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WEATHER, CLIMATE AND WATER

CHy Project: Assessment of the Performance of Flow Measurement Instruments and Techniques

SURVEY ON FIELD DISCHARGE MEASUREMENT INSTRUMENTATION AND TECHNIQUES USED OPERATIONALLY

DRAFT

Prepared by: Janice M. Fulford and Zsuzsanna Buzás

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Survey on Field Discharge Measurement Instrumentation and Techniques Used Operationally

Abstract

The WMO project, Assessment of the Performance of Flow Measurement Instruments and Techniques, conducted a survey during 2008-2009 that compiled information on instrumentation and techniques used for measuring discharge by National Hydrological Services. The survey was distributed to all WMO member nations. The responding countries represent a small (13 % of world population) and relatively wealthy portion of the WMO member nations. Mechanical meters were the most frequently used velocity instrument by the respondents. Submersible pressure sensors with data logging capability (internal or auxiliary logger) are the most frequently used water-level sensing device. Acoustic Doppler instruments are used by 65% of the responding countries for typically less than half of their velocity measurements. Other recently developed technologies, such as surface-velocity radar, and radar water-level devices are used by a few of the responding countries.

Purpose

A survey on field discharge measurement instrumentation and techniques used operationally was conducted as one of the six outputs of the WMO Assessment of the Performance of Flow Measurement Instruments and Techniques project. The project is expected to improve the understanding of the accuracy of various types of hydrometric instruments, thereby contributing to the management of water resources. The survey goal was to compile information on the types and usage of instrumentation employed for discharge measurements by National Hydrological Services (NHSs) and to collect the standards used by NHSs for discharge measurements. A brief overview of the survey contents and a compilation of the survey answers are presented in the following sections. The collected standards for the various discharge techniques submitted by responding NHSs are not included in this report, but are available on the WMO web site.

Survey and Its Distribution

The survey questions were divided into four sections based on general equipment classifications and technique: how often various types of (1) velocity instruments, (2) discharge measuring structures/devices, and (3) water-level sensing devices are used and calibrated, and (4) the types of discharge determination techniques used. The survey was distributed to the 188 members of the WMO during 2008-2009. The complete survey form is in appendix A. The survey was transmitted to NHSs with a cover letter dated 11th June 2008 and signed by Avinash C. Tyagi, the WMO director of Climate and Water Department. Twenty-four countries responded to the cover letter and submitted completed surveys. Two countries, Belgium and Macao, responded to the cover letter that they were not able to complete the survey. To increase the number of surveys used in the compilation, three responses to an earlier trial questionnaire (Sweden, Turkey and Iceland) were included in the survey results with the permission of those nations.

Survey Compilation

The survey results were compiled from surveys received from 27 countries during 2008 and 2009. The compiled surveys are presented as pie charts of average percent usage for various types of instruments or techniques. Each country's response had the same weight or effect on the complied results. Australia sent 6 completed surveys for five states and territories. The Australian responses were weighted to give a single response prior to compiling average percent usage for instrument types. The pie charts represent the instrument or technique usage for the average responding NHS. Results are also presented for the number of responses by percent usage categories for some instrument types. These frequency charts show the number of NHSs that use a particular instrument or technique for a given range of percent usage.

Survey Respondents

A small proportion of the NHSs of the WMO member nations, 14% (27 of 188), responded to the survey. Table 1 lists the responding nations by region. Figure 1 shows the proportion of responding nations by United Nations region. Figure 2 shows the percent contribution by each Region to the compiled survey results.

The responding NHSs represent a small and relatively wealthier proportion of the world's population. Their respective countries have 13% of the world population (http://www.census.gov/ipc/www/idb/ranks.php, 2009) and an average per person gross domestic product (gdp) that is 1.5 times the average gdp of the United Nations membership (http://unstats.un.org/unsd/demographic/products/socind/inc-eco.htm). The average per person gdp of the responding nations is $20,248 (U.S. dollars, 2007). The median per person gdp of the responding NHSs nations is 2.7 times the median of the membership nations of the United Nations.

The survey results have greater representation from the western nations and limited respresentation from other nations. Region VI (Europe) submitted 47% of the survey responses. Western nations (Regions IV and VI) submitted 62% of the survey responses. Significantly fewer responses, 38%, were from other four Regions (African, Asian, South American or South-West Pacific nations).

The survey results may not accurately represent the true state of discharge instrumentation usage by NHSs in 2009 because of the limited response to the survey. Several nations with significant global economic impact, such as Germany, China and Japan, as well as many developing nations did not respond to the survey. Changing the format of the survey and improving the clarity of the questions might increase the response to the survey. It is hoped that another similar survey will be performed in the near future in the hopes of improving the participation and the accuracy of the survey results.

Velocity Instruments

The first section of the survey inquired about the types and frequency of use of various types of velocity instruments for discharge measurements. NHSs indicated which velocities instruments they used. They also gave the percent usage of various types of velocity instruments. Table 2 lists the number of NHSs using a particular type of velocity instrument. Figure 3 summarizes the average use of various velocity instruments by the responding NHSs. Mechanical meters are used for over 65% of the measurements. Acoustic meters account for less than 10 percent of the velocity measurements. Instruments that were not indicated as being used by the responding NHSs are: hot film/hot wire, pitot tube, laser Doppler velocimetry, vane (or drag-body) current meters, vortex shedding meter, and surface velocity-particle image velocimetry.

Table 1. List of nations responding to the survey grouped by Region.

Region	Country	Region	Country
I (Africa)	Burundi	VI (Europe)	Bulgaria
	Cameroon		Estonia
	Cote d'Ivore		Finland
	Mauritius		Hungary
	South Africa		Iceland
II (Asia)	Hong-Kong		Ireland
	Sri Lanka		Italy
	Uzbekistan		Moldova
III (South America)	Chile		Poland
IV (North and Central America and Caribbean)	Canada		Slovenia
	Costa Rica		Slovak Republic
	Mexico		Sweden
	USA		Turkey
V (South-West Pacific)	Australia (6 responses)		

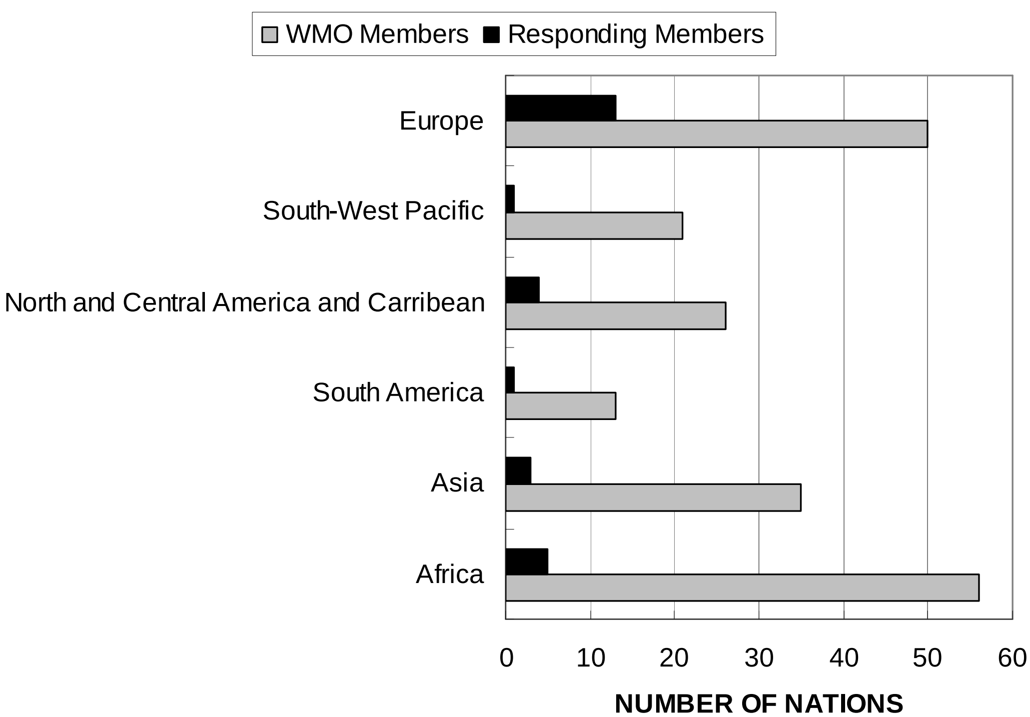

Figure 1. The number of WMO member nations and nations responding to the survey grouped by Region.

