WATER OPERATION AND MAINTENANCE BULLETIN

No. 183 March 1998

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UNITED STATES DEPARTMENT OF THE INTERIOR
Bureau of Reclamation

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: *New Waddell Dam and completed breach in historic Waddell Dam.*

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

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RECLAMATION EXPANDS THE CAPABILITIES OF ITS COMPUTERIZED FLOOD MAPPING PROGRAM

by Ron Miller[1], Kurt Wille, Diane Williams, and Doug Clark

In the December 1996 issue of the *Water Operation and Maintenance Bulletin*, the Bureau of Reclamation (Reclamation) announced that it had adopted new standards for producing dam failure and flood release inundation maps. These standards were in response to Commissioner Beard's directive to take reasonable and prudent actions to ensure the safety of the public and to protect environmental resources potentially affected by incidents at our facilities. Inundation maps, descriptions of potentially flooded areas, tables showing travel times, and other pertinent information are necessary for local emergency management officials to warn and evacuate possibly flooded areas.

Since that time, Reclamation's Remote Sensing and Geographic Information Group (RSGIG) has expanded its suite of flood mapping capabilities. This work has been subdivided into two tasks. The first task is production of a standard map product that can be used for standard operating procedures (SOP), emergency action plans, and risk assessments. The second task is analysis of Topologically Integrated Geographical Encoding and Referencing (TIGER) System census data. Analysis of affected critical infrastructure as well as social and economic impacts is also either under development or under consideration. These mapping and analysis efforts will potentially make significantly more data available to emergency managers than they have had previously. Moreover, since these data can be distributed in digital form on CD-ROM, users can make use of them interactively. Users will be able to locate features on the landscape, set up queries, experiment with "what-if" scenarios, and perform modeling functions.

For the purposes of inundation mapping, hydraulic engineers estimate potential dam breach and operational flood boundaries using the DAMBRK model developed by the National Weather Service (NWS). In addition, the DAMBRK INTERFACE (DBI) software, which was developed by Reclamation's Mid-Pacific Region Geographic Information System (GIS) Service Center, is also being tested and has actually been used in several DAMBRK studies. DBI is an Arc/Info based package designed to utilize GIS analytical capabilities to provide input data for the NWS DAMBRK finite difference model. A toolkit of UNIX scripts, Arc Macro Language (AML) routines and graphical user interface menus has been designed to work within the GIS environment. The digital elevation model and related ancillary data are used to construct transects required by the model. The incorporation of GIS technology makes "what-if" scenarios less cumbersome and reduces the subjectivity of deriving transect elevations and widths from topographic maps. Resulting output is in georeferenced digital

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form. These modeled inundation boundaries are delivered to RSGIG. If DBI software is not used, two additional steps are necessary. First, the hydraulic modeler must draft the inundation boundary onto quad sheets, and, second, the drafted output must be digitized in the RSGIG laboratory.

