EM 1110-2-3600
10 October 2017

U.S. Army Corps
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ENGINEERING AND DESIGN

# Management of Water Control Systems

## ENGINEER MANUAL

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| CECW-CE | DEPARTMENT OF THE ARMY<br>U.S. Army Corps of Engineers<br>Washington, DC 20314-1000 | *EM 1110-2-3600 |
| Manual<br>No. 1110-2-3600 | | 10 October 2017 |

Engineering and Design

# MANAGEMENT OF WATER CONTROL SYSTEMS

1. Purpose. This Engineer Manual (EM) provides guidance to field offices for water management at all U.S. Army Corps of Engineers (Corps) owned and Corps-operated reservoirs, locks, dams, and other water control projects in which water storage is managed and operated for multiple authorized purposes such as flood risk management, navigation, and other uses. It also applies to Corps actions in developing water control plans and manuals or in operating non-Corps reservoirs, locks, dams, and other water control projects in which water storage is managed and operated for flood risk management or navigation, and which are subject to Corps direction pursuant to Section 7 of the Flood Control Act of 1944 or other law. This manual may also provide guidance to the Corps in other cases where water resources infrastructure is similarly operated for flood risk management or navigation and subject to Corps direction through the establishment of water control or operational plans. Water management of these systems, however, may require special techniques beyond those used in the planning, design, and construction phases, to analyze and regulate water conditions at individual projects in order to meet authorized water management objectives. This manual incorporates, by reference, other USACE guidance documents, but unless expressly stated, this manual does not alter or supersede other USACE guidance. Additionally, this manual does not alter or supersede any law or binding regulation, or determine the authorized purposes of any USACE reservoir project, nor does it impose legal requirements on any entity.

2. Applicability. This manual applies to all Headquarters, U.S. Army Corps of Engineers (HQUSACE) elements, major subordinate commands (MSCs), districts, laboratories, and separate field operating activities (FOAs) having civil works responsibilities and activities related to or affecting water control management. This manual also applies to Corps actions in developing water control or operational plans for projects not owned by the U.S. Army Corps of Engineers (USACE), as defined in Para. 1.

3. Distribution Statement. Approved for public release; distribution is unlimited.

FOR THE COMMANDER:

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|---|---|
| 3 Appendices<br>(See Table of Contents) | RICHARD L. HANSEN<br>COL, EN<br>Chief of Staff |

*This manual supersedes EM 1110-2-3600 dated 30 November 1987.

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# Engineering and Design
# MANAGEMENT OF WATER CONTROL SYSTEMS

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# CHAPTER 1

## Introduction

1.1. Purpose. This Engineer Manual (EM) provides guidance to field offices for water management at all U.S. Army Corps of Engineers (Corps) owned and Corps-operated reservoirs, locks, dams, and other water control projects in which water storage is managed and operated for multiple authorized purposes such as flood risk management, navigation, and other uses. It also applies to Corps actions in developing water control plans and manuals or in operating non-Corps reservoirs, locks, dams, and other water control projects in which water storage is managed and operated for flood risk management or navigation, and which are subject to Corps direction pursuant to Section 7 of the Flood Control Act of 1944 or other law. This manual may also provide guidance to the Corps in other cases where water resources infrastructure is similarly operated for flood risk management or navigation and subject to Corps direction through the establishment of water control or operational plans. Water management of these systems, however, may require special techniques beyond those used in the planning, design, and construction phases, to analyze and regulate water conditions at individual projects to meet authorized water management objectives. This manual incorporates, by reference, other USACE guidance documents, but unless expressly stated, this manual does not alter or supersede other USACE guidance. Additionally, this manual does not alter or supersede any law or binding regulation, or determine the authorized purposes of any USACE reservoir project, nor does it impose legal requirements on any entity.

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1.4. References and Resources.

1. Appendix A to this manual lists Engineer Regulations (ERs), Engineer Manuals (EMs), Engineer Circular (EC), Engineer Pamphlet (EP), and other publications that define policy and basic methods directly related to water management activities by the Corps of Engineers, and that are cited in this manual.

2. Appendix B to this manual contains partial lists of Federal Water Resource Management and Environmental Laws.

3. Appendix C to this manual contains a list that defines acronyms and abbreviations used in this manual.

4. This manual contains two sample exhibits: a “Water Control Plan,” and “Standing Instructions to the Project Operator For Water Control.”

1.5. Authorities for the Corps Water Control Management Role.

1.5.1. The Corps is responsible for water control management at the reservoir projects it owns and operates throughout the United States. These projects are referred to in this regulation as Corps-owned projects. This responsibility is prescribed by laws initially authorizing construction of specific projects and any referenced project documents, by laws specific to projects that are passed subsequent to construction, and by the flood control acts and related legislation that Congress has passed that apply generally to all Corps reservoirs. Modifications to project operations may also be permitted under laws passed post-construction.

1.5.2. Corps-owned projects are operated for authorized purposes such as flood control, navigation, hydroelectric power, irrigation, municipal and industrial (M&I) water supply, recreation, low flow augmentation, water quality, and fish and wildlife conservation. Operations for these authorized purposes may derive from the original project authorization, from appropriate revisions within the discretionary authority of the Chief of Engineers, or from modifications permitted under subsequent congressional acts or in compliance with Federal laws relating to the operation of Federal facilities. In addition, water control plans for projects owned and operated by USACE shall be developed in concert with all basin interests that may be impacted by or influence project regulation; public involvement in the development or significant revision of water control plans shall also be provided as required under this regulation. These considerations should be addressed by a water control plan and reflected in an approved water control manual. Questions requiring interpretation of authorizations will be referred to HQUSACE, CECW-CE (USACE, Civil Works – Construction and Engineering) for guidance and resolution, and should include review by District, Division, and HQUSACE counsel. This manual does not determine or define the authorized purposes or legal operating requirements of any USACE reservoir project.

1.5.3. The Corps is also responsible for prescribing flood control and navigation regulations and providing operational guidance for certain reservoir projects constructed or operated by other Federal, non-Federal, or private agencies; such projects are referred to in this regulation as non-Corps projects. These projects include those subject to direction by the Corps under Section 7 of the Flood Control Act of 1944 (which requires the Corps to prescribe regulations for the use of storage allocated to navigation, or flood control at reservoirs constructed wholly or in part with Federal funds) and related legislation, as well as those authorized by special acts of Congress, those for which licenses are issued by the Federal Energy Regulatory Commission on the condition that they be operated in accordance with Corps instructions, those covered by agreements between the operating agency and the Corps, and those that fall under the terms of general legislative and administrative provisions. This regulation establishes the general policies that the Corps shall follow when developing water control management plans or operations for such projects. This manual does not determine or define the purposes or operations of non-Corps projects, nor does it impose obligations on any other entity.

1.5.4. For these non-Corps projects, the intent is to provide guidance to establish an understanding of the water control plan and responsibilities for flood control and navigation between the project owner, operating agencies, and the Corps. Excepted non-Corps projects include those under the jurisdiction of the International Boundary and Water Commission, United States and Mexico; those under the jurisdiction of the International Joint Commission, United States, and Canada; and those under the Columbia River Treaty.

1.5.5. Appendix B to this manual contains more information about authorities prescribing Corps roles and responsibilities for water control management.

1.6. Scope of this Manual. This manual covers water management activities related to the hydrologic/hydraulic aspects of completed projects. These activities include: data collection and handling; determination of project inflow, and planning and implementing of operational decisions, which include releases for flood risk management, hydropower, water supply, water quality, fish and wildlife, and other authorized purposes; and coordination and communication of water management decisions. Water resource projects are regulated to meet water management objectives by operating spillway gates, sluice gates, pumping plants, etc. In this regard, the physical operation of structures, such as the manipulation of gates or recognition of structural constraints, is addressed only in terms of achieving the water management objectives. The term "operation" is used interchangeably throughout the manual to mean "regulation" for water management such as project release scheduling as well as to mean the physical operation of projects. The phrase "project operator" refers to the person who is responsible for the project's physical operation. Non-hydrologic/non-hydraulic aspects of project operation and maintenance are not addressed herein. This manual includes a compendium of elements related to water management systems, including discussions of:

1. Regulation of single purpose projects, multipurpose projects, and systems.

2. Preparation of water control plans and regulation schedules to achieve multipurpose objectives consistent with authorized purposes.

3. Collection, processing, and dissemination of data and information related to water management activities including real-time systems and use of automated data systems.

4. Analysis of river and reservoir systems on a real-time basis to inform water management decisions, including use of automated techniques to simulate hydrologic systems.

5. Considerations related to environmental, social, economic, and aesthetic aspects of water management.

6. Methods to support real-time water management decisions.

7. Development of water control plans and manuals for an individual project and for a system.

8. Coordination of water management activities with stakeholders and the public at a local, regional, and national level.

1.6.1. Chapter 2 describes the objectives and principles for the management of water for various congressionally authorized project purposes. The specific requirements for any of these purposes (functional, economic, environmental, social, and aesthetic) are unique to a given river basin. The manual describes each element, insofar as the principles apply to projects generally, and the necessity for considering all elements as well as the project's safety and integrity. This chapter is not intended to present detailed solutions.

1.6.2. Chapter 3 addresses the technical aspects of developing water control plans, which often encompass multipurpose and multiproject systems. Even in the case of a single purpose project, there are often important aspects to be accounted for in the overall management of a river system. The manual provides guidelines for the formulation of detailed regulation criteria, which are based largely on planning and design studies, together with the use of techniques for water management to attain the overall goals. This chapter discusses the preparation of water control diagrams, which include the regulating criteria in the form of guide curves and release schedules. Section 3.2.5.2 deals with requirements contained in water control agreements for non-Corps projects, as set forth in the revision of Title 33 of Code of Federal Regulations (CFR) Section 208.11, published in the Federal Register, 47184, 13 October 1978, as amended at 46 FR 58075, 30 November 1981; 55 FR 21508, 24 May 1990; 79 FR 13564, 11 March 2014.

1.6.3. Chapter 4 briefly describes the design of hydraulic facilities at water management projects. These include spillways, spillway gates, regulating outlets, bypass and diversion structures, interior drainage facilities, navigation locks, hydropower facilities, fish passage facilities, and special devices for regulating the quality of water released from a reservoir. Special emphasis is placed on the methods for controlling floods through the combined use of spillway gates and/or regulating outlets in order to use flood surcharge storage in reservoirs. Also mentioned are special water control management issues involved in the use of bypass structures, hydropower facilities, navigation locks and dams, and fish passage facilities.

1.6.4. Chapter 5 summarizes the methods available for collecting, processing, storing, and disseminating basic data for project regulation. It discusses the relationship between a water management enterprise system (WMES) and Corps Water Management System (CWMS). This chapter presents methods for coordinating data collection with other organizations and the use of cooperatively developed data systems. It also covers the importance and process for developing solid continuity of operation (COOP) plans.

1.6.5. Chapter 6 includes methods of hydrologic analysis that are directly applicable to water management systems. These include modeling to simulate the continuous natural response of hydrologic and river systems, combined with the effects of project regulation on conditions of streamflow and river stages. These simulations are used to evaluate the effects of alternative conditions or assumptions in forecasting streamflows and project regulation. This chapter also describes meteorological assessments and forecasts that are important to project regulation. Systems analysis techniques discussed in this chapter also include methods for analyzing and projecting long-term regulation of projects for several months to a year in advance. These projections are based on known or assumed conditions of stream and operating criteria. These analyses are useful in evaluating alternatives in system regulation, and in adjusting the water control plan for flood risk management, hydroelectric power generation, irrigation, navigation, water quality, fish and wildlife, or other project purpose as needed to assess the particular observed and to assess projected conditions of hydrology and project regulation on the overall water management. Other aspects of hydrologic analysis include reservoir evaporation, effect of ice and wind, streamflow determination, hurricanes, tsunami waves, tidal effects, artificial flood waves, ground water effects, and effects of changing channel capacities downstream from projects.

1.6.6. Chapter 7 presents the methods for integrating system guidelines for water management, criteria and goals for scheduling water releases. The specific schedules are developed using all existing current information, hydrometeorological data, project data, and projections developed by simulation techniques. This chapter discusses organization and staffing recommended to perform this function, methods of arriving at daily water management decisions, and the way water management decisions may be disseminated and implemented at the project level. It also discusses methods for coordinating releases, streamflow and regulation forecasts with other interests. It describes requirements of regulation during floods or other emergency conditions, as opposed to normal routine regulation, and methods for disseminating vital information to the news media and the general public.

1.6.7. Chapter 8 presents the administrative and coordination requirements of the Corps for water management systems, and discusses the role of the Corps in the regulation of international rivers and the authority for regulating projects constructed by other entities in the United States. Note that the content of this chapter that summarizes the requirements for administrative control by the Corps is derived primarily from existing ERs.

1.6.8. Chapter 9 discusses the preparation of water control documents, and includes standing instruction to project operators, water control plans, and water control manuals.

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# CHAPTER 2

## Objectives and Principles of Water Management

2.1. General Considerations.

2.1.1. Introduction.

2.1.1.1. This chapter defines the objectives and principles for water management by the Corps. A primary objective for water management is to develop and implement water control plans that support the delivery of benefits consistent with congressionally authorized project purposes, functional goals, and applicable legal requirements. The water control plan provides the basis for decisions on the storage and release of water to meet project objectives.

2.1.1.2. This chapter describes fundamental objectives and project purposes that are generally applicable to most projects. This chapter also addresses the principal water management considerations and issues associated with each purpose. The water manager should take this information into account when preparing a water control plan.

2.1.1.3. This chapter discusses various operational objectives, applicable authorities, and standard water management considerations for various types of single and multipurpose projects. In operating all its projects, regardless of their authorized purposes, the Corps always seeks to minimize risk to public safety.

2.1.2. Congressionally Authorized Project Purposes, Related Legal Requirements, and Relevant Case Law.

2.1.2.1. Water management activities are governed by authorized project purposes defined in authorizing legislation and supporting reports, post-authorization legislation, and general legislation applicable to all Corps projects. Water management activities must also be consistent with other legal requirements related to real estate, environmental principles, public use, and public safety. Appendix B to this manual provides a summary of legislation relevant to water management. Water management activities may also need to consider the advice of counsel, written legal opinions, and relevant case law.

2.1.2.2. The Corps is responsible for water management at Corps projects and at Corps-operated projects throughout the United States. This responsibility is prescribed by laws initially authorizing construction of specific projects, laws specific to projects that are passed subsequent to construction, and flood control acts and related legislation that Congress has passed that apply to all Corps projects. Congressionally authorized project purposes may include one or more of the following:

1. Flood control.

2. Navigation.

3. Hydroelectric power generation.

4. Irrigation.

5. Water supply (M&I).

6. Water quality.

7. Fish and wildlife.

8. Recreation.

9. Sediment control.

2.1.3. Single Purpose Project. In some cases, water resources projects are authorized for a single purpose.

2.1.4. Multiple Purpose (Multipurpose) Project.

2.1.4.1. Projects authorized and operated for multiple purposes must balance multiple water management objectives. The water control plan integrates the different project purposes, which are characterized by the storage and release functions. The degree of compatibility among the various project purposes depends on the characteristics of the river system, water use requirements, and the ability to forecast runoff. Some degree of flexibility is needed to achieve the water management objectives. Management of water levels upstream and downstream from projects may achieve project goals and also desires for public use, recreation, and fish and wildlife activities.

2.1.4.2. A project's water control plan should seek to accomplish the project purposes by outlining regulation that benefits them to the greatest extent possible while seeking to minimize the risk to public safety. ER 1110-2-8156, Preparation of Water Control Manuals, provides a format to document the effects and benefits of project purposes, which may be used to improve the water control plan and provide a basis for structural modifications.

2.1.5. System Water Management. Water management objectives may encompass a single project or a system of projects. The system may consist of any combination of rivers, tributaries, reservoirs, and a regional watershed. ER 1110-2-240, Water Control Management, requires that an integrated water control master manual be prepared for system water management of Corps-regulated projects in a drainage basin with interrelated purposes. For example, a master manual may be necessary for projects interconnected hydraulically or with a hydroelectric power generation purpose. A number of the individual water control plans contained in the master manual may include requirements that extend beyond a single river basin boundary and entail regional flood risk management, water supply, or hydroelectric power generation requirements. A system could contain water resource projects in series where project actions directly impact inflows or releases to upstream or downstream projects. A system could also have parallel projects where multiple projects may impact a common downstream control point.

2.1.6. Streamflow Objectives. Streamflow objectives are developed to serve the authorized project purposes such as flood risk reduction, navigation, hydropower, and water supply. For multipurpose projects or systems, operating to achieve one purpose may also satisfy other streamflow objectives. For example, water released for irrigation could also address other in-stream water needs. Streamflow objectives should be documented in the water control manual and supported by analyses that consider project and system benefits and impacts to optimize the use of the water resource.

2.1.7. Climate Change.

2.1.7.1. The Corps Climate Preparedness and Resilience Policy Statement (27 June 2014), states that the Corps will integrate climate change preparedness and resilience planning and actions in all activities for the purpose of enhancing the resilience of our built and natural water-resource infrastructure to reduce the potential vulnerabilities of that infrastructure to the effects of climate change and variability.

2.1.7.2. As water control plans and water management are developed or updated, they should include integrated strategies for adaptation (i.e., manage unavoidable impacts) and mitigation (i.e., avoid unmanageable impacts). Water control plans need to be reviewed periodically and updated as needed to manage climate change and variability impacts. Data and models that support water management decisions must also be periodically reviewed and updated to provide reliable and current information to decision makers. Statistical analyses that relate hydrologic variables such as volumetric runoff or streamflows to meteorological or current system states such as snowfall and snowpack will be influenced if those relationships are changing. Physical or numerical models that have been calibrated to historic conditions may need to be re-evaluated within the context of climate change and calibrated to current conditions as changes are observed.

2.2. <u>Flood Risk Management</u>.

2.2.1. Historical Perspective.

2.2.1.1. General. From the founding of the nation through much of the 19th century, flood risk management activities were viewed as a responsibility of the states and local governments. In 1879, the establishment of the Mississippi River Commission, which Congress tasked with developing plans to improve navigation and prevent destructive floods, represented the first Federal attempt to mature a coordinated plan of development of the Mississippi River. Hampered by restrictive legislation that prevented expenditure of Federal funds for the sole reason of protecting private property from overflow, the commission focused its attention on improving the existing levee system as a means of improving navigation. The passage of the 1917 Flood Control Act, however, fully committed the Federal government to flood control improvements in the Mississippi Valley. The act also extended Federal flood risk management responsibilities to the Sacramento River, CA. Following the disastrous flood of 1927, the Flood Control Act of 1928 authorized a comprehensive plan for management of the Mississippi River and its tributaries. The Flood Control Act of 1936 and the Flood Control Act of 1944 marked the beginning of Corps construction of flood risk management projects throughout the nation. Appendix B to this manual provides a summary of relevant water management-related legislation.

2.2.1.2. Evolution from Flood Control to Flood Risk Management. Although previous legislation and regulations have used the term "flood control," in recent years, the Corps has transitioned through the term "flood damage reduction" and now uses the term "flood risk management." One reason for this change in terminology is that the term flood control has been misunderstood to denote "flood elimination." The term flood damage reduction was adopted in recognition of the fact that the structures built for flood control can only reduce the level of flooding and subsequent damage, and do not totally control all floods. Flood risk management recognizes that there are different levels of risk in flood control projects and activities. The Corps manages risks associated with flood waters, but cannot fully control or eliminate them. Projects described in subsequent sections have a limited capacity to reduce flood risk, and decision makers must understand these limitations and operational constraints. The more recent flood risk management terminology is used as appropriate in the remainder of this manual. The terminology used in this manual does not result in any change in the congressionally authorized purposes or operations of any project.

2.2.2. Flood Risk Management Measures.

2.2.2.1. Management of flood risk by structural remedies, such as reservoirs, levees, drainage systems, and channel improvements, has long been a national objective. Nonstructural means, such as flood plain zoning, flood proofing, and flood insurance have been incorporated into overall flood risk management plans to augment structural operations. In the operational phase, the overall objective is to reduce flood risk in a given region to the extent reasonably possible. Most structural alternative measures require specific plans based on hydrometeorological conditions, flood risk management objectives, and the capabilities of appropriate flood risk management facilities. Water control plans must integrate the flood risk management information outlined above to best manage projects; deviations from the water control plan must be approved in advance for alternate regulation (see ER 1110-2-240, <u>Water Control Management</u>).

2.2.2.2. Streamflow and reservoir forecasting is an important element in managing water during floods, and timely preparation of flood forecasts facilitates the evacuation of people and property from harm's way. In general, Corps policy is to implement operational decisions based on water-on-the-ground while planning and scenario analysis can include precipitation forecasts. Forecasted precipitation may be used in operational decision making as part of an approved water control plan. The National Weather Service is the responsible Federal agency to provide weather, hydrologic, and river stage forecasts, and warnings for the protection of life and property. Specific flood risk management measures and objectives are discussed briefly in the following paragraphs. Types of water management facilities are discussed in Chapter 4.

2.2.3. Runoff Management Using Dams. A principal structural remedy for flooding is to manage streamflow and river levels by impounding runoff using dams. Planning studies to meet flood risk management objectives using reservoirs may require analysis of historical and hypothetical floods, comparison of alternatives that provide varying storage levels and structural locations, consideration of downstream flooding, consideration of inflows from uncontrolled areas below the project, determination of downstream channel capacities, completion of flood damage surveys, cost-benefit analysis, and preparation of a general plan of regulation. These planning studies are used to determine the size and location of dams, the level of flood risk management to be provided, and the multipurpose uses of projects. The studies are based on a comprehensive evaluation of river basin development that considers economic, environmental, and social values. In the design phase, the project studies are refined, and detailed studies are made to finalize hydraulic features and the water control plan for the project.

2.2.4. Objectives for Reservoir Management of Floods.

2.2.4.1. General. Reservoirs cannot eliminate flooding, but do reduce risk. They are designed to operate through a wide range of events including extreme floods. Many reservoirs have sufficient storage to completely retain the local runoff from minor or moderate floods. The water control plan should define the basic goal of regulation, relative to management of minor and major floods. The water control plan should be designed to best use reservoir storage, considering both major and minor floods as well as consecutive rainfall events. Also, the amount of flood storage for a particular project may be varied seasonally to improve benefits of multipurpose regulation. Decisions affecting flood risk management can be planned for the longer term when reservoir inflows can be accurately forecast several days or weeks in advance (e.g., runoff from snowmelt).

2.2.4.2. Operation Conflict. For multipurpose reservoirs, the projects are designed and operated to balance multiple objectives. A project's design and water control plan define the tradeoffs that are to be made among purposes to reduce conflict. When the rules in the water control plan are formulated, water managers should recognize opportunities for flexibility. Adjustments in priority during different times of the year can and should be addressed during initial formation of a water control plan or during a revision process. The water control plan should address any pressures to depart from flood risk management regulations in the interest of other objectives. In operating all its projects, the Corps always seeks to minimize risk to public safety; other purposes should be considered within the context of risk. If, in the attempt to maintain flexibility, water managers consider objectives that fall outside the water control plan, they may follow the deviation process described in ER 1110-2-240, Water Control Management.

2.2.4.3. Evacuation of Flood Storage. Depending on reservoir storage and discharge capabilities, a challenging component of reservoir management is the requirement for post-flood evacuation of stored water. The flood storage should be evacuated as quickly as possible without exceeding the safe rate of release. The water control plan must account for the release of flood storage, which may vary between a rapid evacuation of stored water to provide flood storage for subsequent events and a slow evacuation to allow downstream river levels to recede below bankfull as quickly as possible. This may result in a long duration of downstream river levels at or near bankfull, or produce minor damaging stages at downstream control points. Some projects may designate a portion of the flood storage to meet other project purposes, which is outlined in the water control manual.

2.2.5. Reservoir Systems.

2.2.5.1. A multireservoir system is regulated generally to mitigate for flood risk both in intervening tributary areas and at downstream mainstem damage areas or control points. The extent of reservoir regulation needed to mitigate risk in these areas depends on local flood conditions, uncontrolled tributary drainage, reservoir storage capacity, and the volume and time distribution of reservoir inflows. Upstream or downstream impacts may influence reservoir regulation, but optimum regulation is usually based on a combination of the two. Reservoir releases are based on the overall objectives to manage flood risk at defined control points. The regulation must consider the travel times caused by storage effects in the river system and the local inflows between the reservoir and control points. Since each flood event is caused by a unique set of hydrometeorological conditions, the specific plan of regulation for a reservoir system should be based on the analysis of the particular flood event. This analysis is commonly conducted by modeling the runoff conditions and reservoir regulation to determine the releases at each project needed to meet the desired downstream targets and to achieve the water management objectives at each reservoir or management structure. Water managers should integrate the corporate tool, CWMS, to the extent possible for simulations including hydrologic, reservoir, hydraulic, and flood inundation models.

2.2.5.2. System management may incorporate the concept of a balanced reservoir regulation, with regard to filling the reservoirs in proportion to the flood risk management capability, while also considering expected residual inflows and available storage. Flood water stored in a reservoir system must also be evacuated on a coordinated basis to provide space for managing future floods while managing downstream risks. Regulation criteria in the form of guide curves and regulation schedules for individual reservoirs should be developed to define various amounts of storage as seasonal or exclusive flood storage. The seasonal flood storage zone elevations could vary based on the time of year and the associated risk of flooding along with the ability to forecast reservoir inflows (e.g., snowmelt runoff vs. thunderstorm rainfall runoff). The withdrawal objectives in the seasonal flood storage zone should be determined to balance the need to conserve water for future use with the need to reduce flood risk. The exclusive flood storage zone will typically be evacuated as quickly as possible to provide space for managing future floods while managing downstream risks.

2.2.6. Levees. Flood risk management of land and structures adjacent to rivers is often provided by levees. While most levee projects do not require daily water management decisions, water managers should be informed of conditions along levee systems related to the management of a water resources system. Particularly during major floods, the water management office should be alerted to any signs of weakness in the levee system. The water management office, in coordination with other offices, should disseminate an evaluation of flood hazard areas in conjunction with the regulation of reservoirs or diversion structures. Also, flood fight activities, which involve special precautions to ensure the safety and integrity of levees, require the coordinated efforts of the water management office, Operations Division, Readiness and Contingency Operations (RCO), and other appropriate organizational elements. The latest forecasts of river levels and potential future flooding may be assessed and disseminated to the field. In some cases, special requirements, such as placing temporary bulkheads at street or highway crossings and sandbagging vulnerable locations to ensure the continuity of levee effectiveness, are incorporated into the design of levee systems. Since such requirements must be accomplished before critical conditions or flood levels are reached, timely coordination of river level forecasts must be made with appropriate Operations Division and RCO personnel.

2.2.7. Combined Reservoir and Levee Systems. Flood risk management is provided in many river basins through the combined effects of reservoirs and levee systems. The system design should be based on planning and engineering considerations in an analysis of river basin development to provide a practical and economic flood risk management solution. Water managers should be informed of conditions along levee systems related to the management of a water resources system.

2.2.8. Flood Risk Management Projects Operated and Maintained by Non-Federal Interests. In addition to Corps-operated dams and reservoirs, the Corps prescribes operations and maintenance requirements, which may include water management requirements, for three categories of projects operated and maintained by non-Federal interests: (a) Corps-constructed non-reservoir projects, which usually fall under the responsibility of local interests or non-Federal sponsors for operations, maintenance, repair, rehabilitation, and replacement (OMRR&R), and which are subject to OMRR&R Manuals formulated by the Corps for such projects and to regulations in 33 CFR Section 208.10; (b) projects constructed by non-Federal interests that retain an Active status under the Corps' Rehabilitation and Inspection Program, pursuant to 33 USC 701n (generally referred to as the P.L. 84-99 program) and to 33 CFR Part 203 Subpart D.; or (c) non-Federal reservoir projects that include flood risk management or navigation storage and that were constructed wholly or in part with Federal funds provided for such purposes, the storage of which is operated pursuant to Corps regulations pursuant to Section 7 of the Flood Control Act of 1944 and to 33 CFR Section 208.11. Documentation guidance pertaining to water management requirements is provided in Chapter 9.

2.2.9. Interior Drainage Systems.

2.2.9.1. Areas protected by levees often include the requirement to provide interior drainage for levee seepage or storm runoff from local uncontrolled inflows that drain into the channels on the protected side of the levees. The design of drainage systems to manage these flows may be based on the use of pumping plants, tide or "flap" gates, or temporary storage of water in low-lying areas or channels that are not subject to flood damage. Adequate channels must be constructed to convey the water to the outlets or management structures. The design of the drainage systems may be determined from studies of storm rainfall and associated runoff that reasonably occur while taking into account flooding on the unprotected side of the levee.

2.2.9.2. The facilities constructed to manage flooding in interior drainage systems often operate automatically and only require surveillance during times of floods. Most small pumping stations used in evacuating interior drainage are operated and maintained by local entities. For large pumping facilities that are operated by Corps personnel as part of interior drainage systems, the pumps and gates may be manually operated according to established operating plans or standing instructions. For inflows and water levels that are not described in these plans, water management staff may determine target flows or stages to facilitate operation of outlet structure gates. During high water periods, water management staff should continuously monitor upstream and downstream conditions at these structures and consult with pumping station operators as necessary.

2.2.10. Diversions, Bypass Structures, and Floodways.

2.2.10.1. Temporary diversions are often required during construction of projects. In some river systems, however, excess flood water or water supply is diverted from the main river channel by a permanent diversion, bypass structure, or floodway and auxiliary channels to reduce flood flows and river levels at main stem damage centers. These permanent structures are usually located in flood plains, where river slopes are relatively flat, and adjacent to the main river channel to divert water into the auxiliary channels. Many structures are seldom used or pass only insignificant amounts of water, but significant streamflow could be diverted during flooding. Diversions could be operated continuously. The diversion of water may be managed through use of control gates, pumps, or other methods, or the structure may be designed for uncontrolled operation, depending on the water level in the main river. The capacity of the structure is determined by engineering studies of desired flood stage reduction and downstream channel capacities in the main river and in the auxiliary channels, in connection with the overall plan of flood risk management, which may include levees and impoundment projects upstream. The auxiliary channels may be improved to provide the desired flow capacity without flooding adjacent areas, or may be left as unimproved natural overflow channels. The degree of improvement depends on the frequency and extent of flooding, land use, and economic factors.

2.2.10.2. Diversions, bypass structures, and floodways may require gate operations to manage releases. The timing and use of the structure for diverting flood flows must be based on the best forecasts of river flows and flood conditions. In some cases, the auxiliary channels are designed to be used only under maximum flood conditions to reduce adverse effects of flooding along the auxiliary channels. These channels should be used only for design floods or other necessary conditions. Decisions to use the structures should be based on the most complete basic data and technical evaluations available.

2.2.10.3. Diversion and bypass structures that have ungated spillways or sluices do not require specific water management decisions since the flow of water through the structure is determined solely by water levels in the river. The date and time that the facilities will be operated should be estimated sufficiently in advance to provide timely warnings to the people living along the auxiliary channels and to take other necessary actions.

2.2.11. Hurricane and Tidal Barriers.

2.2.11.1. Hurricane and tidal barriers, which are located along the ocean coastlines, across tidal estuaries, or along the perimeter of very large lakes with long fetches, provide flood risk management against high water levels and surges resulting from hurricanes or severe storms. These projects consist of rock-lined earthen dikes or concrete walls and structures that confine the water and thereby mitigate flood risk caused by storm surges and wave action. Flooding resulting from such conditions is usually of short duration, ranging from a few hours to a few days. Hurricane and tidal barriers are generally designed to withstand an infrequent combination of strong winds and high tides.

2.2.11.2. The barriers protect low lying areas from inundation and wave action and the associated management structures permit drainage of interior runoff during non-flood periods. In estuaries, a movable barrier (sector, Tainter, or flap gates) may be incorporated into the design to permit navigation through the structure during normal conditions. During tidal flooding, this movable barrier closes off the navigation channel to preserve the integrity of the barrier system. During closure, the interior runoff is either discharged by pumps or temporarily stored behind the barrier. In most cases, the Corps retains ownership and management of those barrier elements that contain navigation facilities; however, local communities are usually responsible for the O&M activities for barriers that do not contain navigation features.

2.2.11.3. The management of barrier systems requires a water control plan to regulate the structures, including pumping stations, vehicular gate openings, sewer lines, and sea water intakes. When rivers or tributaries drain into estuarine channels, the water control plan may require management of the entire river system to mitigate risk to the estuary. Forecasts of controlled or uncontrolled tributary inflows may be an important element in the plan, but operational decisions should be made based on water-on-the-ground unless stated in an approved water control plan.

2.3. Navigation.

2.3.1. Historical Background.

2.3.1.1. Improvement of national waterways for navigation was an early concern in the water resources development of the United States. The first artificial waterways were built in the northeastern United States in the late 18th century and early 19th century by private developers. Federal involvement became a matter of national policy, because the waterways were used for interstate commerce, as well as for national and international trade. The Federal government, through the Corps, has been involved in navigation improvements along some 22,000 miles of inland and coastal waterways. Types of navigation improvements include canals, locks, dams, and reservoirs; maintained channels and estuaries; and bank protection, pile dikes, and other forms of channel stabilization. Releasing water from reservoirs to increase river levels is another type of navigation improvement.

2.3.1.2. Navigation improvements along a particular river may involve several of the afore-mentioned methods. Although the requirements are related mainly to commercial navigation, navigation needs may exist for small boat operation and recreational use by the general public. Commercial needs range from intra-river transportation by small draft barges and tows to deep-draft ocean-going vessels for general use.

2.3.2. Water for Navigation.

2.3.2.1. General. The complexity related to water management for navigation use varies widely among river basins and types of developments. Dams, reservoirs, or other facilities with navigation as a project purpose should be regulated to help provide appropriate flows, or to help maintain project navigation depths. Navigation needs are integrated with other water uses in multipurpose water resources systems. In the regulation of dams and reservoirs, efforts to accommodate navigation interests typically involve managing water levels in the reservoirs and at downstream locations as well as providing the quantity of water necessary for lock operation. Navigation constraints may be integrated into the regulation of dams and reservoirs with regard to rates of change of water surface elevations and releases. Numerous special navigation conditions may involve water management, such as the presence of ice, undesirable currents and flow patterns, emergency precautions, and boating events and launchings.

2.3.2.2. Water Requirements for Lockage and Controlled Canals. Navigation locks located at dams on major rivers generally have sufficient water from instream flows to supply lockage flow requirements. Usually, water released from reservoirs for navigation also fulfills other purposes, such as hydroelectric power generation, water supply, water quality, enhancement of fish and wildlife, and recreation. Seasonal or annual water management plans may be prepared to define the use of water for navigation. The amount of water available for release depends on the quantity of water stored in the reservoir system, downstream requirements or goals for water supply, and consideration of all uses of the water in storage.

2.3.2.3. Water Releases for Navigation in Open Rivers. Navigation requirements for downstream use in open river channels may require flows to be managed over a long period of time (from several months to years), to achieve a significant, continuous increase in water levels for boat, barge, or ship transportation. Water released from reservoirs to increase long-term downstream flows for navigation purposes may be a major factor in managing a system that has hydroelectric power generation requirements. A water control plan that includes both hydroelectric power generation and navigation should include analyses to support operating decisions that balance the uses between those two purposes as well as other authorized purposes (e.g., water supply, flood risk management). Extreme daily fluctuations in releases that would result from power peaking operations may need to be prevented due to navigation demands to maintain minimum water levels at downstream locations. These restrictions, which may apply to both daily and weekly fluctuations in streamflow and water levels, are determined by other requirements (e.g., for navigation, boating) of the waterway.

2.3.2.4. Winter Navigation. Winter navigation poses a special concern for water management. The goal of an effective winter navigation plan should be to manage ice accumulations to maintain winter navigation as long as reasonably practicable. If a winter navigation management plan is desired, then it should be a part of the water control plan for the entire system. However, basin conditions may be such that a water control plan does not support winter navigation, and instead provides for seasonal navigation based on normal winter conditions.

2.4. Hydroelectric Power Generation.

2.4.1. Hydroelectric Power in Corps Projects. Hydroelectric power generation is a major element of many Corps water resources projects. Geographically, about three quarters of Corps hydroelectric power is generated in the Northwestern Division.

2.4.2. Hydroelectric Power Evaluation. The methods to evaluate hydroelectric power capabilities, power values, and power system operation are provided in EM 1110-2-1701, Hydropower. ER 10-1-53, Roles and Responsibilities, Hydroelectric Design Center, designates the U.S. Army Corps of Engineers District, Portland, Hydroelectric Design Center (HDC), as the Mandatory Center of Expertise (MCX) for hydroelectric power engineering and design.

2.4.3. Types of Projects.

2.4.3.1. Most projects with a hydroelectric power purpose may be placed into one of two distinct categories: (a) dams and reservoirs that have sufficient storage to regulate streamflows on a seasonal basis and have a flood risk management authorized purpose, and (b) lock and dam (run-of-the-river) projects with minimal storage capacity relative to the volume of flow that are either primarily authorized for hydropower, or that also include navigation as an authorized purpose. Other, less common types of projects and features include off-stream diversions, pumpback facilities, and hydrokinetic projects.

2.4.3.2. Hydroelectric power projects are usually multipurpose, with additional water uses that may include flood risk management, irrigation, navigation, M&I water supply, water quality, fish and wildlife, and recreation. Normally, a reservoir will include provisions for power production at the site as well as for release of water for downstream purposes. A storage project may also be paired with a downstream reregulating dam to allow the powerhouse to fluctuate discharge in response to power demand and to use the reregulating dam to dampen the flow fluctuations to maintain more stable downstream conditions.

2.4.3.3. Run-of-the-river hydroelectric power plants are usually developed in connection with navigation projects. These projects have minimal storage capacity, often allowing for only a limited operating range. Within the operating range, the projects pass inflow either through generating units or through an alternate gated or spillway structure.

2.4.3.4. In addition, power facilities may be developed in off-stream water supply channels or irrigation works. In high mountain areas, off-stream diversions may be used for high-head power plants. Also, pumped storage plants may be used to pump water into a storage reservoir, using less expensive electricity available during times of surplus energy and releasing the stored water to generate hydroelectric power during peak system power demands.

2.4.3.5. In certain conditions, hydrokinetic projects can be developed from wave action or tidal fluctuations in bays or estuaries or from flowing water in large rivers. Many such projects in the United States are in various stages of planning, permitting, and construction.