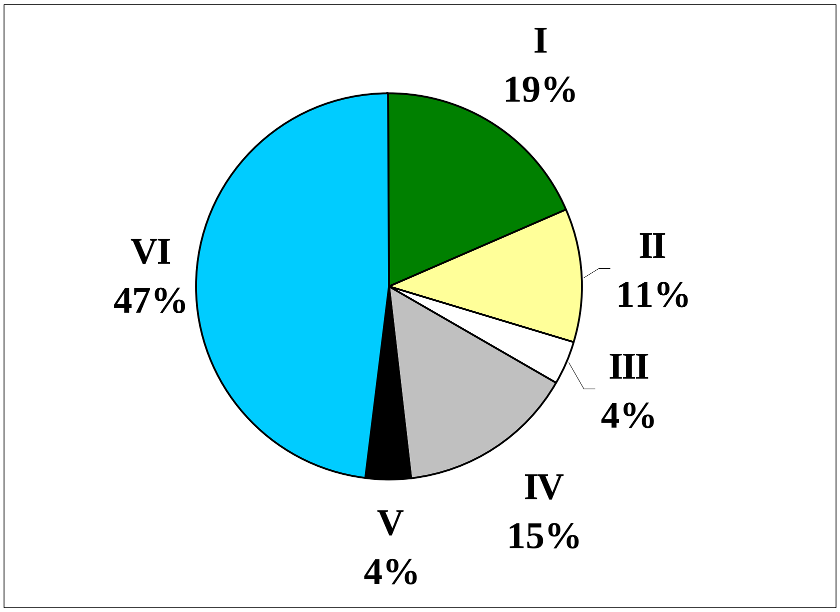

Figure 2. The percent contribution by Region to the compiled survey results based on 27 completed surveys.

The majority of responding NHSs, 21, use mechanical meters for over 50% of their velocity measurements (figure 4). Over 25% of the responding NHSs use mechanical meters for all of their velocity measurements. Most of the mechanical meters in use are the horizontal-axis (propeller) type meter. The manufacturer of horizontal-axis meters most frequently used by NHSs is Ott. Other commerical manufacturers used include Hydrologic Services, Seba, and Valeport. Only five NHSs in South and North America (regions III and IV) reported using vertical-axis (cup) type mechanical meters. Commerical manufacturers of the vertical-axis or Price type meters used by NHSs were Gurley and Rickly Instruments. Some NHSs, such as the United States, build custom designed mechanical meters and supply mechanical meters directly to their NHS offices.

Electromagnetic meters are used by about a third of the responding NHSs for measurements. Of NHSs that use electromagnetic meters, less than 40% of velocity measurements are made with that type of meter (figure 5). Manufacturers of electromagnetic meters used by NHSs included Marsh McBirney, Ott, Seba, and Valeport.

Acoustic Doppler instruments are used by over half of the responding NHSs (table 2). However, the instruments are usually used for less than 50% of the velocity measurements (figure 6 and 7). Only two responding NHSs use acoustic Doppler (moving boat) velocity instruments for at least 70% of their measurements (figure 6). More than a third of the respondents used Acoustic Doppler (side looking) and over half the responding NHSs use acoustic Doppler (moving boat). Most responding NHSs use acoustic instruments for less than 10% of their measurements. Most NHSs indicated using Teledyne RDI instruments for moving boat measurements. Sontek, Inc. instruments were also indentified as being used for moving boat measurements. Sidelooking acoustic instruments manufactured by Nortek (one response), Sontek, Inc, and Teledyne RDI were indentified as being used by NHSs. Acoustic uplooking meters manufactured by HACH-Sigma, Sontek, Inc., Teledyne RDI and Unidata were indentified as being used by NHSs.

Five NHSs, Australia, Canada, Estonia, Sweden, and United States indicated that they used the Sontek Flowtracker, an acoustic velocity meter that measures velocity at a local point in the flow. Discharge is measured with this meter using the same procedure that is used with a mechanical meter.

Figures 8 through 13 summarize the average use of velocity instruments by region for the responding NHSs. Results for a Region may not be very representative of a Region because of the small number of responses received from many Regions. Two regions, Region III and Region V, had only one response each from their NHSs. The data and figures for those regions may not be representative of their region.

Except for Region V, mechanical current meters are used the majority of the time. Acoustic meters have significant use, greater than 10%, in Regions V and VI. Electromagnetic meters have significant use only in Region I. Regions II, III, and IV reported no use of electromagnetic meters.

Some respondents indicated the calibration interval for four types of velocity instruments: mechanical, electromagnetic, acoustic Doppler (boat), and acoustic Doppler (side looking). The survey did not ask respondents to describe the procedure used to calibrate the instrument and the method used by respondents is unknown. Instruments that measure velocity in a small volume are typically calibrated or verified in a tow tank against a precise velocity reference using a standard procedure like that described by ISO 3455:2007. Acoustic Doppler boat and side looking instruments measure velocities at discrete locations throughout a range and are rarely verified against a precise velocity reference. These instruments may be calibrated or verified by comparing the distance measured by the Doppler instrument with the actual distance the instrument traveled in either a tow tank or lake (Oberg and others, 2005).

For mechanical meters (figure 14), 14 responses (including multiple responses from different regions of Australia) gave a range of calibration intervals from 3 to 60 months. For most respondents the calibration interval was from 1 to 3 years. For electromagnetic meters, based on three responses, the calibration interval ranged from 2 to 5 years. For acoustic Doppler (boat), based on 3 responses (Canada, Hungary, and Italy), the calibration interval ranged from monthly, to every two years.

Table 2. Number of NHSs using a type of velocity equipment.

Velocity Instrument	**Number of NHS Using Instrument Type**
Mechanical Current Meter	23
Electromagnetic Current Meter	9
Floats and Float Sticks	3
Acoustic Doppler (Moving Boat)	17
Acoustic Doppler (Side Looking)	10
Acoustic Doppler (Up-Looking)	6
Surface Velocity Radar	2
Stroboscopic, optical current meter	2
Other	5
Hot film/Hot Wire, Pitot tube, Laser Doppler Velocimetry, Vane or Drag Body, Vortex Shedding Meters	0

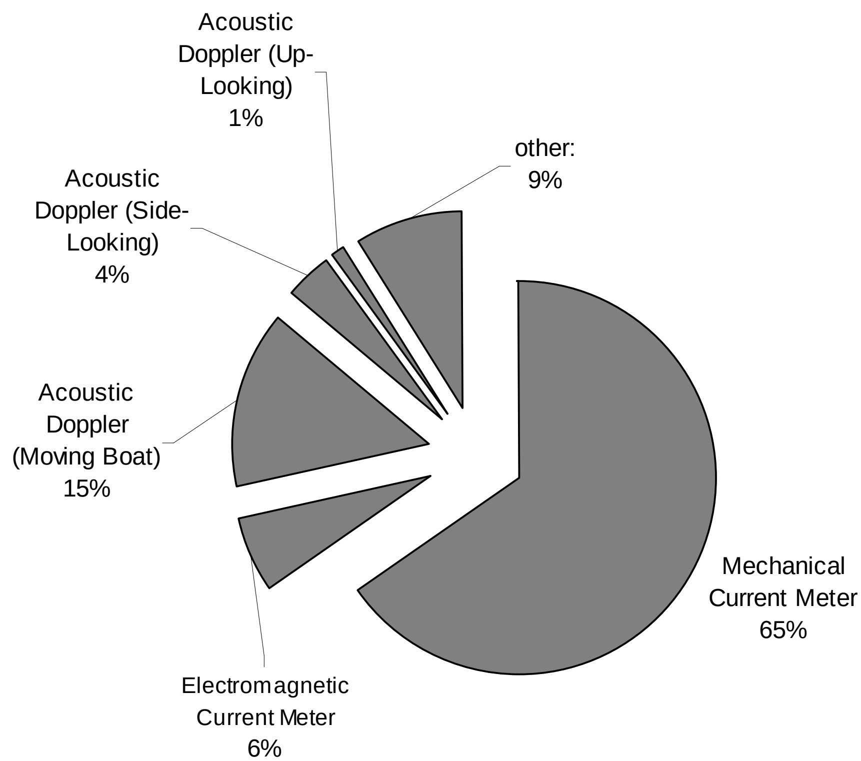

Figure 3. Average usage of various types of velocity instruments.

