WATER OPERATION AND MAINTENANCE BULLETIN

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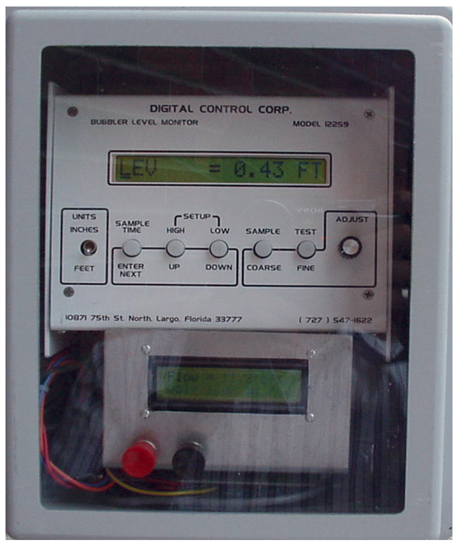

IN THIS ISSUE. . .

UNITED STATES DEPARTMENT OF THE INTERIOR **Bureau of Reclamation**

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This *Water Operation and Maintenance Bulletin* is published quarterly for the benefit of water supply system operators. Its principal purpose is to serve as a medium to exchange information for use by Reclamation personnel and water user groups in operating and maintaining project facilities.

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***Cover photograph*:** Close up of the bubbler electronics on top and the open-channel flow recorder on the bottom. This allows totalizing of the flow from the bubbler water level information.

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CONTENTS

Page

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IRRIGATION FLOW MEASUREMENT—INSTRUMENTATION DEVELOPMENT PART II

by Blair L. Stringam[1] and Kathleen H. Frizell[2]

Background

Early irrigation facilities built by the Bureau of Reclamation (Reclamation) to store and convey water are still being used today. It is now our mission to manage these systems more efficiently and to consider multiple uses for the water resources that were previously used for agriculture. Effective management of water systems is a high priority because many competitors vie for the use of a limited amount of water. Improved operation of water delivery systems is needed to accommodate irrigation enhancements, environmental concerns, and urban growth. In many river systems, more water needs to remain in the natural streams to preserve fish, wildlife, and the surrounding habitat.

Management of older irrigation systems requires the ability to accurately and cost-effectively measure and record existing water use in systems not initially designed with water measurement in mind. Water must be measured, and usage must be known, before conservation and equitable distribution can be implemented.

The Water Resources Research Laboratory (WRRL) is continually working with Reclamation field offices, irrigation districts, and farmers to efficiently operate irrigation systems and to upgrade water measurement and recording capability. Sensors and recorders used on irrigation systems must endure heat, humidity, debris, vegetation, dust, lightning, and vandalism and still maintain reliability and accuracy. Instrumentation must also be easy to use and available for a reasonable cost. As part of this effort, the WRRL has recently developed, and is currently testing, devices to assist farmers and irrigation districts with measuring and recording water. This work has been accomplished in cooperation with Reclamation's Science and Technology Office, Policy Office, Montana Area Office, and Utah State University.

The September 1999 *Water Operation and Maintenance Bulletin* paper entitled, "Irrigation Flow Measurement – Instrumentation Development Part 1," provides a description of several instruments and their initial testing under laboratory and various field irrigation applications. Those instruments included two newly developed devices for open-channel applications and four commercially available flow meters for pressurized pipe system applications[1].

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The objective of this study has been to work with instrument manufacturers and Reclamation engineers to develop and test low-cost devices that could be used by irrigation districts and farmers to manage diverted water. Generally, the more expensive devices are more accurate. But maintenance, ease of use, reliability in the operating environment, and cost often become more important features when selecting the proper device. Each measurement and recording device has strengths and weaknesses that must be evaluated for each application.

This article summarizes a study that is a continuation of that previous work. This article provides a brief description of the instruments, test facilities, and installations and presents the results of laboratory and field tests. The results include comparisons of reliability, accuracy, ease of use, effect of debris on operation, and cost.

Instrumentation

The instrumentation in this study has two types of applications: (1) open-channel applications and (2) pipe flow rate measurement applications. The open-channel applications have been expanded since the previous work [1] and the investigation now includes:

- An open-channel flow recorder (OCFR) with an ultrasonic sensor
- An OCFR with a bubbler sensor
- A low-cost transducer in a pipe water level sensor
- An additional high-frequency cable water level sensor

The pressurized pipe flow meters being investigated are:

- Two paddle-wheel flow meters manufactured by SeaMetrics and Data Industrial
- A propeller meter manufactured by GF+Signet
- A vortex shedding meter manufactured by Fluidyne

Open-Channel Measurement Devices

Three devices were tested for application to open-channel measurement in irrigation systems. Two of the three devices are simply water level sensors that must then be used with a data logging device, and the third device is an OCFR with an ultrasonic or bubbler sensor.

Open-Channel Flow Recorder with Ultrasonic or Bubbler Sensor

The OCFR consists of a small central processing unit chip (CPU), a water level sensor, and a solar power supply (figures 1 and 2). It is designed for installation on the upstream side of a measurement structure, such as a flume, where it measures the water depth. The OCFR can be used with any type of water level sensor and has been tested with an ultrasonic sensor and a bubbler system. We have applied for a patent which is currently pending approval under the name Flume or Weir Flow Rate Sensor and Recorder.[3] A unique feature is the processing and display that has been adapted for irrigation use. The device can be easily adapted for weirs or other flow measurement structures provided a rating equation is available for the structure. A totalizing feature has also been incorporated into the program so that total volume of water diverted can be computed. The flow rate in cubic feet per second and total diverted water in acre-feet is displayed on an LCD screen. A reset feature allows the water user to push a button and reset the totalized flow for a new irrigation period. Data can either be recorded manually or downloaded to a laptop computer.

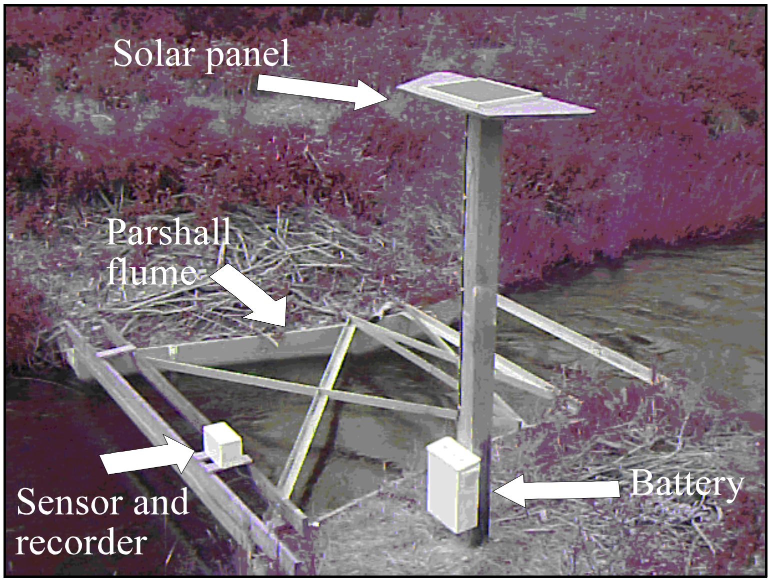

Figure 1.—The OCFR mounted upstream from an 8-foot Parshall flume in Montana.