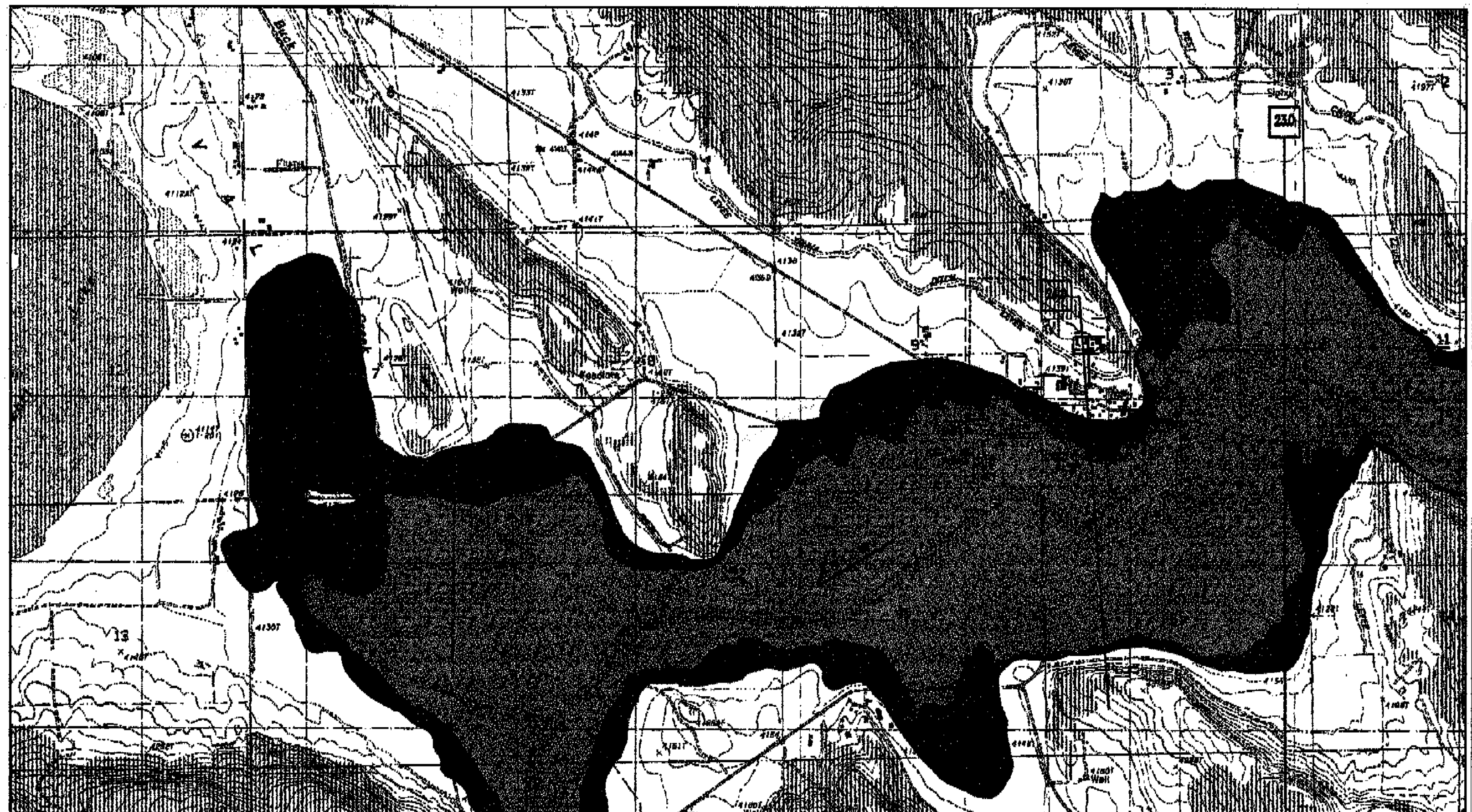
The flood inundation boundaries constitute the input data for the RSGIG "Dam Failure/ Operational Release Automated Mapping Program" (AMP) developed in house. The AMP is a fully automated collection of applications written in AML to guide the flood mapping process from start to finish. Major steps include:

A) Development of vector data set
    1. Generate registration tic files
    2. Create 7.5 minute U.S. Geological Survey (USGS) quadrangle boundaries
    3. Digitize, edit, and attribute inundation boundaries
    4. Digitize, edit, and attribute cross-sections
    5. Map panel index coverage creation and attribution
B) Development of 7.5 minute digital raster graphics (DRGs)
    1. Scan quadrangle
    2. Initiate DRG registration and clipping
    3. Create a DRG mosaic
    4. Develop map panel index clipping
C) Map composition
    1. Solid fill inundation polygons and place on DRG background
    2. Link flood and flow data to visible cross-section lines
    3. Create an index map relating each map panel to the entire flood zone
D) Data archiving
    1. Compress and backup completed mapping project
    2. Archive and unarchive finished projects

It is also possible for the AMP to use existing SOP paper maps as input data. In these instances, the existing SOP inundation maps are color-scanned to produce digital images, registered to the related DRGs, and used as a template for onscreen digitizing.

The AMP application ensures that each flood mapping project is completed in an ordered, consistent, and efficient manner. Quality control procedures are in place at major junctures of the suite of programs. AMP map compositions become part of the SOP manuals distributed by Reclamation. Figure 1 is a black and white rendering of a standard SOP map produced by D-8260.

A second advance in inundation analysis is the calculation of resident populations living in the inundation zone. Reclamation recently gained access to TIGER files census block data from the U.S. Census Bureau that were reprocessed and put into Arc/Info format by the Environmental Protection Agency's (EPA) Office of Information Resources Management. These files contain 1990 total resident population at the block level.



Miles from Gerber Dam	Summary Data				
	Water surface elev.¶	Max. depth above water surface¶	Arrival time of leading edge	Arrival time of peak flow	Maximum flow
23.0	4107 ft	23 ft	8 hr 06 min	1 day 3 hrs	63,700 cfs
24.0	4107 ft	20 ft	8 hr 54 min	1 day 3 hrs	54,100 cfs
23.0	4107 ft	14 ft	NA	1 day 22 hrs	18,000 cfs
24.0	4107 ft	13 ft	NA	1 day 23 hrs	17,600 cfs

¶ Water surface as shown on USGS 7.5" quadrangle maps.

Figure 1.—Standard SOP map product.