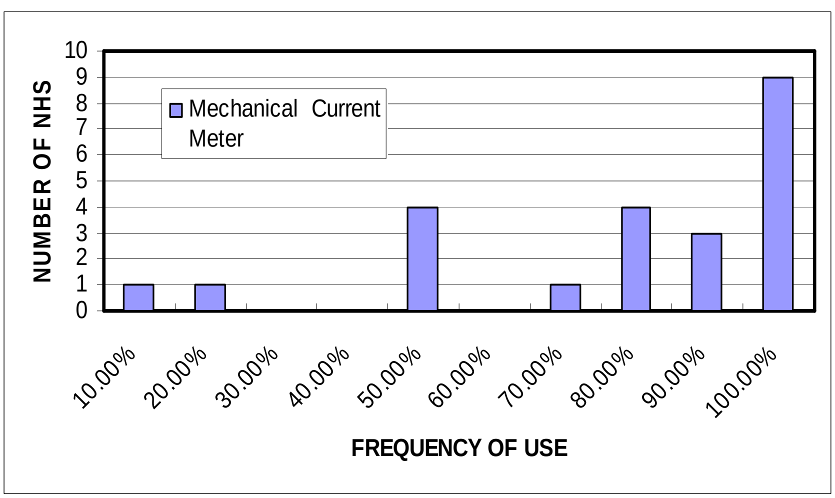

Figure 4. Frequency of use of mechanical current meters.

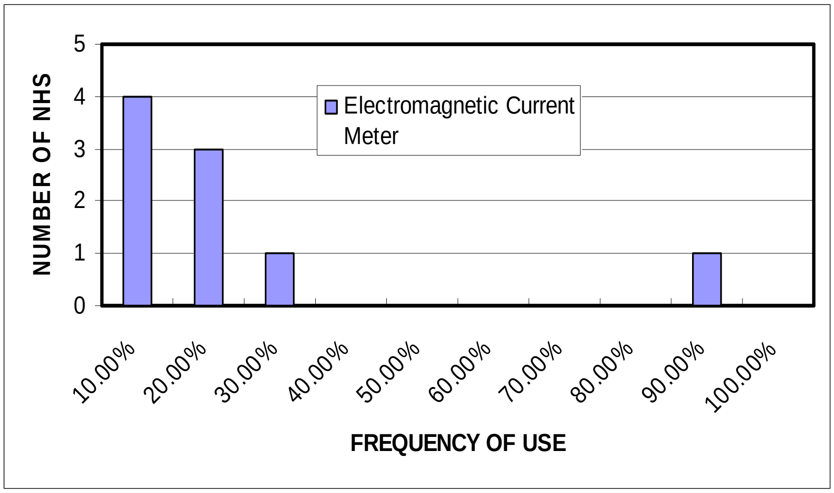

Figure 5. Frequency of use of electromagnetic current meters.

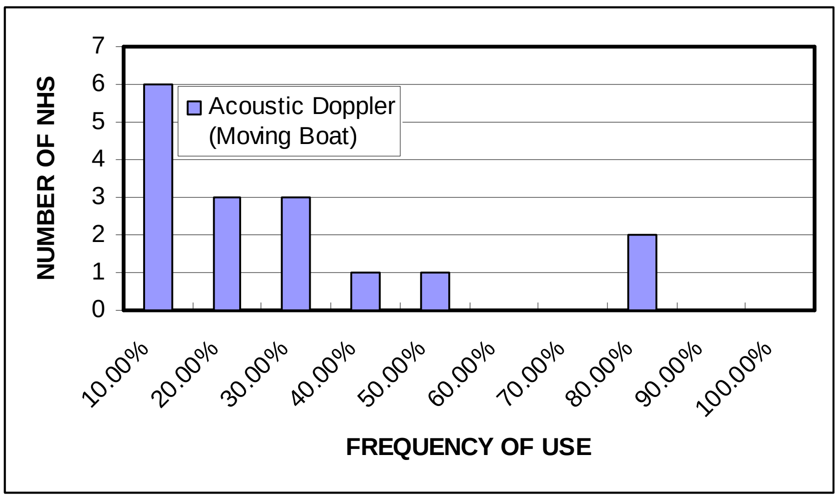

Figure 6. Frequency of use of acoustic Doppler (moving boat) current meters.

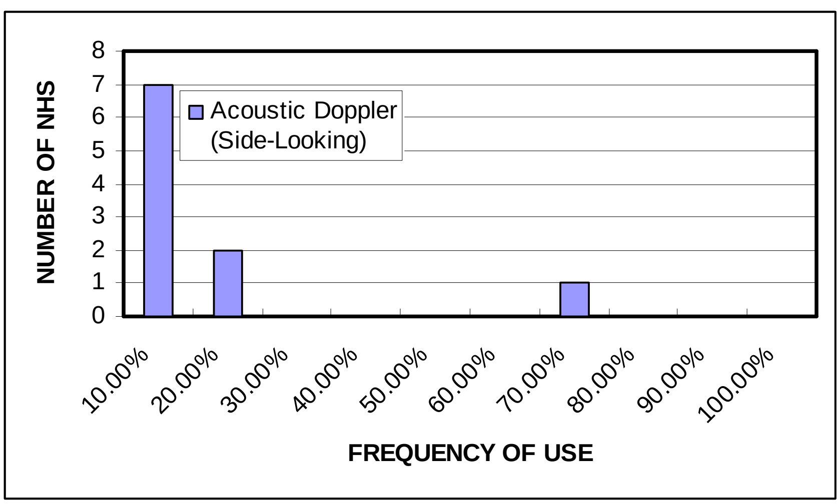

Figure 7. Frequency of use of acoustic Doppler (side-looking) current meters.

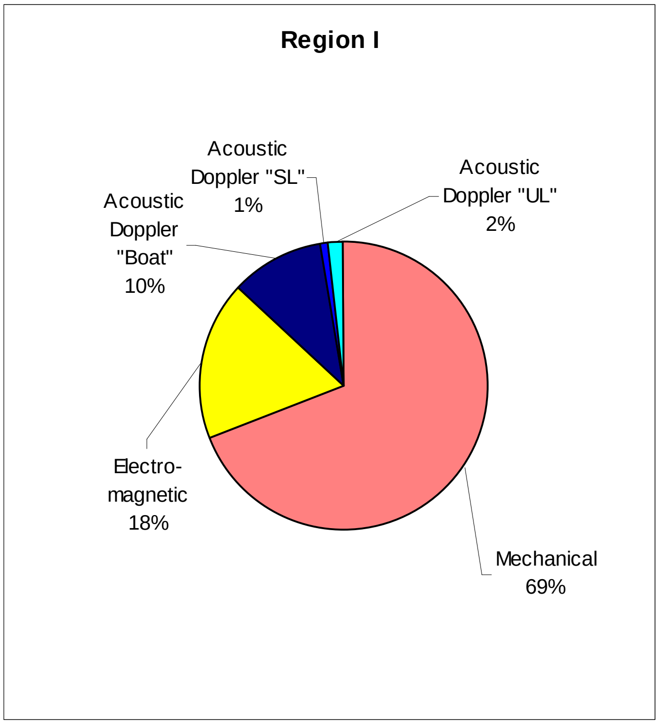

Figure 8. Average usage of various types of velocity instruments by Region I. [“SL”, side looking; “UL”, up looking]

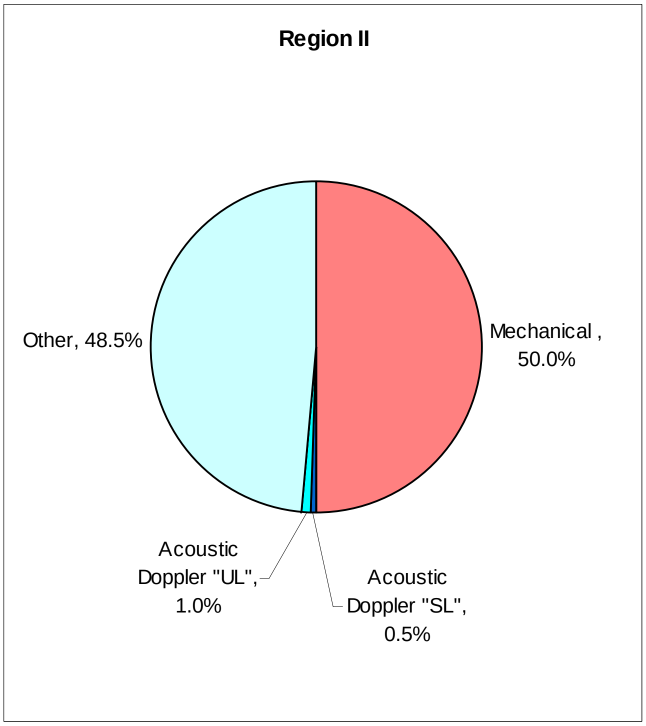

Figure 9. Average usage of various types of velocity instruments by Region II. [“SL”, side looking; “UL”, up looking]