Figure 2.—View looking into the OCFR. The cable is hooked to a laptop computer for easy programming of the CPU or downloading stored data. The display shows flow in cubic feet per second and total flow in acre-feet. The ultrasonic sensor is underneath the box above the water level.

Over the past winter season, the flume or weir flow rate recording device was modified so that it could be used with either the original ultrasonic sensor or a bubbler sensor. The modifications required only a small wiring change to add the OCFR central processing unit to the existing electronics provided by the bubbler manufacturer and a larger enclosure (figure 3). The bubbler sensor increases the cost of the flow recorder, but it allowed investigation into adaptability of the design.

[3] Patent pending case No. REC-3653.

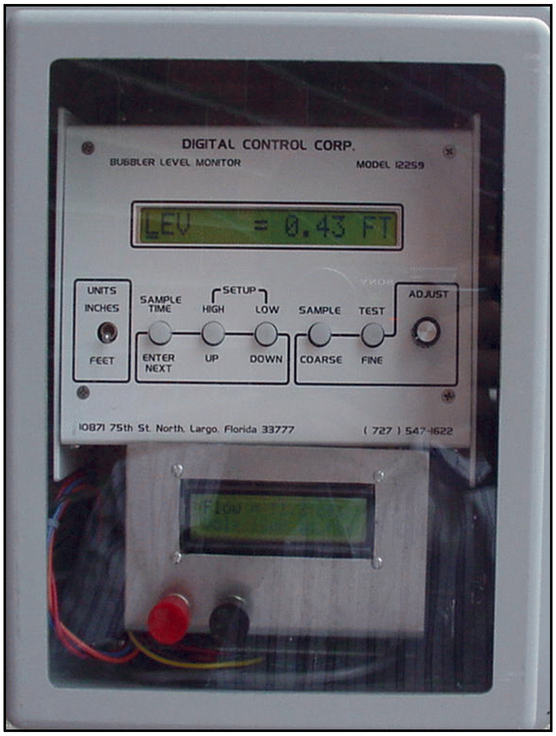

Figure 3.—Close up of the bubbler electronics on the top and the OCFR electronics on the bottom. This allows totalizing of the flow from the bubbler water level information.

Water Level Sensors

The two water level sensors being investigated are:

- Transducer-in-pipe
- High frequency cable

Both of these sensors can be used with the OCFR or other type of data logger.

Transducer-in-Pipe Water Level Sensor.—In many cases, a water level is required to compute flow through a flume or to maintain a canal at a desired level. At the time of the initial investigation, it was thought that commercially available submersible transducers were a little too expensive. Therefore, an inexpensive, nonsubmersible pressure transducer was mounted in a polyvinyl chloride (PVC) pipe to keep the nonsubmersible portion of the sensor out of the water. To construct this device, a cap is drilled and threaded with pipe threads that fit the sensor threads. The transducer is screwed into the cap from the inside, and the cap is fastened to the end of a 2-inch standard size PVC pipe (figure 4). To provide a water level reading, the pipe is fastened to a structure wall so that the transducer pressure port is submerged.

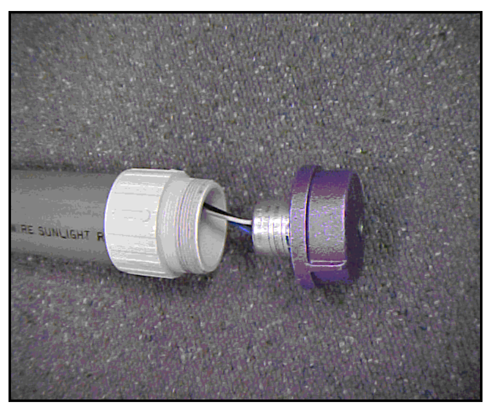

Figure 4.—Pressure transducer threaded into a pipe cap prior to attaching the cap to the end of the PVC tubing. The voltage is then transmitted to a chosen recorder.

We have recently begun investigating another less expensive submersible transducer that could potentially replace this application.

High Frequency Cable Water Level Sensor.—Under a cooperative agreement, Reclamation and Utah State University developed a cable-type water level sensor using high frequency signal reflecting techniques. This newly developed water level sensor consists of a noncoaxial cable similar to the twin-lead line used to bring signals in from a television antenna. One end of the cable is submerged in the water while a high frequency signal is generated down the cable from the electronics. The signal is reflected by the water surface back up the cable to provide information about the length of the cable from the electronics to the water surface, thus giving the water level in the channel. Figure 5 shows the sensor mounted in a clear vertical pipe in the WRRL. Further testing and development is needed because this instrument was only recently received from Utah State University.

Pipe Flow Meters

Figure 5.—Laboratory test setup of the high frequency cable water level sensor. In the foreground, the 7-foot-long coaxial cable is mounted in a PVC pipe with a relief valve at the bottom to vary the water level. Data is being recorded by the people in the background, where the electronics are located on a table.

Four low-cost flow meters are also being tested to determine their compatibility with irrigation water piping systems. There are a number of pipe flow meters available, but the majority of them are unacceptable for irrigation use because of high cost, incompatibility with untreated irrigation water, or high energy losses. Four pipe flow meters were tested:

- Two paddle-wheel-type sensors manufactured by SeaMetrics and Data Industrial (figures 6 and 7)
- A unique propeller-type meter by GF+Signet (figure 8)
- A vortex shedding meter by Fluidyne (figure 9).

In all cases, the pipelines must be flowing full and must have sufficient length of straight pipe upstream of the meters for proper flow measurement. All these meters are mounted with pipe saddles and inserted into the pipes. The SeaMetrics, Data Industrial, and Fluidyne meters must be inserted into the pipe to the proper depth for correct measurements. These meters all have digital readouts that display flow rate and accumulated flow. Data Industrial has several additional options for flow rate display. GF+Signet also has a self-contained battery for operation.

Laboratory Installation and Testing

Many of the instruments were installed and tested in the WRRL. The laboratory is the best location to develop and test new instruments, evaluate accuracy, and test aspects of use and reliability. This section discusses the WRRL facilities and instrument testing.

Figure 6.—SeaMetrics paddle-wheel flow meter with display installed on an 8-inch pipe. These meters may be used on pipes between 2 and 48 inches in diameter. (The white can is placed over the sensor to provide shade.)

Figure 7.—Data Industrial paddle-wheel flow rate sensor installed on an 8-inch pipeline. These meters may be used on pipes between 3 and 26 inches in diameter.

Figure 8.—GF+Signet propeller meter and display installed on a 10-inch pipeline. These meters may be used on pipes from 6 to 30 inches.