A "block" is the smallest geographic unit for which the U.S. Census Bureau gathers demographic data. These blocks are usually "small areas bounded on all sides by visible features such as streets, roads, streams, and railroad tracks, and by invisible boundaries such as property lines, legal limits, and short imaginary extensions of streets and roads" (*Technical Documentation: TIGER/Line Census Files*, 1992). The average population size of a census block is about 100 persons, but there can be considerable variation.

An extensive set of AML programs has been developed to capture, integrate, reproject, and analyze these data to produce tables of the estimated numbers of persons living in the inundation zone by cross-sectional distance and leading edge arrival time. These basic data also become one of the inputs for population at risk and loss of life assessments. Figure 2 is a plot of census blocks in the inundation zone in proximity to Miles City on the Yellowstone River in Montana.

Emergency officials require information about a wide variety of data themes in order to manage an emergency incident adequately. In recognition of this, Reclamation has begun to gather a variety of other attributed data themes. For instance, persons at risk are often crossing bridges, camping in recreation areas, or traveling on roads. Knowledge of which of these will be inundated is vital for purposes of evacuation. These themes have been gathered from the U.S. Department of Transportation via the Federal Emergency Management Agency (FEMA) and from EPA. Knowledge of the location of other transport facilities is also vital because they can both bring in supplies and assist in evacuation efforts. The location of airports has been provided by FEMA, and the rail network comes from EPA sources.

During an emergency crisis, the location of and information about certain critical facilities is also vital. In view of this, Reclamation is gathering location and attribute information on hospitals, including name, address, number of beds, existence of a blood bank, total number of registered nurses, existence of burn care units, and so on. Reclamation is also gathering information on schools, communication towers, and military installations. If funding becomes available, these basic data can be provided on CD-ROM to Reclamation area offices to assist them in their emergency management efforts. Figure 3 is a plot of critical infrastructure in the flood inundation zone near Miles City, Montana.

Other data vital to emergency management efforts will soon become available, if funding is approved. Data themes such as electric powerplants; geological faults; gas pipes, plants, and storage facilities; nuclear powerplants; water supply plants; oil refineries; seismic risk zones; superfund sites; sewer plants; tank farms; toxic release inventory sites; utility lines; non-Reclamation dams; custodial facilities such as nursing homes, orphanages, and correctional facilities; and religious institutions are currently available at nominal cost.

The data that Reclamation currently provides, along with other data which may soon become available, could become part of an Environmental Systems Research Institute ArcView "project." According to a recent survey, the vast majority of Reclamation regional and area offices now own some version of Arc/Info, ArcCad, or ArcView software. With this software, emergency managers can interactively query the data for their own needs. In