2.4.4. Integration of Federal Hydroelectric Power Systems.

2.4.4.1. The electrical power produced at Corps projects in the United States is integrated with electric power produced by other utilities. Power produced by Corps projects is marketed to the utilities and other direct service customers by four regional power marketing administrations (PMAs) of the Department of Energy. In addition to marketing, some of the PMAs also provide transmission and dispatching services. The regional electrical power networks in the United States are complex and highly integrated systems, the operation of which is made possible through formal agreements made between utilities or through informal working relationships to enhance the overall capability of individual utilities.

2.4.4.2. The four regional PMAs are Bonneville Power Administration (BPA), Southeastern Power Administration (SEPA), Southwestern Power Administration (SWPA), and Western Area Power Administration (WAPA). All four PMAs market Federally-produced power from dams owned by the Corps. The Tennessee Valley Authority (TVA), a Federally-owned corporation, also markets and transmits power from Corps-owned dams.

2.4.5. Management of Federal Hydroelectric Power Systems. For Corps hydroelectric projects, schedulers from the PMAs coordinate hydroelectric power operations with Corps water managers to ensure successful integration of the Corps water management operations into the hydroelectric power system. In many cases, the Corps water management operations are constrained (e.g., minimum release, maximum release, release pattern) and are simply communicated to the power marketing agency. At some projects, enough flexibility exists in the Corps regulation schedule to allow for increased input from the power marketing agency. The Corps may prescribe operating limits, such as forebay and tailwater constraints, and allow a power marketing agency to communicate flow changes directly to operating project personnel, while staying within the prescribed constraints. In a river basin with dams owned by both the Corps and other entities, Corps water managers may also have agreements to coordinate water management activities with other dam owners to maximize all hydroelectric power benefits from the system.

2.4.6. Non-Federal Development of Hydroelectric Power at Corps of Engineers Projects. The Federal Power Act, as amended on 1 April 1975, delegates to the Secretary of the Army and to the Commander, USACE certain functions necessary for Federal Energy Regulatory Commission (FERC) administration of the act. ER 1110-2-1454, Corps Responsibilities for Non-Federal Hydroelectric Power Development Under the Federal Power Act, provides policy and guidance for review of preliminary permit and license applications for non-Federal development at or affecting Corps projects.

2.4.7. Special Operating Issues. Issues associated with power operation vary widely among projects and systems, depending on the importance of hydroelectric power generation in relation to other project purposes, the methods of hydropower system control, and the system integration of power regulation with other multipurpose water management requirements. The water manager is concerned with two basic types of issues, both of which result in a large degree of coordination with all users:

1. Seasonal project and system regulation, in which power is a consideration in the water control plan.

2. Power regulation scheduled on a daily, weekly, or monthly basis to meet the power needs in conjunction with the other water uses.

2.4.7.1. Seasonal Reservoir Regulation for Hydroelectric Power Generation. An annual operating plan (AOP) is generally developed on the basis of yearly hydrologic conditions, system power requirements, and multipurpose requirements and goals for reservoir regulation. The studies required for developing the AOP should be coordinated with other power interests and local or regional groups that have an interest in the multipurpose aspects of water regulation.

2.4.7.2. Coordination. Coordination between the Corps and the PMA must occur in formulating power production and power marketing strategies and integrating the operation of power facilities within the regional power grid. This coordination involves many aspects of project operation and reservoir regulation at Corps projects, including the development of the operating plan to achieve the hydroelectric power generation operating objectives, scheduling reservoir releases, and dispatching power under normal and emergency conditions. The coordination requires administrative procedures, technical evaluations, and detailed working arrangements to ensure that the responsibilities of the two agencies are met. This is generally accomplished by executing formal memorandums of understanding (MOUs) that define specific duties and responsibilities, establish coordinating groups composed of agency representatives that oversee the operations, and form work groups assigned to specific tasks.

2.4.7.3. Scheduling and Dispatching Power. Scheduling and dispatching power from Corps projects are performed according to the basic operating strategies and criteria contained in the AOP and water control manual. The AOP consists of guide curves and other operating guidelines generalized from power operation studies performed on the basis of mean monthly historical streamflow data and estimated load and resource evaluations. The actual operating schedules must also be based on current and forecasted hydrologic and power data. For small or relatively simple systems, the schedules can be determined manually from analysis of current data and forecasts of operations. For large integrated power systems, however, the schedules are usually determined from simulations that provide current analyses of all hydrologic and power generation data, load forecasts, interchange requirements, and real-time plant and unit status conditions, and that conform to the constraints of operating rule curves. Forecasted simulations range from several days to weeks or months in duration, and more general projections may be made for periods that extend multiple years. The actual operating schedules are derived from the simulations of project operation. The daily operating schedules are forwarded to the project office for plants not on centralized control or are inserted into the system controller at the power control center. The schedules may indicate hourly generation values for block loaded plants and anticipated plant loadings, unit status, and "break point" settings for plants operating under automatic generation control (AGC) equipment.

2.4.7.4. Power Dispatchers.

2.4.7.4.1. The continuous operation of the power system is managed by the power dispatchers, who monitor all aspects of plant and system operation. The dispatchers should be in frequent communication with plant operators who manage the operation of hydroelectric facilities. The plant operators are responsible for the plant operation according to the operating schedules and other operating criteria that may affect water regulation and the operation of the physical facilities.

2.4.7.4.2. Corps water managers may need to communicate with dispatchers regarding regulation schedules, transmission and generation constraints, emergencies; or to provide project updates. This includes dispatchers for agencies transmitting power from Corps-owned dams, as well as dispatchers for dams operated by other entities for which the Corps directs flood risk management operations or has reservoir regulation responsibility.

2.4.7.5. Constraints on Peaking Operation at Hydroelectric Power Plants. Many hydroelectric plants are designed to meet peaking and intermediate load requirements that result in a low load factor operation. Some plants generate only at times of peak loading, generally for less than 8 hours per day, and the generation is scheduled to help meet the morning or afternoon peak loads. Other plants are scheduled for a more continuous operation, but still respond to daily variations in system loads. While many advantages are obtained from operation for peak-only loading conditions, fluctuating outflows resulting from this operation may cause water regulation issues. Environmental considerations, such as the effect of fluctuating water levels on fish and wildlife, aesthetics, navigation, and public safety are considered in the planning, design, and operation of peaking power plants. In some cases, water fluctuations related to peaking operation are reduced by constructing reregulating reservoirs immediately downstream from peaking power projects. At locations where construction of reregulating reservoirs is impractical, specific operating limits for fluctuations in power production or water level in the river system below the projects are developed on the basis of studies made during the design phase. Pondage projects, which are developed in tandem on a major river, are operated as a system with regard to peaking power operation. The total system output is shaped to meet the fluctuating power loads, so that all plants share in loads and fluctuations of reservoir and tailwater water levels. The analysis of this type of system operation is accomplished through use of the various computer models. In actual operation, requests for restrictions in peaking operation may be made, beyond those set forth in the design or operational studies. Generally, these requests are a result of changed environmental conditions or other unanticipated conditions and should be carefully analyzed.

2.4.7.6. Departure from Normal Hydroelectric Power Operations.

2.4.7.6.1. During operation, circumstances may require minor departures from the operating plans to satisfy unanticipated needs or desires for river regulation. In some cases, departure from operating plan schedules and guidelines may affect the ability to meet one or more of the water management goals, and the issue may have to be referred to an appropriate administrative level for resolution. The water manager must be informed immediately of any large scale interruption of the power system and take actions as necessary to preserve the water management goals and alert others regarding the emergency conditions.

2.4.7.6.2. The PMA may coordinate with Regional Transmission Organizations (RTOs) or independent system operators (ISOs) to ensure the efficient and reliable delivery of power across large areas. Occasionally, power market or regional transmission issues can influence the timing of hydroelectric power releases or the method of releases by requiring water to be released through outlet tunnels or spillways rather than to be used for hydroelectric power generation.

2.5. Irrigation.

2.5.1. Historical Background and Agency Roles. In the arid and semi-arid regions of the western United States, the use of water to irrigate arable lands has been a major factor in developing water resources systems. The seasonal nature of precipitation and the lack of rainfall in the growing season led to the development of agricultural water supplies following the turn of the century. Initially, development of irrigation projects using surface water depended on diversions from the flow of the rivers. As the developments increased in size, reservoirs were constructed to increase the dependable flow of the rivers, thereby assuring water supplies on an annual or multiyear basis when the instream flow was insufficient to meet demands. As the complexity of the developments increased, it became necessary to institutionalize these arrangements. This originated first at the local and state levels of government, but Federal action was initiated by the Carey Act of 1894.

2.5.1.1. U.S. Bureau of Reclamation (USBR). Reclamation law establishes irrigation in the West as a national policy. For purposes of reclamation law, the West is defined as those 17 contiguous states lying wholly or in part west of the 98th meridian. The Secretary of the Interior is authorized to locate, construct, operate, and maintain works for the storage, diversion, and development of waters for the reclamation of arid and semi-arid lands in the west. In these 17 western states, in conformity with reclamation law, the repayment arrangements and agreements for irrigation water from Corps reservoirs is administered by USBR.

2.5.1.2. Corps of Engineers. Section 8 of the Flood Control Act of 1944 provides that Corps reservoirs may include irrigation as a purpose upon the recommendation of the Secretary of the Interior and approval of the Secretary of the Army, after authorization by Congress under the reclamation laws. This provision applies only to Corps reservoirs in the western states. Congressional authorization would also provide the U.S. Department of the Interior (DOI) with the authority to construct, operate, and maintain the additional irrigation works and to contract for the storage. In addition, Subsection 103(c)(3) of the Water Resources Development Act of 1986 (WRDA 1986) establishes a 35% non-Federal share of construction costs for Corps projects authorized for agricultural water supply. Section 931 of WRDA 1986 amends Section 8 to provide that, for any Corps reservoir project, the Secretary of the Army may allocate to irrigation purposes, for an interim period, storage included in the project for M&I water supply that is not under a repayment agreement.

2.5.2. Water Diversions and Return Flows.

2.5.2.1. Water Duty.

2.5.2.1.1. The amount of water needed to meet the demands for growing crops for the entire season is termed the water duty. This is equal to the total amount of water supplied to the land by means of gravity diversions from rivers or reservoirs or pumped from rivers, reservoirs, or underground sources of water. Net duty is the amount of water delivered to individual farm units, considering losses in canals, laterals, and waste from the point of diversion to the point of application on the land. In the western United States, the water duty averages about 2 acre-feet of delivered water per cultivated acre of land per year, and ranges from about one to as much as 6 acre-feet per cultivated acre.

2.5.2.1.2. Irrigation water diverted from reservoirs, diversion dams, or natural river channels is controlled in a manner to supply water for the irrigation system as necessary to meet the water duty requirements. The requirements vary seasonally, and in most irrigated areas in the western United States the agricultural growing season begins in April or May. The diversions gradually increase as the summer progresses, reaching maximum amounts in July or August. Then they recede to relatively low amounts by late summer. By the end of the growing season, irrigation diversions are terminated except for minor amounts of water that may be necessary for domestic use, stock water, or other purposes.

2.5.2.1.3. The return flow of water from irrigated lands is collected in drainage channels, where it flows back into creeks and natural river channels. This return flow augments the prevailing river flow, and depending on water rights and quality, the return flow may be reused for downstream irrigation or to supply some other water use function. Continued improvements in irrigation practices have made higher efficiencies in consumptive, on-farm water application more practical; however, these practices may result in lower return flows and higher net consumptive use from a basin perspective.

2.5.2.1.4. USBR annually completes and provides western Corps projects with a depletion analysis. Depletions are defined as removal of water from a river or reservoir for a specific man-induced activity, such as irrigation of cropland. The depletion estimates are used by the Corps in long-term model simulations as well as calendar year runoff projections. As resource development continues, a growth in depletions can be expected. While increasing depletions likely benefit the flood risk management function, it is evident that they may have adverse effects on other authorized purposes, such as irrigation, that are dependent on the availability of a continuing water supply.

2.5.3. Water Management for Irrigation.

2.5.3.1. Corps reservoir projects have been authorized and constructed primarily for flood risk management, navigation, and hydroelectric power generation. However, several major Corps multipurpose reservoir projects include irrigation as a project purpose. Usually, water for irrigation is supplied from reservoir storage to augment the available streamflows to meet irrigation demands in downstream areas. In some cases, water is diverted from the reservoir by gravity through outlet facilities at the dam that feed directly into irrigation canals. At some run-of-the-river power or navigation projects, water is pumped directly from the reservoir for irrigation.

2.5.3.2. The general mode for regulation of multipurpose reservoirs to meet irrigation demands is to capture all runoff in excess of minimum flow demands and rule curve levels to refill the reservoirs before the irrigation demand season. The water is held in storage until the instream flow recedes to the point where it is insufficient to meet all consumptive and instream demands. At that time, the release of stored water from reservoirs begins and continues on a demand basis until the end of the growing season, or when flow augmentation is no longer needed for water quality or fish and wildlife. During the late fall and winter, projects release water for instream flows, stock water, or other project purposes, such as to evacuate for flood risk management during the annual flood season.

2.6. M&I Water Supply Use.

2.6.1. Basic Considerations.

2.6.1.1. Many Corps reservoir projects supply water for M&I use as an authorized purpose. M&I water users must separately acquire all necessary water rights. At Corps reservoir projects, M&I water supply is typically managed according to long-term water storage agreements between the Corps and nonfederal entities pursuant to the Water Supply Act of 1958. These agreements authorize the use of reservoir storage of water supply to meet demands commensurate with the estimated yield of that storage space, and they require that the water supply users share in the costs to construct, operate, and maintain the project.

2.6.1.2. ER 1105-2-100, Planning Guidance Notebook, describes the objectives, policies, allocations of storage, repayments, obligations, and other aspects of plan formulation involved in incorporating water supply for M&I use into Corps reservoirs projects. The policies stem principally from the Water Supply Act of 1958. While certain water withdrawals may be accommodated under other authority, such as limited uses under approved shoreline management permits, in general, withdrawals or releases of water from Corps reservoir projects for M&I use must fall under a project-specific authority, the Water Supply Act of 1958, or Section 6 of the Flood Control Act of 1944. Questions regarding the authority for water supply withdrawals should be directed to the office of counsel.

2.6.2. Other M&I Water Supply Considerations.

2.6.2.1. Storage rights of the user are defined in the current agreement format in terms of an undivided percentage of usable conservation storage space, including the estimated acre-feet of storage at the time of agreement execution. When storage is available, the user generally has the right, subject to relevant conditions, to withdraw water from the reservoir or to order releases to be made through the outlet works. Availability of storage may be subject to periodic accounting based on proportional sharing of inflows and losses, and to certain rights that are reserved to the Government with regard to the project's overall regulation.

2.6.2.2. Estimates of reliable yield for local users based on their available storage space may decrease over time due to changing hydrologic conditions or sedimentation. Such findings should be communicated to the local users for use in their own planning and operations. Typically, water storage agreements require that, when findings of a sediment survey indicate that the storage available for M&I water supply has been affected by unanticipated sedimentation, the sediment reserve storage will be equitably redistributed among all of the project purposes, and the total remaining storage space in the project will be divided among the purposes in the same ratio as the original storage agreement to the original authorization of other purposes. The resulting change in storage allocated to the M&I user will be described in an exhibit to the storage agreement and update to the water control manual.

2.6.2.3. In times of drought, special considerations may guide the regulation of projects with regard to water supply. ER 1110-2-1941, Drought Contingency Plans, provides policy and guidance to prepare drought contingency plans. Drought contingency planning requires close coordination among all Federal, state, and local interests to maintain reasonable expectations regarding project water levels.

2.7. Water Quality.

2.7.1. General.

2.7.1.1. Corps policy for water quality management at Corps civil works projects is outlined in ER 1110-2-8154, Water Quality and Environmental Management for Corps Civil Works Projects. Although water quality control may not be an authorized project purpose at all projects, the Corps tries to protect and enhance the quality of water and land resources at its projects as a matter of policy.

2.7.1.2. Water quality benefits may accumulate slowly, but become quite substantial over time; this contrasts with the substantial benefits that may quickly accrue from a single flood risk management operation. Potential considerations to address water quality include selective withdrawal, run-of-the-river releases, variable minimum flows, temperature management, and routing of sediments.

2.7.2. Releases for Downstream Management.

2.7.2.1. Water quality releases for downstream management have both quantitative and qualitative aspects. One of the most common measures of water quality is flow. At many projects authorized for water quality management, a minimum flow at a downstream control point is the water quality objective. However, flow alone does not ensure a sustainable downstream habitat for aquatic life.

2.7.2.2. The qualitative aspects relate to Corps policy and objectives to meet Federal, state, local, and tribal water quality standards and to maintain a sustainable downstream habitat for aquatic life. The stream and reservoir water temperature annual cycle of warming in the spring and cooling in the fall is an important consideration in managing the water resources project, as temperature is critical to life cycles in the aquatic community. Dissolved oxygen is related to temperature, and aquatic communities require continuous supplies of dissolved oxygen. Satisfactory average dissolved oxygen concentrations are not sufficient to sustain an aquatic community; for example, a single, brief anoxic project release may cause a fish kill. Reservoirs may stratify during parts of the year creating a potential for anoxic releases. Monitoring the oxygen levels in a reservoir and outlet channel, re-aeration in the stilling basin and downstream area, monitoring the oxygen demand of release water, and use of appropriate intakes and outlets can help to reduce anoxic occurrences.

2.7.3. Monitoring.

2.7.3.1. Water quality should be monitored continuously for effective water management of environmental resources. Data collection guidance and reporting requirements are contained in ER 1110-2-8154. A comprehensive treatment of all aspects of water quality monitoring and data analysis can be found in EM 1110-2-1201, Reservoir Water Quality Analysis. Data collection programs should be adapted to each water resources project, as documented in the water control plan, to ensure that project purposes are not compromised and to monitor effects of project regulation on reservoir and outlet channel water quality.

2.7.3.2. As part of the Clean Water Act, states are required to establish total maximum daily loads (TMDLs) for specific parameters on some streams. TMDLs may have a direct impact on management of a Corps reservoir project, and a coordinated effort to establish TMDLs is important.

2.7.3.3. Known or suspected issues such as harmful algal blooms (HABs) or priority contaminants require special and often intensive data collection efforts. As appropriate, districts should develop HAB response plans coordinated with the division office, as HABs may have devastating consequences on project purposes such as recreation, water supply, and fish and wildlife. Districts responsible for navigation channel maintenance must coordinate with regulating agencies regarding priority contaminants.

2.7.4. Selective Withdrawal for Water Quality Management. Most impoundments exhibit some degree of temperature stratification. Due to water quality variations in the reservoir water column, the primary means of managing the quality of reservoir releases is to provide facilities to withdraw water from various levels in the reservoir, such as multilevel intake structures, when available. Managing the quality of releases through selective withdrawal structures requires sufficient data to coordinate daily decisions. Withdrawing water from any one reservoir elevation layer, based on a water quality vertical profile, may be insufficient to meet all water quality objectives. Detailed technical guidance for selective withdrawal is provided in EM 1110-2-1201.

2.7.5. System Regulation for Water Quality.

2.7.5.1. Water quality maintenance and enhancement beyond the discernible beneficial effects of a single project may also be achieved through coordinated system regulation. System regulation for water quality may be of value during low-flow periods, when available water should be managed carefully to avoid degrading reservoir or river quality.

2.7.5.2. Differences between series and parallel systems and associated downstream impacts should be understood. In series operation, upstream projects release water into downstream projects, directly impacting the water quality in the downstream project. In cases where the system is comprised of parallel projects, water released from multiple projects may impact a common downstream control point.

2.8. Fish and Wildlife.

2.8.1. Authority. Corps projects may be specifically authorized for fish and wildlife. Appendix B to this manual lists several important Federal laws and executive orders that also influence how the Corps manages projects with respect to fish and wildlife. Regardless of the authority, the Endangered Species Act (ESA) requires the Corps to ensure that its discretionary operations do not jeopardize the continued existence of any Federally listed threatened or endangered species. If operations are likely to adversely affect an endangered or threatened species a Biological Assessment and consultation with the appropriate Federal agency is required, usually the National Marine Fisheries Service or the U.S. Fish and Wildlife Service. A Biological Opinion may be issued outlining actions and measures to be implemented to avoid jeopardizing the listed species.

2.8.2. General.

2.8.2.1. Fish and wildlife management opportunities and issues related to water management vary widely depending on the project's geographical location, management objectives, and operational capabilities. Each project's water control manual should contain specific information regarding how the project should be regulated to meet the fish and wildlife objective.

2.8.2.2. Most large water management projects are authorized and designed for multiple purposes and water control plans may contain enough flexibility to permit some manipulation of water levels and reservoir releases for fisheries management and other wildlife considerations. Water managers may work with relevant stakeholders to understand how pool level fluctuations and the quality, quantity, and timing of project releases impact fish and wildlife.

2.8.2.3. Developing guidance to creatively manage projects for fisheries is complicated by consideration of the wide range of hydrometeorological events that may occur and the effects of regulation to meet project authorized purposes. Further complexity is introduced by the fact that habitat requirements for spawning, incubation, and emergence times vary greatly among species.

2.8.2.4. While the project's structural design may limit the flexibility of regulation strategies, objectives and priorities for fish and wildlife management should be identified and coordinated with appropriate fish and natural resources agencies. The agencies may include the U.S. Fish and Wildlife Service, the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service, state fish and wildlife agencies, and tribal groups.

2.8.3. Reservoir Fisheries.

2.8.3.1. One of the most readily observable effects of reservoir regulation is reservoir pool fluctuation. Periodic fluctuations in reservoir water levels present both issues and opportunities to the water manager with regard to fishery management. The seasonal fluctuations that occur at many flood risk management reservoirs and the daily fluctuations that occur with hydroelectric power generation may eliminate shoreline vegetation, thereby leading to shoreline erosion, water quality degradation, and loss of riparian and aquatic habitat, and physical disruption of spawning and nests.

2.8.3.2. Fishery management techniques may include managing pool levels to force foraging fish out of shallow cover areas and into areas more susceptible to predation, maintaining appropriate pool levels during spawning, and minimizing fluctuation in pool levels. Wave action from slowly lowering pool levels can help maintain clean gravel substrates, which are favorable to some target fish species. Alternatively, bank erosion and slumping that removes substrate and prevents establishment of vegetated littoral zones can occur in some reservoirs.

2.8.3.3. The success of each management technique varies regionally and by individual reservoir. The variability in physical, biological, chemical, and operational characteristics and uncontrolled environmental influences create difficulty in predicting the results of changes in reservoir levels and releases on fisheries. Reservoir design, mode of operation, and developmental requirements of target fish species affect water management strategies. Manipulation of water levels to enhance fisheries is often based on the timeliness of flooding or dewatering shoreline vegetation. For recommended seasonal flooding of shoreline vegetation, fishery management plans may include lowering water levels during a portion of the growing season to permit regrowth of vegetation. By regulating the timing and duration of flooding, water level management schemes can be developed for a reservoir to encourage the establishment of desirable, innocuous macrophytes and to reduce nuisance aquatic plants.

2.8.3.4. Water-level management in fluctuating warm-water and cold-water reservoirs generally includes raising water levels during the spring to enhance spawning and survival of young predators. Pool levels are lowered during the summer to permit regrowth of vegetation in the fluctuation zone. Fluctuations may be timed to benefit one or more target species; therefore, several variations in operation may be desirable.

2.8.3.5. Fall, winter, or summer drawdowns are often recommended for shallow reservoirs that support large stands of water plants (aquatic macrophytes). The drawdowns are effective in concentrating prey species and controlling aquatic vegetation. Drawdowns that reduce surface area by as much as 50% may be desirable in some cases. As with other basic approaches to water-level management, numerous variations have been applied and drawdowns for macrophyte and rough fish management are sometimes combined.

2.8.3.6. In addition to small pool fluctuations, periodic major drawdown has been used effectively for fishery management. This procedure includes a drastic lowering of a reservoir pool for an extended time period (at least one growing season) to permit vegetative regrowth in the dewatered zone. This step may be augmented by seeding plants to establish desirable species. Some objectives may be accomplished by selectively removing or killing various fish communities. Finally, the reservoir is refilled during the spring, fish are restocked, and a high water level maintained through the summer. This technique is effective for stimulating production of desirable sport and prey fishes, although authorized reservoir purposes must be taken into consideration.

2.8.3.7. Water-level management in some cold-water reservoirs has been oriented toward the production and enhancement of salmonoids, with anadromous species receiving primary consideration. Management issues related to production of salmonoids include maintaining access to tributary streams for spawning, controlling releases to facilitate passage of anadromous species, limiting losses of important sport fishes, and stabilizing reservoir pool levels during the extended periods of egg and larval development of certain species.

2.8.4. Downstream Fisheries.

2.8.4.1. Guidelines to meet downstream fishery management potentials may be developed for each project based on project water quality characteristics and the water management capabilities. An understanding of the reservoir water quality regimes is critical for developing the water management operating criteria to meet the objectives. For example, temperature is often a major constraint of fishery management in the downstream reach, and water managers should understand the temperature regime in the reservoir pool and downstream temperature goals as well as the project's capability to achieve a good balance between uncontrolled inflows and project releases. Releasing cold water instead of warm water to meet fishery management objectives may be detrimental to the downstream fishery. Conversely, releasing warm water may impact a cold-water downstream fishery.

2.8.4.2. Water management activities can also impact reservoir water temperatures by changing the volume of water available at a particular temperature. In some instances, cold-water reserves may be necessary to maintain a downstream temperature objective in the late summer months. For some projects, particularly in the southern United States, water management objectives include maintaining warm-water sports fisheries in the reservoir, and in some cases, cold-water fisheries in downstream reaches. In other instances, fishery management objectives may include the maintenance of a two-tier reservoir fishery, with a warm-water fishery in the surface layer, and a cold-water fishery in the bottom layer. To meet such an objective, water managers should endeavor to regulate the project to maintain the desired temperature stratification and sufficient dissolved oxygen in the bottom for the cold-water fishery, dependent on the location of intake gates. Also, the water manager should have an understanding of operational effects on seasonal patterns of thermal stratification and the ability to anticipate thermal characteristics. The ability to analyze these effects depends on relevant data being collected throughout the season.

2.8.4.3. Rapid changes in release volumes can have positive or negative downstream effects. Increasing releases from near zero to very high magnitudes, such as those that result from flood regulation or hydroelectric power peaking regulation, are sometimes essential to maintain downstream gravel beds for species that desire this habitat. However, rapidly decreasing releases can be detrimental to downstream fish and other aquatic organisms by stranding fish in relatively low-gradient areas of the channel or in pockets or side channels, dewatering eggs incubating in streambed gravels, increasing bird predation, elevating water temperatures, and reducing the benthic macroinvertebrate population. Other important factors to consider in managing releases include river channel morphology, channel substrate type, time of day, season, water temperature, flow level, and fish species and life stage. Maintaining minimum releases and incorporating reregulation structures are two options available to mitigate adverse effects.

2.8.4.4. The Corps is responsible for providing established minimum releases from water management projects to maintain downstream fisheries and the health of the downstream aquatic environment as specified in the water control manual. The release influences the downstream food supply, water velocity, and depth. Water managers often maintain minimum releases for this purpose along with minimum flow requirements for other instream purposes. Minimum instream flows are often required by state laws to maintain biological productivity, to provide spawning and rearing habitat, to decrease fish vulnerability to predation, and to support necessary oxygen and temperature conditions.

2.8.4.5. In some instances, fishing in an outlet channel is at a maximum during summer weekends and holidays and at times when power generation may be at a minimum and project releases near zero. Maintaining minimum releases during weekend daylight hours may improve the recreational fishing, but may reduce the capability to meet peak power loads during the following week because of lower water level (head) in the reservoir. In this instance, water managers may be particularly challenged to regulate the project for hydroelectric power and downstream fisheries.

2.8.4.6. The development of downstream total dissolved gas supersaturation, which can occur as water is released over a spillway or through a regulating outlet, may impact the aquatic biota. Managing this phenomenon is discussed in Chapter 4.

2.8.4.7. Opportunities to modify reservoir regulation increase with the complexity of the reservoir river system (e.g., Columbia River, Missouri River, White River, and Lower Ohio River basins), in which reservoir regulation is highly integrated. Reservoirs regulated primarily for flood risk management generally provide greater water level management flexibility than do hydroelectric power generation projects.

2.8.5. Fish Migration.

2.8.5.1. Another concern, particularly in the Pacific Northwest, is the maintenance of successful migration of anadromous fish such as salmon; similar objectives exist in the northeastern United States and in places that other anadromous fish, such as striped bass, have become established. Declines in anadromous fish populations have been attributed to dams from physical or thermal blockage of migration, alteration of normal streamflow patterns, habitat modification due to inundation, blockage of access to spawning and rearing areas, delays in migration rates, and changes in water quality.

2.8.5.2. Regulation for anadromous fish is particularly important during certain periods of the year. Generally, upstream migration of adult anadromous fish begins in the spring of each year and continues through early fall, and downstream migration of juvenile fish occurs predominantly during the spring and summer months. The reduced water velocities in reservoirs in comparison with pre-project conditions may greatly lengthen the travel time for juvenile fish to travel downstream through the impounded reach. In addition, storage for hydroelectric power reduces spillage, and as a result, juvenile fish pass through the turbines or a constructed fish bypass system. The longer travel time subjects the juvenile fish to greater exposure to birds and predator fish, as well as delay in physiologic development required to enter the ocean. Passage through the powerhouse turbines may increase fish mortality. To improve juvenile survival, storage has been made available at some projects to augment river flows, to increase spill rates, and to divert flows from the turbine intakes into collector dams. Barges or tank trucks can be used to transport juveniles from the collector dams to release sites below the projects. Other Corps projects have been modified to allow for juvenile fish passage through ice and trash sluiceways or newly constructed surface flow weirs.

2.8.5.3. Catadromous fish, such as eels, may also have migration flow needs. In addition, invasive anadromous species, such as sea lamprey in the Great Lakes region, may need to be limited to support catadromous fish populations.

2.8.5.4. Regulation to allow for adult fish passage may include selective operation of power units and spillway bays to manage downstream flow patterns to attract adult fish to ladder entrances. Chapter 4 discusses water management facilities to protect and enhance anadromous fisheries.

2.8.6. Reservoir and Downstream Wildlife.

2.8.6.1. Drawdowns to manage wildlife may allow for the natural and artificial revegetation of shallows for waterfowl, the installation and maintenance of artificial nesting structures, the management of vegetative species composition; and may ensure mast tree survival in greentree reservoirs. Wildlife benefits of intentional, temporary, and non-damaging inundation could include inhibition of the growth of undesirable and perennial plants, creation of access and foraging opportunities for waterfowl in areas such as green tree reservoirs, and management of water levels in stands of vegetation to encourage waterfowl nesting and reproduction. In the central United States, managers frequently recommend small increases in pool levels during autumn for waterfowl management.

2.8.6.2. Water level manipulations without regard to effects on wildlife habitat may result in many impacts, including the destruction of emergent and terrestrial vegetation, permitting access of predators to otherwise inaccessible areas, abandonment of active nest sites, and rendering soils with iron oxides unproductive. Downstream riparian, floodplain, and wetland habitat may also benefit from periodic flow augmentation from dams.

2.9. Recreation.

2.9.1. Historical Background. In many cases, the use of reservoir projects for recreation stems from the Flood Control Act of 1944 and the Federal Water Project Recreation Act of 1965 (generally referred to as PL 89-72). Regulation of reservoirs for reservoir and downstream recreation interests should be balanced against meeting the other project purposes, such as flood risk management, navigation, or others. Many projects, including those for which recreational facilities may have been included under general provisions of the Flood Control Act of 1944, as amended, do not have separable storage costs for recreation. In these cases, recreation is of secondary importance as an authorized purpose to project functions for which storage was formulated.

2.9.2. General Considerations. The general public uses reservoirs for recreational activities. Also, river systems below dams are frequently used for recreational boating, swimming, fishing, and other water-related activities. Recreational activity is a source of income for businesses catering to water-related recreational pursuits, as well as for service establishments located near the river. Water control plans should consider the effects of streamflow and water levels on recreational activities at the project site, in the reservoir area, and at downstream locations.

2.9.3. Water Management Considerations.

2.9.3.1. Recreational use of reservoirs may extend throughout the year. Under most circumstances, reservoirs yield the optimum recreational use when they are at or near full multipurpose pool during the recreation season. The degree to which this objective can be met varies widely, depending on the regional characteristics of water supply, runoff, and the basic objectives of water management for the various water use functions. Reservoir facilities for recreation may be designed for use under the planned reservoir regulation guide curves, which reflect the ranges of reservoir levels that are to be expected during the recreational season. In low-runoff years, or years in which the runoff is delayed because of weather conditions, maintaining full pool reservoir levels during the recreational season may not be possible.

2.9.3.2. In addition to the seasonal regulation of reservoir levels for recreation, regulation of project outflows could enhance the use of downstream channels and ensure the safety of the general public recreating downstream of a project.

2.9.3.3. Biological opinions to benefit threatened or endangered species may also influence reservoir management. A summer drawdown for downstream flow augmentation or water quality enhancement during the peak of the recreational season is an example of a change to a historic pattern of resource use that may not be supported by the local population.

2.9.4. Water Management for Downstream Recreational Use. Water levels needed to maintain or enhance river recreation are usually much smaller than those needed for other major project uses, but specific objectives could be included in the water control plan to benefit recreation in downstream rivers. The objectives may be to provide minimum project outflows or augmented streamflows at times of special need for boating or fishing. Also, since river drifting is becoming an important recreational use of some rivers, management opportunities may exist to provide this use for relatively short periods of time. Releases should be adjusted gradually and communicated to the public in order to help avoid dangerous or abrupt changes in downstream water levels.

2.10. Erosion and Deposition Considerations.

2.10.1. General. Interruption of the natural sediment processes of a stream generally results in deposition of sediment in the upstream reservoir area, and corresponding erosion and degradation of the streambed and banks immediately downstream from the project. The location of deposits in the reservoir is a function of the size of the reservoir; the size, composition type, and quantity of the sediments being transported; and the pool level at the time of significant inflow. The amount of bank and shoreline erosion is closely related to the rate and magnitude of the pool level fluctuations. Erosion and deposition may impact many project-related functions and should be recognized, considered, and carefully monitored throughout the life of a project.

2.10.2. Downstream Considerations.

2.10.2.1. Large reservoir projects frequently trap and retain suspended sediment and bed material load within the upstream pool, thus releasing sediment-free water. These releases, which often vary from zero to maximum capacity within a very short time period, may erode both the bed and banks of the stream immediately downstream from the outlet structure. The amount and rate of this erosion is related to the composition of the bed and bank material, the volume and rate of water released on an annual or seasonal basis, vegetation along the banks, and the manner in which the flow is released. Fluctuating releases often result in initial bank erosion, and this loss is closely related to the magnitude of the stage fluctuation. Bank erosion causes a loss of riparian vegetation into the adjacent channel. This vegetative debris can cause channel blockages or shoaling. Bank recession is generally highest following initial project operation and usually stabilizes in the first few years of operation as the bed slope adjusts to a revised flow regime. Once an equilibrium bed profile has been achieved, the bank erosion processes may return to conditions similar to those of a natural channel. Periodic wetting and drying of the banks through fluctuating releases may increase bank erosion. Significant reservoir releases may also result in further lowering of the streambed, with the maximum amount of lowering occurring immediately downstream from the outlet protection and decreasing in the downstream direction. This degradation process continues until an equilibrium slope is reached or the bed becomes naturally armored. Armoring occurs when removal of the fine sediment exposes the coarser, less-erodible bed materials. Once the bed becomes naturally armored, future lowering of the streambed is usually insignificant unless an excessively large release has sufficient energy to disrupt the armor layer.

2.10.2.2. Small- and medium-sized reservoir projects often have downstream channels that aggrade over time, much different from the downstream channels of large projects described above. Projects that make only intermittent releases over short periods of time, or low-level releases over extended periods of time may result in extensive downstream deposition and subsequent vegetative encroachment. Aggradation tends to continue, and once established, the process may be difficult to reverse. Annual flushing flows, capable of removing deposits near the mouth of tributaries, are often replaced by low-level non-erosive releases, contributing to the loss of channel capacity and future operating flexibility.

2.10.3. Upstream Considerations.

2.10.3.1. Shoreline Erosion. Reservoir shorelines, which are subject to a number of forces contributing to instability, frequently undergo major changes throughout a project life. Fluctuating pool levels saturate previously unsaturated material, resulting in slides when the pool level is drawn down to lower levels. Reservoir banks are also subjected to attack by both wind and waves, which tend to remove bank material and undercut the banks.

2.10.3.2. Reservoir Deposition. Reservoir sediment deposits may impact not only the reservoir storage capacity over the life of a project, but also many project purposes both adjacent to the pool and in the backwater reach immediately upstream from the pool. Sediment deposits are not restricted to the lower reservoir zone typically reserved as a sediment pool. Deposition often occurs in the multipurpose or flood pool zones in the form of large deltas and may cause a multitude of issues and concerns as the project matures. Major sediment deposits can reduce the storage reserved for flood risk management to such an extent that an adjustment in the flood pool level must be made to maintain the flood storage capacity. The deposits may also have a significant impact on the backwater profile of reservoir inflows over time, resulting in increased groundwater and surface water levels and flooding concerns in the areas immediately upstream from the reservoir pool. The location of the sediment deposits may also affect and contribute to ice accumulations and jams, which become operational constraints during certain times of the year. The impact of sediment accumulations in the reservoir should be recognized and accounted for in the planning, design, and operation of the project.

2.10.4. Monitoring.

2.10.4.1. Water management may include balancing inflow, storage, and release of water from a reservoir or system of reservoirs and the effects in downstream channels. Sediment erosion and deposition in a reservoir can alter system response over time, requiring water managers to adapt management practices to maximize project benefits. Water control plans should be revised as needed to reflect changes in project storage from sediment accumulation that affect operational criteria and management decisions.

2.10.4.2. Sediment monitoring programs may be expensive and should be based on individual project needs, purposes, and conditions, but should generally include the requirements identified in EM 1110-2-4000, Sedimentation Investigations of Rivers and Reservoirs. Considerations for dry reservoirs and those with sediment pools are discussed in EM 1110-2-4000.

2.10.5. Operating Guidelines. Water managers should be aware of the impacts that project operations have on erosion and deposition and should operate to manage both upstream and downstream impacts to the extent reasonably possible in consideration of other project purposes. Problem areas and the potential impact of alternative regulations may influence project operating decisions. Although much of the erosion and deposition may be beyond the control of water management, certain precautions may significantly reduce concerns. These include:

a. Lowering the rate of reservoir pool drawdown.

3. Avoiding sudden increases in project releases and subsequent downstream stage fluctuations.

4. Avoiding sudden cutbacks in hydroelectric power generation and flood risk management releases and resultant stage fluctuations.