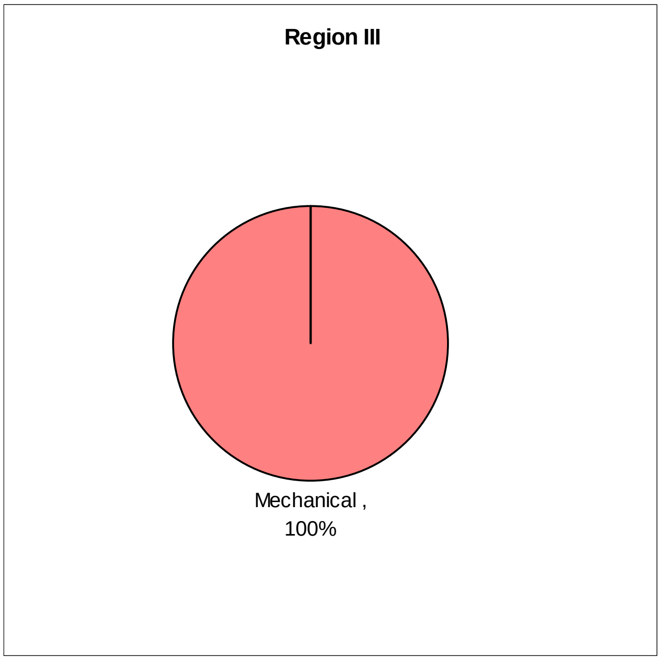

Figure 10. Average usage of various types of velocity instruments by Region III. [“SL”, side looking; “UL”, up looking]

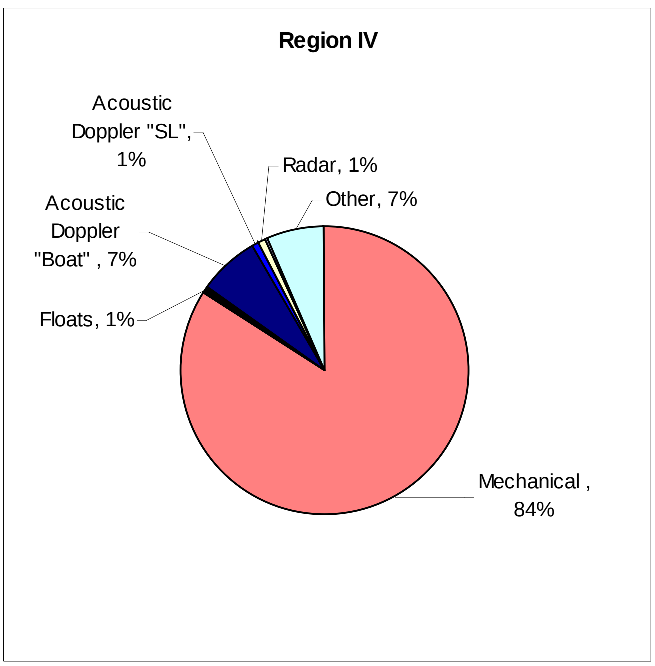

Figure 11. Average usage of various types of velocity instruments by Region IV. [“SL”, side looking; “UL”, up looking]

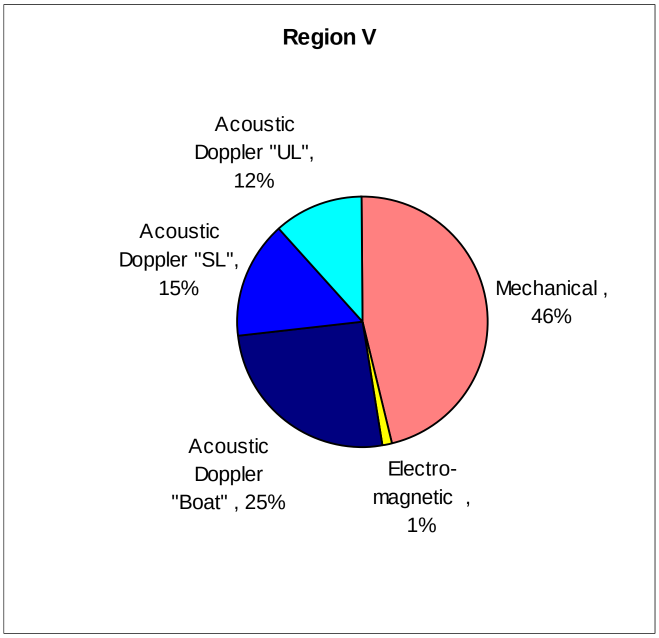

Figure 12. Average usage of various types of velocity instruments by Region V. [“SL”, side looking; “UL”, up looking]

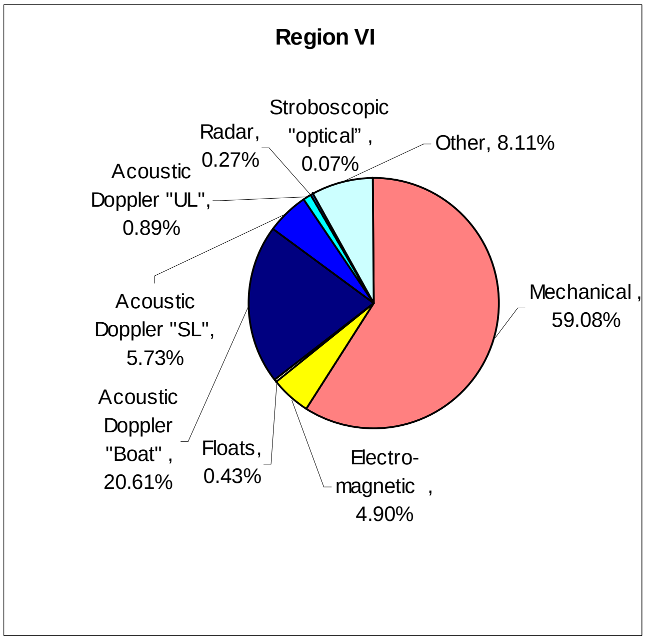

Figure 13. Average usage of various types of velocity instruments by Region VI. [“SL”, side looking; “UL”, up looking]

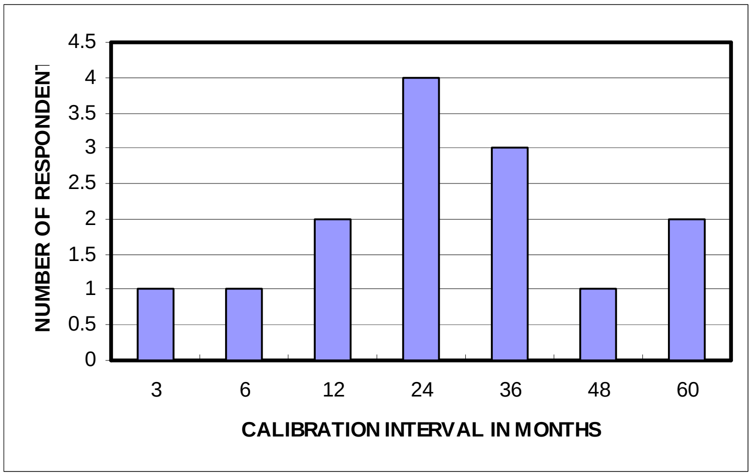

Figure 14. Calibration intervals for mechanical current meters.

Discharge Measuring Structures/Devices

The second section of the survey inquired about the types of structures used to make discharge measurements by the responding NHSs. Figure 15 summarizes their responses. Weirs are used for 39% of the discharge measurements. Structures identified as “other” in the survey (structures that are not weirs, flumes, dams and gates) were used for 43% of measurements made with a measurement structure. The kinds of “other” structures used were not specified by the respondents.

More NHSs (12) identified using weirs than any other listed type of structure (figure 16). The frequency of use of weirs ranged broadly from less than 10% to 100% of discharge measurements made using a structure (figure 16). Flumes were used for less than 50% and dams for less than 30% of discharge measurements made using a structure.

For three types of discharge measuring structures (flumes, weirs and gates) three responses provided calibration intervals. Calibration intervals ranged from monthly to annually for these structures.

Water-Level Sensing Devices

The third section of the survey inquired about the types of water-level sensing devices used to measure water level. Water-level sensing devices connected to a data logger are used to continuously measure and record the water level. Sensing devices not connected to a logger must be read at a periodic interval and recorded by hand. Some water-level devices not connected to a data logger, such as staff plates and tapes, are used as reference devices for other water-level instruments at a gauging site.