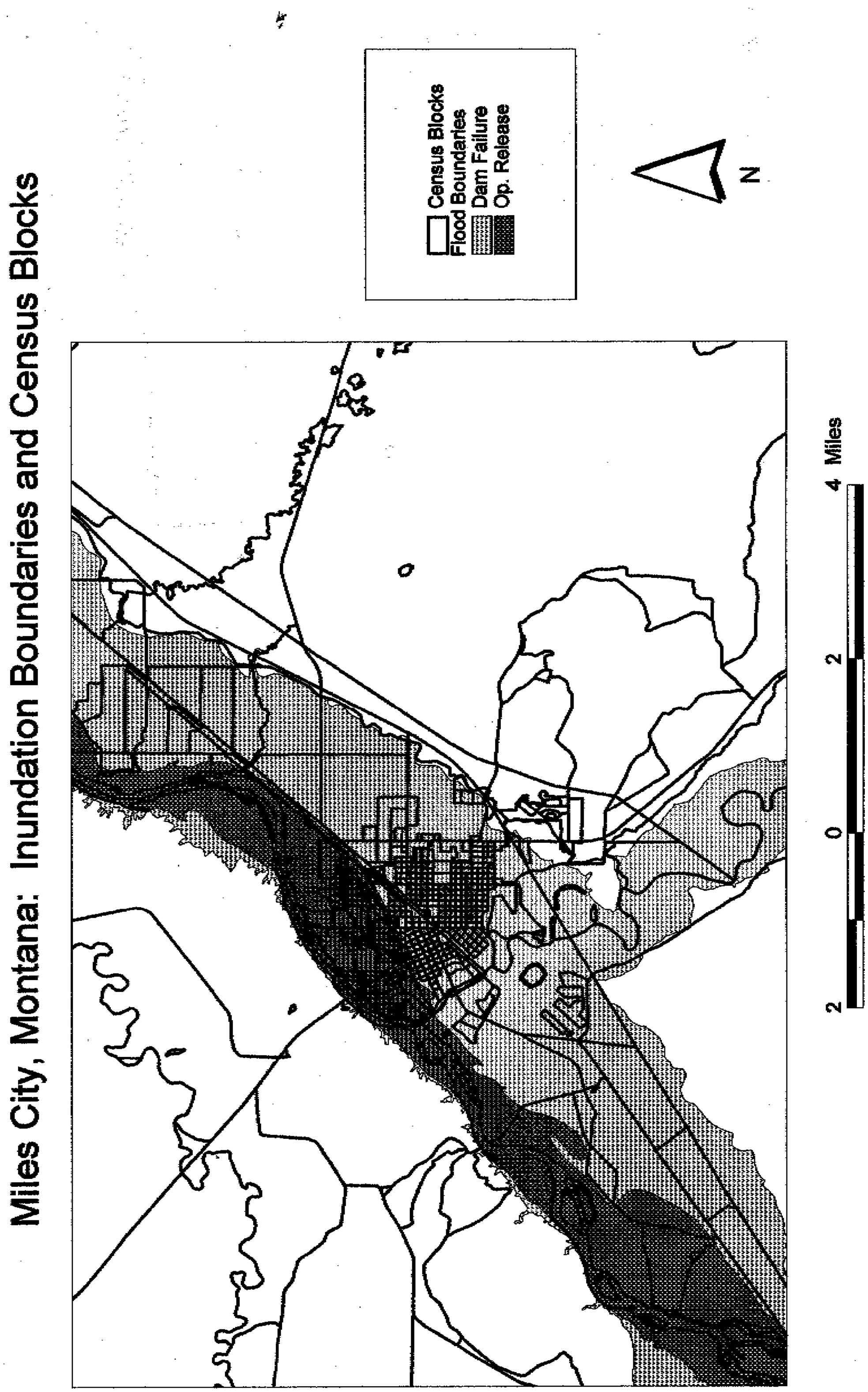


Figure 2.—Plot of census blocks and flood inundation boundaries on the Yellowstone River near Miles City, Montana.