5. Keeping reservoir pool levels as low as possible during known periods of high sediment inflow to encourage sediment depositions in the lower zones of the pool.

6. Raising pool levels sufficiently to inundate existing sediment deposits and preclude the establishment of permanent vegetation and subsequent increased sediment deposition in the backwater reaches entering the pool.

7. Scheduling periodic releases through the outlet works to preclude sediment accumulations in and near the intake structure and in the downstream channel.

8. Recognizing conditions that may impact erosion and deposition, such as ice jams, tributary inflow, shifting channels, and local constraints, and adjusting regulation criteria to reduce impacts.

2.11. Aesthetic Considerations. The effects of water management on the aesthetics of a river system are closely related to the public use of reservoirs and rivers and may be considered in operating decisions. Good management may mitigate harm to the aesthetics and the general beauty of the riverine environment. Such mitigation may include establishing minimum streamflows and related river levels, minimizing the duration of exposure of unsightly reservoir shoreline resulting from reservoir drawdown, or releasing water for special aesthetic purposes. Many water management projects may be unable to fully compensate for such effects and still meet authorized project purposes. For some projects, water control plans may be adjusted to partially mitigate these effects. The relative importance of aesthetic considerations varies widely, and the adjustment of water control plans to meet aesthetic goals is based on judgment and knowledge of all water management functions.

2.12. Cultural Resources

2.12.1. As defined in 36 CFR 800, cultural resources (also referred to as historic properties) include any prehistoric or historic site, district, building, structure, or object, as well as properties of religious and cultural significance to Indian Tribes, that are listed in or eligible for listing in the National Register of Historic Places. Appendix B to this manual includes relevant laws. Corresponding Corps regulations include ER 1130-2-540, Environmental Stewardship Operations and Maintenance Policies, and EP 1130-2-540, Environmental Stewardship and Maintenance Guidance and Procedures, Change 2 (31 July 2005), which outline Corps policy, guidance, and procedures to apply principles of good environmental stewardship to the natural and cultural resources on USACE administered and/or managed lands and waters.

2.12.2. Cultural resources management issues related to water management vary depending on the management objectives and the operational capabilities of the project. Water managers should be aware of the potential adverse effects to cultural resources by continually evaluating the effects of project regulation.

# CHAPTER 3

## Water Control Plans

3.1. General.

3.1.1. A water control plan is based on operating criteria pertinent to the daily water management of Corps water resources projects. The water control plan is documented within the water control manual and provides operating guidelines to deliver congressionally authorized project purposes and benefits. This chapter outlines various steps and technical considerations that should be used to develop water control plans for projects and systems.

3.1.2. Water control plans for all Corps projects must be prepared according to established general principles and guidelines consistent with Federal policy. The variety of projects, their respective congressionally authorized project purposes, and conditions related to water management throughout the nation make it impossible to develop a single water control plan that applies to all projects. Each watershed, river basin, and region has unique requirements. Furthermore, a wide range of infrastructure (dams, canals, culverts, spillways, locks, pump stations, hydroelectric turbines) may exist at the projects. For example, the criteria required for a series of single purpose locks and dams designed for improving navigation are different from the criteria required for large multipurpose reservoir systems involving several projects and complicated interactions among the various authorized purposes. Some Corps projects may have specific legislation requiring preparation of documents other than a water control plan or a water control manual.

3.1.3. The Corps is responsible for conducting operations consistent with the water control plan and for providing oversight of non-Corps entities using a Corps water control plan. In addition, several water resources projects have been constructed through international agreements with Canada and Mexico in which the Corps participates in implementing a water control plan developed and approved by boards or commissions. These international bodies may choose to use this EM as guidance in developing their water control plans.

3.1.4. The principal means by which to provide the most beneficial use of limited water resources and to achieve national water management goals is to operate water resources projects and systems according to an approved water control plan.

3.1.5. Any physical operating constraints should be clearly outlined in the water control plan to ensure that water management features are operated in a safe manner and within design limitations during all phases of project life, including the construction phase.

3.2. Principles and Objectives.

3.2.1. General.

3.2.1.1. The Corps is required to develop water control plans and may provide those plans to a non-Federal sponsor responsible for a project's O&M. The principal guidelines used to schedule project water management activities are discussed in this chapter. A water control plan:

a. Addresses the water management needs and methods required to meet congressionally authorized project purposes through water management operating criteria (e.g., regulation schedule or guide curve, minimum flow, optimum water level range, desirable discharge, drought contingency plan).

9. Considers all water management objectives (functional, environmental, social, and aesthetic) and various techniques, organizations, systems, and facilities involved in the water management of a Corps water resources project.

10. Addresses reasonably foreseeable conditions and may include procedures to respond to hydrometeorological events in a timely manner or to avoid anticipated detrimental impacts.

11. Outlines the process to deviate from normal operation.

3.2.1.2. The development of the water control plan should originate during the earliest studies conducted as part of the planning process and should continue through the various phases of investigation, justification, authorization, design, construction, and O&M of a water resources project. Development of a water control plan should proceed with full knowledge of planning and design studies, and with the realization that changed conditions may require adjustments from the previously developed operating criteria, whether those criteria are associated with early studies or previously implemented water management activities. Chapter 2 contains fundamental information in the development of water management information (e.g., constraints, operating criteria) to meet the congressionally authorized project purposes.

3.2.1.3. Proposed water management operating criteria should be contained in the appropriate final National Environmental Protection Act (NEPA) document (e.g., Letter of Environmental Compliance, Environmental Assessment, Environmental Impact Statement).

3.2.2. Progression of the Water Control Plan through a Project Life. As project facilities are constructed and become operational, a series of water control plans may be required (listed here in chronological order): interim (during construction); preliminary (before full-scale operation); and approved (full-scale operation); water control plans may also be required as a dam safety interim risk reduction measure. A description of such plans is presented in Chapter 9. After completion of project construction, further refinements or enhancements of the water control plan may be made to account for changed conditions resulting from new requirements, additional data, or changed social or economic goals.

3.2.3. Interdisciplinary Involvement. Major system water management involving many authorized purposes often includes multiple disciplines (e.g., hydraulic engineers, hydrologists, meteorologists, biologists, archaeologists, chemical engineers, structural engineers, geotechnical engineers) to support water control plan development. The water control plan for such major systems may include specialized elements such as desirable conditions for species or habitat of concern, surveillance and monitoring plans, water supply demands, flood inundation mapping, and required navigation depths.

3.2.4. Annual Water Management Plans. A water control plan may be supplemented by an annual water management plan for the current operating year for multipurpose regulation. Annual water management plans outline how an office intends to implement the approved water control plan for the coming year. Annual water management plans define guide curves for water supply functions, such as hydroelectric power generation, irrigation, navigation, water quality, etc. based on the water management conditions for the current year. The annual water management plan may be used to develop a regulation outlook for more than 1 year in advance. The methods of systems analysis used in developing the annual plan may be similar to those used in planning and design studies.

3.2.5. Integrating Congressionally Authorized Project Purposes.

3.2.5.1. A water control plan contains operating criteria to meet congressionally authorized project purposes with flexibility to allow for adaptation to actual conditions. This requires an understanding of the extent of the authorized project purposes as defined in the planning studies and subsequent authorizing legislation, an identification and definition of constraints, a familiarity with design information, and the gathering of pertinent information. See Chapter 6 for information on techniques. The preparation of a water control plan also includes information from Federal, state, local, tribal, and other stakeholders, as appropriate, that may be affected by or may affect Corps water management activities.

3.2.5.2. Information presented in the previous paragraph allows for the identification of problems, opportunities, and capabilities for a project and existing non-project infrastructure necessary to develop a water control plan. For projects that have a non-Federal sponsor or are non-Corps projects, the process should include collaboration with the associated entities. The water control plan typically outlines the quantity, timing, and duration of water releases or storage associated with a project.

3.2.5.3. For a project with multiple authorized purposes, the water control plan may balance tradeoffs across multiple needs, since managing for one project purpose can affect the delivery of benefits for other purposes. For example, risk management for threatened or endangered species or public health and safety may be managed with a flexible operating plan that recommends allowable quantity, timing, and duration of water releases or storage for a project.

3.2.5.4. Once alternatives are identified, an iterative approach may be undertaken to predict and analyze the results and associated benefits and impacts. Chapter 6 includes related material. The impacts of preliminary operating criteria may require a request for input from Federal, state, local, and tribal organizations, other stakeholders, and the general public and a consideration of any responses. Responses may reflect existing constraints that become interrelated and typically evolve under specific circumstances such as physical, legal, political, social, and major conflicts between authorized project purposes.

3.2.6. Integrating Public Laws. In addition to the original congressionally authorized project purposes, Corps water resources projects are often subject to public laws enacted after the original authorization. Integrating post-project public laws into a water control plan typically involves a process similar to that discussed above for congressionally authorized project purposes.

3.2.7. Integrating Incidental Benefits. Benefits to one or more congressionally authorized project purposes may be provided by defining water storage and releases in the water control plan. Incidental benefits may be taken into account when developing water control plans.

3.2.8. Input from Other Water Management Interests.

3.2.8.1. Development of water control plans involves input from external agencies, entities, or stakeholders that may be affected by water management activities. These interests may include non-governmental entities as well as Federal, state, local, and tribal organizations.

3.2.8.2. Hydroelectric power generation is an example of a congressionally authorized project purpose that requires coordination for the water control plan. A water control plan for a coordinated power system considers all elements of the system, including estimates of loads and resources for each of the operating utilities, project and power transmission operating characteristics, methods for scheduling, dispatching, and marketing power, and a myriad of details that affect water management activities. The coordinated water management activities, data inputs, and technical evaluations to achieve hydroelectric power generation objectives may be met by establishing coordinating bodies or groups that are voluntarily agreed upon by the parties involved. The coordinating groups may provide for the exchange of data and the establishment of work groups to develop project power operating plans. The water control plan for Corps projects that include hydroelectric power generation include descriptions of this type of data exchange with other operating utilities or power marketing agencies, as appropriate.

3.2.8.3. Other congressionally authorized project purposes may need data input and coordination between the Corps and stakeholders. Releases to maintain or improve water levels to facilitate navigation, for example, should be coordinated with appropriate navigation-related interests (e.g., shipping, recreation). Water supply deliveries to meet demands (e.g., agricultural, municipal, industrial, ecological, water quality, species of concern) require coordination and input from the stakeholders to define the specific water delivery requirements or desired conditions.

3.2.8.4. During water control plan development, stakeholders may also request that a water control plan contain water management criteria related to congressionally authorized project purposes not specifically documented in prior Corps studies. To determine whether to incorporate a request into the water control plan, the Corps water manager should evaluate the request while working with appropriate Corps disciplines. The major determining factors regarding whether the stakeholder request is included in the water control plan are potential impacts and benefits to all project purposes.

3.2.9. Physical Limitations of Projects. The water control plan should reflect any of the project's physical limitations. For example, if an access road to the site gets inundated at a certain pool level or by a known amount of rainfall, then that condition should be identified and a contingency plan for access to the site should be detailed. Potential issues should be identified for higher pool levels or releases such as inundation of operating equipment, flooding of the powerhouse, or issues with the stilling basin.

3.2.10. Use of Hydrometeorological Data.

3.2.10.1. The water control plan (e.g., regulation schedule or guide curve, minimum flow, optimum water level range, desirable discharge, drought contingency plans) is usually developed using historical hydrometeorological data such as water levels, streamflow, and rainfall. Many of the concepts for analyzing data that are contained in Chapter 6 may be used to address items in this chapter.

3.2.10.2. Often, only the most critical high-flow or low-flow hydrometeorological data representing operating criteria for single or multiple purpose projects (e.g., flood risk management and/or water supply) is sufficient for water control plan development. In other cases, all available hydrometeorological data should be used to develop a water control plan, especially for a design with a short period of record. Revisions to water control plans should consider data not previously available. Modification of guide curves may need adjustment if the additional data include records of extreme floods or droughts. A complete system re-analysis may even be needed.

3.3. Flood Risk Management Regulation.

3.3.1. Principles and Objectives.

3.3.1.1. Flood risk management operating criteria are developed in accordance with authorizing legislation to reduce flood damages to the extent possible using available facilities. The best method to attain this objective depends principally on the location and types of damages to be prevented, location and amount of storage capacity, flood characteristics, flood frequencies, and extent of uncontrolled drainage area.

3.3.1.2. To develop a water control plan to provide flood risk management, a study should be made of water management operating criteria alternatives applied to past record floods and selected hypothetical floods. The historical flood record is the principal source of data to derive and test operating events even if it is too basic or short for a comprehensive investigation.

3.3.1.3. Non-damaging channel capacities must be available to achieve flood risk management objectives. A water manager may release stored floodwater that produces downstream stages consistent with the water control plan, provided the releases do not exceed peak inflow into the project or system. Ideally, releases would be made to not exceed channel capacities, but during certain events releases may exceed channel capacity in accordance with the water control plan to ensure the project’s structural integrity. Every effort should be made to prevent encroachments in the channel downstream of dams to achieve optimum flood risk management. If encroachment occurs it may result in public pressure to operate outside the water control plan, which has the potential to impact other authorized purposes and potentially the structural integrity of the dam.

3.3.1.4. Water managers and project operators should collaborate to prevent channel capacity encroachments downstream of dams. However, it should be recognized that the Corps has limited capability to determine the level of development in areas downstream of project. That is normally under the purview of local or county government to review and/or approve the development in “riverfront” areas. That being said, since the Corps is responsible for managing its projects as designed and authorized, the Corps should provide appropriate feedback to local officials if proposed developments may be impacted by the Corps operating their project as designed and authorized.

3.3.1.5. Water managers should work closely with project operators to be aware of upstream and downstream conditions that might impact water management procedures. For example, during public involvement opportunities, stakeholders should be reminded of potential maximum water control plan release rates. Another example is if a downstream area would be flooded with maximum water control plan release rates, the water manager or project operator must contact the owner of the site and, if necessary, follow through with correspondence stating that the Corps will not reduce the existing maximum release rate to prevent flooding of the site. In such cases, correspondence should also be forwarded to appropriate Federal, state, local, and tribal organizations.

3.3.2. Classification of Flood Regulation Methods.

3.3.2.1. General.

3.3.2.1.1. Although various bases exist to classify flood regulation methods, a simple analysis is insufficient in the more complicated situations. This section presents a general plan to classify flood regulation into two basic methods, and a third method, which combines concepts of the first two methods and which is commonly used to provide the most effective flood regulation.

3.3.2.1.2. Each of the proposed methods for defining the flood regulation plan has strengths and weaknesses. The determination of the plan for a particular system should be based on the study results from the planning and design phases of project development, together with more detailed project regulation studies conducted in the operational phase. Alternative methods of flood regulation may be conveniently evaluated using models to achieve the optimum regulation. Furthermore, the experience gained in the application of these models may be applied in real-time conditions with the assurance of achieving an appropriate overall regulation. Section 3.3.8 discusses evacuation of accumulated flood storage.

3.3.2.2. Method A. Method A regulation involves maximizing storage of runoff and limiting releases to lower downstream stages and damages as much as practicable during each flood event. This method maximizes downstream flood risk reduction benefits for small and medium-sized floods, but increases the risk of having an appreciable portion of the flood storage capacity filled when a large, subsequent flood occurs. Obtaining maximum benefits in minor to moderate floods using this method is highly dependent on the ability to forecast inflow conditions at the control structures and incremental flows at the damage centers. CWMS hydrologic and reservoir models for real-time streamflow and pool elevation forecasting can optimize this method of regulation by maximizing flood risk management and analyzing potential regulation of future events. Actual operations must be based on observed watershed conditions to the extent practicable (i.e., water-on-the-ground) per ER 1110-2-240 unless otherwise provided for in an approved water control plan. Method A's effective time-span is limited to the ability to reliably forecast weather-related parameters (rainfall, air temperature, etc.). Method A also makes it possible to take advantage of seasonal damage levels by storing more water when downstream stage targets are lower and allowing higher releases when downstream targets are higher. In reaches principally used for agricultural production, non-damaging stages are generally higher during the non-growing season than during the growing season.

3.3.2.3. Method B.

3.3.2.3.1. Method B regulation involves making reservoir releases strictly according to the release schedule of the inflow design flood (see ER 1110-8-2 [FR], Inflow Design Floods for Dams and Reservoirs). The release rates are based on schedules established to use all the storage capacity during hypothetical regulation of an inflow design flood. The schedules are then followed at all times on the assumption that the result will be the best overall flood regulation. Projects that have a limited amount of flood storage with a primary flood risk management objective may regulate based on continual releases up to specified amounts to provide reservoir flood storage for a specified inflow design flood. Considering the ongoing flood conditions and reservoir levels, Method B regulation consists of releasing water at an established rate and storing all excess inflow as long as flooding continues at specified target locations.

3.3.2.3.2. While Method B regulation provides considerable assurance of successfully regulating major floods, regulation may result in higher releases for lesser floods, potentially reducing benefits. This is particularly true for damage centers where managed releases could be timed to avoid an undesired combination with flows from uncontrolled areas. Uncertainties with the use of Method B may result from being too optimistic about assumed project releases or from considering that each major flood is a single event, which may significantly affect the release patterns for a subsequent flood. Another effect of this method could be a possible increase in the duration of downstream flooding from holding release rates higher for a longer period of time. One example of Method B regulation would be a dam designed with an ungated service spillway and a flood pool sized to store the inflow design flood. In this type of operation, the release rate through the ungated service spillway is a function of the reservoir elevation and induced storage results from restricted capacity of the outlet or weir crest height.

3.3.2.4. Method C. Method C regulation is a combination of Method A and Method B. This method takes advantage of Method A by storing flood inflows and making releases to meet flow targets downstream during small floods, and during larger floods establishes a guide curve to store the inflow design flood as in Method B. A local flood storage zone could be established to store water, thereby enabling reduced releases to meet downstream flow targets during small flood events as in Method A. A decision to provide exclusive flood storage may also be desirable to give increased assurance of flood risk management for an important leveed area or a town generally endangered only by unusual floods or to provide storage for an inflow design flood using Method B. Thus, after the lower portion of the flood pool is filled by regulating with Method A, a fixed schedule of releases would follow to ensure regulation of major floods at the expense of less regulation of moderate floods using Method B. See Section 4.5 for directions to develop induced surcharge envelope curves.

3.3.3. Flood Regulation Schedule for a Single Reservoir.

3.3.3.1. The regulation schedule is a simple matter for the case of a single dam built for flood risk management of the local area immediately downstream from the dam (small uncontrolled intermediate area). The release schedule consists of storing runoff and regulating releases up to the value of the channel capacity. To obtain benefits at remote locations only (where there is appreciable uncontrolled intermediate area between the dam and location), regulation under Method A consists of maintaining the damage center stage at or below bankfull capacity or of providing a minimal release from the dam for damage areas experiencing above-bankfull conditions. For such regulation, releases of available storage at the dam would be based on observed or forecast runoff conditions for the uncontrolled drainage area. The success of such regulation depends on the ability to make a timely, adequate downstream flow forecast based on water already on the ground unless otherwise approved in an approved water control plan. Releases would be based on observed and/or forecasted conditions at the project site and downstream locations. A regulation schedule using Method B would provide for the release of water at specified rates to control the inflow design flood runoff without exceeding flood storage capacity. Method C would incorporate these two approaches into a single water control plan.

3.3.3.2. To provide flood risk management benefits primarily at downstream local and remote locations, additional restrictions on releases would require more reservoir storage capacity to offset reduction of releases. Therefore, the method of regulation and preparation of schedules becomes more complicated than that for local or remote benefits alone. The adequacy of the forecasts is of primary importance, and streamflow simulation models for forecasting river and reservoir conditions are beneficial in real-time regulation for making the most efficient use of reservoir storage for flood risk management.

3.3.4. Flood Regulation Schedules for Multireservoir Systems.

3.3.4.1. General regulation schedules for an integrated system of projects are usually developed first for the tributary projects operating as separate units. The adjustment of the individual regulation schedules for coordinated regulation of the various tributary and main river projects are generally based on system analyses of the basin development, design floods, and historical floods of record. The critical flood regulation plan may be determined by the occurrence of a succession of moderate floods rather than one severe flood, or an unusual flood event that is distributed in time or space differently from normal flood occurrences. Also, flood regulation criteria should be established considering the magnitude of expected seasonal runoff volume for cases in which seasonal runoff volume forecasts are made several months in advance (e.g., snowmelt runoff).

3.3.4.2. Method A is most commonly used for multireservoir systems. If channel capacities below the individual dams are limited and both local and remote benefits are to be achieved, sufficient storage may not be available for complete management during a critical basin-wide flood. Regulation based on a maximum use of available storage probably would provide the most benefits for the system. However, to verify that maximum use of available storage would provide the most benefits and to provide the necessary information for successful regulation of such systems, extensive data should be collected and periodically updated to determine seasonal channel capacities and damage areas. Stream profiles for various combinations of releases from different projects should be established and the areas flooded at successive profile elevations should be determined. These stream profiles along with damage data can then be used to create stage-damage curves for various reaches. Control points may be established to evacuate flood storage in a reasonable length of time and to reduce damage in the basin. The stage-damage curves may be evaluated with simulation models. Through testing various methods of regulation, a plan of flood regulation may be formulated that provides the highest level of flood risk management to stakeholders conforming to the structure's physical features. Water management offices should move toward using CWMS software to optimize multireservoir system operation, including HEC-RAS to create stream profiles and profiles of flooded areas, HEC-FIA for stage damage curve development, and the Control and Visualization Interface (CAVI) for model evaluation.

3.3.4.3. The regulation schedules depend on forecasting both controlled and uncontrolled river stages at all of the control points. If forecasted stages are expected to be above flood level due to runoff in uncontrolled areas, reservoir releases may be adjusted to compensate for the uncontrolled runoff and maintain downstream stages at or below target levels. This is especially true when considering a large uncontrolled area with a difficult to estimate or unknown runoff flow rate. The travel time for releases should be taken into account when considering incremental runoff and downstream stage targets. To achieve system regulation, the reservoir release schedules may be simulated using historical data with different outflow scenarios. The results of the simulations should be used to prepare rule curves or guide curves that define relative amounts of storage between projects and general guides for reservoir filling or evacuation. In real-time regulation, the same principles are applied, but the analysis of data is based on current forecasts of streamflow and reservoir levels rather than on historical data. At each of the projects, revised forecasts result in adjustments to reservoir releases to make the best use of the residual flood storage. Also, various extremes of weather-related factors may be tested and evaluated with model simulation to ensure that sufficient storage space is available for management of unusual rainfall or snowmelt events.

3.3.4.4. In summary, the guide curves provide general guides for reservoir filling and evacuation to meet the flood risk management objective of maximum beneficial use of available storage. In actual operation, the analysis afforded by real-time model simulation of current and forecasted hydrometeorological conditions should be included to make operating decisions that achieve the optimum balanced regulation.

3.3.4.5. Regulation based on Method B may be feasible if relatively large channel capacities exist below dams, and the remote flood risk management benefits are obtained at a few centralized locations. Regulation schedules should be based on making fixed or variable releases that depend on existing or forecasted stages at downstream control points, and by managing the design floods at the individual projects.

3.3.4.6. Normally, the most dependable flood risk management benefits are accrued at major or complex river basin developments using Method A or Method C because they store inflows for the more frequent events and provide higher levels of flood risk management.

3.3.5. Flood Regulation for Projects with Uncontrolled Outlet Works. Some projects have been constructed with uncontrolled outlets or weirs and the resulting release of water depends on conditions of inflow and storage. With no gates or other provisions for water management through controlling the release of water, the induced storage results from restricted capacity of the outlet or weir crest height. These facilities allow for a predictable and consistent approach to water management, but they lack operational flexibility. Detailed regulation schedules, rule curves, or guide curves for this type of project are typically unnecessary, but pertinent water management details and information should be understood. The water manager should include the project's effect on upstream and downstream areas and the relationship to any other projects in the system.

3.3.6. Seasonal Variation in Flood Storage Requirements. Water resources systems are usually multipurpose. Although many Corps projects have been authorized to meet flood risk management or navigation objectives, the other water management functions described in Chapter 2 may also be included as authorized purposes to achieve the full use of available water resources.

While flood risk management may represent the primary function for particular projects, the capabilities of projects to manage floods may be maximized with other functional uses by seasonally allocating project flood storage space. The seasonal variation of flood risk management requirements should be determined by flood routing studies using floods of various magnitudes, distributed seasonally over the period of historic record. Synthetically derived floods may also be analyzed if the historical period of record is insufficient to provide an adequate sample of flood distributions. The seasonal guide curves that define the flood storage space requirement should be determined from these studies for each project or system of projects. These guide curves are drawn as enveloping lines of storage space required for the management of historical floods as a function of the time of year. They are usually drawn as straight lines on a monthly or seasonal basis. The guide curves represent the maximum desirable reservoir storage levels for other multipurpose uses on a seasonal basis. For rain-fed rivers, the seasonal flood storage reservation guide curves generally apply to all years. However, for those rivers that may have a significant contribution of runoff from snowmelt, a family of guide curves representing the flood storage reservation requirements may be derived based on anticipated seasonal runoff volume. Also, flood storage may be designated in different categories. For example, consider that the upper portion of the flood pool (termed primary or exclusive flood pool) is maintained at a fixed level, but the lower portion (termed secondary or annual flood pool) is conditionally maintained. The secondary flood storage may fluctuate, depending on the time of year and other desired multipurpose uses under certain pre-planned operating rules for regulation.

3.3.7. Management of Individual Floods. The water control plans for flood risk management, as described above, provide the general concepts and guidelines for flood regulation. These plans are developed mostly from analysis of historical flood events. They are designed to achieve a generalized, optimally balanced plan of regulation for all floods, considering both minor and major floods of record as well as design floods. No two flood events are the same, and the history provided in the flood records cannot possibly represent all future events. The use of real-time hydrologic modeling provides the water manager a means to analyze the system regulation and to adjust operation hourly or daily to provide the desired flood regulation.

3.3.8. Reservoir Evacuation.

3.3.8.1. General Principles.

3.3.8.1.1. Post flood evacuation of water stored in exclusive flood pools for flood regulation must be accomplished as soon as possible following the flood event. The three general criteria for post flood evacuation are: (a) releases made to regulate streamflows at downstream control points are at or below bankfull or non-damaging channel capacities, noting that non-damaging stages may vary seasonally in agricultural areas, (b) releases made to maintain downstream flows are at levels that do not exceed the peak flows or stages that occurred during the course of the preceding flood event where such peaks exceeded bankfull capacity, or (c) releases made to evacuate storage are at or above bankfull for emergency or other reasons.

3.3.8.1.2. The release of flood storage is made to provide storage to manage subsequent flood events. To avoid the risk of a series of floods having a combined volume exceeding reservoir storage capacity, the stored water should be evacuated as quickly as possible, consistent with downstream runoff conditions and weather forecasts. To evacuate flood storage, evacuation plan (b) provides the fastest evacuation of stored water. Release of stored water that results in above bankfull stages prolongs the period of downstream flooding, but may reduce peak stages if subsequent events occur. Evacuation plan (a), on the other hand, may result in much delayed evacuation of stored water that would increase the risk of flooding from subsequent storms. Evacuation plan (c) could be used to address an emergency dam safety concern, a need to evacuate flood storage before the next runoff season, or a need to evacuate flood storage before the winter ice period. In actual practice, a compromise between evacuation plans (a) and (b) is usually adopted, and the post flood evacuation results in river stages somewhat higher than bankfull, but lower than peak stages experienced during the flood due to the contribution from uncontrolled areas. The decisions made on adopting post flood evacuation criteria should be based on flood routing studies of individual floods, damages that occur from prolonged above bankfull stages, and risks of future flood events. The water control plan should specify how flood storage will be evacuated and address concerns related to physical reservoir conditions such as sedimentation or geotechnical concerns including erosion or slope stability.

3.3.8.2. Quantitative Precipitation Forecast (QPF) Consideration.

3.3.8.2.1. Regulation decisions are typically made based on the principle of water-on-the-ground, which includes observed precipitation that has fallen in the form of rain or snow. As water managers become familiar with stakeholder needs and project hydrology, and as forecasting tools become more accurate, the most effective regulation for a project may include use of forecasted precipitation. Exceptions to the water-on-the-ground policy are permitted when documented as part of an approved water control plan and typically occur during flood storage evacuation to give the water manager the flexibility needed to most effectively regulate the project. These exceptions must be supported in the water control plan by an evaluation of the potential risks, uncertainties, and the risk tradeoffs. A decision process must be included and documented to evaluate and make risk tradeoff decisions in a real-time operating environment. Coordination with stakeholders is important when creating a water control plan that incorporates QPF.

3.3.8.2.2. Several examples follow, of regulation could benefit by considering QPF. Projects that are located in areas affected by tropical storm or hurricanes may need to outline regulation that includes QPF. Another example is making higher than normal non-damaging releases based on a QPF to evacuate flood storage and reduce the risk of uncontrolled spill from a project as a result of runoff from future rain. During a forecasted break in rainfall, a higher than normal release could be made to evacuate water at a faster rate when there is room in the downstream channel, or in advance of planting season. Releases could also be reduced based on QPF to leave more room for local runoff in a downstream channel that is near target or damage levels.

3.3.8.2.3. It is very important that regulation considering QPF be outlined in the water control plan with supporting information and risk evaluation.

3.3.8.3. Ramping Down Releases. Another consideration is to plan the reduction of the releases so that they will be reduced to conservation rates by the time the flood storage space has been evacuated. The rate of fall for releases should be less than the maximum rate of fall observed before the project's existence. When the opportunity exists to reduce the possibility of wasting water for other project purposes unnecessarily, release criteria should be developed to transition between flood management operation and water conservation operation for other project purposes.

3.3.8.4. Emergency Drawdown. Emergency drawdown for dam safety or other similar reasons may be requested and should be coordinated with relevant Corps organizations and stakeholders. This could occur when the reservoir is in the flood pool or below the flood pool.

3.4. Navigation Regulation.

3.4.1. Principles and Objectives.

3.4.1.1. Operating criteria for navigation projects are to provide required water flows and to maintain authorized project navigation depths. Navigation needs should be integrated with other project authorized purposes, such as flood risk management and hydroelectric power generation. Factors to be considered in the water control plan include type of navigation improvement, environmental considerations, design options to accommodate ice or debris passage, normal operation to pass flood flows, and removal of sediment.

3.4.1.2. Navigation constraints may affect the short-term regulation of projects. In some rivers, supply of water for lockage is a significant concern, particularly during extended periods of low flow or droughts. In critical low-water periods, water use for lockage may be curtailed to conserve water and maintain navigation, possibly at a reduced level of service. The need to preserve water quality in a navigation canal may be considered a water requirement for navigation.

3.4.1.3. Additional information to include in a water control plan for navigation are a communication system among projects, water management offices, towing industry, and Coast Guard, as well as a regulation plan for a river system.

3.4.2. Navigation Waterway Types. Types of navigation projects include canals, locks, dams, and reservoirs. In addition, other types of navigation improvements include maintained channels and estuaries, bank protection, pile dikes, and other forms of channel stabilization. Making reservoir releases to increase river levels and thereby improve channel depths is another type of navigation improvement project. A water control plan should reflect the type of navigation project and may include several of the methods mentioned above. Whether a project involves open river navigation or includes spillway structures (controlled or uncontrolled) to provide navigation flows or depths, the water control plan should detail how water will be stored and managed to meet the authorized navigation purpose. The issues to be considered are discussed in Section 2.3.

3.4.3. Navigation Regulation Schedules.

3.4.3.1. Shallow Draft. Regulation schedules for shallow draft navigation projects vary greatly among river basins and development type. Normal and special spillway operations to be included in a water control plan are described in EM 1110-2-1605, Hydraulic Design of Navigation Dams. Items to be included for normal operation are maintenance of navigation pools, low flow periods, flood flow periods, and ice and debris passage. Items to consider for special operation are loss of scour protection, operator error, equipment malfunction, spillway maintenance, and emergency operations.

3.4.3.2. Deep Draft. Deep draft navigation is generally different from inland navigation in that it is geographically connected to coastal waters, and/or the Great Lakes. The design of deep draft systems take into account average high and low water levels as they change with the tides, as well as the size and draft of ships that will be navigating on that system, see EM 1110-2-1613, Hydraulic Design of Deep Draft Navigation Projects. Structures are generally not included in design for the purpose of “managing the water,” and a water control plan or regulation schedule is not typically required. However, most deep draft projects should include a comprehensive plan for project O&M after construction, to include the following elements: changes and costs after construction, a surveillance plan to detail type and frequency of hydrographic surveys, data collection, periodic inspection schedules, and project performance assessments.

## 3.5. Development of Water Management Operating Criteria.

### 3.5.1. Tools for Developing and Implementing Operational Criteria.

3.5.1.1. In addition to being included as text in a water control plan, water management operating criteria may be represented by a diagram, schematic, table, flowchart, or other compilation of regulating criteria, guidelines, guide curves, rule curves, and specifications that govern the storage and release functions of a water resources project. It is important to note that these products are based on the water control plan rather than defining the water control plan. The diagrams indicate concise specifications such as water level and limiting rate of project releases during the calendar year, which act separately or in combination with other projects in a system. The diagrams are used in the decision-making process to determine water management activities to meet congressionally authorized project purposes. The diagrams are sometimes called guide curves, rule curves, or regulation schedules. Figure 3-1 shows an example of a water management guide curve.

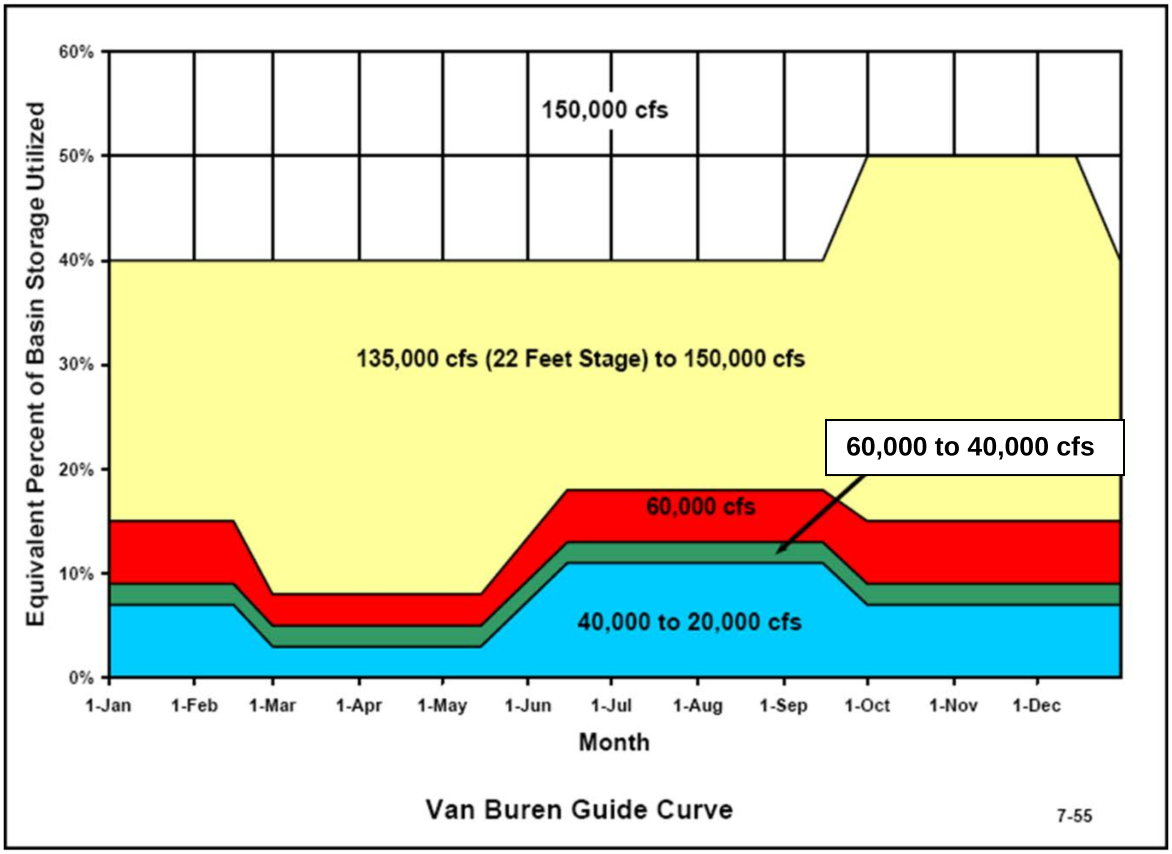


Figure 3-1. Example of Water Management Guide Curve.

3.5.1.1. Guide curves are an important element of the water control plan, since the diagrams provide the technical guidance and specific rules of regulation that are mandated from studies, public input, and the review and approval process in the planning and design phases as well as in the O&M phase. However, the diagrams are only a part of the overall water control plan, which provides for adjusting project water management activities on other factors that may develop in actual operation as the result of unique hydrometeorological or ecological conditions, changing water management needs, and other factors that may influence current project water management.

3.5.1.2. Guide curves must be documented to ensure that project water management is accomplished according to the water control plan as developed from the project and systems analysis studies. Daily water management activities are carried out according to specific operational rules that define the requirements at the project, and at downstream locations to meet congressionally authorized project purposes. Physical operating limits should be established that define the limiting releases and water levels at the project; and in some cases, at downstream locations, together with rates of change of discharge and water levels. Special limitations should also be applied to define limits of operation of water management facilities (e.g., gated culvert, spillway, outlet works, power generation equipment, pump station, navigation lock, fish passage facilities) that may affect the scheduling of water releases. Detailed charts and diagrams should be prepared to define flood risk management operating criteria related to hydrometeorological conditions, storage, and system water management. Similar types of charts and guides should be prepared for management of diversion and bypass structures, hurricane or tidal barriers, and interior drainage facilities for levee projects. For hydroelectric power generation projects, detailed instructions should be provided to define the methods for scheduling power, controlling power facilities, dispatching power in an integrated power system, maintaining the operation of the power facilities within design limitations, and monitoring system operation.

3.5.2. Integration of Basic Seasonal Flood Risk Management Guide Curves with Other Objectives.

3.5.2.1. An increasing number of multipurpose projects have been constructed in connection with basin-wide development of natural resources. Therefore, development of the water management guide curves must be compatible with all water management objectives to the greatest extent possible. For some projects, storage for low water regulation, navigation, irrigation, hydroelectric power generation, water supply, or recreation is provided by allocating storage capacity between particular levels for specific purposes in addition to that required for flood risk management. Note that the regulation schedules for these various uses may be independent of each other. In many reservoir systems, the multipurpose functions are compatible for joint use of the reservoir storage space, and the allocated storage space and project capabilities for all joint use functions are determined from reservoir systems analysis studies. The seasonal storage allocation for flood risk management, as discussed in Section 3.3.6, provides for flood regulation in a manner similar to single purpose flood risk management projects, and the seasonal guide curves that define storage capacities for all functions are depicted by charts plotted with ordinates representing storage amounts and abscissas representing time of year.