Figure 9.—Fluidyne vortex shedding meter and flow display which is also mounted on a 10-inch pipe. These meters may be used on pipes between 3 and 20 inches in diameter.

Open-Channel Applications

The WRRL has a model canal facility that is used to test water measurement devices and instrumentation being considered for application by irrigation districts. The model canal has many of the control and flow measurement features currently being used on irrigation canals. Initial laboratory setup provided an efficient mechanism to ensure that all software and hardware was operational before installing the instrument at the field site in Montana.

Presently, two more OCFR devices are undergoing long-term, side-by-side testing outdoors at the WRRL to ensure accuracy and reliability for future installations in an irrigation system (figure 10). Both devices are measuring and recording the water level in a bucket. These two devices have identical CPUs, with one using the ultrasonic level sensor (figure 2) and the other using a bubbler sensor (figure 3).

No laboratory testing was performed on the transducer-in-pipe water level sensor. The high-frequency cable water level sensor is currently installed in the laboratory for initial testing (figure 5).

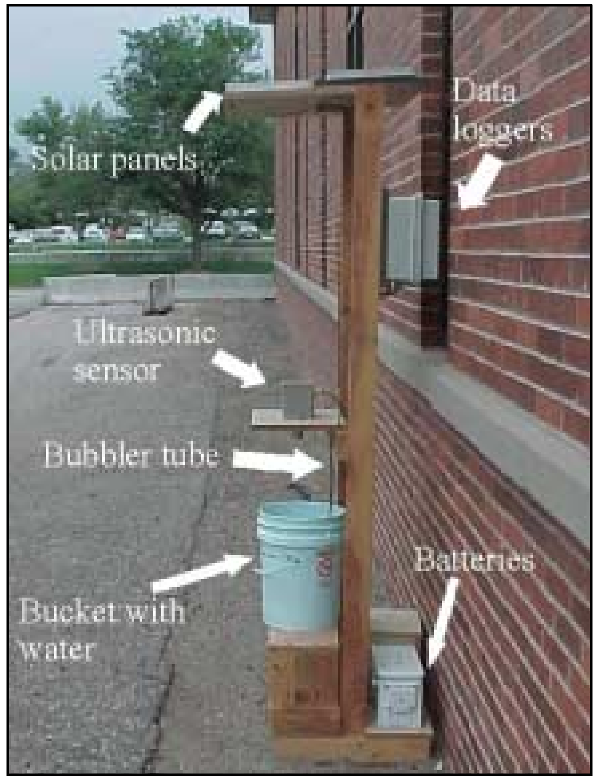

Figure 10.—Long-term, side-by-side testing of the OCFR and the bubbler system. Both instruments are sensing and recording the water level in the bucket.

Pipe Flow Meters

The pipe flow meters were individually mounted into the WRRL pipe test stand. Figure 11 shows the pipe test stand with a pipe saddle where the meters were installed. Each meter was tested throughout a range of flow rates from 250 to 750 gallons per minute. Testing was accomplished by comparing measured flow into the pipe from the laboratory venturi system to the flow rate measured and displayed by the meter. The laboratory venturi meter has been extensively calibrated using a weigh tank to an accuracy of ±2 percent. Each instrument was rigorously tested with final comparisons given in the results.

Field Installation and Testing

Laboratory testing is necessary for development of new instrumentation and accuracy testing. However, field evaluation must be performed to ensure that the instruments will operate as intended in a harsh environment.

Figure 11.—WRRL pipe test stand showing the pipe saddle on the 8-inch pipe where the flow meters were tested. The pipes in the stand are 4, 6, 8, and 12 inches in diameter.

The installation and use of these meters in the field is the main emphasis of this study. Field testing is the only way to evaluate the parameters that matter most to irrigators:

- Ease of installation, including mounting, initializing, and programming
- Ease of use during the irrigation season
- Reliability
- Sensitivity to debris, temperature, sediment, etc.

Field testing of the sensors is ongoing at East Bench Irrigation District in Dillon, Montana, with assistance from the Montana Area Office. The East Bench Irrigation District diverts water from the Beaverhead River into their canal system. The majority of the main canal has a buried membrane lining, and water is diverted from the main canal into laterals or pumped directly into pipelines and sprinkler systems. The pipelines have screened entrances. Silt, vegetation, and trash are present in the water, as is typical of many canal systems in the west.

Open-Channel Applications

Open-Channel Flow Recorder

The original OCFR, as shown in figures 1 and 2, was installed during the 1999 irrigation season and remains at that location today. The measurement system is contained in one enclosure. This allows for quick and easy installation using a simple support spanning the conveyance channel upstream of the flow measurement structure (i.e., flume or weir). The ultrasonic sensor must be pointed normal to the water surface. Programming is accomplished by entering a discharge coefficient and an offset for the head measurement into a universal flow equation programmed into the CPU. At this time, the programming is still being developed to be more user-friendly. At least once a week throughout the irrigation season, field personnel read the flow recorder and the staff gauge located at the flume. Installation, including the solar panel and battery, took about 2 hours to complete. Using conventional power may reduce installation time.

The original OCFR remained in the field over the winter to test the robustness of the instrument to varying temperatures. At the test site, temperatures range from -30 degrees Fahrenheit (°F) in the winter to about 100 °F in the summer.

The two OCFR devices currently located outside the WRRL are slated for field installation near Yuma, Arizona, in September 2000.

Water Level Sensors

***Transducer-in-Pipe* .—**Two transducer-in-pipe water level sensors were constructed in the WRRL and taken to the field site in 1999 for installation. They were originally mounted to irrigation structures using thin metal straps. This initially appeared to be sufficient, but the turbulent waters and the buoyancy force of the sealed pipe eventually caused the instruments to break free from the mounting location. One transducer was destroyed, but the other was salvaged and reinstalled. This installation was quite difficult to perform at the location chosen and took about 4 hours. Zeroing of the transducer could only be accomplished using a staff gauge located nearby. An available recorder was installed with the transducer-in-pipe sensors. Field personnel made observations of the sensor output and staff gauge readings throughout the irrigation season. To date, the transducer-in-pipe water level sensors are still operating.

***High Frequency Cable* .—**The high frequency cable water level sensor has not yet been installed in a field application. This is planned for next fiscal year if funding is available.

Pipe Flow Meters

All the pressurized pipe flow meters were installed on irrigation pipelines for the 1999 and 2000 irrigation seasons. Water is pumped into the screened pipelines from canals with algae, weeds, trash, and silt in the water, producing a realistic test situation at both pipeline test locations. The physical installation of the pipe flow meters was similar for all the meters. All the pipe flow meters required the use of a pipe saddle for mounting the sensor. The installation required drilling a 2-inch hole in the pipe before the saddle could be mounted and the meter installed. The SeaMetrics, Data Industrial, and Fluidyne flow meters required standard pipe saddles. The GF+Signet flow meter required a specialized saddle that was included with the meter. Assuming the installer had all the proper tools and parts, it would take approximately 2 hours to individually install any of these flow meters.