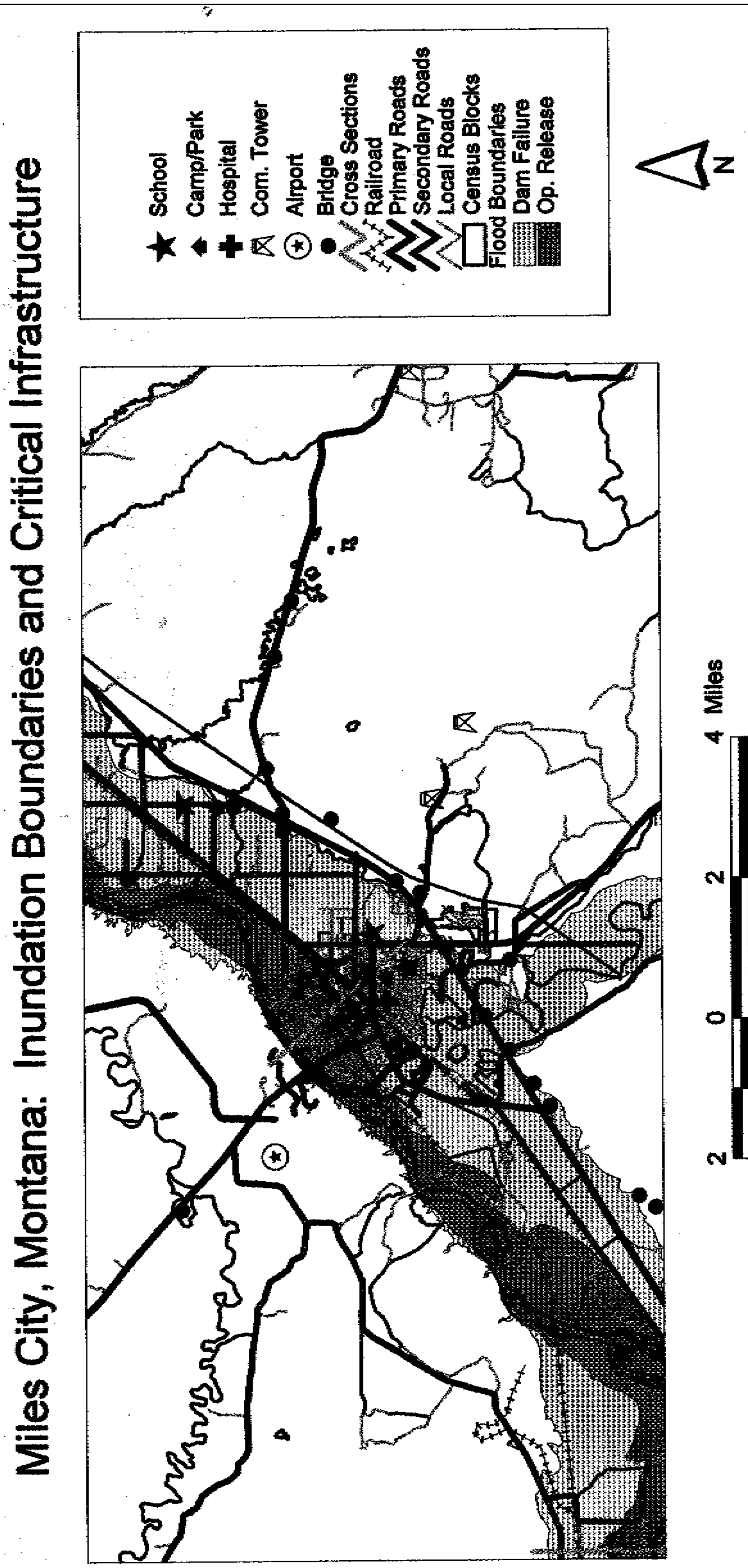


Figure 3.—Plot of critical infrastructure and flood inundation boundaries near Miles City, Montana.

addition, they will be able to supplement the basic package of data themes the Denver Office is providing with others of local importance. Finally, it is entirely possible, using the Avenue programming capability associated with ArcView, to customize each project to suit the very specific decisionmaking needs of each office.

These data and Reclamation's GIS capabilities may also be useful for facilitating other emergency planning activities such as population at risk and loss of life assessment; training emergency management personnel; and performing orientation, table top, and functional emergency exercises. Beyond this, GIS data can be integrated with other electronic decision-making and resource management tools such as an emergency information system for use in an actual disaster response situation.

Glossary of Terms

Computer, GIS, Mapping, and Modeling Terms

***Cartography*:** The art and science of representing the features of the Earth's surface graphically. Synonymous with map making.

Census Block: The smallest geographic area for which the U.S. Census Bureau gathers population data. These blocks are generally rather small areas "bounded on all sides by visible features such as streets, roads, streams, and railroad tracks, and by invisible boundaries such as property lines, legal limits, and short imaginary extensions of streets and roads" (*Technical Documentation: TIGER/Line Census Files*, 1992). This is the spatial unit of analysis for dam breach population at risk studies.

Compact Disc Read-Only Memory (CD-ROM)*:* An optical data storage medium, readable by a computer having a CD-ROM disc drive.

DAMBRK: A flood model program that analyzes dam failure scenarios and uses hydro-dynamic theory to predict dam-break flood wave formation and routing; also known as the National Weather Service Dam-Break Flood Forecasting Model. An enhanced user interface version, developed by the BOSS Corporation, has been used for studies in the Denver Office.

Dam Break Interface (DBI): GIS front end for the DAMBRK model designed by the Mid-Pacific Region GIS Office to enable users to identify and visualize the cross-sections (including 3-D) and generate a set of input files for loading into DAMBRK. The DBI is designed to substantially reduce the time it takes to get cross-section data into DAMBRK, while enabling users to exercise more judgment on cross-section placement and other items. Users can visually inspect and edit the cross-sections before entering them into the model.

This GIS-based software (Arc/Info) can make DAMBRK run and then produces a digital coverage of the inundated area within a relatively short period of time. Improvements are still being made to the program.

Data Set: A collection of similarly formatted records having like information (from one or more data sources). Data sets contain columns and rows. The columns contain the data subject. Examples might be census tract identifier, population, area, and fertility rate. The rows contain observations with measurements on each of the data subjects. Thus, census tract 22.05 might have 3975 inhabitants, an area of .025 square mile, and a fertility rate of 10 children per 1,000 women aged 15 to 45.

Digital Elevation Model (DEM): A raster (row and column) array of elevation values.

Digitizer: A device that converts analog information into a digital format. For flat graphic material, such as maps, a digitizer can either be flatbed or scanning.

Digital Raster Graphics (DRG): Digital Raster Graphics file format. A 4-bit TIFF raster image of scanned and geocorrected 7.5 minute quads or other scale topographic maps, for example, 1:100,000 and 1:250,000 scale maps.

Finite Difference Model: A particular kind of digital computer model based upon a rectangular grid that sets the boundaries of the model and the nodes where the model will be solved.

Flood Inundation Boundary: Polygon delineated around the outer edge of a flood inundation area.

Format: The physical organization of data elements within a data set.

Geographic Information System (GIS): A complete sequence of computer and human elements for acquiring, processing, storing, and managing spatial data.

Georeference: Raster image data or vector elements that have been registered to create a direct spatial relationship to actual ground features. A georeferenced soft copy or hard copy feature must contain a map projection and scale.