3.5.2.2. Reservoirs are designed and built to meet authorized purposes, but sometimes storage is insufficient to fully provide all desirable functions year-round. In this case, priority may be given to certain purposes based on hydrologic conditions and operational requirements, consistent with authorizing legislation. Figure 3-2 shows an example of a seasonal guide curve.

3.5.3. Development of Systems Analysis Studies for All Multipurpose Uses.

3.5.3.1. General. The basic concepts of reservoir systems analysis that are used in the planning and design phases apply to the development of guide curves. The emphasis of the studies in the planning and design phases should be to determine the project capabilities, such as firm or secondary power potential, peaking capability, unit sizes, irrigation capabilities, water supply potential, low flow augmentation, and service to other authorized purposes based on the historical record streamflows and proposed regulation criteria. The emphasis in the operational phase should be to develop the general framework of guide curves that account for changed conditions and refinements of planning and design studies. Also, the water control plan may call for specific guide curves based on the known conditions of project regulation in the current year. System analysis should be used for multi-project or multipurpose systems.

3.5.3.2. Hydroelectric Power. Regulation schedules for hydroelectric power operation cover a wide range of requirements. The general methods for evaluating power capabilities and determining power regulation are described in EM 1110-2-1701, Hydropower, and the application of these methods determines the principles of regulation for a specific project. Power guide curves are developed from the following criteria:

a. The monthly reservoir operating schedule and operating limits for each project as required for system power regulation.

12. The plant and power system capability as related to the sale of electrical energy.

13. The regulation of each project in the system to meet its proportional share of the electrical power system load, in conjunction with all other water management requirements.

Figure 3-3 shows an example of a guide curve for regulation to meet the hydroelectric power generation authorized purpose.

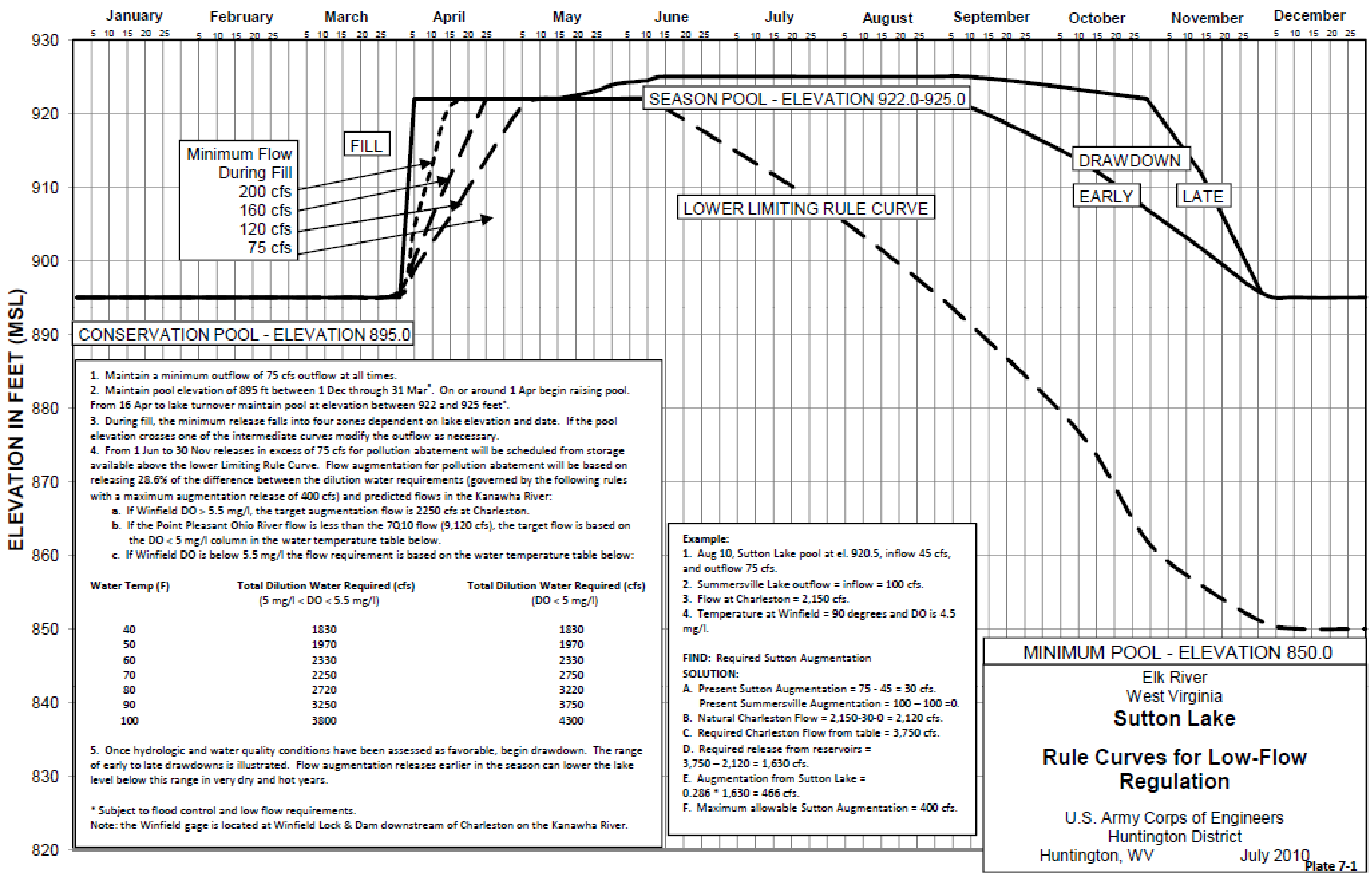


Figure 3-2. Example of a Water Management Seasonal Guide Curve.

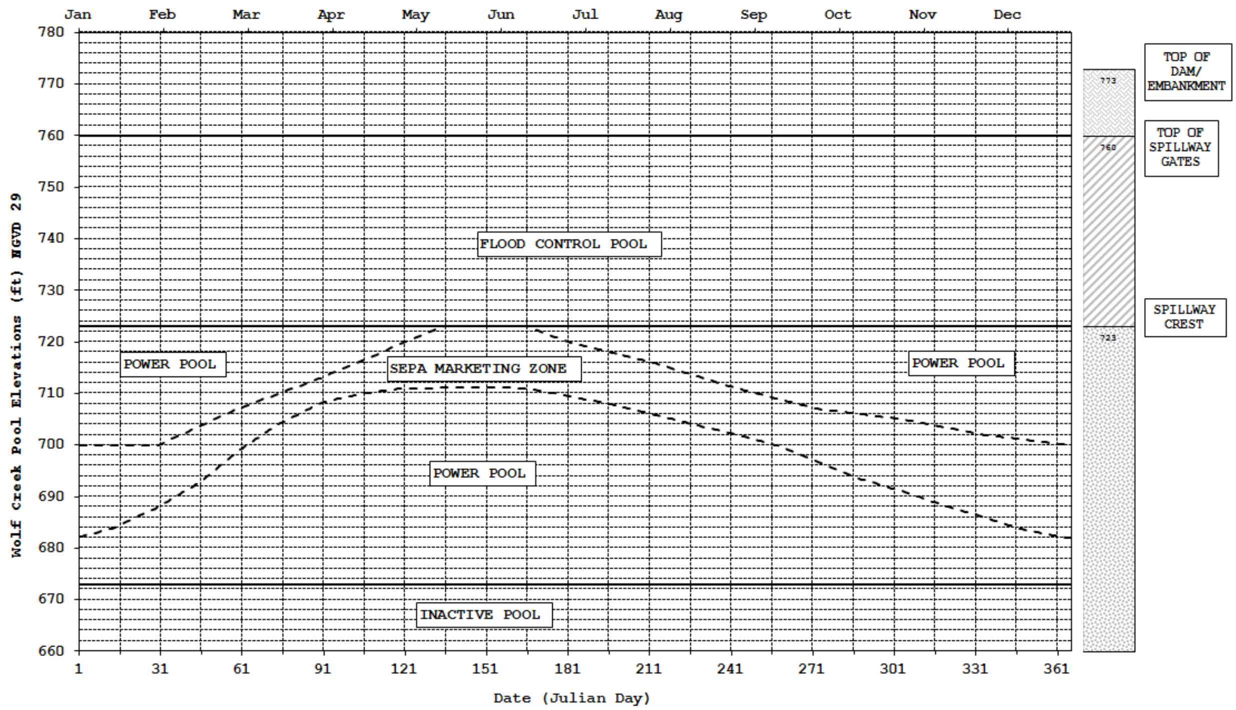


Figure 3-3. Wolf Creek Dam Guide Curve.

3.5.3.3. Navigation. Navigation regulation schedules are developed generally with the basic concepts of reservoir systems analysis studies as described above. Methods for developing navigation requirements, which are described in EM 1110-2-1605, may include hydraulic studies to establish the following criteria:

a. Stage-discharge relationship over entire area affected by the project.

14. Channel discharge rating curves.

15. Water surface profiles.

16. Establishment of navigation pool elevations.

Additional needs vary with type of project. Applications of specific methods are described in EM 1110-2-1611, Layout and Design of Shallow-Draft Waterways, and in EM 1110-2-1613, Hydraulic Design of Deep-Draft Navigation Projects. Navigation regulation during extreme low water conditions should be included in a drought contingency plan, as outlined in ER 1110-2-1941, Drought Contingency Plans.

3.5.3.4. Winter Navigation. A water control plan that includes winter navigation should discuss management of ice accumulations to reduce adverse impacts. Methods to evaluate winter navigation are described in EM 1110-8-1(FR), Winter Navigation on Inland Waterways, and include the following:

a. Ice and related hydrometeorological data collection and monitoring.

17. Ice forecasting.

18. Decision matrix to determine ice conditions that are too severe to maintain project operation for navigation.

3.5.3.5. Water Quality.

3.5.3.5.1. Water quality is an authorized purpose for many projects by specific congressional action. Water quality considerations include both the quality of the water stored by a Corps facility and the quality of water downstream of an impoundment. Corps policy for water quality management at Corps civil works projects is outlined in ER 1110-2-8154, Water Quality and Environmental Management for Corps Civil Works Projects. Critical water quality components may include:

a. Temperature.

19. Dissolved oxygen.

20. Nitrogen supersaturation.

21. Sediment starvation.

22. Organic and inorganic contamination.

3.5.3.5.2. The water control plan could present water quality issues that may occur due to construction of a facility and appropriately balance these issues with the other authorized beneficial purposes. Potential operations that address these concerns may include an augmentation release from the multipurpose storage that specifies the water withdrawal elevation, or physical changes to the outlet structure.

3.5.3.5.3. Unforeseen water quality issues may develop after construction is completed and the water control plan has been implemented. These conditions include threats to fish from inadequate dissolved oxygen levels or to humans from blue-green algae blooms within impoundments. While such issues need to be addressed immediately to alleviate the conditions, changes to the water control plan should be considered to reduce or prevent similar future conditions.

3.5.3.6. Irrigation, Fish and Wildlife, M&I, and Other Functional Use Considerations. Similar to integrating water management operating criteria (diagrams) with hydroelectric power generation, the water supply needs for irrigation, fish and wildlife, M&I, and other functional uses may be integrated with basic flood risk management operating criteria. Since water supply and flood risk management functions need to balance the use of reservoir storage space, guide curves define the upper and lower water level limits for these water supply functions and for flood risk management. These limits are usually defined as seasonally variable water levels, which govern in actual operation except as necessary to meet the specific functional goals set forth in the planning and design phases. The definition of these water levels is to balance the relative use of reservoir storage with conflicting multipurpose functions to meet the project functional commitments. The functional objectives of water management to provide for water supply and associated accounting methods to analyze water control plans have been described above. The methods to achieve these objectives should be incorporated in the water systems analysis operational studies as discussed in this section. Also, the refinements in water management should be incorporated into the seasonal operating criteria. The operating criteria are usually generalized for application to all years and should account for future variable hydrologic conditions. Some basins develop annual operating criteria.

3.5.3.7. Environmental, Social, and Aesthetic Considerations. Environmental, social, and aesthetic values have become a focus of water management for many Corps water resources projects. Some management guidelines related to these values are detailed in Federal legislation, while others result from regional, state, local, or tribal input that may represent the desires of particular interest groups or the general public in preserving or enhancing these values. A wide range of desires may be considered in connection with environmental, social, and aesthetic values, some of which may be easily accommodated in the general concepts of water management for the congressionally authorized project purposes. Other desires may be infeasible or impractical from an economic point of view, considering the functional uses for which the project was authorized and constructed. The evaluation of these issues and the integration into operating criteria should be made with full knowledge of the history of project development, legislative actions, project justification, and the planning of project utilization. Various alternatives to meet environmental, social, and aesthetic goals should be analyzed in connection with water management studies to determine the effects on each of the water management functions, and recommendations for change should be made based on the judgment of the results of the studies. The water management operating criteria, which include environmental, social, or aesthetic values, may be in the form of generalized relationships and rules that apply to all future years. Others may be specifically developed for a particular year or season and may change annually. The detailed operating criteria may include:

a. Seasonal storage guide curves in conjunction with other functional water uses.

23. Minimum project releases that may vary seasonally or as a function of storage, and that are usable for downstream release and surplus to other needs.

24. Rates of change of discharge or water surface elevation, either at the project or at a downstream control point.

25. Special short-term releases for a particular environmental, social, or aesthetic need.

3.5.3.8. Cultural Resources. While most large water management projects are authorized and designed for multiple purposes and must be operated within the constraints of these purposes, there may be enough flexibility to permit some manipulation of water levels and reservoir releases with consideration for effects to cultural resources. Water managers should be aware of the potential adverse effects to cultural resources by continually evaluating the effects of project regulation. This includes being aware of pool level fluctuations, quantity of project releases, and the frequency and duration of droughts. These factors, or a combination thereof, affect cultural resources, primarily as a result of erosion caused by water level fluctuation. Short-term operation deviations may be made to allow protection of significant cultural resources.

3.5.4. Solutions of Systems Analysis to Determine Optimal and Balanced Regulation. The use of reservoir systems analysis techniques, discussed in Section 3.5.3, provides the basic means to develop and test the detailed water management operating criteria and diagrams. Studies may be used to simulate the water management of projects using forecasts of project inflows. For cases that lack an inflow forecast, the observed conditions of runoff may be used for testing, and should be so stated. Various assumptions for operating criteria for each of the elements discussed in Section 3.5.3 may be individually tested in conjunction with all other elements, and the optimum and balanced regulation criteria and schedules may be derived from repetitive solutions of the simulation.

3.6. Drought Contingency Plans

3.6.1. ER 1110-2-1941, Drought Contingency Plans, states that as part of overall water management, drought contingency plans must be developed within existing authorities at all Corps projects with controlled reservoir storage. The drought contingency plan will include the specific conditions needed to enact the plan, such as state or county declaration of drought, or specific flow conditions. The drought contingency plan must be included or referenced within the water control manual for each project, and in addition, basin-wide drought contingency plans should be incorporated into water control master manuals.

3.6.2. After a drought contingency plan has been developed based on existing constraints, forecasts of basin development and water supply needs may present different long-term constraints to a project, requiring modified operating criteria to lower impacts from future droughts and to meet authorized project purposes. To complete such a modified drought contingency plan, a reconnaissance study may be conducted to evaluate alternative actions that involve removing or modifying current operating constraints. Operating criteria modifications may be made to project operation guide curves, minimum flow requirements, and storage allocations.

3.7. Monitoring and Revising Water Control Plans. Operating criteria for water control plans must be revised, as necessary, to ensure that congressionally authorized project purposes are met. Chapter 9, "Preparation of Water Management Documents," outlines a series of water control plan types (preliminary, interim, and final) that address a lengthy project completion period and coincidental changing water management conditions. However, water management activities for a completed project (defined as all project components in the O&M phase) may begin several years after the design phase and perhaps decades after the time that the original planning studies were conducted. In such circumstances, a review of the current water control plan should be conducted, considering new data or changes in project conditions, to verify that plan implementation will meet project purposes. Water managers should be vigilant to perform reviews and necessary revisions to the operating criteria for water control plans. Chapter 9 also discusses steps involved with updating these plans.

3.7.1. Constraints on Water Management Operating Criteria. A constraint on water management operating criteria is a condition that arises subsequent to project design that prevents, or is allowed to prevent, the achievement of a water management objective. Constraints may result from physical, social, or economic impacts on residential, agricultural, industrial, or environmentally sensitive areas that are affected by a project's water management capabilities. The water control plan should attempt to address known constraints.

3.7.1.1. Impacts Due to Incomplete Project Development. Incomplete project development may result in, but is not limited to, the following impacts:

a. The design downstream channel capacity is not achieved, possibly due to delay in clearing and snagging, realignment, enlargement, dredging, or levee construction.

26. Inadequate, vague, or complete lack of easement acquisition that prevents full use of storage or flowage downstream of water management structures.

3.7.1.2. Issues to Consider During Development and Revision of Water Control Plans. Many issues should be considered during development and revision of water control plans. Some potential issues are:

a. Encroachments in the floodplain downstream and in areas upstream of water management structures.

27. Effects of new development in low lying lands on channel capacity.

28. Erosion associated with pool levels or releases.

29. Frequency of filling and runoff volume may increase at impoundments as compared to pre-project conditions, requiring higher release rates from reservoirs and additional pumping capacity at local (interior drainage) projects.

30. An occurrence of an extreme low flow event, more severe than any in the hydrologic record used for design, may impact conservation purposes by restricting releases for water quality, water supply, hydroelectric power generation, etc.

3.7.2. Additional or New Hydrometeorological Data. After a project has been planned or designed and additional hydrologic data from existing or new data stations become available, system regulation schedules should be periodically reviewed. The hydrometeorological data may be in the form of streamflow, rainfall, snow accumulation, or other elements collected routinely to help define the hydrologic character of a drainage basin. The additional records not only extend the period of record of the basic data used in the initial planning studies, but also enhance the determination of regulation criteria and basin watershed characteristics that are used in modeling procedures. The new data may also include records of extreme floods or droughts that require modification of the operating criteria. In some cases, the additional basic data may warrant an updated system hydrologic analysis to refine the derived project streamflows. In any case, all available hydrologic data should be considered during revision of the water control plan.

3.7.3. New Water Management Objectives.

3.7.3.1. Water management goals now include environmental and social aspects of project regulation in addition to the basic public safety and economic functions for which water resources projects were originally authorized and constructed. The water management goals conform to relevant public laws that were enacted after the authorization of most existing water resources projects. The public laws require inclusion of certain aspects of environmental, fish and wildlife, and recreational uses in the management projects, or improvement of the environment of the rivers downstream through project regulation. The specific uses are determined from river basin investigations and are incorporated into the water control plan.

3.7.3.2. Re-evaluations of the water management criteria to meet authorized project purposes should be conducted, as necessary. Significant changes in policy procedures or other conditions may occur between the planning or design studies and the preparation of a detailed water control plan. Such changes should prompt implementation of a study program in connection with the development of water management operating criteria to refine the regulation through the use of additional basic data, authorized purpose requirements, and systems analysis techniques that became available subsequent to the planning and design studies.

3.7.4. Periodic Review for Flood Risk Management. A periodic review of flood risk management parameters is often a result of changed seasonal downstream channel capacities, downstream development adjacent to the river channel, or changed economic values for flood damages prevented. In many cases, encroachments in the flood plain may trigger a re-evaluation of target control elevations for flood regulation or controlled river levels during the post flood evacuation period if it can be demonstrated that modifying the water control plan does not transfer risk to a point where the project would not function as designed. The studies may be used to refine guide curves in conjunction with the additional flood data described in Section 3.7.2. System flood risk management studies for multipurpose river basin developments should be made using hydrologic and reservoir regulation models. Enacting the findings of a study may require an update to the water control plan, NEPA documentation, a public meeting, and potentially further congressional authorization.

3.7.5. Revising or Modifying Water Quality Operating Criteria.

3.7.5.1. Water quality conditions associated with initial impoundment and a short period afterward should be monitored using appropriate techniques. During the first year or so after the first filling, reservoirs are likely to have poorer water quality than the normal quality in subsequent years. For example, in stratified reservoirs, inundated vegetation will generate high concentrations of hydrogen sulfide, which will flush out of the project by the second or third year of operation. A revision or modification of water quality operating criteria and plans should be made, as necessary, to address unanticipated water quality conditions.

3.7.5.2. Changes in water quality and the need to revise operating criteria in response should be anticipated. Land use changes, changes in water user needs, changes in management objectives, and extreme or unusual weather events may induce abrupt or long-term changes in water quality. Operating experience may suggest a need for alternative criteria or major modifications.

3.7.5.3. Monitoring and surveillance activities, which provide data for operating guidance, usually include watershed surveillance, inflow and discharge monitoring, and the plotting of water quality profiles. These practices identify long-term trends as well as abrupt changes. In some instances, special studies of project conditions are used to develop guidance for modifying operating criteria. Such studies may be relatively brief and simple in scope or may require modeling, reservoir systems analysis, or physical modeling.

3.7.5.4. Data obtained from monitoring and surveillance should also be a source of information for revisions of water control plans and manuals. Water quality summaries should be included in project descriptions and used to identify changes in conditions. Operating experience should be documented to describe the success and failure in meeting water quality objectives. Results of studies used to modify operating criteria must be documented.

# CHAPTER 4

## Operational Characteristics of Water Management Facilities

4.1. General Considerations. Any physical operating constraints should be clearly outlined to ensure that water management features are operated in a safe manner and within design limitations during all phases of project life, including the construction phase. Particular care should be exercised during initial acceptance testing of the project's regulating features.

4.1.1. Background Information. The water manager should understand the operational characteristics of water management facilities to achieve water management objectives. This need covers a broad spectrum of knowledge regarding the types of design, hydraulic characteristics, and methods of operation of these facilities.

4.1.2. Types of Facilities. This chapter summarizes the types and design of project water passage facilities used to meet water management objectives and identifies the requirements, operation methods, capabilities, and limitations of each of these facility types. The water management facilities most commonly operated at projects are spillways and outlet works consisting of sluices, conduits, or tunnels. These facilities are usually gated. Several other types of water management facilities have specialized functions related to the regulation of streamflow, water level, and water quality at the project or at downstream locations. These facilities include hydroelectric power generation units, navigation locks, fish passage facilities, sluiceways for passing trash or ice, interior drainage facilities, hurricane and tidal barriers, bypass structures, siphons, and selective withdrawal facilities for outlets or power turbines. The specific design limitations and methods of operation must be noted in the project regulation criteria and in scheduling water releases.

4.1.3. Design Criteria. Guidance to design hydraulic features at Corps projects is presented in ER 1110-2-1150, Engineering and Design for Civil Works Projects. During project development, specific design of hydraulic structures is documented in the feature design memorandums. These design documents include information pertaining to the functional design criteria, design capacities, operating restrictions, control equipment, and methods of operation. During design, these criteria should be developed through coordination between the design, construction, operation and maintenance, and water management functions. After a project becomes operational, experience gained under actual operating conditions may provide additional information regarding facility capacities and operating limits.

4.1.4. Physical Condition of Facility. The water manager needs ready access to documents related to the physical condition of the water management facility. Generally, the stored files should include: as-built drawings, periodic inspection reports (PIs), periodic assessment reports (PAs), post-flood after-action reports (AARs), emergency action plans (EAPs), and any other documents that could aid the water manager in addressing critical decisions.

4.1.5. Spillways vs. Outlet Works. The following paragraphs define and discuss flow passage facilities at dams, spillways and outlet works used in Corps general design practice.

4.1.5.1. Spillways.

4.1.5.1.1. Spillways are typically classified as service spillways or auxiliary spillways and can be gated or ungated structures. A service spillway is designed to provide continuous or frequently regulated or unregulated releases from a reservoir, without significant damage to either the dam or its appurtenant structures. An auxiliary spillway is any secondary spillway that is designed to be operated infrequently, possibly in anticipation of some degree of structural damage or erosion to the spillway that would occur during operations. It may release floodwater that cannot be passed by other water passage facilities at a dam to prevent overtopping of the dam.

4.1.5.1.2. Gated spillways are often designed for flood risk management to provide more discharge capacity when the gates are opened. They allow a lower spillway crest elevation that could not be achieved with an uncontrolled spillway. A gated spillway may be used to make controlled releases other than for flood risk management purposes. For example, gated spillway releases may be needed in addition to hydroelectric power releases to meet downstream water quality requirements.

4.1.5.2. Outlet Works. Outlet works are sluices, tunnels, or conduits used to pass flows from a reservoir to meet project functions or to manage reservoir levels.

4.2. Spillways. Operating problems considered in design of spillways and appurtenant facilities can be significant to the water manager. Routine periodic inspections, periodic assessments, and annual inspections are the appropriate time to address spillway operational constraints, including, but not limited to:

a. Cavitation.

31. Erosion.

32. Uplift.

33. Hydraulic jacking.

34. Vibration of gates.

35. Gate operation related to manual, remote, or automatic operating mechanisms, incremental openings, operation under partial gate openings, and selective spillway gate operation to achieve desired flow patterns for hydraulic considerations or to improve fish passage.

36. Gate operation related to the functional use of storage, particularly to manage floods and flood surcharge storage.

37. Debris passage or management.

38. Ice formation in the reservoir, ice flows, and the effect of ice or subfreezing temperatures on gate operation.

39. Passage of upstream and downstream migrant fish.

EM 1110-2-1603, Hydraulic Design of Spillways, describes the technical design aspects for the hydraulic features of spillways, spillway chutes, energy dissipators, and spillway gates. The following sections describe types of spillways normally encountered at dams and reservoirs.

4.2.1. Energy Dissipation.

4.2.1.1. Energy dissipation is the most important technical hydraulic problem related to the design of spillways and outlet works. The energy to be dissipated is extremely high for spillways constructed at major dams, particularly for those with high head. High spillway velocities can cause considerable erosion in the spillway and along the walls. Energy dissipators are designed to minimize damage resulting from high velocity flows that occur either in the stilling basin or in the areas immediately downstream from the dam. Four typical causes of damage to energy dissipators are:

a. Cavitation resulting from high velocities and negative pressures downstream from baffle blocks, lateral steps, or other projections in the stilling basin.

40. Abrasion due to gravel, boulders, or other hard materials in the stilling basin or roller bucket, which erodes the surfaces and also may increase the damage by cavitation.

41. Pulsating pressures, which may cause failure or deformation of sidewalls or splinter walls constructed in or adjacent to stilling basins.

42. Erosion and scour of the area immediately downstream from the energy dissipator, which may undermine the structure.

4.2.1.2. Three basic types of energy dissipators have been used: (a) a stilling basin (the most common type) that dissipates energy by creating a hydraulic jump; (b) the roller bucket, which has been used at some projects where substantial tailwater is available, and which dissipates the energy immediately downstream from the bucket in the area of turbulent flows created by the rolling action; and (c) the flip bucket (or ski jump spillway), which directs the jet of water a considerable distance downstream from the dam to ensure that riverbed erosion does not occur near the downstream toe of the dam or terminal spillway structure. Flip buckets are generally used at projects where the downstream channel is founded in sound rock, at locations where water depths that receive impinging flow are relatively great, or at locations where erosion in the stream bed will not endanger the dam or appurtenant structures.

4.2.1.3. The performance of the energy-dissipating facilities may be critical to the water manager. If significant damage occurs to the stilling basin, the basin may be inoperative or only partially operative until repairs are complete. Repairs must be conducted to maintain the safety of the structure, and extreme flows must be managed during the repair period. Also, the repair schedule should consider the normal flows that may be impacted by the repair, and any resulting adjustments in the operating schedules. The use of other facilities that may cause damage to the energy dissipators should be limited. In addition, consideration should be given to lower the adverse effects of flow in the stilling basin on fish migration, total dissolved gas supersaturation, navigation, and public safety.

4.2.2. Spillway Gates. Spillway crest gates are used primarily to manage the spillway discharge according to specified operating criteria to achieve flood risk management objectives, but may be used to manage other water uses. Since gated spillways may allow for releases that greatly exceed the reservoir inflow, special care must be used in making gate releases to ensure that the outflows are maintained within operation standards. The following paragraphs describe the three main types of commonly used spillway gates. Engineer Technical Letter (ETL) 1110-2-584, Design of Hydraulic Steel Structures, provides more detailed information.

4.2.2.1. Tainter (Radial) Gates. Many major projects use Tainter gates with a design head of 30 to 60 ft and a width of 30 to 50 ft. Tainter gates are not designed to overtop and are usually designed to maintain 2 ft of freeboard at maximum operating pool with the gates closed. For some Corps projects, the top of the flood pool is the top of the Tainter gates, and no freeboard is included in the design with the gates closed. The gate seal on the spillway crest is usually located downstream from the crest axis to ensure that the water jet issuing from under the gate has a downward direction, resulting in positive pressures immediately downstream from the gate. Tainter gate side arms, which transfer the load to the trunnions, eliminate the need for gate slots. However, some Tainter gates have been identified as needing trunnion arm strengthening so they can be operated as designed. Spillway gates have been known to vibrate for various reasons, such as bottom hip and spill design. After construction, spillway gates cannot always be tested due to lack of water on the spillway gates, but operators should be aware of the potential for vibration.

4.2.2.2. Vertical Lift Gates. Vertical lift gates are most commonly used on low head dams. The split-leaf option for vertical lift gates allows the top portion to be hoisted independently of the low portion. The hydrostatic load of a vertical lift gate is transferred to the structure through bearing plates in the gate slots rather than through a trunnion, as is the case for a Tainter gate. The type of side bearing characterizes the gate as a wheel gate, tractor gate, or Stoney gate. These gates should not be overtopped without verification from the dam safety officer that the design can withstand overtopping.

4.2.2.3. Drum Gates. Drum gates, although seldom used at Corps projects, have been commonly used at USBR dams (e.g., Grand Coulee Dam). A drum gate is designed to float on water in a chamber located in the spillway crest. The water being released flows over the top of the drum onto the ogee section of the spillway. The drum is raised by hydrostatic pressure and has an operating range from the lower limit, in which the top of the drum is at the spillway crest level (fully open), to the upper limit, in which the top of the drum is at full pool level (fully closed).

4.2.3. Spillway Capacity and Discharge Ratings. Spillways are sized according to criteria and methods for accommodating floods contained in ER 1110-8-2 (FR), Inflow Design Floods for Dams and Reservoirs. EM 1110-2-1603, Hydraulic Design of Spillways, provides details concerning the methods for determining the ratings for spillways.

4.2.4. Operation of Spillway Gates. Spillway gate operation is based on prescribed discharges in reservoir regulation schedules. In some cases (e.g., run-of-the-river power-navigation projects), the spillway gates are operated to maintain a particular water level. Some gate control mechanisms have a safety override feature that prevents a gate opening movement more than a prescribed increment without an intentional restarting of the gate operating mechanism. Spillway gate control equipment is usually located near the gate, but at some projects the gates may be operated remotely from a project control room on site or at another location. At a few projects, spillway gates may be operated by automatic control, based on reservoir levels or hydroelectric power generation load as outlined in ER 1110-2-1156, Safety of Dams – Policy and Procedures.

4.3. Outlet Works.

4.3.1. Functional Requirements. The following paragraphs, extracted in part from EM 1110-2-1602, Hydraulic Design of Reservoir Outlet Works, briefly summarize functional requirements and related design considerations for outlet works used to regulate streamflows at dams and reservoirs. This summary provides a general background of the principal elements and engineering considerations in the design and use of outlet works to manage water systems.

4.3.1.1. Flood Risk Management. Flood outlets are designed for relatively large capacities in which fine regulation of flow is less important than other requirements. Although controlled by gates, the conduits may be ungated, in which case the reservoir is normally low or empty. Gates, water passages, and energy dissipators should be designed with special care for projects in which large discharges are released under high heads.

4.3.1.2. Conservation. Reservoirs that store water for subsequent release to support downstream navigation, irrigation, fish migration, water supply, and water quality usually discharge at lower capacity than flood risk management reservoirs, but at these locations, the need for accurate flow regulation is more important. For water quality, multiple intakes and control mechanisms may be installed to ensure reliability, to enable the water to be drawn from any selected reservoir level to obtain water of a desired temperature, or to draw from a stratum relatively free from silt or algae or other undesirable contents. Ease of maintenance and repair without interruption of service is of primary importance.

4.3.1.3. Power. Outlet facilities required for operation of hydroelectric power generation are discussed in EM 1110-2-1701, Hydropower. Power tunnels or penstocks may be used for flood risk management and other water passage requirements.

4.3.1.4. Diversion. Flood risk management outlets may be used for total or partial diversion of the natural stream during construction of the dam.

4.3.1.5. Drawdown. Requirements for low-level discharge facilities for drawdown of impoundments are discussed in ER 1110-2-1156, Safety of Dams – Policy and Procedures.

4.3.2. Sluices for Concrete Dams. Sluices constructed in concrete dams may be rectangular, circular, or oblong. Those designed primarily for flood risk management may be sized to provide a relatively large number of individual sluices, each being in the general range of 4 to 6 ft wide and 6 to 10 ft high. The flow through each sluice is controlled by individual gates or valves, providing a finer degree of control than could be derived from a smaller number of sluices of larger cross-sectional area. Sluice intakes may have trashracks for debris protection.

4.3.3. Outlet Facilities for Dams. Outlet facilities for dams consist of conduits and tunnels. The intake structure may be a gated tower; multilevel, uncontrolled two-way riser; or a combination of these. The control structure may be located either in the intake tower or in a central control shaft. A combined intake and gate structure is most commonly used. Gate passage and control gate designs for sluices also apply to conduits through dams. Special problems involved in the operation of outlet works through dams include:

a. Head loss, boundary pressures, and vortices in the intake structure approach.

43. Debris and important fish species entrainment.

44. Hydraulic loads for vertical lift gates.

45. Gate “catapulting,” resulting from water pressure building up on the downstream side of the intake gate during filling of the area between the service and emergency gates.

46. Vibration and resonance of cable supported gates.

47. Transition and exit flow conditions of the conduit or outlet tunnel.

4.3.4. Gate Passageways. The gate section, which is that portion of the sluice or conduit in which the gates operate, is designed to eliminate or minimize the effects of cavitation. Particularly during operation of partially open high head gates, passageways may be subject to severe cavitation and vibration, and may have a high air demand. Air vents are provided to reduce cavitation for control valves that do not discharge into the atmosphere. Two gates in tandem are normally provided for each sluice to ensure flow regulation in case one gate becomes inoperative. Emergency gates must be provided for each service gate passageway to allow for closure of the gate passageway in the event that a service gate becomes inoperative in any position. Bulkheads, which allow inspection and maintenance of the upstream gate frame and seal, are provided for each gate passage. Gate passages of circular cross section are designed for circular gates or valves, such as knife and ring-follower gates and butterfly, fixed cone, and needle valves. Rectangular gate passages are used for slide, Tainter, and tractor or wheel-type gates.

4.3.5. Control Works. Control works for sluices or conduits are classified as gates and control valves. Vertical lift gates may be slide, fixed wheel, tractor gates, or gate-within-a-gate, which are operated by hydraulic cylinders, cables, or rigid stem connections to the hoist mechanism. Hydraulically operated gates are preferred for high heads and for long periods of operation. Tainter gates are also used as service gates operating at high heads. Control valves, including knife gate, needle-type, fixed-cone, and various commercial valves, have been used for flow control to discharge water freely into the air or into an enlarged, well-vented conduit. Commonly used valves include butterfly, needle-type (hollow jet), fixed-cone, and commercially available valves for small conduits.

4.3.6. Operation of the Control Works. The operation of control valves or service gates may be based on manual, automatic, or remote control. In a few cases, the outlet works are under automatic control using water level sensors. Remote control operations should not be used if a system failure could result in loss of life. Remote control operations are subject to additional safety requirements, including visual verification, as addressed in ER 1110-2-1156, Safety of Dams – Policy and Procedures. Vertical lift gates are usually manually operated by use of lifting mechanisms, which may be “dogged” at fixed increments of elevation to approximate a particular gate setting. Tainter or slide gates driven by hydraulic or electrical hoists may be controlled either at the site of the gate machinery or, in some cases, remotely from the project control room. The gate control mechanisms may have an override feature that limits the opening increment, requiring successive iterations to increase the opening size. Special problems may arise with the operation of the outlet works, such as ice and trash accumulation, excessive vibration, erosion, and cavitation. Such problems must be resolved to meet the water management objectives and also to maintain the integrity of the project facilities.

4.3.7. Discharges. Discharge is normally determined from theoretically derived discharge ratings as described in EM 1110-2-1602, Hydraulic Design of Reservoir Outlet Works; however, metering devices to monitor flow through conduits may be provided under unusual circumstances, especially when flow accuracy is important for regulation.

4.3.8. Low-Flow Facilities. Projects may be required to make comparatively small releases for a variety of reasons, such as water supply or downstream aquatic benefit. The operation of large gates to create small openings (less than 0.5 ft) is not recommended due to the increased potential for cavitation downstream from the gate slot. Projects that require low-flow releases may provide for releases by using low-flow bypass culverts, center pier culverts, multilevel wet well facilities, or a low-flow gate incorporated into the service gate, sometimes referred to as a "gate-within-a-gate." For projects in which a single tunnel is used and no other water release facility is available, a bypass is desirable to maintain low flows in the river during repair periods.

4.3.9. Selective Withdrawal Systems.

4.3.9.1. Selective withdrawal systems may be provided to draw water from specified elevations in the reservoir. These systems fall into three general types:

a. Inclined intake on a sloping embankment.

48. Freestanding intake tower, usually incorporated into the flood risk management outlet facilities of embankment dams.

49. Face-of-dam intake, constructed as an integral part of the vertical upstream face of a concrete dam.

Types b and c predominate at Corps projects due to the types of dams and time of construction, however any of the types may be incorporated during rehabilitation of outlet structures.

4.3.9.2. Each type of selective withdrawal system described above includes the following structures:

a. Elevation specific inlets and collection wells for mixing.