The four pipe flow meters were mounted on two irrigation pumping systems. At one pumping site, both paddle-wheel flow meters, SeaMetrics (figure 6) and Data Industrial (figure 7), were mounted in line in an 8-inch pipe. At the other pumping location, GF+Signet (figure 8) propeller and Fluidyne (figure 9) vortex flow meters were mounted in line in a 10-inch pipe.

The SeaMetrics and Data Industrial paddle-wheel meters and the Fluidyne vortex shedding meter had to be inserted to the proper depth in the pipe to produce accurate flow rate results. The insertion depth of the GF+Signet propeller meter is set by a saddle designed for the meter.

Programming instructions for the SeaMetrics and the GF+Signet meters was easily accomplished using the manufacturer's instructions. The programing instructions that were provided for the Data Industrial flow meter were difficult to understand, but the meter did have more flow rate display options than the other meters. The programming for the Fluidyne meter was performed via a computer with the appropriate pipe dimensions input for it to display the correct flow rate. Therefore, the programming for the vortex meter should be performed before it is installed in the field.

Field personnel monitored the displayed flow rate from each pair of meters. The meter flow rates were compared with each other and with the stated design capacity of the irrigation system. The ability of the meters to stay free of debris and vegetation was compared for all meters.

Test Results

Test results are reported as a combination of field and laboratory testing. Some instruments have limited laboratory data to report because they were mostly used in the field. Table 1 provides a summary of the findings. The overall rating includes general overall reliability aspects of the instruments from the perspective of the field personnel. There is no intent to compare pipe flow meters with open-channel meters even though all results are given in the same table.

Open-Channel Applications

Open-Channel Flow Recorder

Laboratory results for the OCFR devices are limited to one season of testing. In the side-by-side test between the device with the ultrasonic sensor and the device with the bubbler sensor, the totalized flow rates have been almost identical.

The OCFR has been used in the field for both the 1999 and 2000 irrigation seasons. The original CPU worked for the 1999 irrigation season but failed during the winter. The replacement CPU has been more reliable and has operated through the 2000 irrigation season with no difficulties. Field comparison of the flow data gathered with the OCFR versus the computed flow from the staff gauge indicated less than a 5-percent variation. Unfortunately, no other flow rate comparisons were made at the field site. Because the ultrasonic sensor is above the water, most types of debris do not pose a problem with this sensor.

Table 1.—Results from laboratory and field tests of each device with cost comparisons
(The ratings were based on a range from 1 to 10, with 10 being the best possible rating)

Instrument	Accuracy	Ease of installation	Ease of programing	Ease of use	Debris sensitivity	Approx. cost[1] ($)	Overall rating
			Open-channel applications				
OCFR w/ultrasonic	8	6	5	8	10	950	7.4
OCFR w/bubbler	8	5	4	8	9	1,750	6.8
			Water level sensor				
Transducer-in-pipe	8	4	N/A	8	6	300	6.2
			Pipe flow meters				
SeaMetrics	7	6	8	8	9	800	7.8
Data Industrial	7	6	4	8	9	900	6.8
GF+Signet	7	6	8	8	7	850	7.2
Fluidyne	8	6	6	8	3	900	6.2

[1] This cost includes the price of materials, such as the pipe saddles. None of the costs include power supply.

As table 1 shows, the OCFR is easy to install and use, but programming the OCFR could be simpler. The code is still under development, with simplicity the main goal. The OCFR with the ultrasonic sensor was cost effective at less than $1,000; however, the water level sensor chosen for use with the OCFR can produce quite a difference in price. Fast Bench Irrigation District has been extremely pleased with the results.

Water Level Sensors

Transducer-in-Pipe

The transducer-in-pipe water level sensor was only installed in the field. As table 1 indicates, there may be some difficulty in installation. Problems are related both to ensuring the pipe is sealed and to mounting. Because the transducer is nonsubmersible, water must be kept out of the pipe, including condensation. Buoyancy forces and flow conditions must be considered, keeping mounting depths shallow (below 6 to 8 feet) and site turbulence to a minimum.

Field measurements indicated that both of the transducer-in-pipe installations were accurate to within 0.02 foot of the staff gauge reading.

The nonsubmersible transducer is considerably less expensive than a comparable submersible transducer in rigorously sealed enclosures. More expensive submersible pressure transducers typically work reliably for 3 to 7 years. This is the baseline that will be used to determine if this alternative will continue to be successful.

High Frequency Cable

The original Utah State University laboratory tests of the prototype high frequency cable water level sensor indicated that it operated with a resolution of 1 millimeter. Initial testing in the WRRL has uncovered a problem with electrical noise that precludes proper functioning of the sensor. Also, the electronics of the prototype device must be properly enclosed before field testing can be considered. In addition, investigation into modifying the length of the sensor is needed. Further development is ongoing to resolve these issues. Potentially, the high frequency cable could be used as an alternate water level sensor for the OCFR or other recording device.

Pipe Flow Meters

The pipe flow meters were all tested for accuracy in the WRRL pipe test stand (figure 10). Table 2 shows the maximum error within ±5 percent for all the meters tested. Most errors were within the measurement accuracy of the laboratory venturi meter of ±2 percent. The readout on SeaMetrics, GF+Signet, and Data Industrial fluctuated quite a bit. Therefore, a lower accuracy value was given to these meters, but the average of the readings was very good. The Fluidyne meter did not fluctuate significantly because of extended averaging times in the processing before the reading was displayed. GF+Signet is presently modifying their flow meter so that it averages over a longer time period and will likely fluctuate less.

Table 2. - Results for the WRRL tests of the pipe flow meters showing the maximum errors

Flow meter	Meter flow rate (gallons per minute)	Venturi flow rate (gallons per minute)	Maximum error (percent)
SeaMetrics	221	211	4.7
Data Industrial	540	566	-4.5
GF+Signet	343	358	-4.3
Fluidyne	259	272	-4.7

These results are certainly adequate for most irrigation applications. Some adjustments could be made to the coefficients in the flow equations if it was thought necessary.

Field testing for pipe flow meters has just completed a second irrigation season. As shown in table 1, the meters were all easy to install. The Data Industrial meter was confusing to program, and the Fluidyne meter should be programmed before going to the field to install. The SeaMetrics meter initially displayed values that did not agree with the irrigation system capacity, but it was discovered that the meter did not have the proper insertion setting.

Throughout the 2 years of service, the meters have not exhibited significant problems in the field other than varying sensitivity to debris handling. The SeaMetrics and the Data Industrial paddle-wheel-type flow meters have operated through the 1999 and 2000 irrigation seasons without experiencing difficulties with debris. Both the Fluidyne and GF+Signet flow meters stopped displaying a flow rate 1 month into the 1999 irrigation season. When the meters were removed, vegetation was clogging both the propeller of the GF+Signet and the sensing element of the Fluidyne meter. After cleaning and reinstalling the GF+Signet meter, it performed with no further problems through the remainder of the 1999 and the entire 2000 seasons. The Fluidyne meter has continued to have problems handling debris.