Submersible gauge pressure sensors connected to a data logger or equipped with an internal data logger were used for 38% of water-level measurements (figure 17). Float-well system connected to a data logger was used for 23.8% of water-level measurements. Float-well system was also used by more NHSs (22) than any other water level sensor (figure 18). Five NHSs indicated using float-well systems for at least half of their water level measurements (figure 19). Bubbler systems that use gas bubbling through a tube to measure water level with a gauge pressure sensor

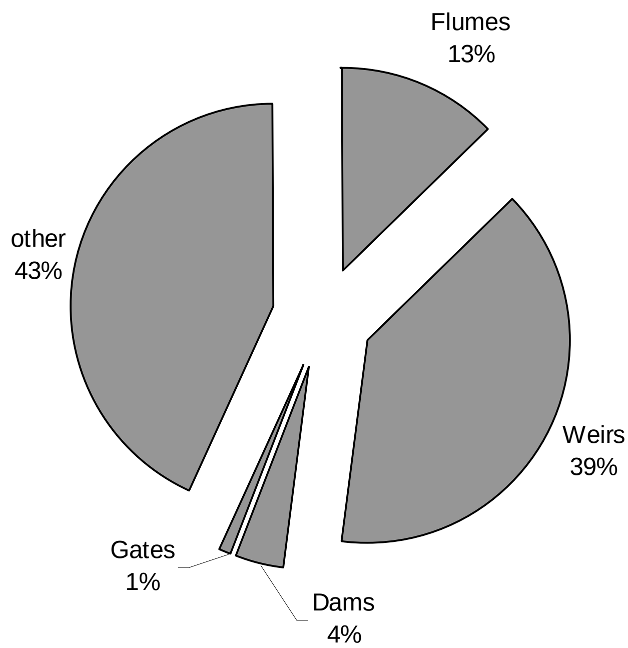

Figure 15. Use of discharge measuring structures and devices by responding NHS.

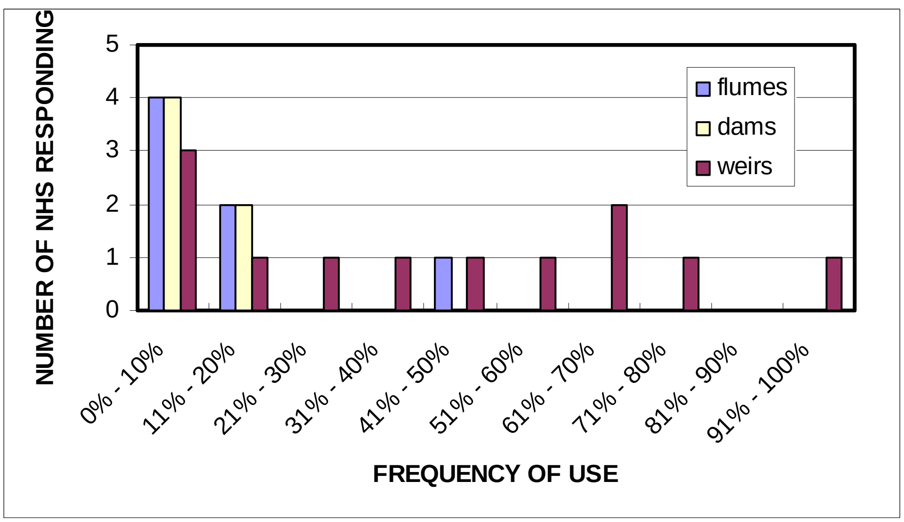

Figure 16. Frequency of use by NHSs of discharge measurement structures.

were used by 15 of the NHSs for water level measurements (figure 18). Submersible gauge pressure sensors were used by 22 NHSs for water-level measurements (figure 18). Twelve NHSs used submersible pressure sensors for more than 50% of their water level measurements (figure 20).

Numerous manufacturers were listed as suppliers of pressure sensors and float-well systems. NHSs used many more manufacturer and suppliers for pressure sensors than for any other type of sensor. Manufacturers and suppliers listed included companies that focus on pressure sensors: Druck, Paroscientific, Pressure Systems Inc. and Tavis; and companies that offer pressure sensors in addition to other equipment: Aplisens Ltd, Campbell, Design Analysis, Greenspan, Hydrologic

Services, Impress, Mobrey-Solatron, Ott, Seba and Van Essen. Float systems manufacturers used by NHSs were Amass, Campbell, Handar, Ott, Seba, Sutron, Unidata and Valcom. Manufacturers of bubbler systems reported as being used by responding NHSs are Design Analysis, Hydrologic Services, Seba, and Sutron.

A few NHSs indicated that they used non-contact water-level sensors. These sensors are relatively new technology. Non-contact water-level sensors, such as radar or acoustic sensors, are positioned over the water. These sensors measure the distance in air to the water surface by transmissions of radio or acoustic waves. Frequency of non-contact water-level sensors usage is provided in figure 21. Six NHSs reported using acoustic sensors - three of which reported using them for over half of their water level measurements. Seven NHSs reported using radar sensors for less than 10% of their water level measurements. Suppliers of acoustic systems used by NHSs were Campbell Scientific and Siemens. Manufacturers of radar systems used by NHSs are Design Analysis, Ott, Seba and Ohmart Vega.

Two NHSs (Australia and Ireland) reported using capacitance sensors for measuring water level. Suppliers used for capacitance sensors were Dataflow Systems and Ott.

Figures 22 through 27 show the average usage of water level sensors grouped by Region. Results for a Region may not be very representative because of the small number of responses received (Figure 1). Only one response was received from Regions III and V. Regardless of Region, systems using some type of pressure sensor are the most common method for measuring water level. Systems using a pressure sensor include bubbler systems as well as submersible absolute and submersible gauge pressure sensors. Regional usage for pressure systems ranges from 39% (Region II) to 95% (Region III). Every Region also reported using float-well systems with Region V reporting the highest usage, 48%, and Region III the lowest usage, 5%. Acoustic sensor usage was reported in 3 Regions. Regional usage ranged from 48% (Region II) to 38% (Region 6). No use of acoustic sensors were reported in regions I, III, and V.

Some respondents to the survey indicated calibration intervals for water-level sensing devices. Float-well systems calibration intervals ranged from monthly to annually, based on five responses. Submersible pressure sensors, either equipped with an internal logger or used with a data logger, were calibrated at intervals ranging from 1, 3, 12 and 36 months, based on 6 responses.

Discharge Determination Techniques Used

The fourth section of the survey inquired about the discharge determination techniques used to compute discharge. Measurements must be used with a determination technique to compute a discharge. A summary of the responses to the survey questions on discharge determination techniques is in table 3. Responses for two groups of discharge determination techniques were combined. Mannings or energy equation includes responses for slope-area, slope-conveyance, critical depth and indirect methods. Rainfall-runoff methods include rainfall/runoff with rain gauges, rainfall/runoff with weather radar and rainfall/runoff coupled with a weather model. Techniques that had only one response (other and satellite/aerial based lidar system) were not included in table 3. Velocity-area methods had the highest number of users, 18, and the highest average use, 46.4%. Tracer, dye dilution technique was used by 4 NHSs and the average use for 27 respondents was less than 0.5%. Stage-discharge relationships were used for 40.2% of the measurements.

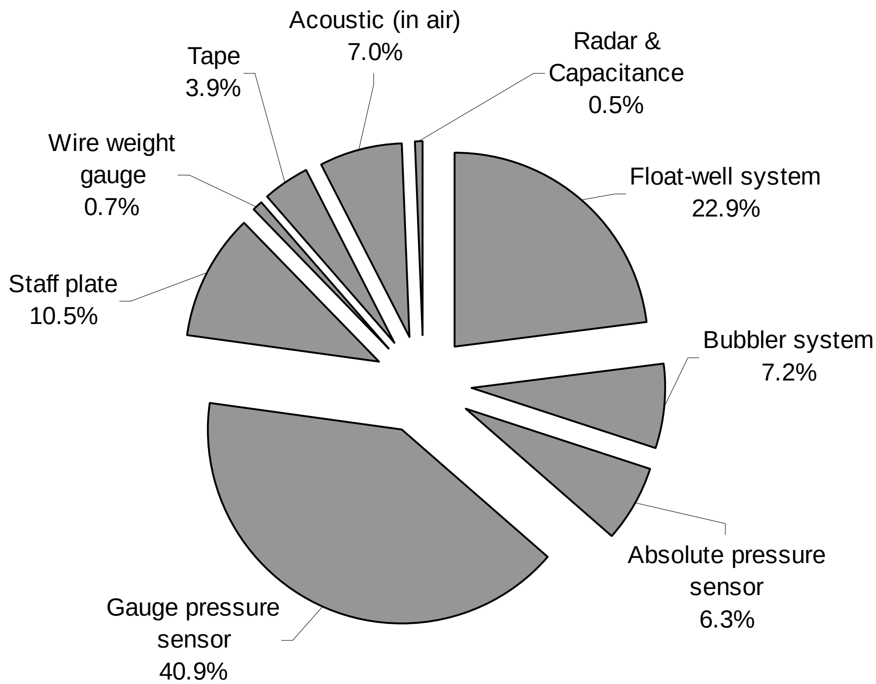

Figure 17. Usage of various types of water level sensing devices.