50. Control gate passages to specify release.

51. Exit passages to discharge downstream.

4.3.9.3. Inlet ports for selective withdrawal are designed to be operated fully open or closed, and the total flow is regulated by a downstream control gate or power unit. The inlet ports are operated manually with gate hoists or other operating equipment. Some successful, single-well systems allow for blending of water withdrawn from more than one level. An inlet port that is not totally submerged can be operated as an inlet weir, and the combined operation of the weir and downstream control can be balanced to provide the desired flow characteristics. Collection wells are provided to direct the flow of water from the intake system to the outflow passages. In dual wet well systems, blending of flows for water quality should be from separate wet wells. Each wet well should have individual flow control, and inlets at only one elevation should be open in each wet well. Submerged weirs upstream of outlet works can be used to prevent withdrawal of bottom waters from reservoirs by conduits and penstocks. Conversely, facilities may be used to withdraw bottom waters as rapidly as possible after a flood, e.g., for turbidity management. In general, all water quality control devices for selective withdrawal are individually designed to meet the particular project requirements, and the regulation of these facilities is based on the experience gained during the operational phase.

4.3.10. Energy Dissipation. Energy dissipation for all types of dam outlet works is an important feature of the project's hydraulic design. A hydraulic jump type stilling basin is most frequently used for energy dissipation from conduits or sluices. The stilling basin may also incorporate the energy dissipation requirements for spillway discharges. Stilling basins are generally designed to provide optimum energy dissipation of managed flows equal to the capacity of the outlet works. The design of the stilling basin requires a detailed hydraulic analysis, which usually includes hydraulic model studies. Energy dissipation using stilling basins or other methods is an important consideration in the overall management of water releases from projects, and the effectiveness of the system may be of particular significance to water and fishery resources managers.

4.3.11. Summary. The water manager should have general knowledge of the hydraulic design of the outlet works to evaluate special operating problems that may arise. Specific knowledge of the detailed design for projects is also required to understand design limitations, unusual operating problems, discharge characteristics, and other factors that may influence the use of these facilities on a daily basis. Note that this summary of outlet work design is only a general description of outlet facilities and design requirements. EM 1110-2-1602 provides a more complete description of the methods of design for outlet works and the individual feature design memorandums for a description of the design of outlet works for specific projects.

## 4.4. Flood Risk Management Operation.

4.4.1. Project Outflows. Chapter 3 presents the basic methods for developing water control plans. Flood risk management releases are usually made through either the spillways or outlet works; however, the total release may be met by combining releases from spillways, outlet works, and hydroelectric power generation units, if available. The regulating outlets are sized to provide the post-flood evacuation of reservoir flood storage. During a flood regulation period, project outflows are frequently adjusted to achieve downstream flood risk management objectives. In general, the outlet works are designed to manage releases during the evacuation of flood storage, while the spillway is used when the reservoir approaches full pool level and during induced flood surcharge operations. Downstream constraints may limit operation as originally designed.

4.4.2. Managing and Monitoring Outlet and Spillway Gate Regulation. The water manager issues flood regulation schedules and operating instructions to the project operators. These instructions may include guidance on total discharge, gate settings, flow rates of change, and the gates and structures to be used. The regulation should clearly state whether the outlet works should be opened or closed in conjunction with spillways to release flood flows. Outlet works should not be used if they are not designed to operate at those extreme heads that are experienced with extreme events. The water manager determines the reservoir regulation plan and ensures that the project operational data reports reflect those decisions detailing discharge amounts, gate settings, and reservoir levels. For some projects, automatic sensors at gate openings provide continuous reservoir regulation data. Chapter 5 discusses WMESs. The water manager must be informed of any problems related to the operation of the outlet works and the spillway. Any adjustments to reservoir regulation that may result from restrictions in the use of the outlet or spillway facilities should be coordinated between the project operator and the water manager.

4.4.3. Combined Use of Outlet Works and Spillways.

4.4.3.1. One technical hydraulic problem related to the flood risk management regulation of reservoirs is the combined use of outlet works and spillways to pass the desired outflows during flood periods. Many projects base the spillway design discharge capacity on the combined use of the full capacity of the spillway and outlet works. In some cases, this capacity also includes a portion of the capacity of hydroelectric power units that can be expected to be operable at the time of the flood. Combined use of outlet works and spillways depends on evaluations of the hydraulic and structural designs at the particular project. These evaluations include:

a. The flow characteristics of the spillway and outlet works with regard to symmetry of flow in the spillway or outlet channel.

1. The allowable head on the outlet works.

2. Cavitation in the outlet works or spillway.

3. Back pressure on the outlet tunnel resulting from high tailwater.

4. Tailwater conditions that affect the performance of the stilling basin.

5. Gate operation with partial gate openings for both outlet and spillway gates.

6. The effect of the discharges on the flow patterns in the stilling basin.

7. Erosion or damage in lined or unlined channels that transport the water to the river below the dam.

8. The interrelationships among flow conditions affecting other facilities, such as fish passage and survival, navigation channels, and revetments.

4.4.3.2. Projects should be operated to limit damage to the project structures. Some projects are designed to use spillways only rarely. For example, using an unlined spillway outlet channel could cause erosion in the spillway and the downstream river channel. In such cases, every effort should be made to use the full capacity of the outlet works and hydroelectric power plant, if applicable, to limit the magnitude and duration of flows over the spillway. Each project has unique design characteristics, and operational decisions should minimize damage to the project structures based on design data, past project performance, performance of similar projects, and anticipated flood regulation.

This information should be incorporated into the project water control manuals, and periodically updated to reflect the experience gained from operation.

4.4.4. Free-Flow Operation of Projects with Little or No Flood Risk Management Mission. Some projects are constructed with dams and gate-controlled spillways to regulate the water surface elevations and outflows of large natural lakes or run-of-the-river impoundments. Such projects may also have on-site hydroelectric power generation installations, navigation locks, or other water management facilities. Usually, the operating range of the reservoir levels is limited to relatively modest amounts; that is, the difference in elevation between minimum and normal full pool levels rarely exceeds 15 to 25 ft. The primary purpose of these projects is to supply water for seasonal uses, such as hydroelectric power production, irrigation, navigation, or water supply. During a flood, such projects are managed to use the storage that is approximately equal to the uncontrolled natural storage in the lake or river reach. Seasonal storage regulation for these projects consists of filling to normal full pool level during the high-flow season, holding the water in storage until needed for on-site or downstream flow regulation, and using the stored water to augment streamflows during the low-water period. Projects of this type use spillways designed to provide approximately the equivalent capacity of the natural outlet. The spillway discharge may be augmented by outflows through power units.

4.5. Induced Flood Surcharge Storage.

4.5.1. General Principles.

4.5.1.1. Flood surcharge storage in projects with authorized flood storage is the volume of water stored above the top of flood pool. For those projects without flood storage, such as a run-of-river lock and dam projects, the flood surcharge storage is the volume above the top of the multipurpose (navigation or hydroelectric power) pool. This volume is not water stored, but is left empty for use when needed.

4.5.1.2. Reservoirs managed with gated spillways present special operating problems during flood regulation. Particularly for large floods, the use of spillway gates (sometimes in combination with the outlet works) must be carefully scheduled to reduce downstream flood flows while optimizing reservoir storage capacity. Spillway releases should be increased gradually, because sudden, large flow increases may pose a hazard to public safety. They could also carry more debris, cause more damage, and complicate downstream emergency responses, e.g., by shortening evacuation times. To protect the project facilities, the facilities should be operated to maintain the integrity of the outlet works and spillway and to keep the dam from overtopping. The operation of spillway gates during floods should be regulated to compensate for current watershed hydrologic characteristics differing from those used for design. Design hydrologic characteristics may be out of date due to upstream valley storage loss, changed river channel hydraulic properties, synchronization of tributary inflows, and changes in basin runoff characteristics. Rain falling directly on the reservoir surface should not be neglected. In summary, three major concerns that the water manager must balance while optimizing storage during a flood surcharge operation are:

1. Protecting the project's integrity – do not overtop gates or embankment core.

2. Limiting downstream damages – peak release should be no more (and preferably less) than the instantaneous peak inflow during the event, i.e., less than the peak flow would have been before the project was built so that damages are not induced by the project.

3. Maintaining the rate of outflow increase within acceptable limits.

4.5.1.3. Reservoir simulation models may be used for study purposes (developing operating criteria) or operational use (calculating the effect of reservoirs on current river system regulation). Additionally, simulation models are useful for comparing natural and regulated flow conditions for the system, both for real-time reporting and economic studies.

4.5.1.4. Figure 4-1 illustrates the various levels and conditions involved in spillway gate operation for induced flood surcharge storage. The dotted lines in Figure 4-1 show the gate in a closed position and the solid lines show the gate in an open position. As the gate is opened, additional water is stored in the reservoir as flood surcharge storage and water is released under the gate.

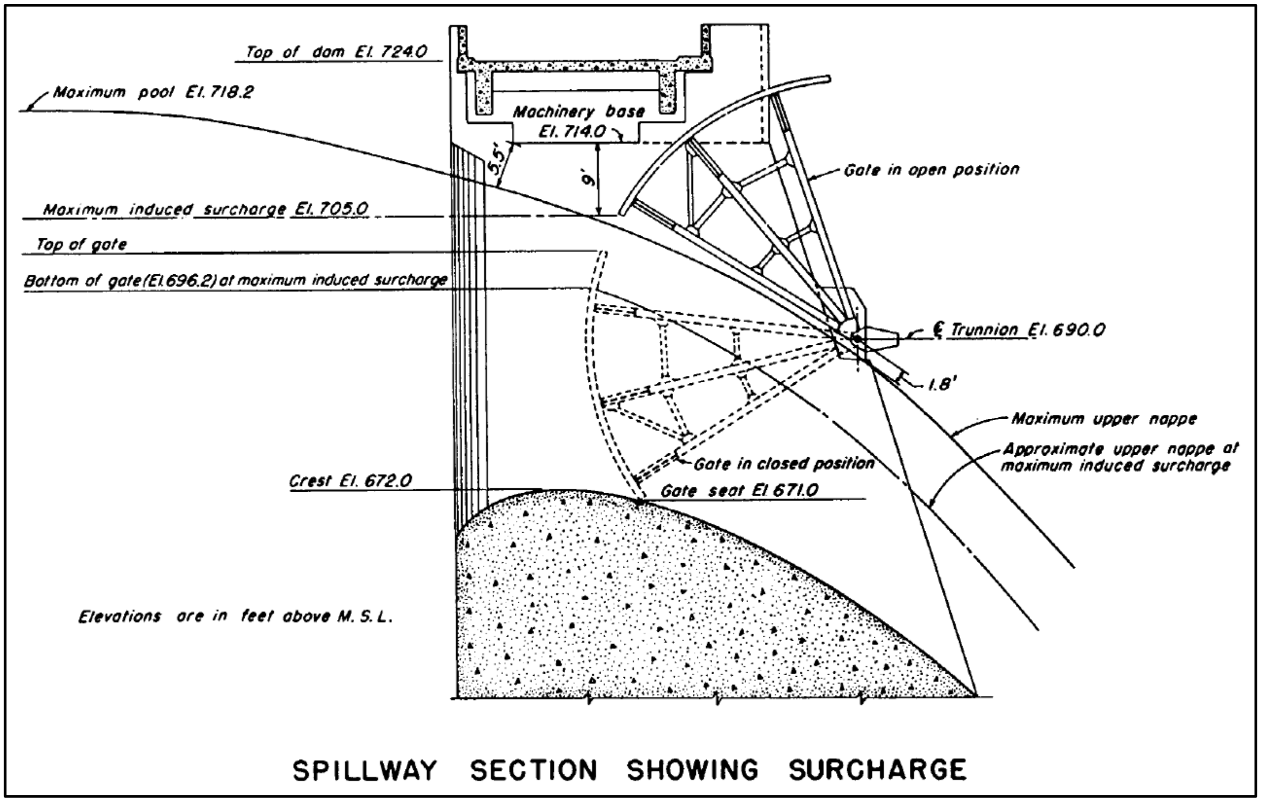


Figure 4-1. Spillway Section Showing Surcharge.

4.5.2. Flood Surcharge Storage for Uncontrolled Ungated Spillways. The degree of control afforded by an uncontrolled spillway is determined by outlet capacity and reservoir storage. Storage routing may be calculated by a number of methods using basic storage and flow relationships for a particular reservoir. Uncontrolled reservoir spillways store water above the spillway crest, and the reservoir pool elevation rises and falls according to the inflow, outflow, and storage relationships. Since flow regulation is determined by the inflow, storage, and spillway design and characteristics, the water manager has little capability to affect the releases from this type of project. It is important that communities and landowners downstream from the project are aware of this so that they fully understand the limited regulation capabilities during high inflow, and possible high outflow, flood events.

4.5.3. Development of Induced Surcharge Envelope Curves.

4.5.3.1. The induced surcharge envelope curve defines the maximum permissible reservoir elevation for a given reservoir release. The maximum induced flood surcharge storage elevation depends on the design characteristics of the dam and spillway; design flood elevations; limitations imposed by flowage rights in the reservoir; economic, critical infrastructure; and life safety issues, particular to the basin. The envelope curve is developed using the following steps:

1. Compute a set of spillway-rating curves as shown in Figure 4-2.

2. Define top of gate limit.

3. Identify the greatest non-damaging flood risk management release.

4. Select fully-open-gate pool elevation.

5. Draw the induced surcharge envelope curve.

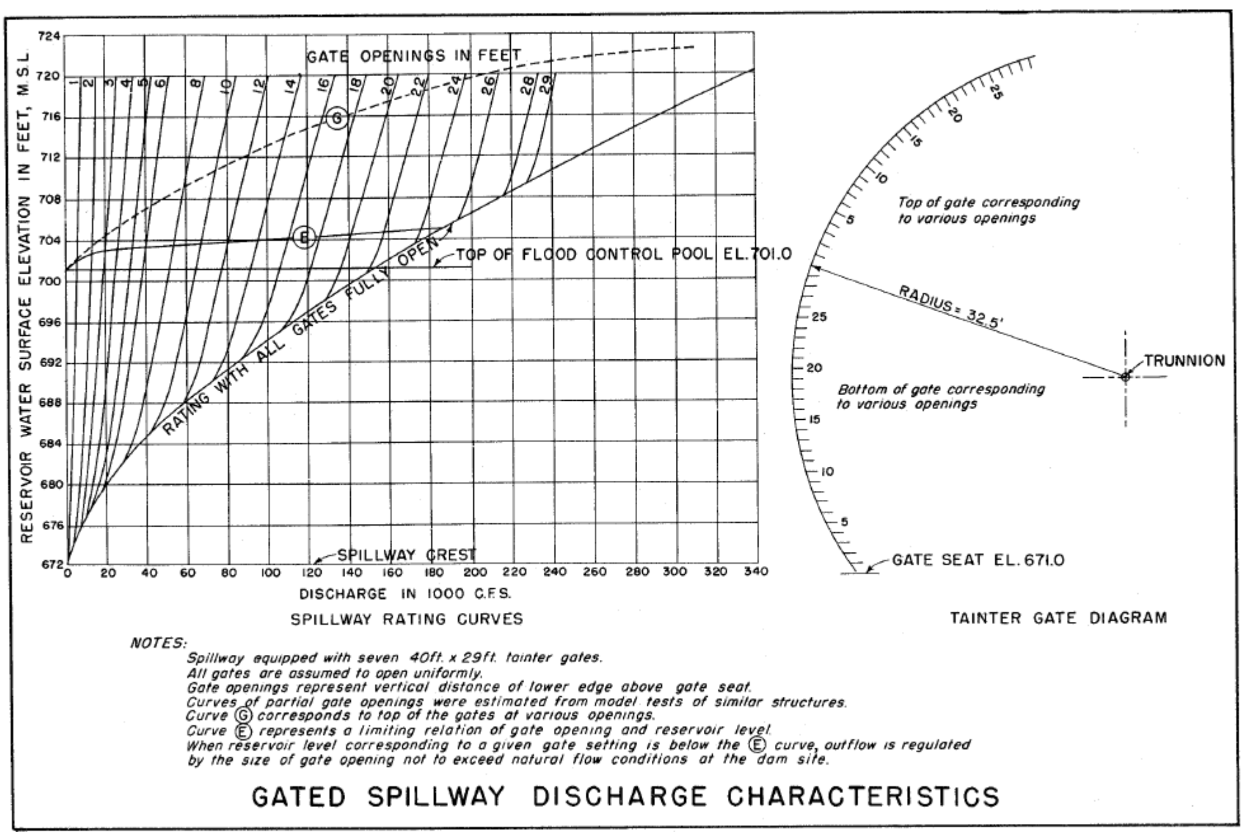


Figure 4-2. Gated Spillway Discharge Characteristics.

4.5.3.2. The steps in the development of the envelope curve are more fully described below.

1. Compute a set of spillway rating curves (see Figure 4-2). Generally, the discharges are computed in 1-ft pool elevation increments and 1-ft gate openings (with all gates open same amount) including the fully open gate configuration.

2. Define top of gate limit. Top of spillway gate elevations corresponding to various gate openings are superimposed on the rating curves (see Curve G, dashed line, Figure 4-2). Induced flood surcharge storage cannot exceed the elevations indicated by this curve without overflowing spillway gates in the partially open position. In practice, the pool should be limited to a lower elevation to provide some freeboard, particularly after gate openings of a few feet are attained. Ideally, the gate limit curve provides a risk margin of 1 or 2 ft above top of flood pool with gates in the closed position. EM 1110-2-1420, Hydrologic Engineering Requirements for Reservoirs, addresses freeboard requirements.

3. Identify the greatest non-damaging flood risk management release. Usually, the non-damaging release equals the downstream channel capacity or the flow associated with flood stage at a downstream regulating station.

4. Select the fully-open-gate pool elevation. Selection of the fully open elevation must consider economics, critical infrastructure needs, and life loss risks. The economic portion of the decision must balance upstream and downstream flood damage risks. Often, the upstream property damage risks are identified by setting the project real estate taking line (see EM 1110-2-1420). The downstream property damage risks are identified by overlaying economic data (e.g., Hazus mapping) on downstream inundation maps. Critical infrastructure and life loss concerns are often connected, with releases or pool elevations impacting evacuation routes, capacity of downstream dams, dam safety concerns, areas of high population density, and national security sites. The water manager should exercise proper engineering judgment to ascertain whether the spillway gates should be completely opened. Consideration should include current and forecasted inflow and corresponding reservoir elevations as well as recommendations from the district and division dam safety officers.

5. Draw the induced surcharge envelope curve from a point corresponding to the non-damaging flood risk management release at the top of the flood pool elevation to the discharge capacity of the spillway at the elevation at which all gates must be fully opened, as illustrated by Curve E, solid line, Figure 4-2.

4.5.3.3. A straight-line connection ensures the minimum rate of increase in spillway discharge under critical flood conditions and may be the proper form in some cases. However, curvature as illustrated by Curve E, Figure 4-2, permits lower release rates in the lower flood surcharge ranges, the most common event scenario. The minimum permissible slope of the line is governed by the rate of increase in spillway discharge considered acceptable during extraordinary floods. Determination of the minimum permissible slope of the curve should reflect downstream impacts and project capabilities. Although consideration should be given to the timeliness of the closure of downstream evacuation routes during the highest discharge of the flood surcharge release, a more important requirement is to confirm that the gates can be opened at a sufficient rate to route the design event using the proposed induced surcharge envelope curve.

4.5.4. Development of Spillway Gate Regulation Schedules.

4.5.4.1. Projects with gated spillways may require a spillway gate regulation schedule, which is a family of curves that relate inflow, outflow, and project storage. The schedule is used to identify the minimum release required to evacuate the forecasted inflow volume that exceeds available storage (including available flood surcharge storage) and could occur on the rising or falling limb of the inflow hydrograph. The general methodology to develop a spillway gate regulation schedule is to calculate the required storage to pass a given inflow at a given outflow; the required storage is used to identify the correlated pool elevation. This procedure is used to determine the minimum volume of inflow expected at a particular time during a flood. The forecasted inflow volumes should be modeled and based on observed precipitation. The procedure is also used to compute a family of curves (termed the spillway gate regulation schedule) that relate the inflow and residual reservoir storage volume (including induced flood surcharge storage) to determine the outflow required to avoid making regulated downstream flows greater than under a pre-project condition while at the same time providing for an orderly increase in outflows during extreme floods such that project overtopping is prevented. The computations are presented in the Institute for Water Resources, Humphreys Engineer Center (IWR-HEC) publication Volume 7, Flood Control by Reservoirs. The spillway gate regulation schedule is developed using the following steps:

1. Define recession constant ($T_s$).
2. Calculate the inflow storage ($S_A$).
3. Identify the elevation ($El_E$) on the surcharge envelope curve.
4. Determine the total reservoir storage ($S_E$).
5. Calculate critical storage ($S_c$).
6. Determine the tentative maximum allowable pool elevation ($El_t$).
7. Test each tentative maximum starting reservoir elevation ($El_t$).

4.5.4.2. Each of the listed steps is discussed below.

1. Define recession constant ($T_s$). The first step in the procedure is to analyze recession characteristics of inflow hydrographs to obtain a recession constant to predict a minimum inflow volume that can be expected, with the only known information being the reservoir elevation and the rate of rise of the reservoir elevation.

   For conservative results, the assumed recession curve should be somewhat steeper than the average observed recession; it can normally be patterned after the inflow design flood recession. A variety of decay functions can be used to fit the recession curve; however, in most cases, an exponential function is adequate, where the flow ($Q$) after a time period

($t$) is predicted for the initial flow ($Q_i$), and where the recession constant is defined by $T_s$, as shown in:

$$Q = Q_i e^{-t/T_s} \tag{4-1}$$

Graphically, the recession constant can be obtained by plotting the recession curve as a straight line on semi-log paper, with the flow on a logarithmic scale and time on an arithmetic scale. The recession constant, $T_s$, is defined as the time required for the discharge to decrease from any value, say $Q_A$, to a value $Q_B$, where $Q_B$ equals $Q_A/e$, and $e \approx 2.7$. Mathematically, the recession constant is the time required for a given inflow to recede by about 63%.

2. Calculate the inflow storage ($S_A$). The volume of water that will need to be stored given an inflow peak and outflow is the total future event volume (area under the recession curve) minus the outflow volume (release rate multiplied by the time required for inflow to recede to match outflow). Consider Figure 4-3, which schematically illustrates terms to be used in solving for the volumes to be stored, $S_A$. In Figure 4-3, $Q_1$ represents the inflow, $Q_2$ represents the constant outflow, and $c$ represents the conversion constant (in most cases, $c = 1.983$ to convert cfs-day into ac-ft). The recession constant, $T_s$, may be defined as the additional volume stored ($V_s$) and released ($V_r$) during the duration for the inflow to recede until matching the release:

$$T_S = \frac{V_s + V_r}{\Delta Q} = \frac{(S_A / c) + Q_2 t}{Q_1 - Q_2} = \frac{S_A + cQ_2 t}{c(Q_1 - Q_2)} \tag{4-2}$$

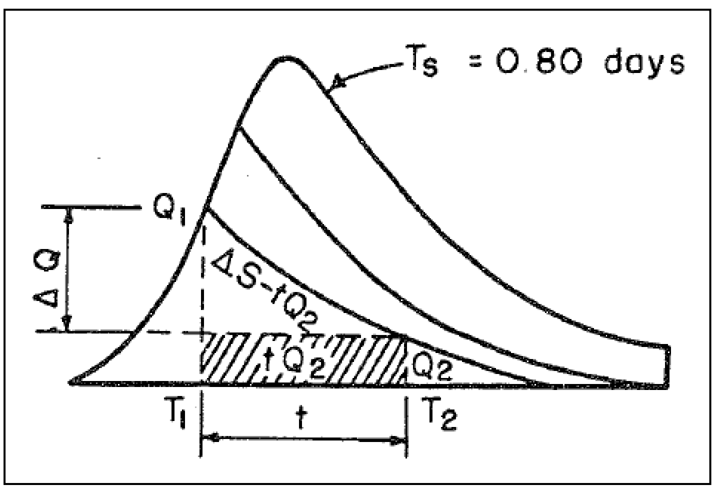


Figure 4-3. Schematic Hydrograph.

The time (t) for the inflow to recede until equal to the release may be solved by:

$$t = T_2 - T_1 = -T_S \log_e(Q_2/Q_1) = T_S \log_e(Q_1/Q_2) \tag{4-3}$$

Substituting (4-3) into (4-2) and rearranging:

$$S_A = cT_S\left[Q_1 - Q_2 - Q_2 \log_e(Q_1/Q_2)\right] \tag{4-4}$$

$$S_A = cT_S\left[Q_1 - Q_2(1 + \log_e(Q_1/Q_2))\right] \tag{4-5}$$

For each of various inflow rates and for each of various outflow rates, compute the volume of water that must be stored, $S_A$, using Equation 4-5.

3. Identify the elevation ($\boldsymbol{El_E}$) on the surcharge envelope curve (see Section 4.5.3) that correlates to each inflow ($Q_i$). For example, in Figure 4-4, the elevation on the induced surcharge envelope curve corresponding with an inflow equaling release of 40,000 cfs is 1571.1 ft.

4. Determine the total reservoir storage ($S_E$) corresponding to each surcharge envelope curve elevation ($El_E$) using the project elevation-storage relationships.

5. Calculate critical storage ($S_c$) given each inflow volume to be stored ($S_A$). The critical storage is the maximum allowable storage that can be used in the reservoir during the inflow event such that the reservoir elevation does not exceed the surcharge envelope curve. The critical storage ($S_c$) is the total reservoir storage ($S_E$) less the volume to be stored ($S_A$).

$$\mathrm{S_c} = \mathrm{S_E} - \mathrm{S_A} \tag{4-6}$$

6. Determine the tentative maximum allowable pool elevation ($\boldsymbol{El_t}$) given each critical storage value ($S_c$) using the project elevation-storage relationships.

7. Test each tentative maximum starting reservoir elevation ($\boldsymbol{El_t}$) against spillway limits to determine the maximum starting reservoir elevation ($El_c$). The maximum starting elevation represents the maximum pool elevation for which an operator could begin a flood surcharge operation for a given peak inflow and release condition and meet the induced flood surcharge objectives listed in Section 4.5.1. The regulation schedule seeks to answer the question: Is the spillway capable of passing the set outflow given the calculated maximum starting pool elevation? The lower limit is the outlet works crest elevation, at which the maximum pool level ($El_c$) equals the spillway crest. The upper limit is defined by the maximum discharge curve (spillway free-flow capacity); if the tentative maximum starting reservoir elevation ($El_t$) does not provide enough head to pass the given inflow, then the critical elevation ($El_c$) is the elevation capable of passing the inflow. Otherwise, if the tentative starting elevation is between the spillway limits, then the tentative elevation is the maximum starting elevation ($El_c$).

4.5.4.3. The family of curves based on inflow is shown as Regulation Schedule A in Figure 4-4. Families of curves, such as those shown in Figure 4-4, are appropriate to use in a central office, but the relationships for an emergency operation schedule for dam tenders can be applied more directly if the rate of rise of reservoir level is substituted for the inflow. This is readily accomplished by obtaining the difference between the volume of inflow and outflow for a selected time interval and expressing the volume as a rate of rise for any particular reservoir elevation. A typical family of curves based on rate of rise is shown as Regulation Schedule B in Figure 4-5.

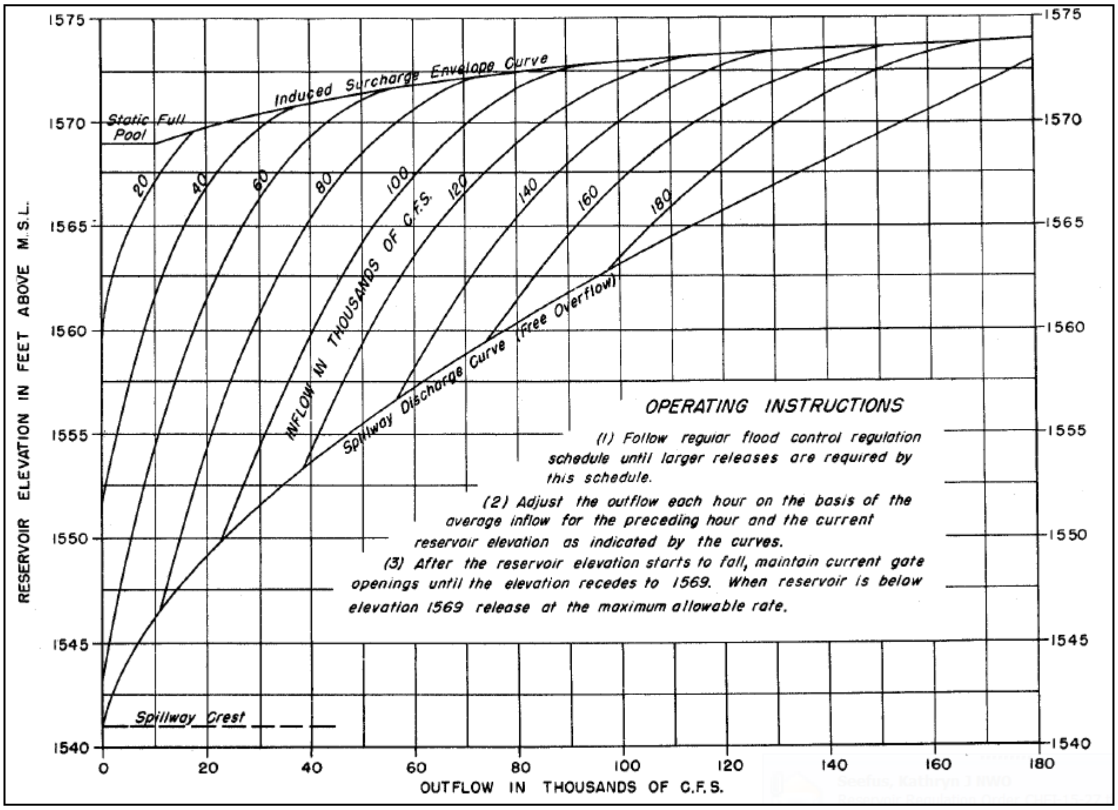


Figure 4-4. Spillway Gate Regulation, Schedule A.

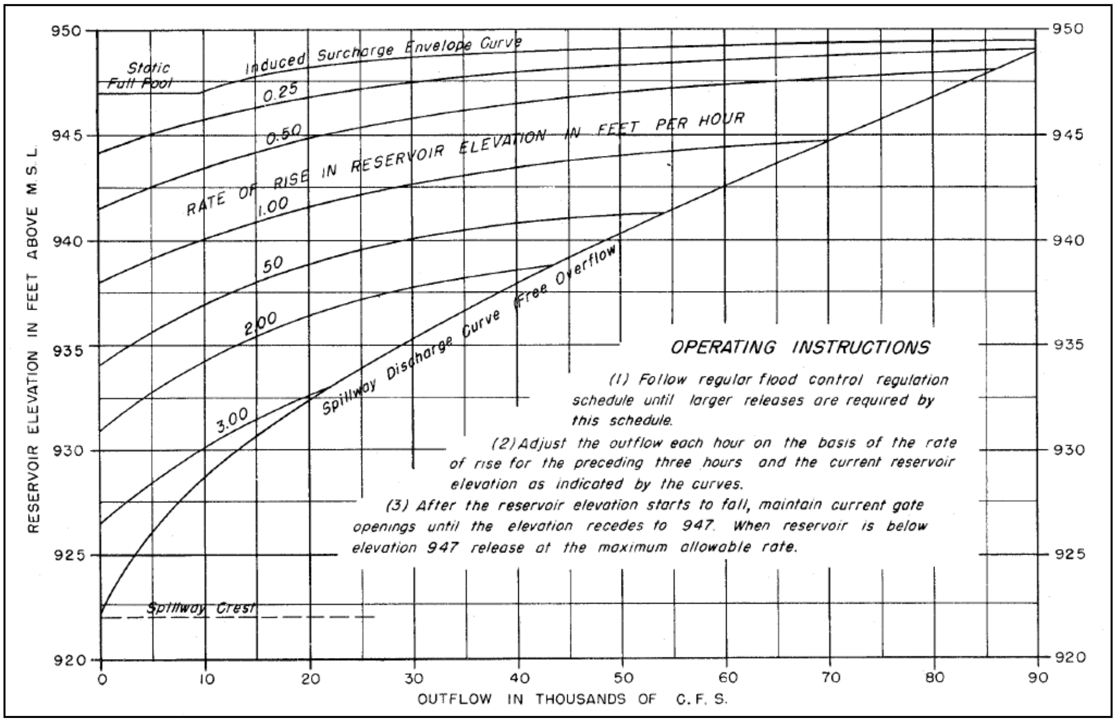


Figure 4-5. Spillway Gage Regulation, Schedule B.

4.5.4.4. The steps to convert an inflow regulation schedule to a rate of rise gate regulation schedule are:

1. Select the appropriate time interval (T).

2. Find each difference between the inflow and outflow.

3. Calculate each storage change.

4. Determine the critical storage ($S_c$).

5. Calculate each storage ($S_{t-T}$) for one time interval in the past.

6. Identify each elevation (El) for one time interval (T) in the past.

7. Finally, determine the rate of rise.

4.5.4.5. Each of the listed steps is more fully discussed below.

1. Select the appropriate time interval (T) to measure the change in pool elevation. The time interval to determine rate of rise should be based on the reservoir and drainage basin characteristics, with 1 to 3 hours being typical, given that adjustment in gate openings at 1- or 2-hour intervals is adequate for most projects.

2. Find each difference between the inflow and outflow; $\Delta Q = Q_1 - Q_2$.

3. Calculate each storage change; $\Delta S = \Delta Q/\text{T}$.

4. Determine the critical storage ($S_c$), given each critical elevation ($El_c$) using the project elevation-storage relationships.

5. Calculate each storage ($\boldsymbol{S_{t-T}}$) one time interval (T) in the past; $S_{t-T} = S_c - \Delta\, S$.

6. Identify each elevation (El) for one time interval (T) in the past using the project elevation-storage relationships.

7. Finally, determine the rate of rise, which is the difference of the critical elevation and the previous elevation divided by the time interval; $R = (El_C - \text{El})/\text{T}$.

4.5.5. Testing Spillway Regulation Schedule. Spillway gate regulation and induced surcharge envelope curves should be tested by simulating regulation of historic or hypothetical floods. Several computer programs are available to model regulation conveniently, most notably HEC-ResSim software (which is also capable of calculating spillway regulation schedules given the elevation-storage curve and surcharge envelop curve), developed by the Hydrologic Engineering Center. Testing should include a variety of storm patterns and magnitudes considered reasonable for the project.

4.5.6. Methods of Operation. Operating options available during rising and falling reservoir levels should be described in project water control manuals and water control plans.

4.5.6.1. Rising Reservoir Levels.

4.5.6.1.1. If forecasts based on observed precipitation indicate that runoff from a storm will appreciably exceed the remaining reservoir storage capacity, the opening of spillway gates may begin before the time required using the spillway gate regulating schedule. This could occur on the rising or falling limb of the inflow hydrograph See Section 7.3.2 for further discussion on operating based on water-on-the-ground.

4.5.6.1.2. Opening of spillway gates should be scheduled to limit the rate of increase in outflow to acceptable values to the extent possible. For outflows required by the spillway gate regulation schedule, induced flood surcharge is used to partially manage outflow rates. The elevation attained and the volume of induced flood surcharge storage used varies with the volume and rate of reservoir inflow during individual floods and the exact schedule of gate operation.

4.5.6.2. Falling Reservoir Levels.

4.5.6.2.1. Releases should be based on the most appropriate of the available options once flood surcharge storage has peaked. The flood surcharge storage should be evacuated as rapidly as possible, while considering conditions downstream from the project as well as project safety. The type of project (e.g., concrete arch, rolled earth embankment) should be considered when ascertaining how long high pool levels should be maintained. Also, Corps water resource projects vary greatly in design, storage, and release capability as well as dam safety action classification (DSAC). Each of those components must be considered on a case-by-case basis when determining the drawdown strategy from flood surcharge storage. On completion of drawdown to the top of flood pool level, the regulation schedule for releasing stored waters should be followed. Some of the more common procedures for drawdown of induced flood surcharge storage for falling reservoir levels and decreasing inflow are:

1. Drawdown gradually to top of flood pool level within a specified time (e.g., hours or days).

2. Maintain maximum spillway gate opening.

3. Release a flow equal to a fixed percentage (over 100%) of the mean inflow for the preceding 3 hours without exceeding the event's instantaneous peak inflow.

4. Make the release in excess of the current inflow by some specified increment of discharge without exceeding the event's instantaneous peak inflow.

5. Make the release conform with a hydrograph similar to the natural inflow hydrograph.

6. Maintain a non-damaging or channel capacity discharge.

7. Make releases that do not induce additional damages at downstream control points.

4.5.6.2.2. If all spillway gates are opened fully during the storage operation, discharge is uncontrolled until the outflow decreases to the value at which the uncontrolled condition began. Regulated operation should then conform to one of the preceding release schedules for falling reservoir levels.

4.5.7. Effect on Spillway Gate Design. The most efficient induced storage operation would normally require that the spillway gates be designed for operation with partial openings and with individual operating mechanisms. Unless the gates are designed for overtopping, the height of gates should be 1 or 2 ft greater than required for the induced flood surcharge operation, since all gates cannot feasibly be operated simultaneously to obtain the desired discharge on some structures. The design should also consider that gates should not be operated such that only the lip of the gate is in the flow.

4.6. Outlet Works Releases.

4.6.1. General Considerations. The design requirements for outlet works to support water supply are different from the requirements for flood risk management. Generally, the water releases for irrigation, navigation, M&I water supply, fish passage or habitat enhancement, and other water uses are fairly uniform over a period of days or weeks as compared with the rapidly changing requirements for flood risk management. The use of outlet works for water supply may involve special operating issues, which should be considered by the water manager. The regulation should clearly state whether the outlet works should be open or closed in conjunction with spillways to release flood flows.

4.6.2. Special Considerations. Outlet works designed primarily for flood risk management may have some restrictions during low-flow regulation due to cavitation. Also, operation of flood gates may not provide the degree of gate control to achieve the low-flow requirements.

Some types of gate operating mechanisms have a tendency to creep over time, and the gate setting must be recalibrated periodically to maintain the desired uniform outflow from the project. As the reservoir rises or falls gates may need to be adjusted to account for the changing head to maintain a desired release. The water manager must also be aware of hydraulic problems associated with long-term operation of outlet works, such as the adverse effects of spray that may result from the use of a ski jump energy dissipator, turbulence or undesirable flow patterns in the downstream tailwater area, problems related to ice formation and cold weather operation, and the general continuity of operation of outlet work facilities generally unattended except as needed to make adjustments in outflows.