The meters compared favorably to the design capacity of the irrigation system, which was the only field flow rate comparison made. Costs were almost the same for all the pipe flow meters.

Conclusions

Testing of the newly developed OCFR has proven its applicability and cost effectiveness for use with water measurement devices and any number of water level sensors. The device is easy to install and use, reliable, and cost effective compared to other combined data logging and sensor systems on the market today.

Each of the water level sensing devices has advantages and disadvantages. The important point is to select the instrument appropriate for each individual irrigation application.

All the pressurized pipe flow meters performed adequately in the field. However, vegetation is still a concern for most of these types of applications.

Future Work

Several items of future work are being considered if funding is available. Many irrigation districts have expressed an interest in the OCFR. Additional field test sites would allow investigation of long-term performance in the OCFR under varying environmental conditions. Some work is needed to refine the software that operates the OCFR. We would also like to investigate a low-cost, commercially available, submersible transducer for measuring water levels. Continued development of the high frequency water level sensor is needed before it would be applicable for field sites.

References

[1] "Irrigation Flow Measurement – Instrumentation Development Part I," Stringam, Blair L. and Kathleen H. Frizell, Bureau of Reclamation, *Water Operation and Maintenance Bulletin*, September 1999.

"ALL HAZARDS" EMERGENCY ACTION PLANNING FOR DAM OWNERS: AN EFFICIENT EMERGENCY ACTION PLAN FORMAT AND INCIDENT SEVERITY CLASSIFICATION SYSTEM[1]

by Barbara R. Schuelke[2], Mary Ahlstrom[3], Robert K. McGovern[4], Larry K. Nuss[4], and Chris Veesaert[5]

Abstract

The dam owner's ability to recognize a potentially hazardous situation, classify its severity, and provide early notifications to potentially impacted jurisdictions are key elements in implementing an effective emergency response and in reducing the dam owner's liability. An efficient Emergency Action Plan (EAP) format has been developed that the dam owner can use as a guide when addressing these and other elements for all types of emergencies and potentially hazardous situations at dams. The EAP format is a "fill-in-the-blank" template (EAP template) that prompts the user for information and therefore is adaptable to any type of dam.

The EAP template introduces a method for classifying the severity of incidents that was developed using the assumption that any adverse impact that originates or occurs at the dam or on the dam owner's property represents a liability to the dam owner. Therefore, this incident classification system offers great flexibility when classifying the severity of "all hazards," whether the impacts are minor or major, to population, structures, or the environment, or upstream or downstream from, adjacent to, or at the dam. A matrix chart that will assist the dam owner in recognizing and classifying the severity of potentially hazardous situations was also developed for the incident classification system. To address notifications, the EAP template uses notification flowcharts that display the appropriate agencies and jurisdictions and the order in which they would be contacted.

Introduction

Based on experience gained during developing and exercising EAPs for United States Bureau of Reclamation (Reclamation) dams, the authors have developed an EAP template. The

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template can be used for the full range of facilities, large or small, and for either concrete or embankment dams. The EAP template also introduces an incident severity classification system that can be used to classify the severity of all types of emergencies or potentially hazardous situations that originate or occur at dams or on the dam owner’s property. This paper discusses the EAP template, with emphasis on the format, incident severity classification system, triggering events, notifications, and expected actions. The use of the term, "dam owner," throughout this paper is meant to include the dam owners and operators.

Emergency Action Plan

Format

Making decisions during emergency situations and dam failures is difficult for even technical experts. The goal of the authors was to facilitate decisionmaking by developing an EAP format and incident severity classification system that is easy to use and that provides for early notifications to potentially affected jurisdictions during hazardous situations. The EAP template leads the decisionmakers through a logical series of efficient charts aimed at reducing potential adverse impacts and consequently reducing the dam owner's liability. The user customizes the "fill-in-the-blank" template with the specific attributes of the dam owner's organization and the facility. The format contains the following sections:

I. *General guidelines* – This section consists of an introduction, the purpose and scope, a discussion of the responsibilities and authorities, and a paragraph in which to discuss the applicable requirements for updating and exercising the EAP.

II. *Facility information* – This section provides a description of the facility, attendance, accessability, monitoring equipment, primary and backup communications systems, and hazard analysis.

III. *Response procedures* – This section presents the Incident Command System functions, the definitions of the severity classification system, a decision tree, a chart to assist with recognizing and classifying the severity of problems, notification charts, and an expected actions chart.

IV. *Maps* – This section presents a location map, the inundation maps, and a brief description of the inundation study and inundation area.

V. *Annexes* – The annexes present the forms used for official reporting and documentation, the communications directory, a list of contractors and suppliers, the reference list, and the certification page.

Incident Severity Classification System

While downstream flooding due to large releases or dam failure is usually the main event that dam owners are concerned about, there are other situations that could result in minor or major impacts to population, structures, or the environment. The impacts may also occur upstream, adjacent to, or at the dam rather than downstream. The following incident severity classification system assumes any adverse impact caused by a situation at the dam or on the dam owner's property represents a liability to the dam owner. Therefore, the classification system offers great flexibility when classifying "all hazards." "All hazards" encompasses any situation that may cause *minor or major adverse impacts* to *population, structures, or the environment*, whether the impacts are *upstream or downstream from, adjacent to, or at* the dam. The urgency of the situation is the major factor in classifying the severity of the situation.

The incident classification system uses the following three levels of severity in which the dam owner may classify unusual situations:

Internal alert – No adverse impacts are anticipated, and no external (outside the dam owner or operator organizations) assistance is needed to manage the situation.

Developing situation – There is potential for adverse impacts, or external assistance is needed. The situation is progressing slowly, some time is available for analyses, decision-making, and mitigation efforts.

Imminent situation – There are immediate or inevitable adverse impacts, or external assistance is needed. The situation is progressing rapidly, no time is available, or the situation can not be mitigated.

If the user can answer "no" to the following two questions, the situation can be classified as an internal alert.

(1) Is external assistance needed?

(2) Are there potential, inevitable, or immediate adverse impacts to population, structures, or the environment?

If the answer to one or both of the questions is "yes," the user proceeds to the *assessing unusual situations* matrix (discussed in the following section) to assist with classifying the situation into a developing situation or imminent situation. These questions and decision process are displayed in a decision tree within the EAP template and also in figure 1.