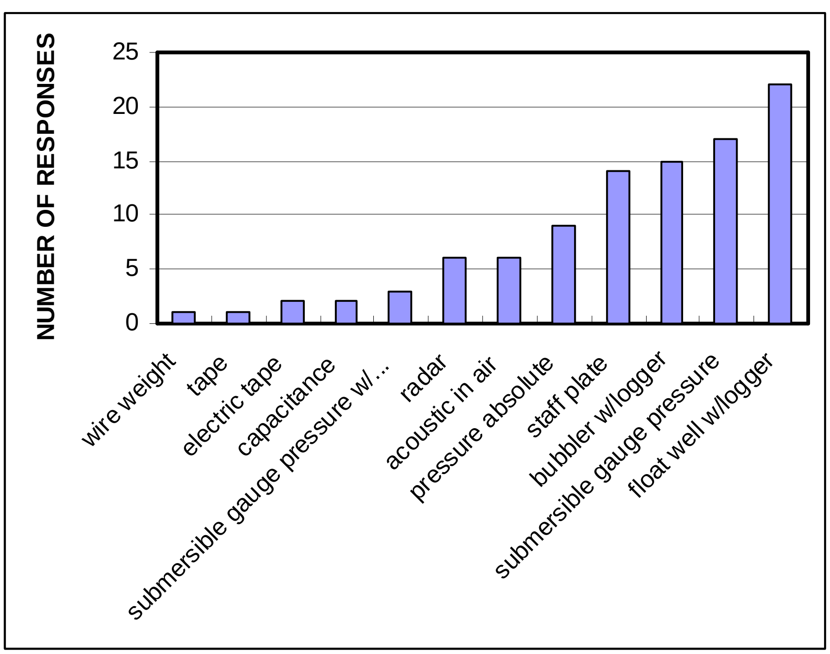

Figure 18. Number of responses indicating use of a water-level sensing device.

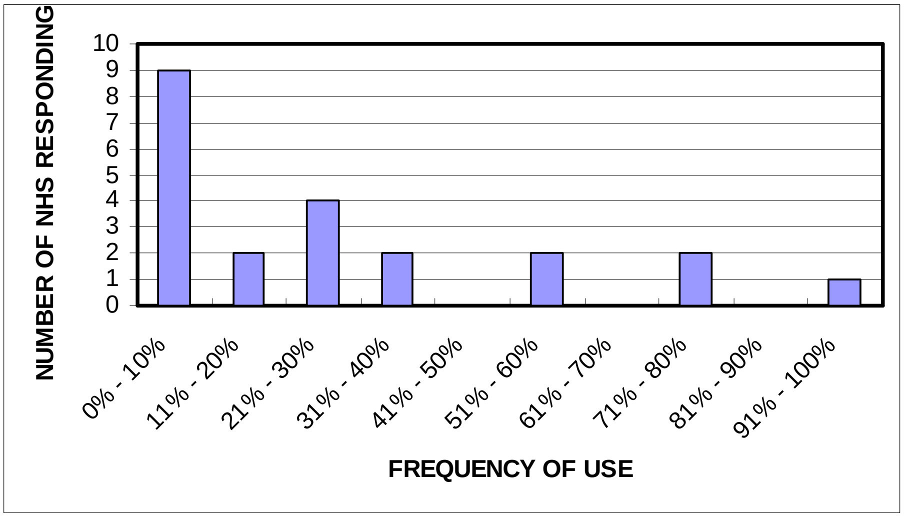

Figure 19. Frequency of use of float-well water-level sensors by responding NHSs.

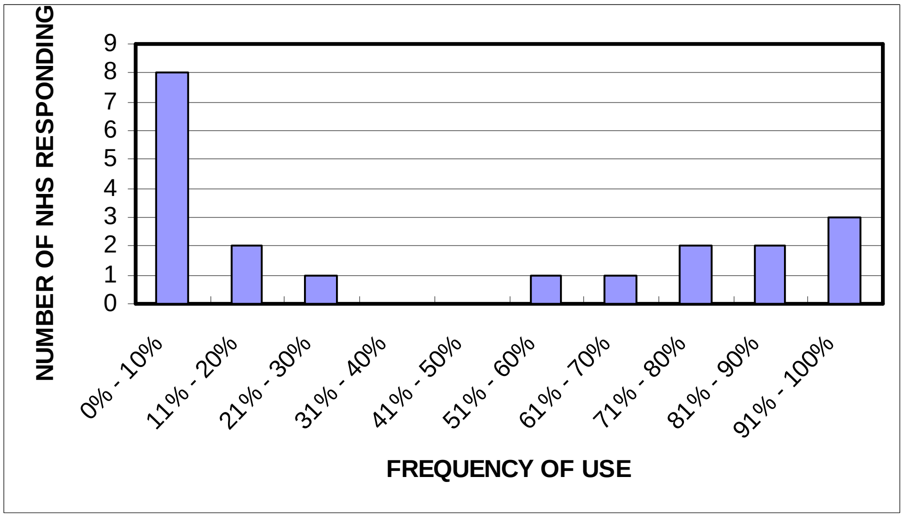

Figure 20. Frequency of use of submersible pressure gauges by responding NHSs.

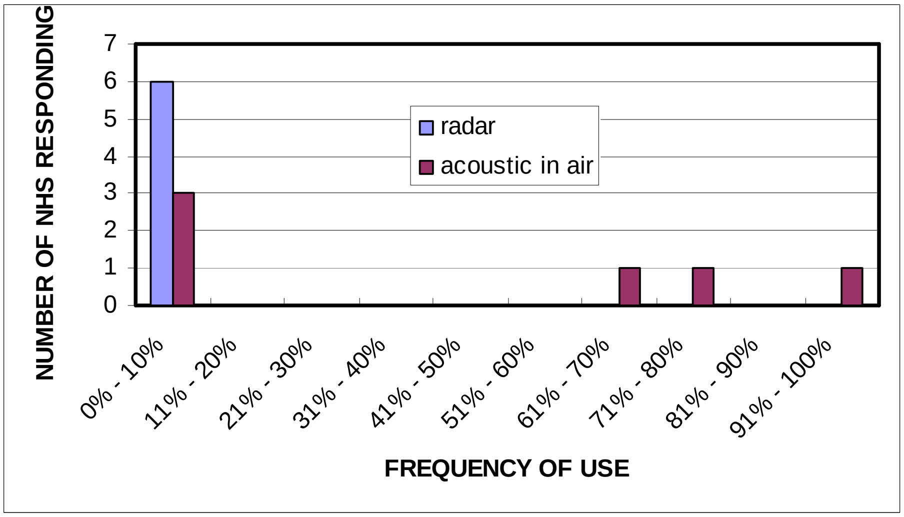

Figure 21. Frequency of use of non-contact water-level sensors by responding NHSs.

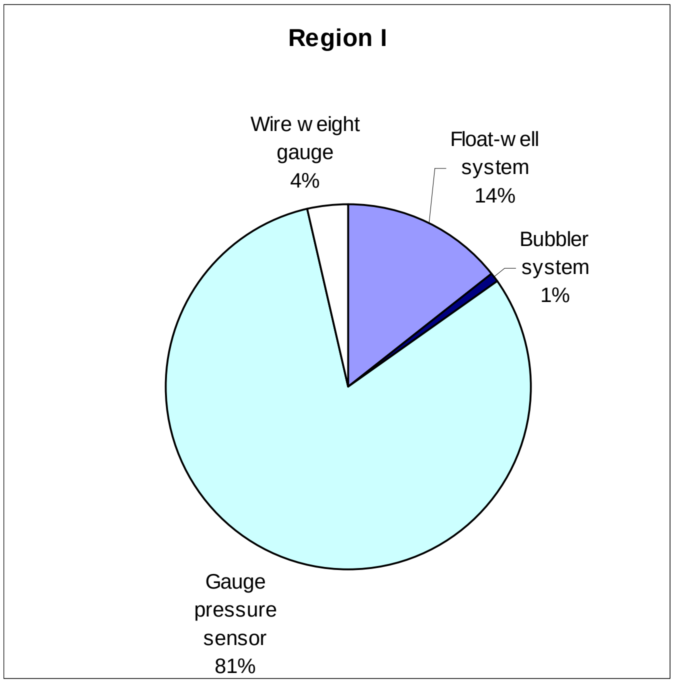

Figure 22. Usage of water-level sensors by Region I.