4.7. Diversion and Bypass Structures.

4.7.1. Project Purposes and Types. Diversion structures and systems vary widely in size, complexity of operation, and degree of control. In many cases, excess flood water is transported from a main stream by a management structure and auxiliary channel to reduce flood flow and stages at potential damage centers on the main stem. Water supply diversions for M&I and irrigation purposes are the most common and include closed conduit bypass facilities and open channels. Other reasons for diverting flow may be to accommodate recreation, to improve conditions for fish and wildlife, to suppress saltwater intrusion in estuaries, or to lower the ground water table. Diversions to existing channels for other purposes may provide incidental navigation benefits. Water is diverted into some reservoirs at night, following a hydropower generation cycle (pumpback) and is reused for the same purpose in the next generation cycle. A diversion may generate power by passing flow through turbines in route to an auxiliary channel used for other purposes. Some diversion systems have seasonal objectives for high-flow conditions, for low-flow conditions, and for both high- and low-flow conditions. Other diversions operate continuously: some manage the flow both into and out of a given area.

4.7.2. Regulation Procedures and Schedules. Diversion projects that have uncontrolled structures do not require water management decisions. However, knowledge of the periods that these structures operate may be needed to notify the general public, evacuate auxiliary channels, and take other appropriate action(s). The most complete hydrometeorological data available, including stage and discharge forecasts, should be used for regulation. Detailed analyses are often made for controlled structures for water management, whether for flood risk management, water supply, or other project purpose. Withdrawal from a stream or impoundment may be a highly sensitive issue; therefore signed agreements with appropriate interests are advisable to address both normal and rare climatic events. Long-range regulation schedules are made to define the duration of an event and to define stage and discharge hydrographs upstream and downstream of the management structures. Various factors that should be taken into account in developing regulation schedules include:

1. Duration of inundation.

2. Stream and channel capacities (stage or flow reduction targets).

3. Navigation channel (width and depth).

4. Relationship to dredging.

5. Levee grades.

6. River stage and reservoir levels.

7. Water quality in reservoirs, streams, and estuaries.

8. Seasonal considerations.

In general, physical operating characteristics of the management structure, such as energy dissipation and velocities, are critical.

4.8. Hurricane or Tidal Barriers. Hurricane barriers are operated to protect coastal communities from tidal flooding associated with severe storms. The design and operation of these projects must include the effects of interior runoff, pumping station requirements, and availability of ponding. The length of time that navigation gates will be operated is needed, as well as gate head differentials that allow gate opening. The manager should also be aware of the discharge capabilities of emergency sluices in case a navigation gate becomes inoperable in the closed position or must be closed for maintenance for a long period. A description of the protected area, including expected damages associated with various levels of flooding, should be prepared.

4.9. Interior Flood Risk Management Facilities.

4.9.1. General. Interior floodwater is normally passed through line-of-protection gravity outlets whenever interior water levels are higher than exterior water levels (gravity conditions). The floodwater may be stored, diverted, or pumped past the line-of-protection if exterior stages are higher than interior stages (blocked gravity conditions). Gravity outlets, pumping stations, interior detention storage basins, diversions, and conduits are the primary measures used to reduce flood damages in interior areas. Other measures, such as reservoirs, channels, flood proofing, relocation, regulatory policies, flood warning, and emergency preparedness, may also be integral elements of the interior flood reduction system. EM 1110-2-1413, Hydrologic Analysis of Interior Areas, provides general guidance for the analysis of interior flood risk management facilities.

4.9.2. Operating Criteria. Generally the Corps plans, designs, and documents detailed operating criteria for newly completed interior flood risk management facilities for use by the local personnel responsible for operation and maintenance. These criteria should include instructions to obtain and report appropriate hydrologic data, including current and forecasted values of river stages, interior runoff from area rainfall, and ponding levels. The criteria should be supported by a description of the proper use of the data to effectively operate the water management facilities. Provisions to obtain supplementary data should be included, as needed. General flood emergency preparedness plans should be carefully described, including all arrangements to ensure timely closure of gravity drains, to implement emergency closures, and to operate pumping plants. Periodic schedules to inspect, test, and maintain the facilities should be defined.

4.9.3. Legal Requirements. The capability of an interior flood risk reduction system to function over the project life must be ensured. This requires legally binding commitments from the project's local sponsors to properly operate and maintain the system. Real estate requirements and specifications for operating and maintaining detention storage areas, pumping facilities, and conveyance networks are integral to all agreements for implementation of an interior system of flood measures.

4.10. Hydroelectric Power Generation Facilities.

4.10.1. General. The functional use of hydroelectric power facilities encompasses a broad spectrum of technical knowledge. At Corps hydroelectric power generation projects, the turbine-generator units, control facilities, power transformers, switchyards, and operational techniques include complex equipment that is under Corps operational control. However, a higher level of electrical power system operation and integration exists, which involves not only the physical hydroelectric power facilities, but also regional electrical power system operation. A clear understanding at the higher level is needed to support decisions affecting the operation of the total regional electric power resource and the relationship between power operation and the management of multipurpose river developments.

EM 1110-2-1701, Hydropower Engineer Manual, provides guidance on the technical aspects of hydroelectric power generation studies from pre-authorization through the General Design Memorandum (GDM) stage. Specific topics addressed include the need for power, determination of streamflows and other project characteristics, estimation of energy potential, sizing of power plants, cost estimating, and power benefit analysis. Other EMs address design details for hydropower facilities, such as powerhouses, turbines, and generators. While EM 1110-2-1701 primarily concerns hydropower, background information is also provided on power systems operation and the general features of hydroelectric development.

4.10.2. Major Hydroelectric Facilities. Hydroelectric power projects are classified by type of operation as run-of-the-river, pondage, storage, pumped storage, and reregulation. All hydroelectric power plants include the following major hydraulic components: dam and reservoir, intake, conduit or penstock, surge tank (when necessary), turbine-generator unit, draft tube, and tailrace. The types and designs of each of the components are determined by the specific design requirements for individual projects and vary widely, depending on the project's type of operation and physical characteristics. The heart of a hydroelectric power plant is the powerhouse, which shelters the turbines, generators, control and auxiliary equipment, electrical buswork, circuit breakers, disconnects, and, in some cases, erection bays and service areas. Generator step-up (GSU) transformers are usually placed on or adjacent to the powerhouse, and switchyards are located nearby.

4.10.3. Plant and Unit Control Systems.

4.10.3.1. Control equipment is necessary to facilitate the automatic or manual operation of the power units and other necessary power plant equipment. Larger multi-unit attended plants often have a central control room and automatic control, which require large computer-based supervisory control and data acquisition (SCADA) control systems. These SCADA systems need to be in compliance and have or be working towards receiving a current Authority to Operate (ATO). In general, individual power units, multiunit power plants, and large interconnected power systems are operated by a variety of manual and automated control systems. At Corps projects, the hydroelectric power facilities and control systems are generally operated under the supervision of the operations division, which has direct responsibility for the operation and maintenance of the individual projects. The operation of these facilities for daily regulation and functional management to meet all water management objectives, including hydroelectric power generation, is performed according to instructions and schedules provided by the reservoir management center, water management center, or other water regulation unit that has responsibility to schedule plant operation.

4.10.3.2. The water manager responsible for projects operated under AGC must be familiar with the interrelationships between system controllers and the planned use of equipment to schedule plant operation for normal and emergency conditions. Although the planned and scheduled use of power plants is coordinated through the water managers, the ultimate plant operation is determined by the AGC equipment. The plant operation should be continuously monitored to ensure that the water management objectives are being met, and that any necessary corrective action(s) are taken.

4.11. Use of Water Management Facilities for Fishery Enhancement.

4.11.1. General Information.

4.11.1.1. Fish passage features and water management operations have been used predominately to preserve anadromous fish runs, such as for salmonids. However, the importance of avoiding adverse impacts to other fish, such as lamprey, paddlefish, and sturgeon, has been increasing and the design and operation of water management projects have been changing to better support other species of interest.

4.11.1.2. Specially designed facilities and operations for fish passage and enhancement of fish life have been incorporated into many water management projects. Physical features for these facilities may include adult fish passage (fish ladders, attraction water, counting stations, bypass channels, fish collection and transport facilities, etc.), juvenile fish passage (bypass and transport facilities), "fish-friendly" turbines, spillway surface passage, fish hatcheries, water quality improvements (water temperature and multilevel flow control outlets, modified spillways to reduce nitrogen supersaturation, etc.), and improvements to fish spawning areas. In addition to physical facilities, special water management operations may be desired, such as regulating project water releases to meet fishery specifications (streamflow, water level, spill level, and temperature) and making special test operations to support biological research.

4.11.1.3. Special release operations for the downstream migrant fish passage season are typically developed for the full range of seasonal river flows to provide the most efficient egress of the fish along a path that avoids high predation risk zones.

4.11.2. Operations to Aid Dissolved Gas Supersaturation.

4.11.2.1. Dissolved gas supersaturation may occur in rivers below dams. As water plunges down a dam spillway, the churning and deep plunging action can cause gas (mostly nitrogen) to be pressurized in the stilling basin and become dissolved in the river. Long exposure to gas supersaturation may injure juvenile and adult fish by causing gas bubble disease. Supersaturation has been successfully reduced by modifying the structural shape of spillways, by adjusting the water regulation in the system where possible to reduce spillway releases, and by adjusting the distribution of spillway releases. Although gas supersaturation caused by dam spillage can be reduced, a method to eliminate damaging levels of supersaturation for all streamflow conditions does not exist.

4.11.2.2. As feasible, the plan for system-wide operation should be to lessen the spillway releases at downstream locations to minimize gas supersaturation. The timing of the spillway release reductions may be scheduled to better coincide with the fish runs. These objectives may be incorporated into the AOP and into daily schedules.

4.11.2.3. Depending on the project type, the most direct way to reduce gas supersaturation through water management is to adjust spillway releases between projects under real-time operation. This can be accomplished by shifting power loads to maximize spillway releases at those projects in which the spillway releases produce the least amount of gas supersaturation. Also, spillway releases may be reduced by arrangements to increase power loads on the hydroelectric power system and by reducing loads on thermal plants or other outside resources. Models are available to simulate the levels of gas supersaturation and may be used to analyze and forecast the levels resulting from the scheduled system releases. These programs use current system data, which are essential to initialize and evaluate the effects of current release conditions.

4.11.3. Operations to Aid Passage of Downstream Migrants.

4.11.3.1. A number of alternative project operations are being tested at large dams to assist fish passage and to determine the most satisfactory and economical methods. For example, voluntary project releases (not needed for flood risk management) are being used to enhance the passage of downstream migrants. Furthermore, due to the longer travel times of downstream juvenile fish migration that result from the impact of reservoirs in the river system, increasing streamflows by releasing water stored in upstream reservoirs may be desirable at times to increase velocity in the stream. During warmer water periods, provision of cooler water from upstream reservoirs is desirable to reduce downstream water temperatures and reduce fish stress and increase survival rates. These three factors are considered in the daily management of the water facilities in conjunction with all other project purposes.

4.11.3.2. Multilevel intakes, usually considered to provide general water quality control, may have been justified primarily to meet the fishery specifications for management of water temperatures or other water quality parameters that affect fish life. Scheduling the use of multilevel intakes is usually based on the fishery needs, and the water manager should understand the fishery management programs and the desired conditions affected river reaches.

4.11.3.3. Although operating plans may recognize and account for fishery concerns under actual operation, the values of many variables that affect the daily fishery needs cannot be accurately estimated more than a few days in advance. This is particularly true of the need for induced releases and increased discharge through the reservoirs during critical times in the spring. Mathematical modeling systems to simulate and evaluate hydraulic and fishery conditions are being used as an aid in scheduling water regulation during critical times of downstream fish migration.

4.11.4. Fishery Regulation and Coordination. Detailed knowledge and management responsibility of the fishery resource may be shared by the state and Federal fish and wildlife agencies, tribes, and international organizations. The fish and wildlife agencies represent the interests of sport and commercial fishing. The tribes have treaties that may involve fishing rights. International organizations represent fishery interests of other countries that share in the responsibility for fishery management through treaties and compacts. To support fishery concerns, input from all of these organizations should be included in the water control plans and in the daily management of the water and fishery resources.

4.11.5. Fish Hatcheries. Fish hatcheries are used to mitigate fish losses caused by the construction of dams, to maintain and increase overexploited fish stocks, and to enhance fish production in areas deficient in production. Water intakes for the hatcheries, which may be from the reservoir or from the downstream channels, may require water management activities. Water quality characteristics, including temperature, pH, dissolved oxygen, and nitrogen, should be maintained within specified tolerances.

# CHAPTER 5

## Water Management Enterprise Systems

5.1. Overview.

5.1.1. Water Management Decision Support System.

5.1.1.1. ER 1110-2-249, Management of Water Control Data Systems, provides guidance for the management of Water Management Enterprise Systems (WMESs) including descriptions of the equipment and software used for acquisition, transmission, and processing of real-time data used to regulate Corps water projects. A WMES includes all Corps hardware and software being used for acquisition, transmission, processing, display, and dissemination of hydrologic, meteorologic, water quality, and project data to support the Corps water management mission, along with the software using the data. Chapter 6 of this manual further discusses the software portion of a WMES.

5.1.1.2. A WMES is the automated system supporting water managers in making real-time operational decisions to determine and set water release schedules for Corps water resources projects. The WMES performs the continuous acquisition; storage; computational analysis; and watershed modeling, visualization, and dissemination of the hydrometeorological information necessary to operate Corps projects and provide project benefits. Through proper administration, the WMES provides an effective means of data management that supports daily water management activities. In addition to being used to assist in daily decision making, the data collected or generated are frequently used internally and externally for various purposes (e.g., navigation studies, floodplain studies, construction activities). These data are also provided to various tribes, Federal, state, and local agencies, private entities, and the general public.

5.1.1.3. Water management forecasts, operational decisions, and guidance are coordinated with many Federal, state, and local government agencies. Various computer and server-based applications are used and are a component of the WMES. One of the fundamental purposes of the WMES is to provide a mechanism to efficiently streamline two-way communication between the water management office and a variety of internal and external stakeholders.

5.1.1.4. The primary system components of the WMES are standardized so they provide for common use, inter-office compatibility, and continual nationwide support and development. Hydrometeorological data are acquired, stored in a database, validated, transformed, and used to model watersheds in real-time. The resulting processed, transformed, and modeled data are then used by the Corps water management decision makers to regulate their projects to meet the congressionally authorized project purposes. The standardized WMES tool set allows each district/region to report out on both the standard project parameters common to all similar projects as well as any unique project parameters unique to a project. All collected and processed data are used for the purpose of supporting mission and appropriately reporting out on the project's status to Corps staff and leadership, associated decision makers, and the public.

5.1.1.5. The size and complexity of each WMES will be dependent on the specific water management mission requirements of the district.

5.1.1.6. Primary system components include:

1. Data Acquisition. The real-time acquisition and decoding of hydrometeorological information.

2. Data Storage, Validation, and Transformation. Storing information in Corps database, screening information for accuracy, and computing dependent values (e.g., stage to flow, elevation to storage).

3. Watershed Modeling. Numerical simulations of watershed hydrology, reservoir operations, and river hydraulics.

4. Visualization and Data Dissemination. Presentation of river and reservoir conditions, operational forecasts, model results, and other information for water managers, associated decision makers, and the public.

5. COOP. Documented and tested plan to ensure the capability to accomplish the water management mission under all conditions.

5.1.2. Corps Water Management System (CWMS).

5.1.2.1. As described in Section 6.2.2, CWMS is a national Corps automated information system (AIS) that was designed and developed to be a critical and significant core component of a WMES; Corps water management offices are required to use CWMS. CWMS software suite provides the Corps Water Management Community with a common interface to a set of data management tools and watershed models with which to perform the water management mission. The Corps Hydrologic Engineering Center (HEC) is the CWMS system developer and is responsible for CWMS development and implementation oversight. Development and implementation of nationwide systems such as CWMS provides tremendous long-term benefits to the water management community, allowing for economy of cost (i.e., by developing one basic system for many) and easing the ability of water managers to provide assistance to a neighboring office during a significant hydrometeorological event, e.g., a flooding event. Independent efforts to supplement CWMS should consider the overall nationwide viewpoint and purposes of an AIS. Figure 5-1 shows an example of the integration of a CWMS AIS into a WMES.

5.1.2.2. A full CWMS suite of models is the goal for every regulated basin in the Corps. Other software is currently used and a transition is expected to take a decade or more, depending on funding.

5.1.3. Modeling. The WMES provides the foundation for development of CWMS watershed models. A nationwide CWMS-based modeling effort has been initiated in response to several significant flooding events that have involved multiple major subordinate commands (MSCs). The main objective for collaboration of modeling efforts between multiple Corps civil works programs is to increase the effectiveness of meeting the overall water management mission. See Chapter 6 for detailed information related to water management modeling methods and implementation.

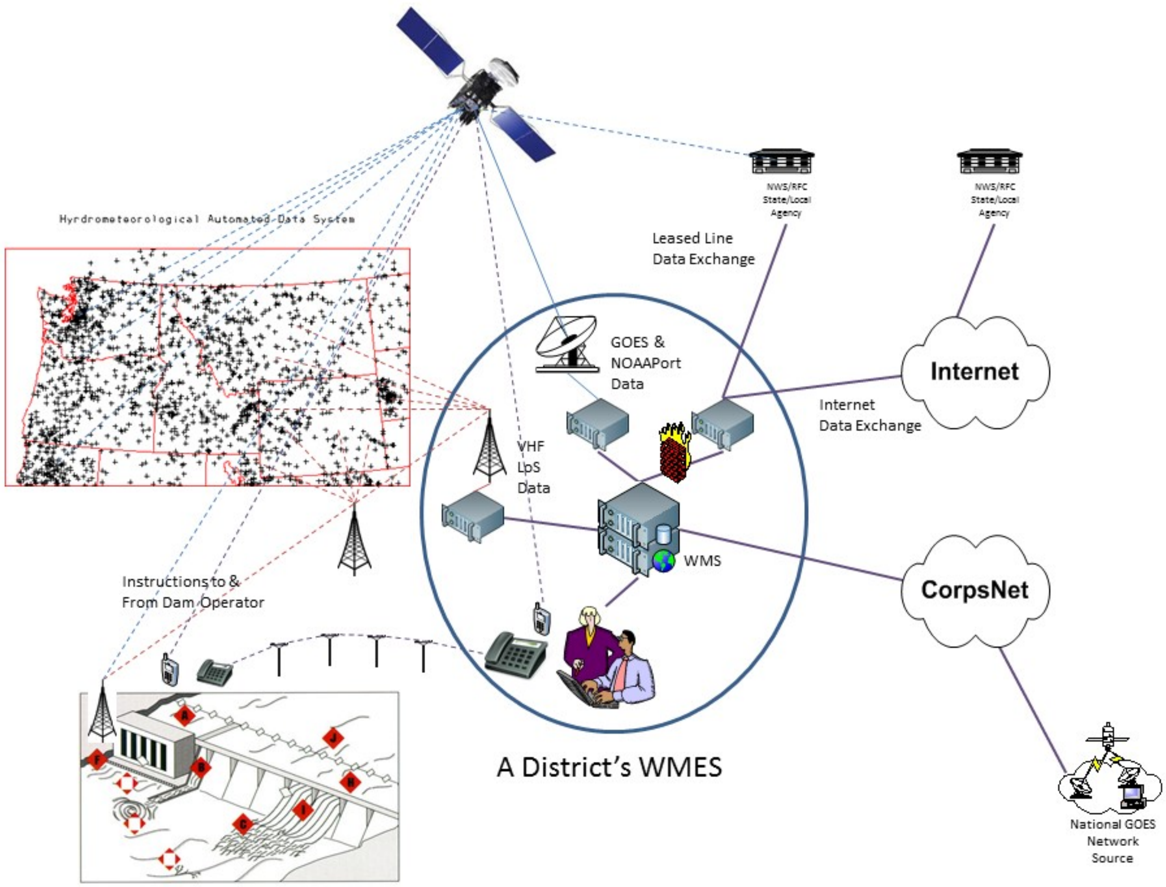


Figure 5-1. Typical Example of CWMS AIS Integration into a WMES.

5.2. Water Management Enterprise System Hardware.

5.2.1. Hardware requirements have been established via the WMES initiative. This initiative is reviewed and revised on an ongoing basis and its purpose is to establish standard systems that can be deployed and maintained by the Corps enterprise information technology (IT) service provider.

5.2.2. The risk of hardware failure is always present, but can be mitigated to some degree. Redundant hardware availability can increase system reliability.

5.2.3. Some examples of redundancy at the hardware level that are part of the WMES include:

1. Multiple Servers. A failover server that can run in place of the production server provides an excellent level of protection against the breakdown of the production server.

2. Dual Power Supplies in the Server. Server downtime can be reduced by ensuring that the power supplies are hot swappable.

3. Disk Arrays. Disk arrays are storage systems that link multiple physical hard drives into one large drive for advanced data control and security. The array drives are hot swappable to minimize data downtime. The array may be accessed by the server either through direct bus (small computer system interface [SCSI]) connection, or via the network (network attached storage [NAS]). The use of a disk array ensures hardware and software availability.

4. Uninterruptible Power Supplies (UPSs) and Emergency Backup Generator/Power. UPSs are essentially battery packs that keep the server and associated hardware powered up for a limited time during a power failure. This provides time for an effective shutdown of the hardware. The UPS may also provide power between the point of the power failure and resumption of power via an emergency generator. Emergency generator power is ideal during times of prolonged power failure, but represents a significant maintenance cost.

5. Remote Server/Disk Array Location. Servers located in areas prone to natural disasters (hurricane, earthquake, tornados, etc.) are at high risk of being offline for extended periods of time. Data centers in remote locations (staffed by water managers or accessed via the network during emergencies) can mitigate the risk associated with prolonged events.

5.3. Water Management Data.

5.3.1. Data Acquisition.

5.3.1.1. Types of Data.

5.3.1.1.1. Hydrometeorological conditions at projects and remote field sites are automatically sampled by specialized sensors to provide real-time information to water managers. The most commonly sampled parameter is water level (reservoir level or river stage). Various types of sensors may be used to collect water-level information, including bubblers, pressure transducers, encoders attached to floats, and radar. Another frequently sampled parameter is rainfall using tipping buckets or impact sensors. For precipitation measurements other than rain (e.g., snow, sleet), weighing buckets may be appropriate. Other hydrometeorological conditions, such as air temperature, wind speed and direction, solar radiation, and relative humidity, may be sampled. Water quality parameters, such as water temperature, dissolved oxygen (DO), pH, and turbidity may be sampled. Some project data, such as gate positions, can also be sensed automatically. Each sensor is controlled by a programmable device known as an electronic data logger (EDL). The water managers determine the frequency of data sensor sampling and program the EDL to query the attached sensors at the prescribed sample frequency.

5.3.1.1.2. Mountain snowpack accumulation may be represented by direct measurement of snow accumulation at snow courses or automated U.S. Department of Agriculture (USDA) National Resources Conservation Service (NRCS) Snow Telemetry (SNOTEL) sites, or by indirect measurements of seasonal precipitation at selected climatological stations.

5.3.1.1.3. There are generally two sources of plains snowpack information: ground surveys and modeled snowpack assessments that combine ground measurements, airborne assessments and satellite estimates. Ground surveys of snowpack performed by the Corps, the National Weather Service, state agencies, the Community Collaborative Rain, Hail, and Snow (CoCoRaHS) Network, and other enlisted volunteers measure the snow depth, snow water equivalent, snow density, and other characteristics of snow at random or predetermined locations. Surveyed assessments of snowpack over large areas possess inherent uncertainties because of snow movement due to wind, snow accumulation, and melting cycles, and changing land surface conditions at measurement locations that cause inconsistencies in the long-term measurement record. Modeled snowpack assessments can compensate for some of these uncertainties by combining multiple sources of information into a product modeled over large areas. A primary modeled snow product is available through the National Weather Service National Operational and Remote Hydrologic Sensing Center (NOHRSC). NOHRSC's snow product is a modeling and data assimilation system that integrates snow data from satellite, airborne platforms, and ground stations with model estimates of snow cover. Another source of snowpack information is the National Aeronautics and Space Administration (NASA) National Snow and Ice Data Center, which develops a satellite-based daily snow covered area assessment.

5.3.1.2. Methods of Receiving Data.

5.3.1.2.1. Data Collection Platforms. The majority of EDLs used by Corps water managers are fitted with Geostationary Orbiting Environmental Satellite (GOES) transmitters. An EDL combined with a GOES radio transmitter is commonly termed a Data Collection Platform (DCP). The transmission of DCPs to GOES satellites is regulated by the National Environmental Satellite Data and Information Service (NESDIS), which issues a DCP owner a GOES transmission channel, transmission time, and transmission interval for each DCP. A field-installed DCP sends its data to either the GOES-East or GOES-West satellite. The telemetered sensor data are then bounced off of the satellite back to a ground receive station. A Direct Readout Ground Station (DRGS) is a ground receive station that can directly monitor the specific transmission channels from either the GOES-East or GOES-West satellites. Several Corps water management offices use a DRGS, but the majority of Corps water management offices use ground receive systems that monitor a retransmitted complete channel GOES data stream that is uplinked to secondary set of satellites and receives data within a few seconds of a DRGS. All ground receive stations can be software-linked over the network to provide a reliable GOES data acquisition system. All environmental data transmitted to a GOES satellite is public and can be collected using a ground receive system regardless of the originating agency. The digital Low Rate Information Transmission (LRIT) is an international standard for data transmission, including GOES data, that was developed in response to a recommendation on digital meteorological satellite broadcasts. Figure 5-2 shows a schematic example of a typical data transmission.

5.3.1.2.2. Line of Sight Radios. Line of Sight (LOS) radios are another method to transmit field-collected data to a WMES. LOS systems typically consist of gaging stations, base stations, and repeaters. Equipment at a typical LOS radio gaging station consists of an EDL, a battery, a radio transceiver, and an antenna aimed at a repeater or at the base station. The station transmits data at specified times and frequencies. The station also can receive instructions from the controller located at the base station, which can be useful for remote configuration and ad hoc polling of data. Power may be supplied by commercially available power lines, solar cells, or on-site generators. Repeaters that re-broadcast transmissions are used to forward transmissions between the base station and DCPs that are either out-of-range and/or behind a mountain range obstructing a direct LOS transmission between the base station and one or more DCPs. Repeaters are usually located on prominent high points to meet LOS requirements. Repeaters are powered the same as gaging stations. Base stations consist of a transceiver, controller, and antenna array. Base stations are typically located in project offices and water management offices.

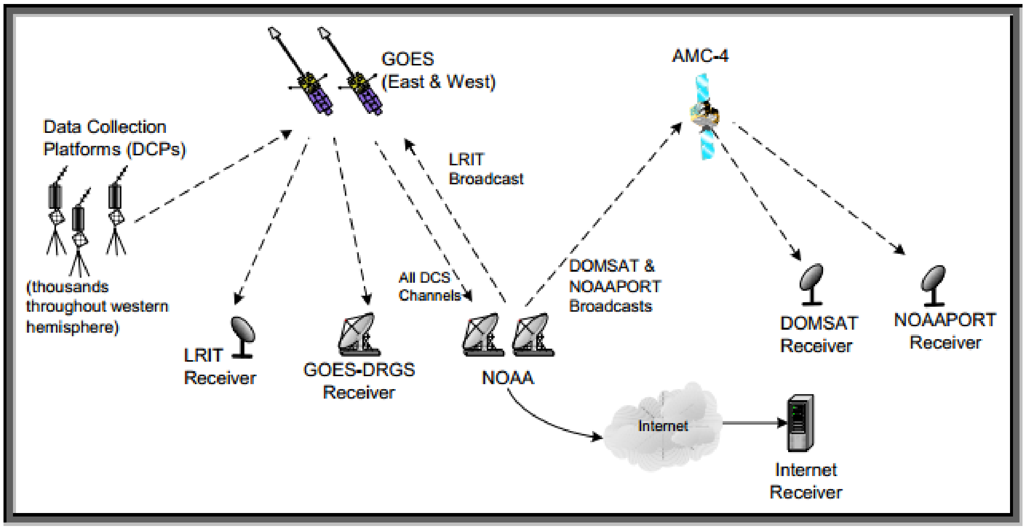


Figure 5-2. Typical Example of Data Transmission.

5.3.1.2.3. Networked Data Loggers. EDLs can be connected to computer networks and use those networks for two-way communication. This allows for near real-time, frequent transmission of sensor data to the office and provides the means for water management personnel to remotely troubleshoot and reprogram the data logger.

5.3.1.2.4. Receiving Data from Internet Sources. Some data needed for making water management decisions are only available from internet sources. This may require water management offices to develop custom procedures to securely receive internet data from data acquisition partners. Two examples are the need to acquire data from a hydroelectric power company that posts current water usage as well as forecasted water needs for several days, and the need to acquire SNOTEL information from the NRCS.

5.3.1.2.5. Project Data. Some data continue to be collected manually by staff at the project as part of their routine daily tasks or part of their routine during operational periods. Examples of the data collected this way include current gate settings; and reservoir, downstream channel, lock, gate and local weather conditions. Methods used to transmit this data to the WMES include voice communication between the project staff and the district water management staff, email or a software interface allowing the project staff to enter the data on a local workstation that then transmits the data directly to the district's WMES.

5.3.1.2.6. National Weather Service Data. The National Weather Service (NWS) is one of the key partner agencies with which the Corps exchanges hydrometeorological data. Key data that the Corps receives from the NWS include precipitation and snow forecasts (both point forecasts as well as gridded coverage forecasts) and river forecasts that are used by Corps Water

Managers to model future watershed conditions and likely reservoir release scenarios. The Corps then sends the NWS its reservoir operational scenarios, which are in turn used by the NWS to formulate their next round of river forecasts. The NWS encodes and transmits its data in standard/agreed-on formats, e.g., the Standard Hydrologic Exchange Format (SHEF). The CWMS software suite provides utility tools that can decode data received from the NWS and store it in the CWMS database, making the data available for further processing, watershed modeling, or simply for direct access/viewing. Three main sources for NWS data are:

1. A direct network connection between the NWS and the Corps.

2. A dedicated NWS satellite feed (commonly termed NOAAPORT).

3. NWS public web pages (internet source).

5.3.1.2.7. Telephonic Data. Some water management offices connect cellular or local area network (LAN) telephone lines to remote EDLs to enable the water managers and project staff to directly receive real-time site-related conditions. These data are not automatically input into the WMES; however, the data can be very valuable in the decision making process during rapidly changing conditions at a remote site.

5.3.1.2.8. Other Data Systems. Several private companies provide satellite communications capabilities using private satellite constellations. These for-profit companies provide another method to send and receive EDL data and offer two-way communication with the EDLs equipped with a specific type of transmitter. Water managers may be required to use data systems owned or operated by non-Federal sponsors responsible for O&M of Corps projects and will need to work access issues with the individual sponsors.

5.3.1.3. Data Acquisition Partners.

5.3.1.3.1. The U.S. Geological Survey (USGS) is another key partner in deploying and maintaining DCPs. Depending on the water management office, the Corps may independently support a DCP network. In other cases, the Corps partners with the USGS to fully or partially fund the USGS DCP network through the USGS Cooperative Streamgaging Program.

5.3.1.3.2. In addition to the USGS, the NWS, USBR, TVA, NRCS, private hydroelectric power companies, and other Federal, state, and local water resources agencies make data available to the Corps.

5.3.2. Data Processing.

5.3.2.1. Data processing begins with the arrival of data to one of the data receive components of the WMES such as a Commercial-off-the-Shelf (COTS) satellite data receive appliance or a system running a network data exchange service. The initial goal is to have the system that is processing the data either decode the data and store it directly into the Corps CWMS database, or to minimally decode the data into a CWMS supported format (e.g., SHEF or one of several Gridded data formats) so that the CWMS data ingest utilities can store the data into the Corps CWMS database. Some of the data received are text data or graphic images that simply need to be stored in the appropriate WMES that then makes the data/files available for review and analysis by a water manager.

5.3.2.2. For data destined for the Corps CWMS database, once the raw or initial data are stored in the Corps CWMS database, further processing of the data is usually triggered that validates the data (e.g., performs range checks and quality checks) and that then transforms the data (e.g., transforms a river stage to a flow value or computes a reservoir inflow based on the reservoirs current release and pool level change) into values that are of use by watershed models and/or meaningful in evaluating the hydrometeorological condition of a watershed by a water manager.

5.3.2.3. Format conversions is a common preprocess that may occur. Though the Corps will request that data be sent in a standard format (e.g., SHEF), many cooperating agencies and power companies may not be able to convert their data into a standard text and/or standard binary format. The office's water management team will then need to script a local conversion process to handle the non-standard data sets.

5.3.2.4. A Corps CWMS database is the goal for every water management office, but it is not yet the operational database in some places. A complete transition to the CWMS database for operational use is expected over the next decade depending on funding.

5.3.2.5. Gridded Data.

5.3.2.5.1. Gridded data may be used to visualize approaching storms and to follow a storm track moving throughout a watersheds and river systems. Gridded data may also be used to quantify climatological events and to provide a runoff forecast, based on the effects of temperature on an accumulated snowpack.

5.3.2.5.2. Although gridded data can come from a variety of sources, these data are typically generated and obtained from the NWS Next-Generation Radar (NEXRAD) system. The system, which is composed of approximately 160 radar installations, provides up-to-the-minute scans of the national weather system. The NWS uses the system to provide a variety of products such as temperature and precipitation grids, wind shear data, and severe weather alerts.

5.3.2.6. Data Transformation. Transformations of data are an essential process in the WMES. At a basic level, water management data are collected in the field and transmitted as river stages, reservoir levels, and gate opening increments. That data are then verified and transformed; the river stage is transformed to river flow, the reservoir level is transformed to reservoir storage, and the gate opening amount to a flow. More complex data transformations are calculated for differing datums, dimensions, scales, and coordinate systems in both time and physical domains.

5.3.2.7. Data Quality Control.

5.3.2.7.1. Data acquired and transformed should be visually reviewed and corrected, if necessary, before being integrated into real-time models. Various quality assurance/quality control (QA/QC) applications are available within CWMS or have been developed specifically to meet office requirements.

5.3.2.7.2. Validations can be part of an automated process that quantitatively evaluates the quality of data. This data quality is signified by modifying a quality flag associated with each data/timestamp pair within a time series of data. The validation process identifies missing data, questionable data, and erroneous data through range-checking and rate of change checking.

5.3.2.7.3. Data correction processes may be automated or manual. Automatic data correction processes include the interpolation, extrapolation, or smoothing of missing and incorrect values. Values that have been automatically corrected should be flagged as such. Manual data review and manipulation interfaces are available to allow the water management data technicians or managers to quickly review and correct values that are either clearly out of bounds or missing. Manually updated/corrected values are also flagged as having been manually modified. For an external data source, a process could be established to communicate corrections back to the data provider.

5.3.3. Data Storage and Retrieval.

5.3.3.1. The database and associated management software comprise the database management system (DBMS), which is essential for the storage, manipulation, retrieval, security and, if necessary, recovery of water management data. The CWMS database provides these features and meets applicable Army and Corps standards for data storage and retrieval.

5.3.3.2. The DBMS must be capable of storing a variety of data types:

1. Data/timestamp time series data, both regular and irregular interval.

2. Paired data (e.g., rating curves or gate curves).

3. Relational/metadata, which includes pertinent project data, reservoir rule curves and zones, rating curves, control point regulating criteria (seasonal), water quality profiles. Metadata is sometimes referred to as "data about data" and allows for the user to further describe the data collected.

4. Gridded data, which consists of a multidimensional rectangular array of grid points containing values. Gridded data are used in modeling applications such as rainfall/runoff computation.

5. Geo-spatial data, i.e., raster data (basin topography) and vector data (point data, outlines of basins, rivers, reservoirs, roads, and political boundaries).

5.3.3.3. The DBMS must be capable of storing, retrieving, and revising high volumes of data. Revising data in a database includes adding new records, deleting existing records, and changing information within a record.

5.3.3.4. The DBMS must support concurrent updates. These are updates that occur when multiple users make updates to the database simultaneously.

5.3.3.5. Data must never be permanently lost. The DBMS must have the capability to back up data and, in the event of a catastrophe, restore the database to a pre-damaged state.

5.3.3.6. The DBMS must be capable of preventing unauthorized access. Authorization for data access must be based on a user or group (e.g., office, region) and incorporate allowable permissions for those individuals or groups (view restrictions, edit values, etc.).

5.3.3.7. The DBMS should be installed on server-level hardware, preferably on a dedicated server for maximum resource availability and custom software flexibility.

5.3.3.8. The database must be available at all times.

5.3.4. Data Dissemination.

5.3.4.1. Methods.

5.3.4.1.1. The data collected and processed by the WMES are ultimately used for reporting the status of CWMS and the subsequent dissemination or publishing of this information to others. This reporting may be for Corps decision makers and operating staff, external stakeholders, and the general public.

5.3.4.1.2. Data may be for internal or external use. Internal use is data that are intended for use and review by the Corps only. Reports that are intended for internal use only will be marked as Unclassified – For Official Use Only, in accordance with existing regulations.

5.3.4.1.3. There are two types of external users, namely the general public and other Federal, state, and local agencies or organizations that are involved in water resources management activities or other related public services or earth science missions.

5.3.4.1.4. Examples of external data users are the USGS, NOAA, USBR, Bureau of Land Management (BLM), U.S. Forest Service (USFS), National Park Service (NPS), USDA, NRCS, state agencies, county agencies, regional river authorities, irrigation districts, levee boards, water suppliers, flood warning systems, and law enforcement agencies.

5.3.4.1.5. The Water Management mission is a real-time mission that makes it difficult to fully perform quality control checks on all data that need to be released either to staff and leadership within the Corps itself or to customers outside of the Corps. Data that are released and/or used to report on the current status of projects do go through several automated validation checks, as well as human checks as the data are used internally and/or during the running and evaluation of watershed model runs. Even so, some erroneous data will slip through. Therefore, all reports (either textual or graphical) need to be marked as containing “Provisional Data” subject to further review and change.

5.3.4.1.6. Historic data distribution was typically done by paper reports. Printed reports are still commonly used in all Corps offices, although the reports are now usually created using desktop printing technologies that produce electronic reports that can be posted on a web site and are only printed if a paper copy is needed. Public meetings, especially before, during, and after major events such as flooding, still require a paper copy for distribution and are still a highly effective way to inform the public and affected agencies.

5.3.4.1.7. In today's world, just about everyone has access to a network connected device. Data on the status of Corps water management projects is published on both publicly accessible and internal only accessible Web services. In addition to general Web services, the Corps will establish direct data links (e.g., sftp [secure file transfer protocol] feed/socket) to specific servers of stakeholders. This type of connection is used when either or both agencies expect to be routinely exchanging high value data needed by both the Corps and the stakeholder agency (e.g., exchange hourly or daily data sets between the NWS).

