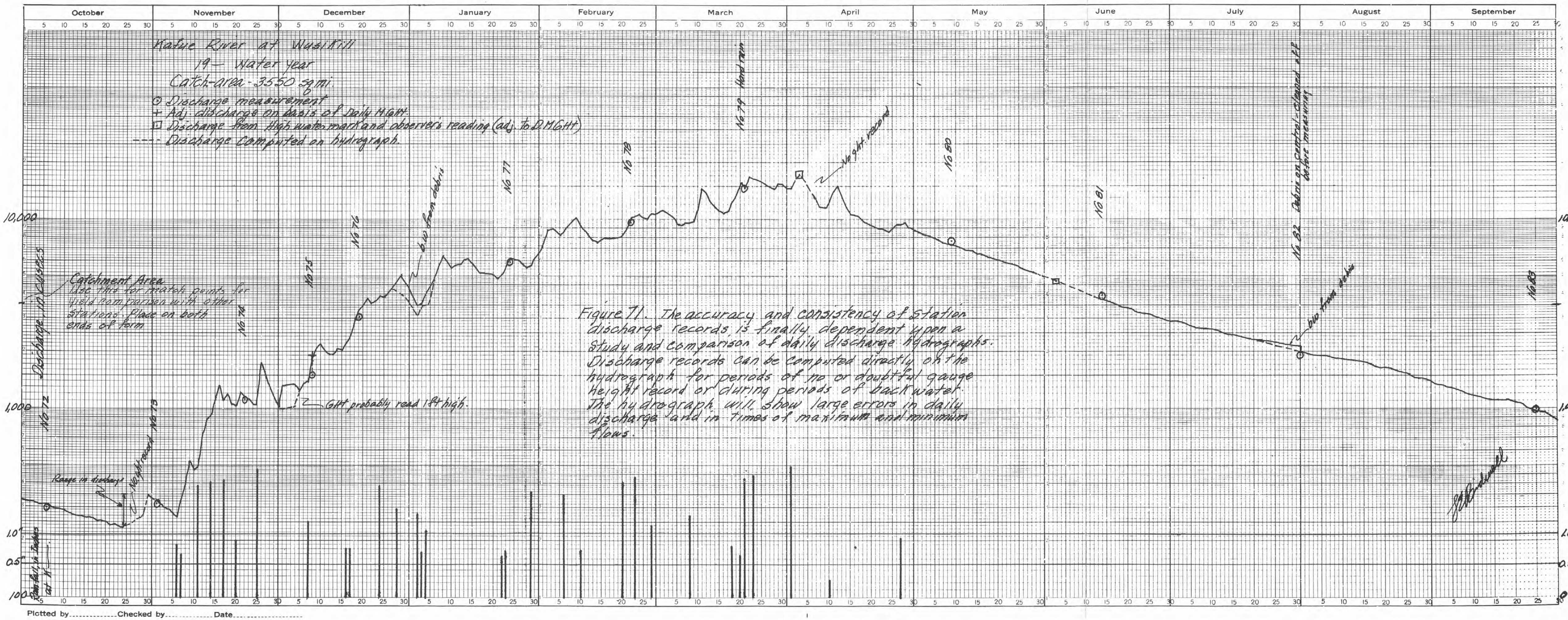

Figure 71. The accuracy and consistency of station discharge records is finally dependent upon a study and comparison of daily discharge hydrographs. Discharge records can be computed directly on the hydrograph for periods of no or doubtful gauge height record or during periods of backwater. The hydrograph will show large errors in daily discharge and in times of maximum and minimum flows.