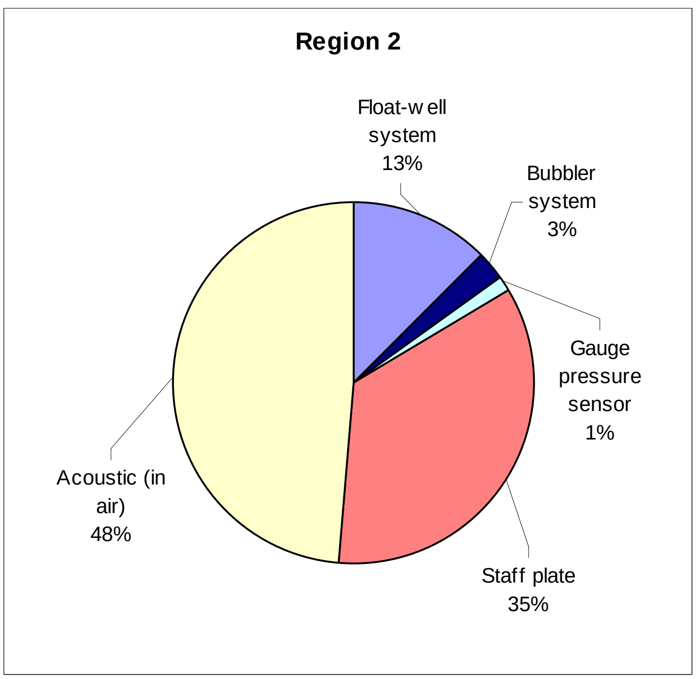

Figure 23. Usage of water-level sensors by Region II.

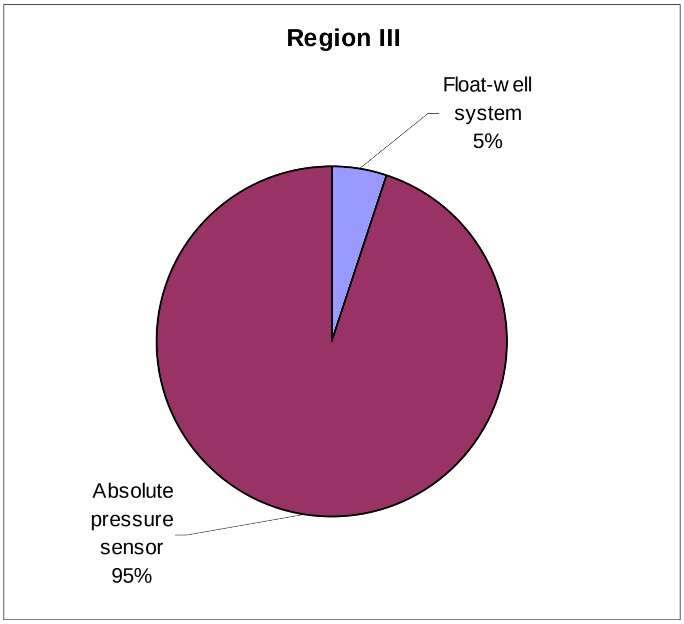

Figure 24. Usage of water-level sensors by Region III.

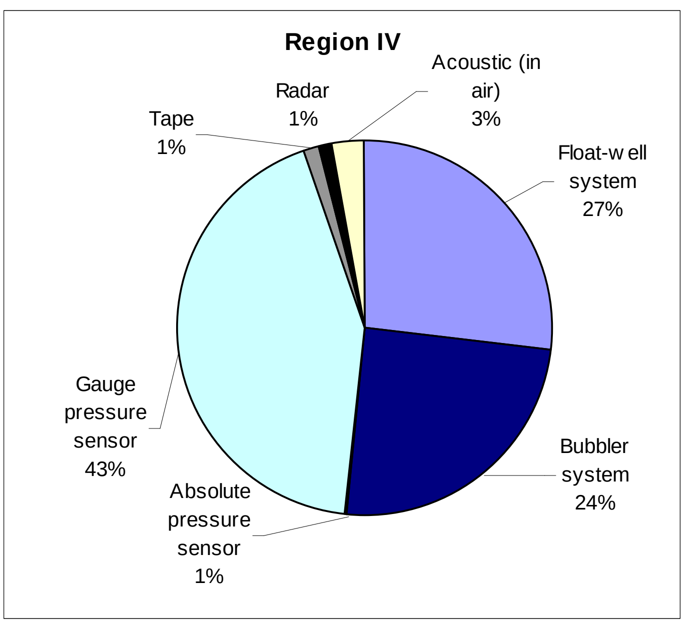

Figure 25. Usage of water-level sensors by Region IV.

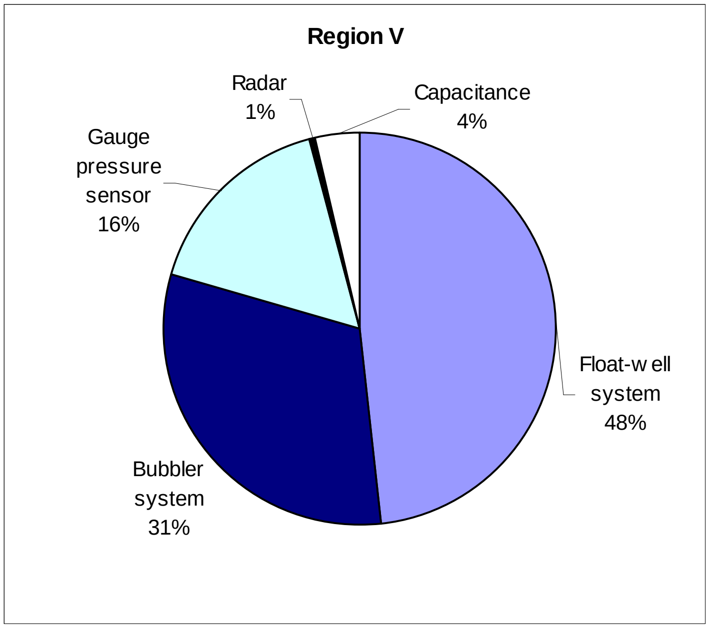

Figure 26. Usage of water-level sensors by Region V.

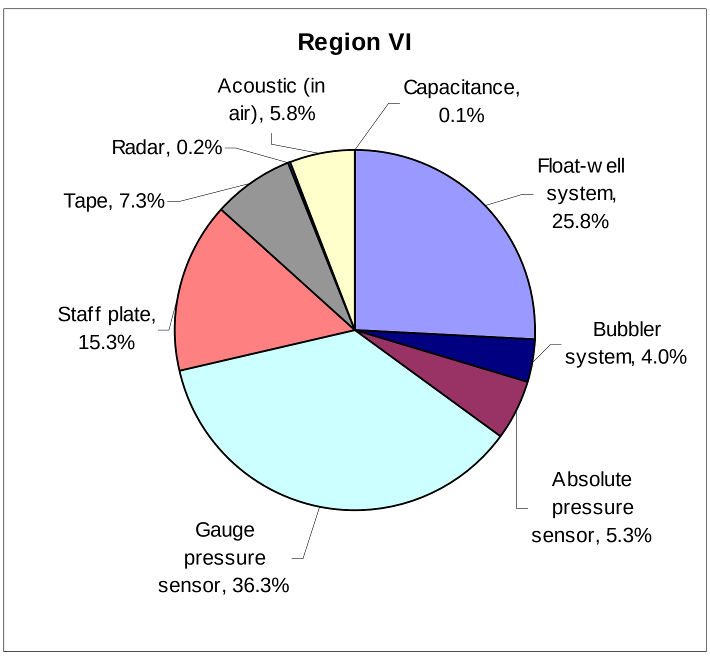

Figure 27. Usage of water-level sensors by Region VI.

The average percent usage for stage-discharge relations may not be meaningful because of inconsistant responses to the stage-discharge relation technique question. Some respondents indicated using stage-discharge relationships at every site and also indicated using other techniques. Other respondents indicated that they did not use stage-discharge relations. Stage-discharge relationships are often used with automatic, recording water-level instruments at sites when nearly continuous measurements of discharge are desired and are often used by NHSs at every discharge measurement site. Those respondents not indicating any usage of stage-discharge relations may have interpreted the question to be restricted to discharge measurements that are not automated and are performed by a field person on site. The inconsistent responses probably affected the average results for discharge determination techniques.