5.3.4.1.8. Even historical data are now available for download off of Corps websites. Occasionally large data sets are requested and a special one-off compact disk (CD), digital video disk (DVD), or possibly even an external hard drive must be prepared and shipped off in the mail. Given the ever increasing bandwidth and evolving data compression technologies, those one-off data exchanges are expected to disappear too.

5.3.4.2. Types of Reports.

5.3.4.2.1. Many different types of reports are generated and disseminated by all Corps water management offices. The data disseminated in water management offices throughout the Corps are very similar. Though the type of information contained in these reports is very similar, the format of these reports varies regionally, because the reports have been developed over the past several decades to meet the needs of the stakeholder, cooperating agencies, partners, and the general public within the local area of responsibility.

5.3.4.2.2. Some examples of typical reports are inflow reports and plots, hydroelectric power, reservoir elevation forecasts and plots, gate rating tables and plots, tile gage readings, gate settings, facility closure reports, project weather reports, daily reservoir and system summaries, release reports, related links pages, and many more. Many of these reports contain preliminary data or analysis and are intended for official use only by Corps decision makers in evaluating water management regulation options.

5.3.4.2.3. The level of access to the various reports is determined by each district related to the individual missions and circumstances. Efforts to provide more standard reports and data delivery methods are being pursued by Corps water management offices to improve the experience and ease of use by end users, whether internal, external stakeholder, cooperator, or the general public.

5.4. Continuity of Operations Plan and WMES.

5.4.1. Every water management office should have a viable, current, and complete COOP that includes provisions to recover or remotely access a WMES. The main objective of a WMES COOP is to provide guidance to water managers and affected local and enterprise information management (IM) support personnel on how to restore WMES access and functionality to an acceptable degree for emergencies, disasters, and mobilization. This may require a remote site. In addition, the WMES COOP is needed to maintain a state of readiness to provide the necessary information to meet the water management mission should the primary method be unavailable (e.g., server failure, internet outage). Note that COOP planning does need to address a total WMES failure, i.e., a worst case scenario where a functioning WMES is simply unavailable for a prolonged period of time. Fallback to paper copies of the projects' water control manuals and training of project staff and water control managers on paper and pencil operations should be included in the planning.

5.4.2. Ideally, each WMES will be designed such that each component previously discussed in this chapter will include high availability (HA) capability. HA will ensure that each component of the WMES has at least two levels of functionality. Whether a local WMES does or does not implement HA design concepts, each office should maintain a documented and annually tested COOP plan that addresses how the office will deal with the failure of their primary WMES.

5.4.3. The HA capability becomes more viable for certain aspects of a WMES as enterprise initiatives are implemented into each local WMES. Each water management office is expected to continue to customize portions of the WMES to meet specific mission requirements. However, with the implementation of nationwide applications, aspects of data acquisition, data processing, data dissemination, and modeling could be simultaneously maintained at multiple locations (e.g., local off-site, national processing center, division, other district, cloud) to maintain HA capability. Care should be taken to ensure that the development of the multiple-location structure meets the water management objective. To meet this critical objective, the non-local COOP structure may require that certain WMES components, such as data acquisition, be divided between multiple locations. Determination of non-local COOP sites should consider that an emergency or disaster requiring COOP capability (e.g., flooding, internet outage) may also affect nearby WMES locations. The system should also be sufficiently robust for emergency, simultaneous use by multiple water management offices due to large regional and or geographically concurrent floods.

5.4.4. Maintaining a viable, current, and complete WMES COOP may be challenging, expensive, and time-consuming. District and division leadership beyond water management, not just an individual in a water management office, is responsible for ensuring that the local water management mission can be met should the primary means not be available. Since security and access capability, and application upgrades are ever-changing, each office should test various portions of the WMES COOP several times each year to ensure that full COOP functionality is maintained. Non-working portions of the WMES COOP should be addressed as soon as possible.

5.5. WMES Master Plan.

5.5.1. ER 1110-2-249 outlines the requirements for WMES master plans. WMES master plans include all the essential information related to the requirements, justification, scope, and recommend procedures for implementing water control data systems. Master plans may include an outline of performance requirements to adequately maintain a fully functioning WMES at the district, division, and national levels. Since water management mission requirements can vary considerably by district and division, this outline will need appropriate detail. In addition, changing missions may require that this outline be reviewed and revised annually.

5.5.2. Performance requirements to provide all aspects of a fully functional WMES may include:

1. Local servers and processing power to acquire and process data and operate real-time models.

2. Local Area Network/Wide Area Network (LAN/WAN) connectivity, speed and reliability.

3. Database with the size, speed, and ability to backup and retrieve lost data.

4. Scalability to increase/decrease system components as mission requirements change.

5. Reliability and performance of associated equipment/services (e.g., switches, processing centers).

6. Support from the U.S. Army Corps of Engineers–Information Technology (ACE-IT) for hardware, software and connectivity.

7. Replacement of non-working, non-compliant hardware and software.

5.5.3. A master plan should describe alternative approaches taken and associated successes or failures and recommendations for future upgrades to the system, both at a local and enterprise level, to meet requirements unmet by existing facilities or to provide a more cost effective system.

5.5.4. Justification and recommendation of a system should consider timeliness, reliability, economics, and other important factors.

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# CHAPTER 6

## Water Management Techniques

6.1. General Considerations.

6.1.1. Importance of Technical Evaluations.

6.1.1.1. Real-time regulation of a major water resource system depends ultimately on the experience and judgment of the water manager. Complex interactions among the many meteorologic and hydrologic processes, combined with the effects of project management, encompass a wide range of continuously changing conditions that must be evaluated and understood. Judgments made by the water manager must be founded on the best available scientific and engineering evaluations, and must consider time constraints and available data.

6.1.1.2. There are many analytical tools now available that may be used to quantify those elements that would otherwise be subjectively determined to forecast and mitigate flood risk throughout the nation. Optimal operation of flood risk management reservoirs and accurate prediction of flooding may prevent damages on the order of many millions to billions of dollars each year. Hydrologic and hydraulic modeling programs may enhance such operations by providing information to support decisions made by water managers and other Corps staff. These computer models must incorporate rigorously defined analytical procedures and methods based on hydrologic and hydraulic theory.

6.1.1.3. Accordingly, the overall objective is to perform technical evaluations using these recognized and approved models, rather than subjectively determined estimates. These models are used to analyze water resource systems to meet water management objectives. These computer models may also constitute the technical foundation for making water management decisions for project regulation, and provide the basis for the planning of water management activities.

6.1.2. Hydrologic Analysis.

6.1.2.1. A primary technical challenge in real-time water management is hydrologic analysis. Water is the prime resource to be managed in water systems, and this demands an understanding of the natural processes by which water is distributed and accounted in a river system. The science of hydrology is defined as the body of knowledge related to the behavior of water in the atmosphere, on the surface of the ground, and underground. Although hydrology is considered to be a science, a blending of scientific theory and empirical knowledge occurs in the application of hydrology to the analysis of river systems.

6.1.2.2. For many years, the Corps has used widely accepted hydrologic analysis procedures in flood hydrology. Refer to EM 1110-2-1420, Hydrologic Engineering Requirements for Reservoirs, for a discussion of factors to be considered in determining the magnitude of design floods. ER 1110-8-2(FR), Inflow Design Floods for Dams and Reservoirs, defines design flood requirements to evaluate dam and spillway adequacy. Application of these principles was also extended to rivers affected by snowmelt runoff and is described in EM 1110-2-1406, Runoff from Snowmelt. Another good source of technical information on snowmelt is the Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory (ERDC-CRREL). Initially, these methods were used for project planning and design studies, but more recently have become the basic method of analysis for project planning and real-time project regulation. Detailed methods of analysis have been refined through continued development of computer models that incorporate recognized procedures for analyzing runoff. Computer models such as Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS) are tools that blend theory and empirical knowledge to provide hydrologic analysis for project planning and real-time regulation. Additionally, some offices rely on the NWS to provide the hydrologic analysis component of real-time forecasting. Other computer models, such as Hydrologic Engineering Center – Reservoir System Simulation (HEC-ResSim), allow the water manager to evaluate proposed operations based on hydrologic input. The Hydrologic Engineering Center – River Analysis System (HEC-RAS) may be used to compute the extent of flooding for various alternatives.

6.1.2.3. Long-range analyses of river and project conditions may be based on historical or derived streamflows (using a hydrologic model such as HEC-HMS) that are used in connection with the development of water control plans. Simulations of project regulation incorporating streamflows may be accomplished using computer models such as HEC-ResSim or RiverWare, which incorporate system analysis techniques to predict river and reservoir conditions for an extended period of time, based on current reservoir conditions and historical or derived streamflow. Thus, this type of continuous simulation, in which the end conditions of the previous time step serve as the starting conditions for the next time step, can be used to test the system capability to meet the project's authorized purposes over an extended period. Project regulation simulations may also consider each year of historical record to be an individual event or independent event. These may be very useful in obtaining a probability distribution of project regulation conditions during an ensuing year or a portion thereof, to assess the probabilities of meeting water demands based on historical records of streamflows, current reservoir levels, and water or power demands.

6.1.2.4. In summary, the overall objective in analyzing real-time water management systems is to use all the current water management data available using computer models to derive streamflows (if necessary), to regulate projects in the most effective manner possible, and to evaluate the effects of those operations. This analysis may provide information to schedule the regulation of individual projects and to forecast system regulation needs. Project regulation schedules, including the operating criteria, guidelines, rule curves, and specifications that govern the reservoir operation, must be generalized since the schedules are based on historical data and known or simulated operation. When plans are applied in real-time, however, operational decisions need to follow the guidelines of the water control plan, or possibly be adjusted to meet unique conditions. The use of computer models can facilitate this effort.

## 6.2. Analytical Methods in Modeling for Water Management.

6.2.1. Modeling Concepts. Models that express the hydrologic functions affecting streamflow must be based on sound hydrologic and hydraulic theory, but must also be practical representations of hydrologic processes that consider the availability and quality of the data. These models must also be intricately linked to real-time and forecasted data within a system to provide the optimum means of decision making. These computer models are tools that may provide real-time and forecasted water conditions data to the water manager to support improved water management decisions, detailed schedules, and better planning. In summary, computer modeling should be used by the water manager to test various alternatives and conditions affecting regulation related to water control plans. The Hydrology, Hydraulics and Coastal Community of Practice (HH&C CoP) maintains a list of approved software that can be used for these purposes. An enterprise standard for software evaluation also exists.

6.2.2. Types of Models.

6.2.2.1. The Corps Water Management System, or CWMS, is the Corps recognized AIS for accomplishing the water management mission. CWMS consists of a database (software and hardware) and a suite of computer models (hydrologic, reservoir, hydraulic, and flood impact analysis). CWMS may be used to collect, validate, and store real-time hydrometeorological data from many sources and formats for real-time reporting and water management decision support. CWMS also may provide support for operational decisions by forecast modeling using a combination of hydrologic models that incorporate recognized analytical and empirical methods. The types of computer models and systems that may be applied to real-time project regulation using CWMS are generalized into the following groups:

1. HEC-HMS — Hydrologic models to simulate the hydrologic cycle to estimate streamflow, to forecast flow resulting from rainfall or snowmelt, and to calculate base flow and interflow estimated from known hydrologic conditions (e.g., observed, real-time) and forecasts of future meteorological events.

2. HEC-ResSim — Reservoir system analysis models to simulate the response of single or multipurpose projects, based on observed or derived streamflows, and to determine future project capabilities from known river and reservoir conditions.

3. Reservoir water temperature and water quality models to simulate the conditions of water quality in a reservoir and at downstream locations for assessing future conditions of water quality and scheduling the operation of multilevel outlet works or other facilities related to water quality project management.

4. HEC-RAS — Hydraulic models to compute river stages and water surface profiles for steady and unsteady flow regimes for proposed project regulation and to compute an inundation boundary and depth map of water in the flood plain.

5. Flood inundation models such as RAS mapper to map impacted areas and contribute to economic and life safety impacts (HEC Flood Impact Analysis [HEC-FIA]) determination of different flow alternatives.

6. Water supply and forecast models to forecast seasonal runoff, based on statistically derived procedures using predictor hydrometeorological variables such as precipitation, snowmelt, streamflow, and recognized and approved climate indexes.

7. Special auxiliary programs to determine release schedules, summarize data, display data, and analyze particular functional needs that affect water regulation. Note that these applications or tools can be considered to be post-processing in nature. For instance, the

applications may distill model output from a reservoir operations model necessary for water managers to provide instructions to operators.

6.2.2.2. The user-configurable sequence of modeling software allows engineers to evaluate operational decisions for reservoirs and other management structures, to and view and compare hydraulic and economic impacts for various “what if?” scenarios. These same models may allow an engineer to perform technical analyses of alternative water control plans in the development of a new water control plan, to develop interim risk reduction measures, and to analyze a deviation request.

6.2.2.3. A full CWMS suite of models is the goal for every regulated basin in the Corps. Other software is currently used and a transition is expected to take a decade or more depending on funding.

6.3. Meteorological Forecasts Used in Water Management.

6.3.1. General.

6.3.1.1. River system response is ultimately the result of hydrometeorological factors that affect runoff. The time, form (e.g., rain, snow, sleet), and areal distribution of precipitation, together with meteorological factors that affect energy inputs that cause evapotranspiration and snowmelt, are controlled by meteorological processes in an ever-changing atmosphere. The analyses described in the preceding sections are concerned not only with the current conditions of hydrometeorological factors affecting runoff, but also with forecasts of these conditions. For this reason, meteorological analyses are an important consideration in making forecasts of project regulation, and the water manager should have basic knowledge of weather-related phenomena, both physical and statistical. A higher level of meteorologist expertise may be retained if needed due to the complexity of a district or division’s water management operations or the geographical location. Note that the NWS currently provides observed precipitation based on gaged or radar-based precipitation (gridded), QPFs, and other future precipitation scenarios that can be used to provide forecasts of uncontrolled flows into and downstream of reservoirs. It is important to note that water management decisions at Corps projects must be based on water-on-the-ground (as further discussed in Section 7.3.2) unless otherwise provided for in an approved water control plan.

6.3.1.2. All streamflow forecasts must make some specific assumption regarding additional meteorological input during the forecast period. These expectations may be based on subjective evaluations made from cursory examinations of current weather data, or by detailed analyses and forecasts that quantify the expected precipitation, air temperature, wind, humidity, solar radiation, and other factors that affect the hydrologic balance during the forecast period. Basic weather forecasts (precipitation and temperature) are prepared nationally by the NWS. As stated in ER 1110-2-240, Water Control Management, NWS is the authorized Federal agency with responsibility for issuing weather forecasts and flood warnings to the public. Local or regional analysis, including the development of streamflow projections from meteorological forecasts, may be done by the local offices of the Corps or through cooperative arrangements with the NWS forecast offices. The Corps produces streamflow forecasts solely to enable appropriate project operation, and that are not meant for release to the general public. The NWS produces the official Federal streamflow forecast for public release.

6.3.1.3. Analyses may be performed to provide a family of forecasts, sometimes referred to as an ensemble forecast, to provide a means of estimating the uncertainty in forecasted meteorological conditions such as rainfall, air temperature, and snowmelt. Application of ensemble probabilities provides insight into the time range of reasonably accurate weather forecasts. Ensemble datasets are most commonly created using multiple iterations of numerical weather or climate prediction models, or through an application of historical datasets modified to current conditions. Ensembles based on numerical weather and climate models are based on a statistical aggregation of output from numerous model runs to quantify the uncertainty in the results. In situations with high forecast confidence, the majority of models will have similar forecasts of temperature, precipitation, and other parameters. Ensemble data sets created using historical meteorological data apply each individual water year on record to current basin conditions to determine a range of possible streamflow scenarios. Either method may be used to determine not only most likely projections of future runoff and project conditions, but also extremes that may occur under unusual circumstances.

6.3.2. Short-Term Weather Forecasts.

6.3.2.1. Quantitative Precipitation Forecast. One of the more important types of weather forecasts for project regulation is the QPF. Refer to Section 3.3.8.2 regarding use of QPF in a water control plan and to Section 7.3.2 regarding the use of QPF in real-time operations. Note that QPF can come in the form of a basin-averaged forecast or gridded basin forecast. In some cases, gridded forecasts may provide better forecasts, depending on the areal extent and direction of storm movement within the basin. New products are being developed on a frequent basis and can be used in computer models once the data have been acquired, transformed, and validated. As noted, weather forecasts are the purview of the NWS, in conjunction with national support centers and local Weather Forecast Offices (WFOs).

6.3.2.2. Air Temperature Forecasts. Air temperature and associated forecasts also have a significant impact on hydrologic response. Note the NWS can also produce temperature forecasts for a basin average or on a gridded basis. These temperature forecasts are used to differentiate between liquid and frozen precipitation, the contribution of snowmelt in runoff accounting, or for the impact to flow attenuation due to ice formation. Air temperature forecasts are usually specified as maximum daily or minimum daily. Consecutive days of air temperatures below freezing, may reduce flow from a watershed. During low water conditions, the significant reduction in flow due to upstream ice formation at locks and dams and on the smaller tributaries (known as “ice bite”) can have a significant impact to navigation in winter months. In addition to surface air temperatures, upper air conditions at particular atmospheric levels provide a vertical temperature profile that enables the forecaster to identify freezing levels or warm/cold layers, which are particularly important for determining the type of precipitation falling across a basin.

6.3.2.3. Forecasts of Snowmelt Runoff Parameters.

6.3.2.3.1. Hydrologic forecasts for those rivers that are fed at least in part by snowmelt runoff need weather forecasts of appropriate snowmelt parameters for the runoff portion of the season. Water supply forecasts (regression-based) can provide estimates of total volume runoff in the basin; however, evaluations of snowmelt runoff are needed to determine how the runoff will occur. These are very complex from a theoretical point of view, and considerable research effort has been made to determine the relationships between meteorological parameters and snowmelt runoff. (See EM 1110-2-1406, Runoff from Snowmelt, and EM 1110-2-1417, Flood-Runoff Analysis.) Note these parameters include snow water equivalent (SWE), precipitation, streamflow, and in some cases the El Niño Southern Oscillation (ENSO) Index.

6.3.2.3.2. Weather forecasts for snowmelt runoff forecasting are generally confined to forecasts of air temperature and, in some cases, forecasts of short-term precipitation. Forecasted air temperature is used as indexes for snowmelt. The air temperature forecasts may be either maximum temperature, mean temperature, or a combination of maximum and minimum temperatures. Other parameters such as dew point, relative humidity, wind, or solar radiation may also be needed. These include initial conditions, boundary conditions, and the current state of the parameters. Note that short-term precipitation forecasts can be extremely useful during years where the runoff is delayed due to cooler than normal temperatures in conjunction with an increasing snow pack or a full reservoir.

6.3.2.4. Forecasts for Tropical Storms.

6.3.2.4.1. EM 1110-2-1412, Storm Surge Analysis and Design Water Level Determination, provides guidance for storm surge analysis and design water level determinations in coastal areas. The factors affecting operations for a hurricane are the forward speed moving toward a project and the track of the storm center approaching the coastline.

6.3.2.4.2. For each hurricane season (June 1 – November 30 for the Atlantic and 15 May– 30 November for the Eastern Pacific), the NWS Climate Prediction Center (CPC) provides a probabilistic outlook of storm activity, relative to activity of previous years. Ongoing storm activity results in the National Hurricane Center (NHC) providing forecasts containing valuable information such as tidal surge, rainfall, wind speed, storm speed, probable track, and cone of error for approaching storms (e.g., tropical depression, tropical storm, hurricane). These characteristics associated with the approaching storm affect the available time for implementation of water management activities. The water management decision making process must consider these storm characteristics, post-storm hydrometeorological condition forecasts, and project accessibility and functionality.

6.3.2.4.3. All tropical storms in the northern hemisphere rotate in a counterclockwise direction due to the Coriolis effect, therefore, locations subject to the northeast quadrant of the approaching storm typically have the greatest potential to receive the highest winds and largest storm surge. High winds, flooding, and the occasional tornado associated with hurricanes can cause damage to the equipment needed to operate gates. Backup equipment has now been installed at many of these coastal locations, but timing is critical. Gate position should be determined, if possible, before the storm while also considering that access to or functioning of the gate may be interrupted due to storm effects. All of these components are additive. Such conditions may cause abnormally high tides and waves that are often intensified at the head of coves and bays. Thus, in operating a hurricane project, it must be assumed that mobilization of personnel and closure of gates will be necessary. Some predicted storm paths will change and produce no appreciable tidal surge. The gate closure timing would be a combination of blocking surge while releasing the water upstream if rainfall is on land before the surge reaches a point where gates need to be closed. The difficult decision as to the time to close gates should be made with the best knowledge, modeling, and experience available.

6.3.2.5. Forecasts for Extratropical Storms. Extratropical storms also produce abnormal tides above damage stages; for these storms, operation of a barrier is dependent on the wind speed and direction as well as the predicted tide and estimated surge. Based on past studies and operating experience, the highest abnormal tides during an extratropical storm nearly coincide with the time for a predicted astronomic high tide (within 1 to 2 hours). Therefore, the time of operational requirements can be more readily predicted than for a hurricane. However, slow moving extratropical storms often produce abnormally high levels for several consecutive tide cycles, which may require more than one operation of a barrier.

6.3.2.6. Severe Weather Forecasting. Beyond the activities involved in management of water management systems, the Corps relies on real-time weather forecasts to ensure safe operating conditions at construction projects and other District operational projects and facilities. In addition to real-time weather data, forecasts of anticipated severe weather such as damaging winds, hail, and tornados can be used in support of any resulting Corps emergency response mission. For severe weather information, the Corps and appropriate functional offices partner with the respective local NWS WFO.

6.3.3. Long-Term Weather Forecasts.

6.3.3.1. Long-term (monthly, seasonal, or annual) weather forecasts can be useful for planning purposes and for developing reservoir runoff forecasts several months in advance. These weather forecasts from the CPC are updated and released on a monthly basis for the United States and are based on a combination of global climate model guidance and long-term climate trends. The information from the climate forecasts can incorporate heavy or light snowpack or rainfall potential into runoff forecasts and can influence the timing of snowmelt runoff between early spring and mid-summer.

6.3.3.2. Some of the commonly discussed large scale weather patterns are limited in their ability to be incorporated into long-range forecasts, such as the Arctic Oscillation (AO), Pacific Decadal Oscillation (PDO), and Atlantic Multidecadal Oscillation (AMO). The onset and duration of the AO can occur at relatively short durations of less than a month; thus, its overall seasonal impact can often be muted and difficult to forecast with any significant lead time. Conversely, while a PDO event can persist for several decades, its effects on a particular season are often diluted by the impacts of the much shorter lived ENSO events. Nevertheless, a “cool” PDO period could enhance a “cool” ENSO cycle, and “warm” episodes would behave similarly.

6.3.3.3. The ENSO cycle, however, has been demonstrated to having distinct impacts on various regions of the continental United States based on both the phase (warm versus cold) and intensity. These correlations are greatest from late fall into early spring with the general correlation during an El Nino event being cooler and wetter along the southern tier states and warmer and drier from the Pacific Northwest into the Northern Rockies. The opposite impacts are often observed within these regions during a La Nina episode.

6.3.3.4. However, it should be noted that not every event within the ENSO cycle has the same characteristics or intensity so the water manager should be cautioned not to reduce the level of flood risk management based solely on long-range weather forecasts or climatic indexes. These forecasts can inform the water manager of the possibility of those conditions; however, an unjustified use of such forecasts may, in the long run, result in inaccurate regulation of project facilities, and under extreme conditions, impact the projects' authorized functional use.

6.4. Simplified Analytical Procedures for Analyzing River Response.

6.4.1. Manual Aids for Use in Emergency. Manual analytical procedures may be required to ensure continuity of project regulation during a COOP situation. Simplified analytical techniques must be available for use by field or project offices in the event that communication is lost between the management center and the projects. If appropriate, generalized manually applied aids should be developed that can be used in an emergency. These would be simplified index procedures or graphical relationships that can be used to estimate runoff conditions from whatever data may be available. These aids may also be guides for project regulation, including in emergency situations that require increased discharge to avoid dam overtopping or an unnecessary fill-and-spill scenario, as determined from known project inflows or other water management data. These aids or guides may be developed from analyses of historical data and may also be derived through computer simulations of hydrologic conditions and project response.

6.4.2. Creating a Graphical Runoff Relationship. A particularly convenient and useful method for deriving multivariable graphical aids for estimating runoff is based on the use of calibrated hydrologic simulation models. As part of a hydrologic study, the forecasting diagrams are derived by simulating the runoff processes for a range of conditions, including variable amounts of rainfall and variable initial conditions of the basic soil moisture and base flow infiltration indexes. This information can be generalized into linear or curvilinear relationships as multiple-function co-axial diagrams. As outlined in Linsley, Kohler and Paulhus (1982) Hydrology for Engineers (3rd ed.), forecasting diagrams of this general type have been developed for use in operational forecasting based on observed conditions of rainfall and runoff that have been correlated with computed runoff index values, as, for example, the Antecedent Precipitation Index (API) method. The use of a computer simulation model in developing these relationships is beneficial because the various ranges of values for each of the runoff indexes and rainfall amounts may be tested as individual parameters. A series of simulation runs covering all ranges, including use of historical data, provide an array of data that can conveniently be put into a graphical relationship. A procedure that is based on runoff characteristics derived from multiyear calibration studies for streamflow simulation models provides good evaluations of runoff potentials is described in: Smith, P. (2012). Cut to the chase: Online video editing and the Wadsworth constant (3rd ed.). Washington, DC: E & K Publishing.

6.5. Long-Range Predictions of Streamflow.

6.5.1. General. Section 6.3.3 examined long-range weather forecasts and their potential impact on water management. There is a need to consider long-range predictions of streamflow that cover periods up to several months in advance of the date of forecast. Long-range weather forecasts do not provide sufficient accuracy for application to real-time project regulation, but are used in planning future regulation scenarios. The interrelationship of hydrometeorological factors affecting runoff imposes similar restrictions in long-range streamflow forecasts, but some hydrologic factors have carry-over effects, which provide the ability to develop useful and reliable long-range streamflow forecasts. The following paragraphs describe situations for which long-range streamflow forecasts may be significant.

6.5.1.1. Rainfall Runoff. For rain-fed rivers, these effects are limited to long-range changes in ground water conditions that may be determined at a particular time and projected into the future as a basis for long-range streamflow forecasts. The accuracy of such forecasts limits the use to assessing general trends in low-flow conditions of runoff that may have significant effects on project regulation for hydroelectric power generation or water supply functions. These long-range streamflow forecasts for rain-fed rivers would have little or no significance to flood regulation.

6.5.1.2. Low-Elevation Mountain and Plains Snow Runoff. Spring runoff from snowmelt is an important component of spring streamflow and runoff forecasts. Snowmelt runoff forecasting methods have used simple empirical relationships between spring runoff and snowpack indices including snow depth and snow water equivalent, monitored winter precipitation and land-surface conditions such as soil moisture conditions and soil frost. Deterministic hydrologic models combine snowpack information, forecasted precipitation and forecasted temperature to model spring snowmelt runoff. To understand the uncertainties associated with deterministic model results, ensembles of forecast input data based on either an ensemble of historic input data or modeled meteorological input data may be simulated in hydrologic models to provide a range of forecasted runoff due to snowmelt.

6.5.1.3. High-Elevation Mountain Snow Runoff. The runoff from predominately high-elevation mountain snow-fed rivers may be forecasted several months in advance on the basis of known conditions of the accumulation of the snowpack over the watershed. In general, the snowpack accumulates progressively through the winter season and then melts in the late spring or early summer. The knowledge of the water equivalent of the snowpack based on regression analysis or a more physically based hydrologic model provides as much as 4 to 6 months advance notice of the expected runoff volume. The water supply forecasts based on this knowledge are extremely useful in managing project regulation for all purposes, including water supply, irrigation, navigation, flood risk management, hydroelectric power generation, fish passage, recreation, and other environmental functions. Long-range forecasts of snowmelt runoff provide an estimate of the volume of runoff to be expected in the runoff period, but do not forecast the time-distribution of runoff. Factors affecting daily snowmelt are related to weather parameters that cannot be forecasted on a long-range basis. See the discussion in Section 6.3.2.3 on the use of forecasts of snowmelt runoff parameters in a physically based hydrologic model to determine the time-distribution of runoff and even as a check to a regression based procedure.

6.5.1.4. Statistical Procedures for Forecasting Seasonal Mountain Snowmelt Runoff Volume.

6.5.1.4.1. Determining snowmelt runoff volume based on regression analysis of snowpack is extremely efficacious. There is a long history of development and application of procedures for forecasting seasonal snowmelt runoff volume. This development has occurred mostly for the rivers of the mountainous west, in connection with regulation of multipurpose projects, and for management and forecasting of uncontrolled rivers as related to irrigation developments and flood risk management needs. Some of the principles involved in these methods have also been applied to rivers in the Northeast, Midwest, and Alaska. Nearly all of the procedures are based on the use of relatively simple month-to-month indexes of snow accumulation and precipitation. Some forecast procedures may take into account climatic indexes, such as the ENSO Index, particularly to inform early-season forecasts before a snowpack is established. Refinements in procedures are made through use of indexes of other factors involved in the water balances of the areas, including soil moisture increase, evapotranspiration, and changes in ground water storage.

The forecasting relationships are generally derived by mathematical statistical correlations of runoff with single or multivariable indexes. This type of analysis generally uses the multiple linear regression technique, applied to historical data of runoff and index parameters. While variables such as climatic indexes may reduce error in the streamflow forecast, consideration should be that climatic indexes shift the probability of, but do not negate or guarantee the occurrence of, a given weather pattern. Although nearly all procedures are based on statistical analysis of simplified indexes of runoff, some attempt has been made at a more rigorous water balance approach to seasonal runoff forecasting.

6.5.1.4.2. EM 1110-2-1406, Runoff from Snowmelt, presents a summary of methods used in developing procedures for forecasting seasonal snowmelt runoff volume. The manual describes the index and water balance approaches and discusses at length the various indexes that may be used. In summary, the main emphasis of procedural development is to use rationally based indexes of snow accumulation that represent the water balance of the area involved. EM 1110-2-1420 also presents methodology for developing regression-based equations used for forecasting seasonal snowmelt runoff volume. Additionally, other agencies such as the U.S. Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) have also developed methodologies and tools for regression based analysis.

6.5.2. Use of Models for Long-Range Streamflow Forecasts.

6.5.2.1. A logical extension of the use of deterministic hydrologic models is the application to long-range streamflow forecasting as an alternative to the use of statistically derived forecasting procedures. The principal objective in formulating statistical procedures for forecasting seasonal snowmelt runoff volume is to select indexes that are most highly correlated with runoff and are also representative of the physical hydrologic processes defined by the water balance of the area involved. Although the lumped hydrological parameters used in deterministic simulation models are also considered to be indexes of the hydrologic processes, the parameters represent an average basin or zonal value, or in some cases, gridded values of these processes as best estimated from a large array of available data. The parameters are more physically based and represent the best of analytical and empirical methods. The model simulation is considered to represent the water balance of the area involved. The models are rigorously applied in daily or smaller time increments to best represent the physical processes of snow accumulation, snowmelt runoff, and all other hydrologic processes involved in the water balance of the area.

6.5.2.2. Deterministic hydrologic models can not only incorporate all of the data used in statistical procedures, but can also use additional data that pertain to evaluations of snow accumulation and other hydrologic processes, and thereby better represent the true determination of those factors that affect future runoff. Therefore, deterministic models account for the processes in daily or smaller time increments and provide a much more rigorous analysis of runoff events than can be done by monthly based statistical methods. Furthermore, the fact that the application of this type of model allows for maintaining daily continuity of all hydrologic parameters in a forecast mode permits a continuous appraisal of runoff conditions for operational forecasting in a way that is completely infeasible with statistical models developed from monthly data. This is particularly important for appraising changed conditions of runoff potential at any time within the monthly forecast evaluation period commonly used with statistical procedures. These procedures also allow for rational determination of the effects of an array of assumed weather conditions subsequent to the date of the forecast; examples are median, mean, percentile of exceedance, or extremes.

6.5.2.3. While deterministic models can give a range of results by altering the assumed weather conditions, it can be desirable to obtain a more complete range of possible long-range streamflow forecasts. Probabilistic forecasts provide the user with flow estimates by varying the model inputs to account for uncertainty and error. Ensemble forecasts can be created by using a set of historical weather conditions as inputs into a hydrologic model considering current basin conditions. Ensemble forecasts can also be produced by varying inputs based on uncertainty of historical weather pattern observations. In both cases, the intent is to provide a long-range forecast that more realistically conveys the uncertainty and range of possibilities in the forecast and to give a sense of potential impacts on project operations.

6.6. Long-Range Analysis of Project Regulation.

6.6.1. General.

6.6.1.1. Long-range analysis of project regulation may be necessary on a current real-time basis to assess the planned regulation beginning with currently known project conditions and with knowledge of current regulating criteria, which may include revisions to the generalized criteria contained in the water control plans. Projections of this type are used primarily in connection with analyzing water management plans for hydroelectric power generation, water supply, flood risk management, or environmental considerations. Examples of revisions to water management criteria would be changed hydroelectric power needs caused by revised load estimates or unplanned plant outages, special needs for preserving fish runs, or other functional or environmental needs that arise on a current basis that were not anticipated in the water management studies.

6.6.1.2. As discussed in Chapter 3, development of the water control plan involves a lengthy process of studying project regulation from the planning and design stages to preparation of the regulation schedules and documentation in the water control plan. Furthermore, an AOP may be developed that applies the regulation principles contained in the water control plan to the current year's regulation. The regulation would be based on assumed hydrologic and project conditions, which may depart significantly from actual conditions. Accordingly, there is a need to re-evaluate the current regulation as conditions change from those contained in the water management studies, to reflect the effects of the current operating experience on future regulation.

6.6.2. Analytical Techniques. The methods used for this type of analysis are essentially the same as those used in developing the water control plans, but some modification in the methods of application of those techniques may be made. Thus, the concept of reservoir system analysis, which is fundamental to planning system regulation, is routinely applied to current regulation of a system of multipurpose projects. Chapter 3 discusses the analyses used to develop water control plans and simulation models that can be used.

6.6.3. Basic Data and Types of Analyses. Long-range analyses normally cover the current year's operation, but when planned use of reservoir storage occurs over a multiyear critical period, the projections may be extended over a 2- to 3-year period. The hydrologic data used as input for current system analysis studies could be similar to the topics in Section 6.5, or it could be the same historical mean monthly streamflow data used in water management studies with a minor modification of streamflow data made to reflect a transition from the currently observed streamflow conditions to the historical data. The historical streamflows can be analyzed to represent the effect of the most critical streamflow sequence on system regulation, a statistically derived sequence of streamflows representing median or mean conditions, or an analysis of the entire historical record as a continuous process to determine the long-range effects of future system regulation based on the most recent data. Also, it may be desired to test the current year regulation by analyzing system regulation for each yearly historical streamflow data as an independent event, commencing with the current project conditions, and to thereby obtain a statistical distribution of future probabilities of all of the elements of system regulation for the remainder of the operating year.

6.6.4. Using Results of Long-Range Analysis.

6.6.4.1. The long-range analyses of system regulation as discussed above have the greatest significance in assessing low-flow water supply and hydroelectric power capabilities. Specifically, the analyses provide the technical evaluations necessary for optimizing power production, for determining the strategy for marketing surplus power, for assessing probabilities of meeting firm power commitments, and for determining the probable effects of power operation on non-power functions. The same principles of analysis may also be applied to assess future conditions of regulation as related to other project functions, such as navigation, irrigation, water supply, recreation, fish and wildlife related activities, and other environmental uses. Thus, by maintaining continuity and surveillance of system regulation, long-range analyses provide the water manager with the ability to anticipate future conditions that may be averse to meeting the overall water management goals and to take appropriate corrective action in time to be effective.

6.6.4.2. In summary, real-time long-range projections based on monthly (or smaller) reservoir system analysis techniques are used primarily as an aid in regulating large multipurpose reservoir systems. The importance of such analysis depends on the particular hydrologic and project conditions that are being experienced. Any modification of the planned regulation to meet such circumstances does indeed depend on these types of long-range projections, and reanalysis on a monthly or weekly basis may be required.

6.7. Water Quality Forecasting.

6.7.1. General. Up to this point, this chapter has dealt with water management techniques that are geared basically to managing the quantity or potential quantity of water in a river-reservoir system. ER 1110-2-8154, Water Quality and Environmental Management for Corps Civil Works Projects, is the policy regulation for water quality and environmental management. Many environmental impacts are attributed to Corps water management projects, and some are quite significant. Even though water quality may not be an original authorized project purpose, the Corps tries to protect and enhance the quality of water and land resources at its projects as a matter of policy. Therefore, the water management team must recognize and address the environmental potential of each project or system of projects. This awareness comes from a team approach that blends and balances a wide range of disciplines, which should include hydraulic engineers, water chemists, biologists, and individuals from additional specialized disciplines as the particular system warrants. Incorporating these team members into the projects' real-time operation offers the best opportunity to generate environmental benefits from water resource projects. Many situations and opportunities arise in real-time water management that can only be recognized by specialized team members. Several important aspects of water quality management of Corps projects are forecasting future quality, evaluating existing quality, and predicting the effect of various management options with respect to project purposes on the projects and the areas influenced by the projects. Several analysis and forecasting techniques are available.

6.7.2. Analytical Techniques. Analytical techniques vary widely, but follow the same general types of analysis that are involved in weather, flow, and volume forecasting. These analyses may involve computer simulation of historical records to evaluate various management options for planning purposes, or be models of real-time, existing conditions that allow tests of a variety of management choices on present and future water quality conditions. Recognized water quality models in the Corps include CE-QUAL-W2 and the water quality component of HEC-RAS.

6.7.3. Forecasts.

6.7.3.1. General. Many aspects of water quality may need to be forecasted. Some of the more typical parameters are temperature, dissolved oxygen, turbidity, nutrients, sediment, pH, dissolved solids, algae, fish migration, metals, and contaminants. Long-range cycles of some parameters, such as temperature, may be needed to evaluate the impact of various operating scenarios on the project waters and on the downstream zone of influence. In other cases, short-term factors, such as the passage of an "acid slug" in a stream influenced by mine drainage, may need to be forecasted, and a real-time response may need to be developed. At some reservoirs, management decisions made today may have an impact that could last for years or possibly decades. Water managers should understand that long after the physical and chemical effects of a management decision have occurred, the biological consequences may linger for weeks, months, or years, depending on the project and associated conditions.