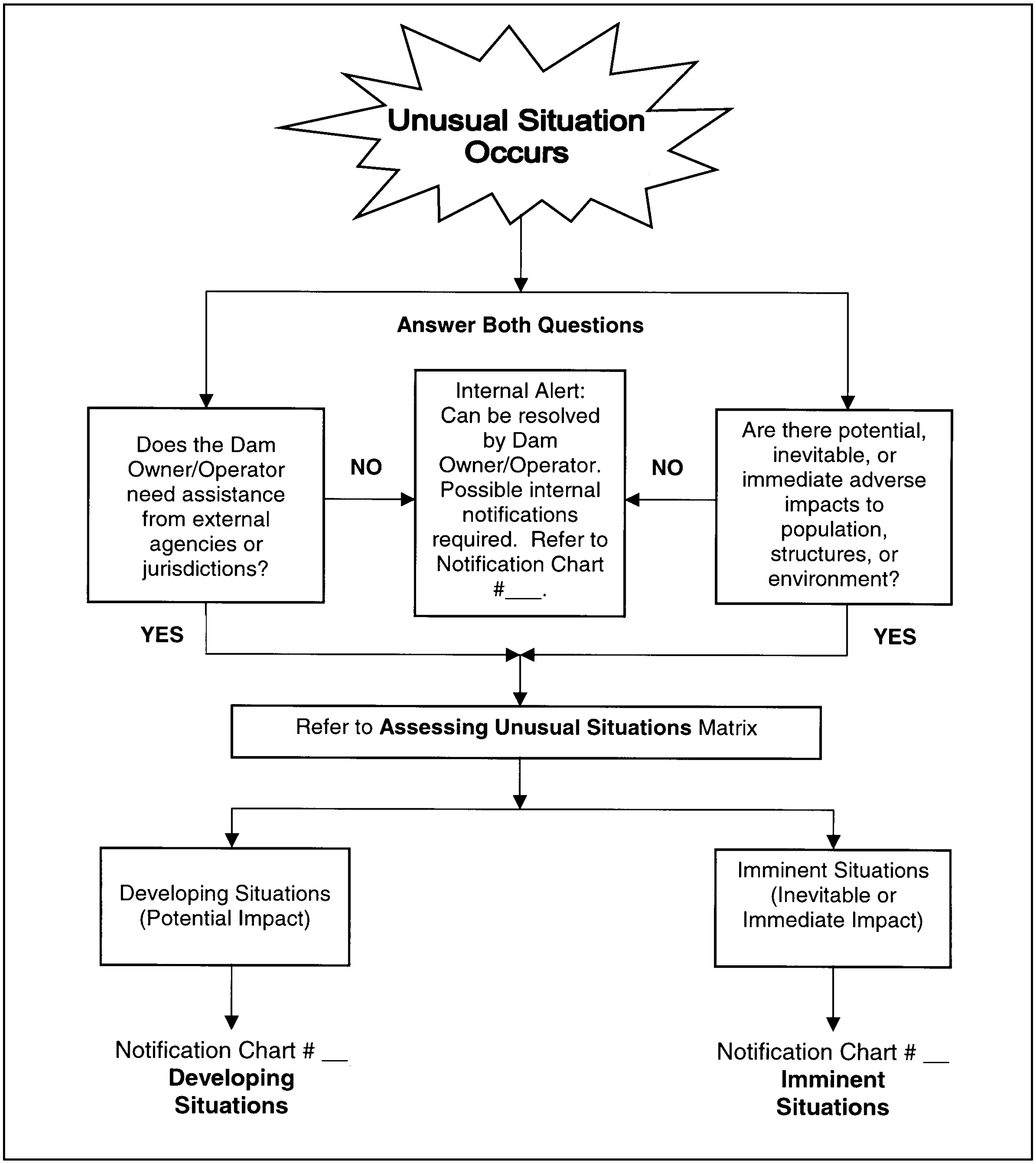


Figure 1.—Decision tree.

The definitions for developing and imminent situations apply to any situation where external assistance is needed or when there is potential for adverse impacts, whether the impacts might be:

- Minor or major – recreational users such as fishermen, campers, rafters, or an entire community

- Upstream, downstream, adjacent to, or at the dam – a campground adjacent to the reservoir that is threatened by a wildfire or a community or fishermen downstream from the dam

or impacts might affect:

- Population, structures, or the environment – people, buildings, fish, wildlife, or water quality that are threatened by hazardous material spills, flooding, fire, criminal actions, etc.

The incident classification system calls upon the dam owner to provide factual information to potentially impacted jurisdictions as soon as it is determined the potential for adverse impacts exists and at regular intervals thereafter. The jurisdictions have the responsibility to consider the situation at the dam along with other factors and sources of impact when determining and implementing their response actions in accordance with their legal authority.

Triggering Events

The triggering events assist dam operations personnel in deciding if there is a problem at the dam and in classifying its severity. They describe problems that are developing; therefore, each problem has a described observation or "triggering" event for each of the levels of incident severity being used.

An "Assessing Unusual Situations" matrix chart has been developed to assist the dam owner and operating personnel in distinguishing between developing and imminent situations. The single-sheet chart contains a general list of potential structural and hydrologic problems for both concrete and embankment dams. Additional problems (such as hazardous materials spills, accidents, fires, and impacts to fish and wildlife) that are not typically failure modes are also addressed. Occurrence of these situations would likely cause adverse impacts and require assistance and external notifications. The problems that do not apply to the specific facility can simply be deleted.

The body of the matrix describes the triggering events for developing and imminent situations and is a baseline which is supposed to be customized for a specific dam. For example, specific reservoir elevations, reservoir rate-of-rise criteria, and safe channel capacity data can be added to the chart for a specific facility. Although the chart is intended to fit on one large sheet, for purposes of this paper, the matrix for developing situations is shown as figure 2, and the matrix for imminent situations is shown separately as figure 3.

Notifications

Early notifications are key in allowing potentially impacted jurisdictions to implement appropriate response actions. Reducing the dam owner's liability depends on the dam owner to provide timely, factual, and up-to-date information about the situation at the dam to the potentially impacted or involved jurisdictions. An outline of the type of information that should be given in a notification is presented in a prescripted message in the EAP template. During development of Reclamation's EAPs, a pattern was observed in which internal notifications (within the dam owner's and operator's organizations) and external notifications (to potentially impacted and involved authorities) were typically used in three ways:

(1) Internal notifications only

(2) Internal and external notifications with internal notifications occurring first

(3) Internal and external notifications with external notifications occurring first

Therefore, the levels of incident severity defined previously are integrated with notifications. Internal notifications are made during an internal alert (although external notifications are not prohibited). Both internal and external notifications are made during developing and imminent situations. Internal notifications would be made first for a developing situation, and external notifications would be made first for an imminent situation. The EAP template provides two examples of notification flowcharts to express this distinction. Many notification flowcharts may not be as complicated as the examples, and some users may be able to show all the information on one sheet or perhaps on one chart.

Expected Actions

The expected actions describe actions to be taken in response to an unusual situation or emergency event at the dam. The EAP is the response plan for the facility and its owner and operator. Regardless of the type and severity of an emergency, the persons responsible for making decisions and the key response actions taken within the dam owner's organization are usually the same.