Comparison of discharge at stations in KAFUE River Basin

for the year ending Sept. 30, 1964

HYDROLOGICAL SURVEY OF ZAMBIA

DISCHARGE

Line	Station	Drainage Area* (square miles)	Period	October Mean	October Per square mile	November Mean	November Per square mile	December Mean	December Per square mile	January Mean	January Per square mile	February Mean	February Per square mile	March Mean	March Per square mile
1	KAFUE RIVER AT KIPUSHI RD.	170		27.4	.161	67.4	.396	124	.729	284	1.67	266	1.56	244	1.43
2	MUCHINDAMU R. AT MUCHINDAMU	11.0	NO	RECORDS - NOT USED			—	—	—	—	—	—	—	—	
3	KAFUE R. AT NGOSA FARM	1570		148	.094	247	.157	616	.392	1252	.797	2169	1.38	2914	1.85
4	DIFFERENCE [LINE 3-2]	1400		121	.086	180	.128	492	.351	968	.691	1903	1.36	2670	1.91
5	% OF NGOSA FARM	89.2%		81.8%		72.9%		79.9%		77.4%		87.8%		91.6%	
7	KAFUE R. RAGLAN FARM	1930		149	.077	309	.160	625	.324	1367	.708	2635	1.36	3337	1.73
8	DIFFERENCE [LINE 7-3]	360		1	.0027	62	.172	9	.025	115	.319	466	1.29	423	1.18
9	% OF RAGLAN FARM	18.7%		0.7%		20.0%		1.4%		8.4%		17.7%		12.6%	
11	KAFUE R. AT MPATAMATO	4500		675	0.150	1340	.298	2558	.568	4386	.975	9359	2.08	6788	1.51
12	DIFFERENCE [LINE 11-7]	2570		526	.205	1032	.401	1933	.752	3019	1.17	6724	2.62	3451	1.34
13	% OF MPATAMATO	57.1%		78.0%		77.0%		75.6%		68.9%		7.9%		50.8%	
15	KAFULAFUTA R. AT KAFULAFUTA	1860		161	.086	255	.137	1098	.590	1296	.696	3241	1.74	1973	1.071
16	TOTAL [LINE 11+15]	6360		836		1596		3656		5682		12600		8781	
18	KAFUE R. AT NDUBENI	7230		969	.134	1593	.220	3372	.466	5878	.813	12720	1.76	10860	1.50
19	DIFFERENCE [LINE 18-(11+15)]	870		133	.152	-3	-.0034	-284	.326	196	.225	120	.137	2079	2.38
20	% OF NDUBENI	12.0%		13.7%		-0.2%		-8.4%		3.3%		0.9%		19.2%	
22	KAFUE R. AT MACHIYA FERRY	8850		1025	.115	1661	.188	3965	.448	6737	.761	15430	1.74	13280	1.50
23	DIFFERENCE [LINE 22-18]	1620		56	.034	68	.042	593	.366	859	.530	2710	1.67	2420	1.49
24	% OF MACHIYA FERRY	18.3		5.5%		4.1%		15.0%		12.8%		17.6%		18.2%	