Graphical User Interface (GUI): A software capability that uses pictures, buttons, menus, and icons to generate program input and output. Runs on a windows computer platform.

Hard Copy: Graphic and textual features that are plotted on paper, mylar, or other material.

Hardware: The physical components of a computer: central processing unit, memory, disk storage, tape drives, etc.

Image: A two-dimensional data representation. Examples include a photograph or a multi-spectral imaging sensor's data output.

Map: Usually a two-dimensional representation of all or part of the Earth's surface, showing selected natural or manmade features or data, preferably constructed in a definite projection with a specified scale.

Mosaicing: An assemblage of images whose edges are clipped and matched to form a continuous representation of a portion of the Earth's surface.

Population at Risk: All individuals who, if they took no action to evacuate, would be exposed to flooding of any depth. The population at risk is dependent on the dam failure or flooding event analyzed.

Projection: A systematic construction of features on a plane surface to represent corresponding features on a spherical surface. Common types are conic, cylindrical, and azimuthal. Each has strengths and weaknesses in terms of showing true distance, true area, and true shape.

Raster: A cellular data structure or organization of spatial data. In a raster structure, a value for the parameter of interest (elevation in feet above some known point, land use class from a specified list, etc.) is developed for every cell in an array over space.

Registration: Superposition of locations on an image or map with coordinate values associated with one of a variety of projections which model locations on the Earth's surface.

Scale: The ratio of map distance to Earth distance. Thus, in a 1:24000 scale map, one centimeter, inch, or foot equals 24,000 centimeters, inches, or feet on the ground. Graphic scales typically show equivalent map and ground distance in the form of a line or bar.

Topologically Integrated Geographic Encoding and Referencing System (TIGER): A geometric and tabular representation for demographic data that can be used for flood inundation impact analysis.

Topography: The collective features of the surface of the Earth, especially the relief and contour of the land.

Travel Time: Time measured from the dam breach location to flooding at a particular location. The flood level corresponding to that travel time is usually either the arrival of the leading flood wave or the peak flow at that location.

UNIX: A computer operating system which is interactive, time-sharing, multiple user, and multiple tasking.

Vector: Generally, a quantity possessing both numerical value and direction. In terms of GIS, typically representing a boundary between spatial objects. Vector GISs typically display spatial data in terms of points, lines, and polygons, as opposed to raster data, which display them as picture elements.

Emergency Response Terms

Emergency Information System (EIS): An emergency management computer application. EIS integrates maps, data bases, models and sensors, and communications all into one package. The mapping capabilities range from USGS maps on CD-ROM to photographs or satellite images calibrated to their proper latitude and longitude. EIS supports TIGER line files from the U.S.Census Bureau and nearly 20 GIS formats converted through the utility in ArcView and scanned maps or images (PCX, TIFF, BMP, and CUT). The data bases include hazard site analysis, census data, emergency plans, special needs, incident logs, incident actions, and incident situation reports.

The communications package is titled ECOMM. This module allows for the exchange of maps and data with any EIS user and commercial programs using the Xmodem, CRC, and Kermit protocols, National Weather Service Wire, cellular and landline telephone systems, packet radio systems, flood warning systems, and meteorological towers and sensors.

HISTORIC WADDELL DAM BREACHED (IN 1992)

On the cold, rainy morning of December 4, 1992, Waddell Dam was breached, and a large part of this historic structure sunk below the waves of Lake Pleasant. Although the weather proved to be a deterrent (probably a frigid 50 degrees) for many less hardy souls, representatives from the Phoenix Area Office, Maricopa Water District, Central Arizona Water Conservation District, Arizona Game and Fish Department, Maricopa County Parks and Recreation Department, and even the Coast Guard, braved the elements to witness the breaching of the original dam. Members of the local news media documented this historical event. Why would anyone, especially the Bureau of Reclamation (Reclamation), want to breach a dam as beautiful as Waddell Dam?

Reclamation completed construction of New Waddell Dam, located about 1/2 mile downstream of Waddell Dam, in October 1992. The historic Waddell Dam, constructed in 1927 by private interests, was the largest multiple arch dam in the world. New Waddell Dam was constructed to store Colorado River water delivered by the Hayden-Rhodes Aqueduct (formerly the Granite Reef Aqueduct) under the Central Arizona Project. With New Waddell Dam, the Central Arizona Water Conservation District could perform scheduled maintenance on the canal between Lake Havasu on the Colorado River to the turnout for the reversible Waddell Canal to the new dam while deliveries continued to downstream customers of the district. The dam could also provide flood protection by controlling riverflows into the Phoenix metropolitan area from the Agua Fria. The new reservoir added 6,300 surface acres to Lake Pleasant, tripling the size of the lake and greatly increasing the recreational value of Lake Pleasant Regional Park. Maricopa Water District, the owner of the original Waddell Dam, was provided an outlet to allow diversions into their canal distribution system.