The EAP template presents a matrix chart that lists the key response actions the dam owner would implement during any emergency and at any level of severity. These actions can be expanded upon and customized to fit the complexity of the facility. The response actions are categorized by incident command system functions, which is the accepted standard in the

Determine if a situation is developing or imminent, then refer to the appropriate notification chart	
Problem	Developing situations (minor or major) 1) There are **potential** adverse impacts, **OR** 2) The dam owner/operator needs assistance from external agencies or jurisdictions (**Qualifiers – potential threat, progressing slowly, can mitigate, some time is available, “Oh My!”**)
Embankment piping	Significant new or increasing seepage or sandboils downstream from the embankment. Significant new or larger sinkhole(s) or crest settlement. Reservoir is falling without apparent cause (such as outlet or spillway releases). New, stable, or slowly increasing seepage rates transporting some sediment.
Embankment cracking	Cracks significantly increased in length, width, or offset. Cracking is the beginning of a large slide. Refer to "embankment deformations" below.
Embankment deformations	Large deformations or slides. Potential for breach of dam.
Embankment overtopping	The reservoir is projected to rise above the dam crest. Potential for embankment erosional failure or piping.
Movement of concrete section (sliding or overturning)	Significant new or enlarged cracks or offsets. May be accompanied by abnormal instrumentation data (decreased drain flows, increased uplift pressures) and/or increased seepage through structure.
Failure of spillway gates, outlet works, or supporting structures	Significant new or enlarged cracks or offsets. Damage may occur with releases expected to exceed the design limit of ___m^3/s or reservoir elevation of ___ m. Significant changes in flow conditions. May by accompanied by significant erosion occurring in spillway or outlet works.
Spillway and outlet works releases	Releases expected to exceed (or contribute to streamflows which exceed) safe channel capacity of ___ m^3/s.
Concrete dam overtopping	Overtopping may occur. Foundation or abutment erosion may occur, which could lead to dam failure.
Earthquake occurs	Refer to indicators for embankment piping, embankment cracking, embankment deformations, and movement of concrete section.
Abnormal instrumentation data (also address early warning system, if applicable)	Readings outside expected range and data confirmed.
Other problems: Equipment failure, wildfire or structural fire, criminal action, accident, loss or negative impact to fish/wildlife, oil or hazardous material spill or release, etc.	**Potential** adverse impacts, progressing slowly, mitigation is possible, some time is available before adverse impacts.

Figure 2.—Assessing unusual situations matrix (developing situations).

Determine if a situation is developing or imminent, then refer to the appropriate notification chart	
Problem	Imminent situations (minor or major) 1) There are **immediate or inevitable** adverse impacts, **OR** 20 The dam owner/operator needs assistance from external agencies or jurisdictions (**Qualifiers – immediate or inevitable threat, progressing slowly, cannot mitigate, no time is available, "Oh No!"**)
Embankment piping	Rapidly increasing seepage and/or transporting large quantities of materials. Sand boils rapidly increasing in size or number and/or rapidly increasing flows. Failure expected. Sinkhole(s) or settlement rapidly increasing in size or number. Failure expected. Whirlpool or other signs of the reservoir draining rapidly through the dam or foundation. Rapidly increasing seepage transporting large amounts of sediments. Failure expected.
Embankment cracking	Rapidly increasing flow through crack(s) and transporting materials. Failure expected. Refer to "embankment deformations" below.
Embankment deformations	Large deformation and breach of dam is imminent or occurring.
Embankment overtopping	Overtopping is imminent or occurring. See "embankment piping" information. Failure expected.
Movement of concrete section (sliding or overturning)	Movement of concrete section(s) with water flowing through cracks and section(s) or breach of the dam.
Failure of spillway gates, outlet works, or supporting structures	Rapidly increasing cracks or offsets. Failure expected. Failure may occur with releases exceeding the design limit of ___ m^3/s or reservoir elevation of ___ m. Major and rapidly developing erosion or headcutting. Breach expected.
Spillway and outlet works releases	Releases exceeding (or contributing to streamflows which will exceed) safe channel capacity of ___ m^3/s.
Concrete dam overtopping	Overtopping and major foundation or abutment erosion is rapidly occurring. Movement is occurring. Failure is expected.
Earthquake occurs	Dam is failing, will fail, or has failed due to vulnerability of facility and magnitude of earthquake. (Failure predicted by analysis.)
Abnormal instrumentation data (also address early warning system, if applicable)	Early warning system instrumentation indicates failure of the dam or structure(s) or releases exceeding (or contributing to streamflows which will exceed) safe channel capacity of ___ m^3/s.
Other problems: Equipment failure, loss or negative impact to fish/wildlife, oil/hazardous material spill or release, wild/structural fire, criminal action, accident, etc.	**Immediate or inevitable** adverse impacts, progressing rapidly, mitigation not possible, no time is available before adverse impacts occur.

Figure 3.—Assessing unusual situations matrix (imminent situations).

response community. The user is supposed to customize the column headings with the people or organizations that are responsible for implementing the response actions. The body of the matrix is then filled in with either check marks or notes.

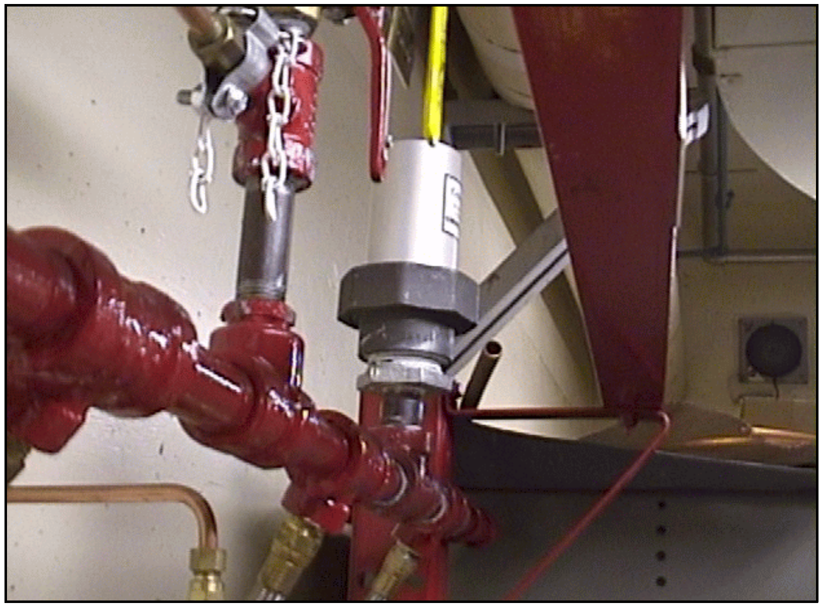
Summary

The EAP template, incident severity classification system, and matrix charts offer a good baseline that can be customized to fit the needs of most dam owners. EAPs are living documents—they should be updated annually, following actual emergency events and emergency exercises. All or portions of the EAP template discussed herein could be used to develop an EAP or to revise an existing EAP.