Figure 28 shows the average percent usage of the measurement techniques when the stage discharge relations responses are removed and the remaining technique responses are weighted so that the sum of the percentages equal one. This is accomplished by dividing the percentage of each technique by the sum of the percentage of the remaining techniques. When responses for stage-discharge relations are removed, velocity-area methods are the dominate technique used to determine discharge by survey respondents.

Summary

The survey was distributed to all WMO member nations. The responding countries represent a small (13 % of world population) and relatively wealthy portion of the WMO member nations. Mechanical meters were the most frequently used velocity instrument by the respondents. Submersible pressure sensors with data logging capability (internal or auxiliary logger) are the most frequently used water-level sensing device. Stage-discharge relations and velocity-area methods are the most frequently used techniques for determining discharge. Older technologies are used by most of the respondents. Recently developed technologies, acoustic Doppler velocity meters and radar water-level devices are used by a small portion of the responding countries.

Because survey results were based on a small number of responses, the results may not accurately represent the true state of discharge instrumentation usage in 2009. Many nations that have significant global economic impact did not participate in the survey and two Regions had only one NHS participating in the survey. It is hoped that another survey on field discharge measurement instrumentation and techniques used operationally be conducted in the next few years. The experience gained from this survey will be used to improve the clarity of the future survey and increase the participation of NHSs.

Table 3. Summary of use of discharge techniques by NHSs responding to survey. Mannings or energy equation includes responses for slope-area, slope-conveyance, critical depth and indirect methods. Rainfall runoff methods includes responses for all types of rainfall runoff methods.

Discharge Technique	Average Use in Percent	Number of Respondents Using	Percentage of Respondents
Stage-discharge relations	40.2	14	51.9
Velocity-area methods	46.4	18	66.7
Stage-velocity relations	1.2	6	22.2
Hydraulic structures	9.4	8	29.6
Mannings or energy equation	1.2	6	22.2
Rainfall runoff methods	1.6	5	25.9
Tracer, dye dilution	<0.5	4	14.8

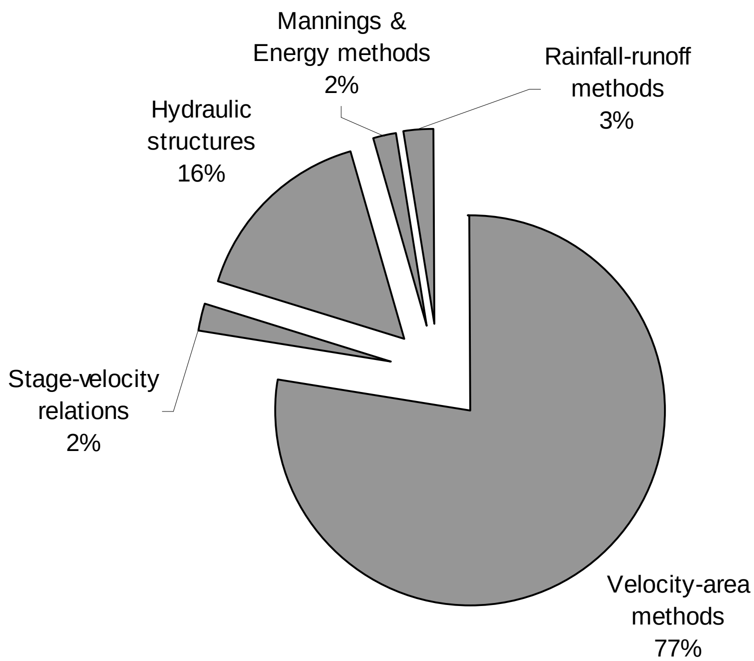

Figure 28. Percent usage of discharge measurement techniques, excluding the use of stage-discharge relations.

References

Oberg, Kevin A., Morlock, Scott E. and Caldwell, William S. (2005), Quality-Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers, Scientific Investigation Report 2005-5183, U.S. Department of Interior, U.S. Geological Survey.

ISO 3455:2007 Hydrometry – Calibration of Current-Meters in Straight Open Tanks, International Organization for Standardization, Geneva, Switzerland.

Appendix A. Survey materials sent out to member nations.

Survey on Field Discharge Measurement Instrumentation and Techniques used operationally

As part of CHy's **"Initiative to assess the performance of flow measurement instruments and techniques"**, you are kindly requested to respond to the following survey.

There are two main objectives of the survey. They are:

1) to increase our knowledge of the degree of use of various instrumentation and techniques, as this will help focus the Initiative on the most critical areas; and
2) to initiate the collection of international and national standards and guidelines regarding field discharge measurement instrumentation and techniques and of test reports on their performance.

We recognize that it may be difficult for a single person to have a complete picture of flow measurement activities at the national level. In case of doubt, please provide your best estimation, as we are not looking for exact figures, rather we wish to have the best possible assessment of what the current practices by NHSs are.

In filling the attached form, you may find the following definitions/instructions valuable:

Velocity Instruments - Instruments used to measure a local velocity, either magnitude or vectors.
Discharge Measuring Structures/Devices - Structures or devices that are installed and used to measure flow (or flux) in a stream or other body of flowing water.
Water-level Sensing Devices - Instruments used to measure either flow depth or water elevation.
Discharge determination techniques - Techniques used for calculating discharge based on the measurement of one or more ancillary variables.
Percent usage - Percentage of all measurements of a certain category done using the relevant instrument/technique.

For each entry, we would be very grateful to learn of the existence of specific national standards and/or guidelines that your organization may be using. In the case where these are in one of the official languages of WMO (English, French, Russian, Spanish, Chinese and Arabic), we would be very interested in obtaining them, either in the form of a pdf, link to websites or hardcopy (identifying the source, issuing authority, and any copyright restrictions that may exist).

In addition, we would also be interested in obtaining, under the same conditions described in the previous paragraph, reports of tests on the performance of instruments and techniques that your organization may have undertaken.

Please send your response by **15 June 2008** to:

Claudio Caponi
ccaponi@wmo.int
Tel: + 4122 730 8407
Fax: +4122 730 8043

Survey Form
Field Discharge Measurement Instrumentation And Techniques

Please return, preferably via e-mail by 15 June 2008

Respondent Country, Institution: ___________________________________

Name of Respondent (with address & e-mail) __________________________

Velocity Instruments	**Percent Usage**	**Make & Model**	**Manufacturer Website**	**Calibration Methodology & Frequency**
Mechanical Current Meter				
Electromagnetic Current Meter				
Hot film/Hot Wire				
Pitot tube				
Laser Doppler Velocimetry				
Floats or float sticks				
Vane (or drag-body) current meters				
Acoustic Doppler (Moving Boat)				
Acoustic Doppler (Side-Looking)				
Acoustic Doppler (Up-Looking)				
Vortex shedding meter				
Surface Velocity - Radar				
Surface Velocity - Particle Image Velocimetry (PIV)				
Stroboscopic “optical” current meter				
(other)				
Total	100%			

Discharge Measuring Structures/ Devices	**Percent Usage**	**Type**	**Manufacturer Website**	**Calibration Methodology & Frequency**
Flumes				
Weirs				
Dams				
Gates				
(other)				
Total	100%			

Water Level Sensing Devices	**Percent Usage**		**Make & Model**	**Manufacturer Website**	**Calibration Methodology & Frequency**
	P*	S*			
Float-well system					
Bubbler-type pressure sensor					
Submersible pressure sensor (Absolute)					
Submersible pressure sensor (Gauge)					
Staff plate/gauge					
Wire-weight gauge					
Electric tape gauge					
Tape					
Crest stage gauge					
Laser					
Radar					
Acoustic (in air)					
Acoustic (in water)					
Capacitance					
Needle gauges (point and hook gauges)					
(other)					
Total	100%				

* P = Primary sensor,   S = Secondary or Auxiliary

DISCHARGE TECHNIQUES

Discharge Technique	**Percent usage**	**Reference for Documentation or National Standard describing technique***	**Web site for technique**
Velocity-area method			
Tracer/Dye-dilution method			
Stage-discharge relations			
Stage-velocity relations			
Slope-area			
Slope-conveyance			
Indirect Methods using energy equation (culvert, bridge, etc.)			
Critical Depth			
Hydraulic structures			
Rainfall/runoff with rain gauges			
Rainfall/runoff with weather radar			
Rainfall/runoff coupled with weather model			
Satellite/aerial based lidar system			
(other)			
Total	100%		

* Example: Hydrological Guidelines, National Standards, ISO Standard Number, CEN Standard Number, Other (Namely)

Note 1: Hydrological Guidelines are technical guidance published internally to the NHS and have no binding legal value.

Note 2: Please provide list of Hydrological Guidelines and National Standards (preferably in one of the six WMO recognized languages)