Because the new reservoir's water level may fluctuate as much as 125 feet during a year's operation, the recreation facilities would need to be accessible during both high and low water periods. A new marina was located between the original dam and the new downstream dam. With the top of the original dam being exposed during low water levels, plans were to cut a breach in Waddell Dam to allow boaters to safely travel to the marina and provide storage continuity to the new dam.

First, the old roadway deck, spillway gates, piers, and miscellaneous machinery were removed. Then, a subcontractor, Advanced American Diving Service, Inc., of Oregon was hired to create a breach 224 feet wide and 70 feet deep in the original dam. The breach consisted of cutting through the concrete structure with a diamond-wire saw. Four arch barrels and three buttresses were cut using these methods. A few bolts were installed to hold the large blocks of concrete in place until all the cutting was complete. The bolts were then blasted with demolition charges which allowed the separated sections to fall safely into the lake.

The following photos are courtesy of the Department of the Interior, Bureau of Reclamation, Phoenix Area Office and Arizona Projects Office.

Historic Waddell Dam, constructed in 1927.

New Waddell Dam, completed in 1992, and historic Waddell Dam before the breach.

Blocks of concrete at historic Waddell Dam begin to fall away after cuts to create breach.

Blocks of concrete from historic Waddell Dam sink into Lake Pleasant.

A breach is created in historic Waddell Dam.

USING RECLAMATION'S NEW *WATER MEASUREMENT MANUAL* TO SAVE WATER

By Clifford A. Pugh[1]

Figure 1.—Weir box turnout with Cipolletti Weir.

What is the *Water Measurement Manual*?

The *Water Measurement Manual*, Third Edition, is a reference updating water measurement information previously published by the Bureau of Reclamation. Previous editions date back to 1913. The 1997 edition contains information about several new technologies, including acoustic and electromagnetic flow meters, as well as contributions from the Agricultural Research Service and the Natural Resources Conservation Service.

The new manual places increased emphasis on the use of long-throated flume measurement structures. Ramp flumes are a form of long-throated flume. These structures can be applied in situations where Parshall flumes might have been used in the past, but they are easier to

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fabricate and more tolerant of high tailwater conditions. Therefore, they are ideal for installation in existing canal systems, where available head (elevation) may be limited. Long-throated flumes are also preferable because they can be installed within the existing canal section. Information on Parshall flumes has been reduced in the new manual and incorporated into the more general "Flumes" chapter.

New chapters added to the manual are

- Basic Concepts Related to Flowing Water and Measurement
- Selection of Water Measuring Devices
- Measurement Accuracy
- Inspection of Water Measurement Systems
- Acoustic Flow Measurement
- Discharge Measurement Using Tracers

Other chapters with applicable information for farm installations are

- Weirs
- Flumes
- Submerged Orifices
- Special Measurements in Open Channels
- Measurements in Pressure Conduits

Why do we Need to Measure Water?

The ultimate goal of water measurement is to conserve water through improved management of its distribution and application. Accurate water measurement helps in the distribution because it is very difficult to manage something when you do not know precisely how much you are using.

Management of water supplies is changing. Increasing competition exists between power, irrigation, cities, industry, recreation, aesthetic, and fish and wildlife uses. Within the United States, critical examinations of water use will be based on consumption, perceived waste, population density, and impact on ecological systems and endangered species. Water districts and farmers will need to document their use of water and seek ways to extend the use of their share of water by the best available technologies. Best management measures and practices without exception include conservation of water.

Rather than finding and developing new sources, water often can be supplied more economically by conservation. Each cubic foot of water recovered as a result of improved water management costs less than supplying the same amount from a new source. Better measurement procedures extend the use of water because lack of information usually results in the delivery of excess water or loss through waste. Attention to measurement, management, and maintenance will take advantage of the farmer's water and help prevent reduced yields and other crop damage caused by underwatering or overwatering.

How to use the *Water Measurement Manual* to Conserve Water

The "Flumes," "Weirs," and "Measurements in Pressure Conduits" chapters will provide much of the information and illustrations needed to install flow measurement devices on farms and canals. Tables in the text and the appendix also list flows for some of the more common measuring devices, making the manual a valuable asset in the field.

Special attention should be given to the "Long Throated Flumes," section 8-8, since these flumes are the most adaptable to existing canals and require less complicated construction forming (figure 2). Usually, the farmer can construct the device in place. The flumes have few problems with debris, sediment, and downstream submergence. Measurement of the flow is simple since only the upstream water depth is needed. The new manual provides standard designs for typical situations, and straightforward computer software is also available for developing customized flume designs.