WARNING ODOR ADDED TO CO_2 SYSTEM

by Jim Canning, Region Safety Engineer

The Curecanti Field Division of the Upper Colorado Region Power Office has installed a system to add odor on the CO_2 Fire Protection piping at the Morrow Point Power Plant. The system will inject an odor-producing agent into the carbon dioxide stream any time the system is discharged. Carbon dioxide is a colorless and odorless gas and may linger in the untended plant after a discharge. The new system will provide a strong wintergreen odor, warning the employees that there might be a problem which would require testing of the air prior to unprotected entry. The rest of the plants in the division will be modified in a similar fashion by the end of this fiscal year. If you would like more information on this system, contact Gary McDermott, 970-249-5278, at the Morrow Point Power Plant.



ACTIVITIES OF RECLAMATION CLIMB TEAMS

by Dan Drake, Technical Service Center, Hydraulic Equipment Group

Bureau of Reclamation (Reclamation) Climb Teams inspect facilities that are difficult or otherwise impossible to access or would require significant expenditures in time and money using conventional inspection techniques such as cranes and man baskets.

Rescuing an injured climber off the face of Hoover Dam.

The climb teams provide expertise and equipment to access difficult areas to allow for inspection, evaluation, installation of monitoring instruments, nondestructive testing, and material sampling. Climb teams also facilitate geologic mapping for high-angle surfaces such as faces of concrete dams, spillways of dams, dam outlet structures and tunnels, rock faces of dam abutments, powerplant penstocks, and other confined space environments where climbing is required, such as interior or exterior structural and architectural components of buildings and dam spillway and outlet control gates.

One victim, in a vertical shaft in a confined space, is placed in a SKED litter device and hoisted out of the shaft.

Climb teams use alpine climbing techniques and equipment, in combination with industrial inspection equipment, to provide the safest and most efficient access to the best possible inspection positions and instrumentation, test, or sampling points. All procedures and equipment used for climb team inspections conform to current Occupational Safety and Health Administration standards, International Union of Alpine Association standards, and Reclamation Safety and Health Standards.

Each team member is thoroughly trained in climbing techniques and their application in conjunction with industrial inspection requirements, standards, and safety procedures. The climb teams consist of geologists, technicians and geotechnical staff, civil, structural, and mechanical engineers.

Using a pickoff strap to connect injured climber to descent device of rescuer.

After the scope of work is understood, the job is scheduled, the job hazard analysis (JHA) and job plan are written, reviewed, and commented on by field personnel, including field safety officers, climb team members on the job, and the Technical Service Center Safety Officer, George Taylor. When the climb team arrives at

A high-angle rescue session at Red Rock Canyon National Conservation Area.

the job site, the JHA and job plan are reviewed, and the Hazardous Energy Control requirements are discussed with the field personnel, then implemented. Only then does the inspection begin. After the inspection is completed, the hazardous energy control *Lock-Out, Tag-Outs* are removed, and an exit interview is held. As part of ongoing training, climbers from all over Reclamation participated in a high-angle rescue and advanced first aid class in April 2000. This training was held in Las Vegas, Nevada, with some of the sessions at Red Rock Canyon National Conservation Area and some on the downstream face of Hoover Dam. The course was directed toward the first aid and rescue of an injured climb team member.

Rescue of a victim using a litter and two climbers.

One exercise involved lowering and raising a litter with two litter tenders (climbers), which included setting up anchors with sufficient strength for a load larger than normal.

Another exercise was to rescue an *injured* climber off the face of Hoover Dam using a pickoff strap which is used to connect the *injured* climbers harness to the descent device of the rescuer. After the *injured* climber is attached to the rescuers ropes, the rescuer disconnects the *injured* climber from his/her ropes and descends down the face of the dam, controlling the speed of both the *injured* climber and the rescuer.

At Hoover Dam, a climber was partway up the face of the dam when he was *injured*. The rest of the group rigged equipment to raise a litter with two litter tenders to rescue the *injured* climber. This involved stabilizing the victim, securing him in the litter, and lowering the litter, *victim*, and two litter tenders.

One *victim* was found in a vertical shaft in a confined space. This *victim* had to be accessed, treated for first aid, placed in a SKED litter device, and hoisted head first out of the shaft.

The final exercise consisted of three *victims* with various injuries in various locations. One *victim* was hanging on a cliff face, one *victim* was on the upper edge of the cliff, and one *victim* was located at the top of the cliff. The rescuers had to reach the *victims*, stabilize them, administer first aid, and transport them to a safe place.

First aid rescue of injured team member on the upper edge of a cliff.

HOW TO KEEP BATS OUT OF YOUR GATE HOUSE

Unless your name is Dracula, chances are that you do not appreciate the exotic fertilizer that bats leave in your gate house or spending precious maintenance dollars to remove it. Granted, all creatures in this world are entitled to their own habitat. However, in this era where workers should be concerned about Rabies and Hanta Virus (since bats are really just flying mice), dealing directly with bats in an environmentally friendly way is critical. *Water Operation and Maintenance Bulletin* No. 157, issued September 1991, has some helpful information regarding bat control and basic facts to dispel rumors you may have heard or movies you might have seen. So, why are we rambling so much about bats?

At Horse Mesa Dam, on the Salt River in Arizona, the maintenance personnel for the Salt River Project had a difficult time dealing with the pungent odor of bat droppings when it came time to inspect or perform operations and maintenance in the gate house for their fixed-wheel spillway gate. The excrement not only collected on the beautiful concrete floor, constructed by the Bureau of Reclamation in 1936, but also created a mess on the mechanical hoist equipment for the gate. Staff at the dam cut plywood panels for the floor openings of the hoist chain for the gate. Expanding foam was sprayed to seal the annular spaces between the plywood and the concrete deck. Barring an assault from bats using power tools, this prevention scheme should suffice until the next flood occurs on the Salt River and requires major releases, usually a 10-year cycle.

Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

The purpose of this bulletin is to serve as a medium of exchanging operation and maintenance information. Its success depends upon your help in obtaining and submitting new and useful operation and maintenance ideas.

Advertise your district's or project's resourcefulness by having an article published in the bulletin—let us hear from you soon!

Prospective articles should be submitted to one of the Bureau of Reclamation contacts listed below:

Jerry Fischer, Technical Service Center, ATTN: D-8470, PO Box 25007, Denver, Colorado 80225-0007; (303) 445-2748, FAX (303) 445-6381; email: jfischer@do.usbr.gov

Vicki Hoffman, Pacific Northwest Region, ATTN: PN-3234, 1150 North Curtis Road, Boise, Idaho 83706-1234; (208) 378-5335, FAX (208) 378-5305

Dena Uding, Mid-Pacific Region, ATTN: MP-430, 2800 Cottage Way, Sacramento, California 95825-1898; (916) 978-5229, FAX (916) 978-5290

Albert Graves, Lower Colorado Region, ATTN: BCOO-4846, PO Box 61470, Boulder City, Nevada 89006-1470; (702) 293-8163, FAX (702) 293-8042

Don Wintch, Upper Colorado Region, ATTN: UC-258, PO Box 11568, Salt Lake City, Utah 84147-0568; (801) 524-3307, FAX (801) 524-5499

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