Line	Station	April Mean	April Per square mile	May Mean	May Per square mile	June Mean	June Per square mile	July Mean	July Per square mile	August Mean	August Per square mile	September Mean	September Per square mile	Year Mean	Year Per square mile
1	KAFUE RIVER AT KIPUSHI RD.	105	.617	74.5	.438	58.1	.341	47.6	.280	37.3	.219	25.3	.148	114	.670
2	MUCHINDAMU R. AT MUCHINDAMU	—		—		—		—		—		—		—	
3	KAFUE R. AT NGOSA FARM	1774	1.13	704	0.448	399	.254	321	.204	230	.146	159	.101	909	.579
4	DIFFERENCE [LINE 3-2]	1669	1.19	630	.450	341	.244	273	.195	193	.137	134	.096	795	.568
5	% OF NGOSA FARM	94.1%		89.3%		85%		85.1%		83.9%		84.3%		87.4%	
7	KAFUE R. RAGLAN FARM	2200	1.14	760	.394	406	.210	325	.165	232	.120	148	.077	1038	.537
8	DIFFERENCE [LINE 7-3]	426	1.18	56	.155	7	.019	4	.011	2	.0055	-11	.031	129	.358
9	% OF RAGLAN FARM	19.4%		7.4%		1.7%		1.2%		0.9%		-7.4%		12.4%	
11	KAFUE R. AT MPATAMATO	3763	.836	1902	.422	1259	.279	1011	.225	787	.175	548	.121	2849	.633
12	DIFFERENCE [LINE 11-7]	1563	.608	1162	.452	852	.331	686	.267	555	.216	400	.155	1811	.704
13	% OF MPATAMATO	41.5%		61.1%		68.6%		67.8%		70.5%		73.0%		63.6%	
15	KAFULAFUTA R. AT KAFULAFUTA	700	.376	436	.234	361	.194	289	.155	208	.111	131	.070	842	.453
16	TOTAL [LINE 11+15]	4463		2338		1620		1300		995		679		367	
18	KAFUE R. AT NDUBENI	4986	.689	2455	.339	1721	.238	1415	.195	1127	.156	846	.117	3977	.550
19	DIFFERENCE [LINE 18-(11+15)]	523	.624	117	.134	101	.116	115	.132	132	.152	167	.192	286	.328
20	% OF NDUBENI	10.5%		4.8%		5.9%		8.1%		11.7%		19.8%		7.2%	
22	KAFUE R. AT MACHIYA FERRY	6090	.688	2850	.322	1880	.212	1490	.168	1180	.133	903	.102	4684	.529
23	DIFFERENCE [LINE 22-18]	1104	.681	3950	.243	159	.098	75	.046	53	.033	57	.035	707	.436
24	% OF MACHIYA FERRY	18.1%		13.9%		8.5%		5.0%		4.5%		6.3%		15.1%	

Note

These data have been compiled for illustrative purposes only. No attempt has been made to explain the apparent discrepancies.

LEB.

* Catchment area

Computed by slide rule and Calculator

Computed by L.E. Bidwell

Checked by Mr. Rami

Date 18 Aug. 196-

Sheet No. 1 of 1 sheets.

Figure 72.- A quantitive comparison of station records shows gross errors and inconsistencies in basin discharge records.

Max Disch. .... at .... on .... (G. H. ....). Max. G. H. .... at .... on ....

Min. Disch. .... on .... (G. H. ....). Min. G. H. .... on ....

Daily Gauge Height, in ~~Feet~~ Meters, and Discharge, in ~~cusecs~~ cumecs of Kafue

~~Near~~ At Kasaka for the Year Ending September 30, 1967

Drainage Area 150,970 Square ~~Miles.~~ Kilometres Water-Stage Recorder — Ratio ....:..

Day	October Gauge height	October Discharge	November Gauge height	November Discharge	December Gauge height	December Discharge	January Gauge height	January Discharge	February Gauge height	February Discharge	Mar Gauge height	D
1	4.10	40.8										
2	4.13	43.6										
3	4.12	42.5										
4	4.12	42.5										
5	4.11	41.4										
6	4.08	39.1										
7	4.05	36.2										
8	4.08	39.1										
9	4.08	39.1										
10	4.08	39.1										
11	4.08	39.1										
12	4.07	37.7										
13	4.05	36.2										
14	4.05	36.2										
15	4.05	36.2										
16	4.01	32.7										
17	4.01	32.7										
18	4.02	33.4										
19	4.00	32.0										
20	4.01	32.7										
21	4.01	32.7										
22	4.01	32.7										
23	4.00	32.0										
24	3.97	29.4										
25	3.97	30.8										
26	3.97	29.4										
27	3.97	29.4										
28	3.97	29.4										
29	3.97	29.4										
30	3.96	28.9										
31	3.96	28.9										

	October	November
Total	1085.3	
Mean	35.01	
Cu M/S Km	0.0002	
mm	0.6	
Millions of CuM	93.77	
Max.	43.6	Figure 73
Min.	28.9	

Note - The rounding limits of daily and monthly discharge in metric (SI) units are shown by the computation of discharge records for Kafue River at Kasaka for October, 1966.

JE Bidwell