The *Water Measurement Manual* can be accessed on the World Wide Web at http://ogee.do.usbr.gov/fmt/wmm/ or a hard bound version can be purchased from the Government Printing Office, Superintendent of Documents (202) 512-1800, fax (202) 512-2250, PO Box 371954, Pittsburgh PA 15250-7954. The stock number is S/N 024-003-00180-5. The price for U.S. customers is $34.00. For customers outside of the U.S., the price is US$42.50. Reclamation offices can order copies from the warehouse in Denver, mailing code D-7913, attention: T Marvel.

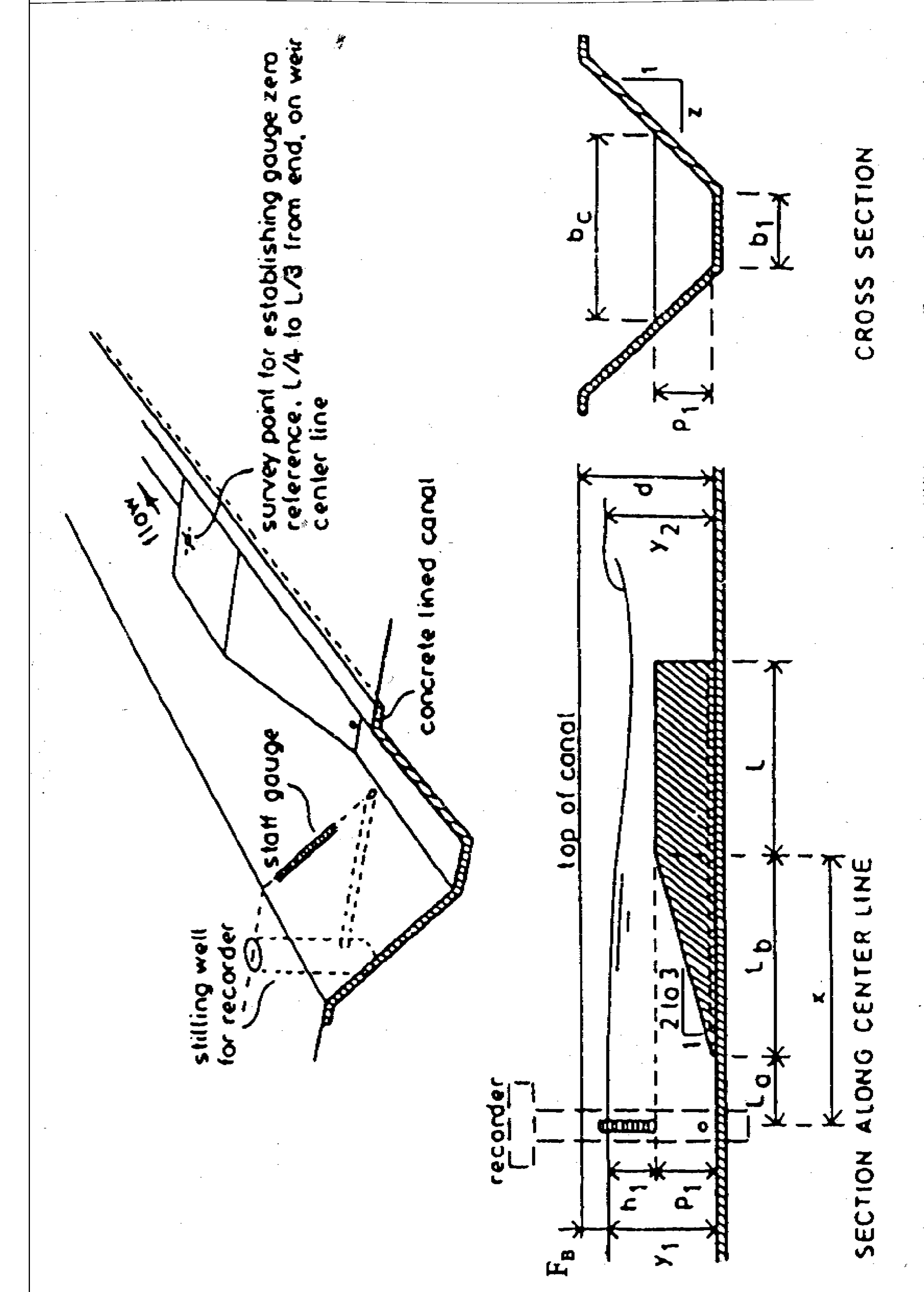

Figure 2.—Flat-crested long-throated flume (ramp flume) in concrete-lined canal.

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:

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