6.7.3.2. Long-Range Forecasts. Long-range forecasting of water quality should include projection of conditions as far in the future as is practical and useful to project management decision making. Reasonable forecast computer models for many physical and chemical parameters can be used to estimate weeks and months ahead. Long-range forecasting can also be much less sophisticated, using a graphical evaluation and projection of conditions. EM 1110-2-1201, Reservoir Water Quality Analysis, is a good reference for analytical techniques. Long-range forecasting is usually important to large projects with longer retention times.

6.7.3.3. Short-Term Forecasts. Short-term forecasts are those that evaluate or forecast for only a few days or, at most, a week or two. These forecasts are used to evaluate real-time conditions and project management alternatives and may be especially useful for managing small projects. Short-term water quality forecasts should always be made to evaluate the consequences of possible project management alternatives before making a decision. These decisions may be as simple as changing a port in a selective withdrawal tower or decreasing a release to stabilize a pool level. Each decision in one form or another is based on a forecast. Decisions should not be based solely on a flow forecast, but also include a water quality forecast to determine any better alternatives and the possibility to manage the project environment more positively.

6.8. Special Hydrologic Analyses.

6.8.1. General. Many other special analysis types concern specific hydrologic problems, including:

1. Determination of streamflows and water level in a major river that incorporates diversion structures in the management of water levels (e.g., the Lower Mississippi River), where the determination of unsteady flow two-dimensional flow conditions within the confines of the river is the dominant hydrologic problem.

2. Behavior of rivers and reservoirs under conditions of ice and sedimentation, and the effects on projects, project operation, channel capacities, and flooding along the rivers.

3. Effects of winds, storms and tides on water levels in rivers, reservoirs, and estuaries, together with the effect on determination of project inflows.

4. Determination of reservoir evaporation and its effect on regulation.

5. Determination of special water quality operations.

6. Dam break scenarios, DSAC project develop interim risk reduction measures (IRRMs).

7. Risk and uncertainty and consequence analysis of proposed deviations or IRRM.

8. Determination of effect of bank storage on reservoir capacity.

9. Changing effects of forest removal and urban development on runoff.

10. Determination of backwater effects and three variable relationships.

The above list indicates only the more general types of hydrologic problems that are encountered during water management activities, and each river system has unique problems that may involve many other facets of hydrologic analysis. The particular analytical methods for solving these problems are usually developed by the operating office in which the problems occur, and the use is usually limited to the particular application areas. The following sections summarize briefly some of the specific problems and methods that have been developed for solving these problems.

6.8.2. Unsteady Flow Determinations in Major Rivers. Many common methods are used to simulate the response of unsteady flows in river systems. Streamflow routing procedures range from simple, empirical methods for translating and computing the attenuation of the unsteady flow fluctuations, to highly complex and completely rigorous computerized solutions of the unsteady-state flow equations. Each has particular types of applications, depending on the type of river system; the general ranges of flow variations normally experienced; the effects of variable backwater conditions caused by tides, project operation, or “looped” ratings of channel flow; the overall accuracy of the computed fluctuations in relation to the needs for a particular application;

the time and effort that can be expended in the solution for timely use; and the availability of basic data needed for application. In some cases, a 2-dimensional model may be necessary to accurately represent braided streams or flooding scenarios.

6.8.3. Effects of Sedimentation in Rivers and Reservoirs. Sedimentation has long been an important aspect of planning and designing projects. In the operational phase of water resource development, potential problems may develop as the result of sediment deposits in both reservoirs and natural stream channels. The problems may involve the loss of active storage space in reservoirs, changes in channel characteristics and sedimentation balance for rivers downstream from projects, effects of sediment deposits in small tributaries entering reservoirs, changes in maintenance dredging resulting from water management, and the lack of knowledge of sediment density currents in reservoirs. These effects relate to water management activities in relation to changing conditions for downstream control, to the management of water levels, and to the control of the regulation of multilevel intake structures or other outlet facilities.

6.8.4. Effects of Ice in Rivers and Reservoirs.

6.8.4.1. The occurrence of ice has major significance to management of water resource projects in the northern tier of states and Alaska. River ice forms in the fall or early winter and may gradually increase in thickness until the spring thaw. River ice may constitute a major threat for flooding as the result of ice jams that build up at critical locations, especially at the time of the spring thaw or at other times when streamflows increase and the ice jams severely restrict the flow of water in the river channels. The prediction of the occurrence of ice jam flooding involving the release of water from upstream reservoirs may be important. Ice jams are also likely to occur where tributaries enter reservoirs. This is mainly the result of reduced channel velocities in the river immediately upstream from the reservoir. This type of occurrence may require special regulation of the water surface in reservoirs to help mitigate adverse effects in the upstream tributaries. The occurrence of ice in river channels also affects the flow rating relationships used for determining streamflows from reports of water levels, and special efforts must be made to properly apply rating curves under these conditions. Formation of ice in reservoirs is common in cold climates, and ice cover may persist for as much as 6 months, with thicknesses up to 3 ft. The occurrence of ice on large reservoirs may be of concern in the vicinity of the dam or control works related to navigation. Ice flows caused by wind may build up in reservoirs in the vicinity of the dam and could impair the operation of outlets, spillways, navigation locks, or other facilities. In cold weather, spillway gates are susceptible to freezing, which may restrict normal operation unless specific measures such as seal heaters are incorporated into the design. The occurrence of frazzle ice in penstocks may also restrict the operation of hydroelectric power facilities at certain times.

6.8.4.2. ERDC-CRREL has made extensive investigations of the formation and movement of ice in river channels, reservoirs, navigation locks, and other water management facilities. The results of the investigations are contained in research documents and reports, which are available from the headquarters office located in Hanover, NH.

6.8.5. Effects on Discharge. The occurrence of upstream and downstream aquatic habitat, vegetation, and debris can have an effect on discharge capacity. For example, debris clogging intake trash racks can affect penstock efficiency. Additionally, debris downstream can cause a backwater effect, thus requiring reduction in discharge. These are just some of a few of the things that can affect discharge and thus should be considered if these are an issue.

6.8.6. Reservoir Evaporation. The hydrologic methods used in river system analysis for managing water systems usually entail the logical accounting of the water balance from both natural and man-caused effects. Reservoir evaporation may result in significant water losses to the river system. These losses are in addition to those that occur by natural evapotranspiration from the drainage area contributing to runoff. The streamflow data used for operational studies are usually adjusted to account for water loss by reservoir evaporation. Many procedures are being used for making such adjustments. The degree of refinement in developing these procedures depends on: (a) the relative importance of reservoir evaporation in the overall water balance of the region and the effect on the management of the system; (b) the types of basic data available to make estimates to be applied to current and historical data; and (c) practical considerations concerning the accuracy of the estimates to be attained, as compared with the effort required to obtain and apply the basic data in a computational method.

6.8.7. Determination of Effect of Bank Storage on Reservoir Capacity. Reservoir area-storage-capacity curves used in operational hydrology are normally determined by the use of topographic maps of the reservoir area or special field surveys. The reservoir level pool area is determined incrementally for each of a range of elevations that will represent the variations of area and storage within the operating range of the reservoir. These determinations, however, do not normally take into account any possible effects of storage of water within the aquifers underlying the reservoirs. Evidence may exist of significant bank storage in some reservoirs, based on the geology of the area and water balance computations. In most cases, however, bank storage is not believed to be of sufficient magnitude relative to the computed inflow and outflow to warrant water management consideration.

6.8.8. Effect of Wind Setup on Water Levels in Reservoirs, Lakes, and Tidal Estuaries.

6.8.8.1. Water levels observed and reported for reservoirs, lakes, and tidal estuaries may reflect the effects of wind or storm tides, superimposed on the hydraulic effects of flow and tides that occur without wind effects. Particularly in lakes and large reservoirs, the normally assumed “flat pool” or “static pool” as used for computation of daily or period inflows from observed outflows and change in storage may be invalid. Inflows computed in this manner may show apparent fluctuations that are not real and reflect the effects of daily variations in wind on the lake or reservoir. Corrections must be made to properly account for the effects of wind in this type of computation. A practical expedient for doing this is to maintain a continuous graphical plotting of inflows computed from change in storage computations for the reservoir, along with a plotting of key index inflow gaging stations, the streamflows of which contribute to the reservoir inflow. The total computed inflow is “smoothed” by eye, as judged by the inflow gaging station plots, to best represent the actual variations of project inflows. When the operation of spillway gates or other outlet facilities are determined, the project releases should be based on best estimates of inflow as adjusted for the effects of wind discussed above, or on inflows computed directly from fixed relationships between total project inflow and observed inflows at key upstream gaging stations.

6.8.8.2. Prediction of the effect of storm tides and hurricanes on water levels in estuaries is of great importance to water management activities in coastal regions. A third factor is the effect of tsunami ocean waves generated by earthquakes that may occur in coastal areas or in the ocean hundreds or even thousands of miles away. Flood risk management works that are constructed for coastal rivers and estuaries are designed for the effects of storm tides, hurricanes, or tsunami waves as applicable. When these projects become operational, the occurrence of storms that would affect the areas should be monitored, and, if necessary, special precautions should be taken to ensure the proper project operation or to institute flood fights. The methods of monitoring and predicting floods under these conditions should be developed on the basis of requirements for each particular area or project.

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# CHAPTER 7

## Real-Time Water Management

7.1. Basic Considerations. Corps offices have the responsibility to manage projects under Corps jurisdiction. Water management at Corps water resources projects is conducted in real-time, over the short-term, and in a way that addresses anticipated long-range effects. The water manager uses iterative, adaptive, real-time management of water resources projects to achieve congressionally authorized project purposes. Water managers must make informed real-time decisions based on observed conditions and on an understanding of location-specific cause and effect relationships. Water managers should revisit these decisions regularly to incorporate the latest information available. Experience with these decision processes helps develop abilities that are applicable to both short-term and long-term water management. Daily real-time water management prepares the water manager to make sound decisions during non-routine conditions such as floods.

7.1.1. Integration of Generalized Operating Criteria, System Analysis, and Water Management Activity Scheduling.

7.1.1.1. Chapter 3 discussed the methods used in developing regulation schedules and operating criteria for project or system water management as documented in the water control manual. These criteria represent the commitment to an assured water management plan based on congressionally authorized project purposes, environmental policy, project infrastructure considerations, operational constraints, state and local stakeholder agreements, and overall public health and safety. Consideration should be given to historic factors that could lead to reduced detrimental impacts or that could provide additional benefits to project purposes. The operating criteria are documented through such items as: seasonal guide curves, optimum water level range, downstream control points, drought contingency plans, and deviations from normal regulation.

7.1.1.2. Special situations or unanticipated conditions may arise during water management activities. These conditions may require that a certain degree of flexibility be maintained in the water control plan to adapt operating criteria. Any decision to deviate from the approved water control plan must follow the process outlined in ER 1110-2-240, Water Control Management.

7.1.1.3. Unusual occurrences, such as the spill of pollutants into waterways, may require immediate action that departs from normal project operation, and the water control plan should allow for emergency response flexibility, to the extent possible. For example, toxic spills into projects with water supply require immediate response from water managers, including prediction of dilution rates and time of travel. Such an event may require extensive, complicated coordination and quick development of alternative operating strategies. Similarly, unanticipated changes in requirements may occur that involve the safety or use of navigation facilities and waterways, such as vessel groundings or sinkings, shoaling of waterways or docking facilities, or special water needed for managing terminal or vessel repair facilities; the rescue of persons in the waterway; or other circumstances that require immediate action for the safety and well-being of the general public. In addition to the problems related to projects' normal functional use, a water management office is often requested to perform a variety of miscellaneous water management activities for special purposes, such as maintaining water levels on a short-term basis for construction activities near or in a water body or in the upstream or downstream waterway, maintaining flows for recreation activities, or regulating reservoir levels for improvement of wildlife habitat.

7.1.1.4. All of the above conditions require that decisions by the water manager adapt the approved operating criteria to real-time water management. The water manager should rely on information provided by the WMES and obtained from any necessary additional sources to make decisions for daily, short-term, and long-term water management activity scheduling. The majority of the daily decisions based on the approved water control plan or an approved deviation do not have far-reaching effects on project regulation and are part of routine water management activities. However, some proposed operating criteria may constitute a departure from approved operations and should follow the deviation process outlined in ER 1110-2-240.

7.2. Appraisal of Current Project Water Management. Monitoring system response and scheduling future project activities should be coordinated. The objective of monitoring project response is to verify that the regulation is proceeding according to the operational objectives, within the water control plan or approved deviation from normal operation. Ongoing water management activities, hydrometeorological occurrences, evolving ecological conditions, concerns for safety, or other conditions require routine assessment of operating criteria by the water manager. Assessment of operating criteria may also occur as a result of stakeholder input that includes specific concerns related to the effect of ongoing or planned Corps water management activities.

7.3. Performing System Analyses for Water Management Activity Scheduling.

7.3.1. Analytical Considerations for Scheduling of Projects.

7.3.1.1. Changing conditions and corresponding water management actions result in situations in which the water manager continually applies a comprehensive, iterative approach to water management that considers possible cause and effect relationships. This may include:

1. Assessing current conditions and forecasts (e.g., hydrometeorological, ecological).

2. Determining effectiveness of implemented water management activities in reference to water management operating criteria.

3. Evaluating the need and risk of implementing additional/alternative water management activities.

4. Determining whether deviation from normal operation is beneficial.

5. Developing a condition-based schedule for future water management activities.

6. Beginning implementation of scheduled water management activities.

7.3.1.2. This approach should be repeated, as needed, based on evolving conditions, as more definitive forecasts becoming available.

7.3.1.3. The water manager may also consider input from others that affects water management activities (immediate needs for hydroelectric power generation, navigation, water supply, or other multipurpose functional needs). The water manager must also review current hydrometeorological conditions and the latest forecasts of weather elements that will affect project regulation.

7.3.1.4. For simple projects, experience and judgment or general estimates for operating decisions may be sufficient to properly evaluate and schedule project activities with knowledge of the changing conditions. However, the regulation of complex or major water management systems and the many variables that must be considered in a detailed manner precludes the use of simplified procedures or general estimates for scheduling. Computer-based analyses may be used to perform comprehensive, timely analyses of the water management systems. Computer modeling may sometimes account for the effects of each of the major hydrologic and project regulation elements on various alternative project schedules or hydrologic conditions. Ultimately, the development of operating criteria to achieve congressionally authorized project purposes should consider a water management approach to achieve shared benefits across multiple project purposes or to prioritize project purposes.

7.3.2. Operations Based on Water-on-the-Ground.

7.3.2.1. In general, regulation decisions are made based on the overarching principle of water-on-the-ground, which includes observed precipitation that has fallen in the basin in the form of rainfall or snow. However, exceptions to this philosophy are permitted when included as part of an approved water control plan as described in Section 3.3.8.2, or in a deviation to an approved plan under certain circumstances. Both of these exceptions require careful consideration of forecasting methodologies that incorporate future precipitation and/or runoff, and identification of the associated risks and benefits.

7.3.2.2. The principal objective is to ensure that releases from reservoirs are restricted insofar as practical, to quantities that, in conjunction with uncontrolled runoff downstream of the dam, will not cause water levels to exceed the controlling maximum non-damaging stages that are currently in effect or that exceed peak inflows. Other factors to consider when determining whether to include future precipitation/runoff in regulation decisions may include the potential for future runoff, whether on the rising limb of an inflow hydrograph or evacuating flood water from an earlier event, downstream channel capacity, dam and levee safety, and impacts to other authorized purposes.

7.3.2.3. Refer to ER 1110-2-240, Water Control Management, for policy related to evacuating stored water based on the principle of water-on-the-ground. In addition to this principle, the water manager relies on reservoir and streamgage information provided by the WMES and data from additional sources to make real-time, short-term, and long-term release decisions. These additional data include the use of QPFs, streamgage forecasts, and runoff forecasts based on snowmelt. This is where the monitoring of system response (real-time conditions) and scheduling of future water management activities must be closely coordinated, applying a comprehensive and iterative approach within the context of sound engineering experience and professional judgment.

7.3.3. Components of a Comprehensive Analysis. Analysis of water management-related conditions and operating criteria may be conducted with computer applications based on historical, real-time, and forecasted hydrometeorological data. The scheduling of water management activities requires analysis of comprehensive water management-related information and data sets, including:

1. Non-variable data, which describe physical features such as drainage areas, watershed run-off characteristics for each component watershed, channel routing characteristics, reservoir storage and flow characteristics, and other physical parameters that define the system.

2. Current conditions of all watershed indexes; ecologically driven indicators related to items such as fish spawning, estuary conditions, and species of concern; incremental flow routing values for upstream and downstream watersheds and channels; current project water levels and outflows; and downstream water levels.

3. Time-variable data expressed as a time series for representing hydrometeorological inputs and forecasts such as precipitation, air temperature, snowmelt, and evapotranspiration functions, streamflow data, project regulation data, or other time-variable elements that affect runoff, project regulation, and system requirements.

4. Infrastructure constraints such as maximum allowable gate opening, gate opening sequence, maximum allowable head differential, and minimum allowable elevation for pumping.

7.3.4. Input from Others.

7.3.4.1. Water managers often have some flexibility in the operations to meet required objectives. For example, an operation to meet a required flood risk management drawdown may be achieved in various ways, and those options could, in turn, have various effects on the river system. To determine the operations that will be used to satisfy the water control plan, the management of nearly all water resources projects can benefit from multiagency or multipurpose input. Even though some Corps water resources projects may have been constructed initially as single purpose projects, potential environmental, economic, social, and safety aspects related to Corps projects have resulted in the establishment of a variety of entities with an interest in the Corps water management decision making process. These stakeholders may include non-governmental entities as well as Federal, state, local, and tribal agencies. While the Corps is ultimately responsible for determining water management decisions at Corps projects, stakeholders may be uniquely qualified to provide input on current hydrologic, ecological, and fish and wildlife conditions that optimize regulation within the water control plan.

7.3.4.2. In addition, historic, current, and forecasted hydrometeorological conditions and data useful in the Corps decision making process are often provided by other entities. These include:

1. Streamflow, water quality, and water level data from the USGS or other agency.

2. Current weather data, weather forecasts, and hydrometeorological data from NWS.

3. Snow water equivalent data and related hydrometeorological data and basin data (e.g., soil moisture, frost depth, runoff potential) from NOAA and NRCS.

4. Hydrometeorological and water use project data from state and local agencies.

5. Hydrometeorological data from foreign agencies.

7.3.4.3. Chapter 8 discusses the methods for coordinating interagency water management activities in greater detail.

7.3.5. Collaboration with Non-Federal Sponsor. For Corps water resources projects at which a non-Federal sponsor conducts daily water management activities, appropriate collaboration with district or division water management staff is necessary. As stated in Section 208.11, Title 33 of the CFR, the Corps is responsible for prescribing water management operating criteria and providing oversight to ensure that congressionally authorized project purposes are met. This may include assessment of water management operating criteria and current water management activities, processing of requests for deviation from normal operation, development of water control manuals, and revision of water control manuals and plans.

7.3.6. Results Evaluation. As stated earlier, the main purpose of system analysis is to provide the water manager with information related to the potential effects of proposed water management activities for use in making decisions. The most complete knowledge of recent hydrometeorological trends, as well as current conditions and future forecasts, should be used to produce desired effects over a specified time frame. After operational decisions are made, the resulting effects must be monitored and compared to desired conditions. Often multiple analyses are necessary to allow depiction of a range of potential future conditions that can be compared and considered in making water management decisions.

7.4. <u>Water Management Decisions and Project Scheduling</u>. Water management includes making decisions that consider all the congressionally authorized project purposes for a Corps project. The process to determine the storage or quantity, timing, and duration of the potential releases from a Corps project includes consideration of water management information. This information may include project design information, project operation manuals and procedures, hydrometeorological information, river and reservoir levels, and forecasts and ecological and fish and wildlife information that are specific to the project as well as upstream and downstream from the project, as appropriate.

7.4.1. Need for Judgment in Project Scheduling.

7.4.1.1. Even with the engineering analysis described in the preceding section, the final decisions in formulating project schedules may require the judgment and experience of the water manager. The water control plans provide the general guidance for project regulation, and when applying that judgment, the operating decisions must still fall within the boundaries established by the water control plan unless a deviation is approved. Actual conditions (e.g., limitations to the project operations, upstream and downstream activities) must always be considered in the implementation and scheduling of water management activities.

7.4.1.2. On a broader scale, judgment may be required to adjust the operational plan for conditions that indicate a particular need, for example, a mid-month adjustment in operating guide curves, which are specifically defined as month-end values, and current analysis and projections indicate a probable change in conditions by month's end. The simulation of streamflows and project conditions may be used to estimate future conditions. These evaluations may form the basis for mid-month adjustments of guide curve operation. By monitoring changes in runoff potentials, the overall efficiency of multipurpose project regulation may be significantly improved. Modifications of the guide curve operation must be based on rational evaluation of runoff conditions that warrant such departures. At the time such modifications are made, the water control manager must detect conditions that would require a return to normal guide curve operation.

7.4.2. Water Management Coordination Agreements.

7.4.2.1. Coordination of water management activities with appropriate agencies and stakeholders must be conducted by the water manager to avoid unintended detrimental effects, maximize benefits, and provide alerts. In some cases, coordination is outlined in:

1. Interagency water control management agreements with power marketing authorities, fish and wildlife agencies, etc.

2. Hydroelectric power generation utility coordinated power operating plans and contractual agreements.

3. Water control plans for non-Corps projects that involve flood risk management or navigation requirements.

4. Water control plans for water regulation projects developed under international treaties.

5. Water compacts with state, regional, or local agencies or councils.

7.4.2.2. Other types of input from agencies or entities outside of the Corps are not based on formal operating procedures, but through voluntary informal arrangements. The many types of inputs covered by these operating arrangements and agreements may have widely varying significance as considered in making decisions. Typically, this informal coordination process informs water management decisions that fit within the approved water control plan. However, at times, the water manager may determine that the input received would lead to water management activities inconsistent with the water control plan, which would require a deviation request and approval by the division engineer or delegated party per ER 1110-2-240. Examination of the impacts on other authorized purposes must be undertaken before proceeding with a deviation request, and may result in the water manager denying the request from outside agencies or entities.

7.4.3. Water Management Activity Schedules and Operating Instructions.

7.4.3.1. The monitoring, coordinating, scheduling, and evaluation of project regulation is performed on an ongoing basis, and the schedules usually represent an operating commitment for a defined period of time. However, all schedules are subject to change based on evolving conditions or new information. The schedules and operating instructions may take various forms, including one or more of the following provisions:

1. Mean total project discharge in cubic feet per second for weekly, daily, hourly, or other specified release periods.

2. Gate opening sequence and amount; gate closing or opening prompted by water level at downstream location.

3. Target water level (e.g., canal, lake, impoundment, reservoir) as an end of daily or period value.

4. Target pulse release in duration of pulse and daily release quantity.

5. Mean reservoir storage change in acre-feet per day or day-second-feet (the volume of water represented by a flow of 1 cubic foot per second for 24 hours; equal to 86,400 cubic feet).

6. Specific operating constraints for the ensuing day, as, for example, maximum and minimum reservoir levels, maximum and minimum project discharges, rates of change of tailwater levels, etc.

7. Power plant generation as scheduled daily or hourly amounts.

8. Special operating instructions not covered by the specified normal limits of project operation.

9. Special operating instructions for multilevel intake structures.

7.4.3.2. All water management activities should be accomplished with consideration of all known operating constraints whether specified in water control manuals or in other documents. The constraints apply to conditions at the project and at upstream and downstream locations, and may vary seasonally or apply to specific needs that depend on the conditions of tributary flow, recreational activities, water supply or irrigation intakes, or other downstream water use functions. The water manager is responsible for determining that the water management activities are consistent with all operating constraints and that the schedules and operating instructions are properly implemented.

7.4.3.3. In times of flood or other types of emergencies, the project schedules must be revised as necessary to meet the flood risk management or other emergency objectives. This may require 24-hour staffing during emergencies, at which times considerable effort is needed to keep abreast of conditions and to adjust the project schedules to reflect changed conditions. These issues are discussed further in Section 7.6.

7.4.3.4. In periods of extreme low water, drought contingency plans provide details for the proper assessment of project scheduling needs by balancing congressionally authorized purposes and project goals with regard to available water in the system and applicable water law. In general, project releases are reduced to preserve stored water while meeting critical downstream needs such as municipal water supply, industrial water supply, water quality or environmental flows, agricultural water supply, and navigation. A critical aspect of drought operations is coordination with state and local agencies or tribal representatives that may have primary jurisdiction over water use in times of shortage. Special local water supply requirements may be needed during drought situations that are not part of normal water management activities. These requirements and any special coordination requirements should be documented in a drought contingency plan. The drought contingency plan is discussed in Section 3.6.

7.5. Disseminating Water Management Activity Schedules.

7.5.1. Within the Corps of Engineers. Water management activity schedules and operating instructions for real-time, short-term, or long-term implementation must be communicated in a timely and accurate manner from the water management office to project operators. Internal communication with other Corps offices (e.g., operations, geotechnical engineering, RCO) may be necessary to provide information on the effects of future water management activities such as projected water levels and release targets that have the potential to affect those offices' activities. As necessary, oral communication with appropriate staff should accompany written documentation or communication transmitted through fax, electronic mail, internal or public website, or other electronic means. For water management activities that have potential upstream or downstream effects beyond the jurisdiction of the water management office, information associated with the activity should be disseminated to the affected group (other districts or divisions).

7.5.2. To Non-Corps Projects. Water management activity schedules may be transmitted to the project owner of a non-Corps project according to approved operating agreements. However, some operating agreements require the project owner to prepare all schedules and the Corps water management office to monitor the operation to ensure that coordinated project operating criteria is followed. Section 7 of the Flood Control Act of 1944 and 33 CFR Section 208.11 require the Corps to prescribe regulations for the use of storage allocated for flood control or navigation at reservoir projects constructed wholly or in part with Federal funds (other than TVA projects, except in case of danger from floods on the lower Ohio and Mississippi Rivers).

7.5.3. To NWS Offices. The NWS is the responsible Federal agency to provide weather, hydrologic, river stage, climate forecasts, and warnings for the protection of life and property. Water management activity schedules may contain information of importance to NWS in forecasting water levels. Often, the information to be transmitted to the NWS is customized to more effectively support NWS forecast needs. The water manager should fully understand the regional responsibility of the NWS office with regard to the areas both upstream and downstream of planned or implemented water management activities. The water management activity schedule and other information may be transmitted to the appropriate NWS office orally or by fax, email, or other electronic means.

7.5.4. To Stakeholders. The Corps should share water management activity schedules as necessary, with other stakeholder agencies or entities that are not project owners or operators. These stakeholders include non-governmental organizations, private utilities, power marketing authorities, streamflow forecasters, fish and wildlife or environmental protection agencies, public safety agencies, navigation partners, and recreational businesses. The schedules are provided, as required, to communicate the water management activity details such as targeted outflow, anticipated water level, and implementation time and duration. These schedules may be distributed by press release, public website, email, or automated process.

7.5.5. To the General Public. Normally, the water management activity schedules are considered to be internal working directives that are distributed externally to Federal and state agencies, local entities, or stakeholders that may be particularly affected by water management activities. The general public may benefit from water management information distributed by press release, public website, email, or other electronic means. The public affairs office can assist with posting information to social media locations as desired. Fishing, boating, irrigation, construction, flow measurement, water sampling, and academic research are activities that can benefit from publication of water management schedules. Dissemination of information to the public should follow policy set forth in ER 25-1-110, Information Management Enterprise Data Management Policy Corporate Information.

## 7.6. Water Management Activities during Emergency Events.

### 7.6.1. Importance of Water Management Activities.

7.6.1.1. Water management decisions and the scheduling of water management activities typically occur on a daily cycle consistent with division and district staff administrative work hours. To be prepared for unexpected events, project operators or stakeholders should have contact information for water managers. The intensity of the water management office workload, as well as communication with internal and external parties, may increase significantly during times of flooding and approaching severe weather (e.g., tropical storm, hurricane, cold front), requiring the water management office and affected projects to be staffed 24 hours per day, including weekends and holidays. Water managers must closely monitor rapidly changing hydrometeorological conditions and be prepared to re-evaluate tidal surge, storm track, wave runup, precipitation and temperature forecasts, and runoff conditions, as necessary, since the conditions may affect project schedules along with upstream and downstream conditions.

7.6.1.2. In rare circumstances, floods may result from dam breaks, earthquakes, landslides, or volcanic eruptions, which may cause serious and unexpected life threatening flood disasters. While this type of occurrence cannot be forecasted, such disasters require immediate action. During normal floods resulting from rain or snowmelt runoff, frequent direct communication should occur between the water managers and project operators to ascertain the most recent project conditions that affect project regulation. The water management office must issue flood reports to higher authority and keep other office elements fully informed of operational conditions that may affect other Corps activities (e.g., flood fighting, disaster emergency operations, coordination with Federal, state, and local authorities, public relations).

7.6.1.3. The entire effort of Corps installations within a region may be diverted to the activities associated with extremely critical flooding. The district and division office elements often involved in such emergencies include engineering, operations, construction, planning, procurement, personnel, public affairs, as well as other supporting elements. Activities related to such extreme events must be directed and coordinated by top level management, and because of the potential for rapidly changing circumstances during emergencies, management must be prepared to respond intensively. Water management provides support to the RCO group during floods and emergencies in the form of written and oral communication. Special situation reports may be required and are discussed in Section 9.5.2.

7.6.2. Collaboration with National Weather Service. The NWS is the Federal agency responsible to provide weather, hydrologic, river stage, climate forecasts, and warnings for the protection of life and property. During emergencies such as tropical storms, hurricanes, and high water events, a critical need exists for the timely and accurate information exchange between Corps water managers and NWS personnel. NWS rainfall forecasts may influence water management activities, which in turn may influence NWS flood forecasts. The typical exchange of information through email and other electronic means during non-flood conditions should be expanded to include oral communication or co-location of staff with the appropriate NWS office to ensure that critical details are understood by both water managers and NWS personnel.

7.6.3. Coordination of Corps Activities.

7.6.3.1. Corps office activities during floods require coordination and centralized direction. One of the important aspects of coordination is the provision of authoritative and timely flooding information. Responsible Corps office elements must be fully informed of current conditions. The USACE Operations Center (UOC) located at Headquarters is responsible for national level situations awareness for all Corps Contingency Operations. The typical communication process is for districts to provide a situational report to division through ENGLink that is then passed to the UOC for use in their situational awareness briefings. Depending on the circumstances, extensive coordination with RCO, geotechnical engineering, project operations, levee and dam safety program managers, and other Corps offices may be essential. For events that span more than one district or division, extensive coordination must take place to ensure an appropriate agency response. Therefore, the water management office must be prepared to provide the latest pertinent information on flood conditions, including:

1. A general summary of current weather and hydrologic conditions, the associated effects on runoff, and areas of flooding.

2. Weather conditions forecasts, with particular emphasis on the flood potential outlook.

3. Natural and regulated streamflows forecasts at project and key downstream locations.

4. The current status of water control facilities as related to project and system wide water management for all project purposes, with special emphasis on the effects of flood regulation throughout the system.

5. The expected water levels at all key downstream locations, with special emphasis on those areas protected by levees or other control structures.

6. The planned use of storage, interior drainage facilities, and bypass and diversion structures for the duration of the flood.

7. The planned use of non-Corps projects (including international projects) for current flood regulation and the coordination necessary to achieve the flood risk management objective.

8. Flood regulation coordination in the management of multipurpose water control projects with other interests such as public and private utilities, power marketing authorities, fish and game agencies, and state or local water agencies.

9. A description of any special conditions related to weather and river conditions that might affect water regulation and Corps activities being undertaken as the result of the flood.

10. Coordination and awareness of operational constraints that affect the projects capability to be operated according to the approved water control manual.

7.6.3.2. If conditions warrant, district resources may follow current policy regarding release of inundation data.

7.6.3.3. During floods, the water management office is not only responsible for analyzing the system, scheduling and coordinating project regulation, and maintaining continuity of data systems, but also for displaying information in briefings. Facilities available for normal river and reservoir briefings that ideally should provide all of the needed aids may not be sufficient for a larger district-wide event. During a larger scale flood, an emergency operation center may be set up to assist the district or division commander in directing flood activities. Section 8.2 discusses the design and use of briefing room facilities.

7.6.4. Monitoring and Reanalyzing River and Reservoir Conditions during Emergencies.

7.6.4.1. The principles and methods of real-time system analysis for normal scheduling operations are also applied during emergencies, but with special emphasis on maintaining knowledge of current hydrometeorological conditions. Maintaining the ability to respond to potentially rapidly changing events during emergencies requires intensive analytical efforts. Using all available tools, the relationship between forecasted and observed conditions must be coordinated frequently and sound judgments must be made to schedule project water management activities most effectively.

7.6.4.2. An awareness of changes in a river system and proper maintenance of the hydrometeorological data system are critical to prepare water managers for floods. During floods, water managers must make decisions based on hydrologic and hydraulic data developed from calculations and historical observations. These can include stage-discharge relationships, stage-damage relationships, level of levee flood risk management, levee integrity, hydraulic travel times, and many other assumptions. In dynamic systems and during floods, these relationships may change from event to event, and water managers should be in contact with field personnel to provide visual confirmation of river and reservoir conditions and the level of impacts. Observations may be made by Corps employees, local or Federal RCO personnel, or USGS or NWS field personnel. It is critical that river and reservoir gage levels be verified throughout a flood event to ensure that water managers are making decisions based on accurate data. The hydrologic conditions during flood events could test the performance limits of the automated gaging equipment. Additionally, temporary stream gages may need to be installed during a flood.

7.6.5. Adjusting Reservoir Water Management Activity Schedules. Monitoring and reanalysis of conditions during emergencies may require frequent adjustment of water management activity schedules. The needs are determined from the knowledge and experience of the water manager.

7.6.6. Non-Federal Sponsor Water Management Activities. Corps water management oversight of the non-Federal sponsor application of Corps-developed operating criteria is typically increased during flood events. During floods, the exchange of accurate, timely information between water managers is critical. The typical exchange of information through email and other electronic means that occurs during non-flood conditions should be expanded to include oral communication, as necessary, to ensure that critical details are understood by water managers of all agencies. In some instances, Corps assistance may be provided to the non-Federal sponsor to address project-related technical questions or staffing beyond normal duty hours.

7.7. <u>Coordinating Flow and Water Level Forecasts</u>.

7.7.1. General.

7.7.1.1. Corps water management personnel must recognize and observe the authorized responsibility of the NWS for issuing weather forecasts and flood warnings to the public as described in ER 1110-2-240, Water Control Management. Consistent and timely communication of Corps water management activities that may prompt flood notifications or affect forecasts must be provided. Corps water managers often need to make additional forecasts of streamflows and river levels to best meet multipurpose project water management objectives, although unnecessary duplication of effort among forecasting agencies should be avoided, and forecasts should be coordinated and shared to the greatest extent possible. If the Corps and NWS develop separate forecasts that indicate significant differences, increased coordination should occur, such that both agencies fully understand the reasons for the differences.

7.7.1.2. The exchange of the most current hydrometeorological and operational data is an important part of coordination among the offices. Water management and water level forecasting agencies should coordinate the hydrometeorological and operational data to support water management decisions and forecasts. Coordination of forecasts and water management operations can be accomplished through oral communication, regionally coordinated electronic communication, and the distribution of flow schedules to the forecasting agency. Corps water managers must continually provide current operation plans to Federal and state agencies involved in streamflow and water level forecasts because accurate information is critical to the forecasting ability and emergency planning efforts of the agencies.

7.7.2. Basin-Wide Forecasting Services.

7.7.2.1. The Corps is engaged in ongoing cooperative efforts to develop and implement basin-wide river forecasts and to estimate the impacts of those forecasts.

7.7.2.2. The Columbia River basin offers a good example of a joint operation that provides basin-wide forecasting of a river system, in conjunction with requirements for project operation and preparation of river forecasts for the general public. Since 1963, the Northwestern Division Office of the Corps of Engineers and the Northwest River Forecast Center of the NWS have jointly developed reliable and timely forecasts of streamflow at key locations in the Columbia River basin. The current method of creating the joint basin-wide forecast uses the NWS Community Hydrologic Prediction System (CHPS), which enables NWS forecasters to create natural streamflow forecasts and Corps water managers to remotely input and route projected reservoir releases in the same computer model. The result is a basin-wide, regulated streamflow forecast for the entire Columbia River system, distributed by the NWS.

7.7.2.3. During emergencies, forecasting of releases, stages, and flows often supports an overall flood fight, which may include monitoring of critical infrastructure, emergency levee construction, evacuations, and reinforcement of levee systems. District resources may provide real-time inundation mapping or previously prepared inundation maps that complement forecasts and help locate trouble areas during emergencies. The Corps, USGS, NWS, and Federal Emergency Management Agency (FEMA) develop and maintain inundation maps. Ongoing and future inundation mapping efforts should proceed collaboratively among the agencies and focus on the development of consistent end products to support future emergencies.

# CHAPTER 8

## Administrative and Coordination Requirements for Water Management

### 8.1. Administration of Water Management Activities.

8.1.1. Organization.

8.1.1.1. The overall responsibility for water management throughout the Corps is assigned to the Engineering and Construction Division, HQUSACE (CECW-CE). CECW-CE establishes major policy and guidance pertaining to Corps-wide water management activities and has assigned water management as part of the HH&C CoP.

8.1.1.2. ER 1110-2-1400, Reservoir/Water Control Centers, delegates water management responsibilities and defines roles for Headquarters (HQ), divisions, and districts.

8.1.1.3. The divisions may contain water management offices in the division office, in district offices within the divisions, or in both district and division offices. In division or district offices that do not have separate water management offices, the water management responsibilities are usually carried out by the hydrology/hydraulics element located within an engineering or operations division. Each division-led water management office is responsible for division-wide oversight of district water management activities. The organizational structure and responsibilities of water management division offices vary across the Corps. Although the basic mission and water management objectives of each division are similar, differences exist in the types of water management projects and responsibilities in the division and district offices. Many districts operate independently, according to established operating procedures, with varying degrees of division oversight.

8.1.1.4. In addition to the duties described in ER 1110-2-240, Water Control Management, and ER 1110-2-1400, examples of other functions are listed in Section 8.1.2. Three division offices, Northwestern Division (NWD)-Portland, NWD-Omaha, and Great Lakes and Ohio River Division (LRD), have direct reservoir regulation responsibility for mainstem projects within the respective geographic regions.

8.1.2. Functions.

8.1.2.1. Water management decisions are made by the Corps each day throughout the nation during normal and extreme hydrometeorological conditions. The number and difficulty of these decisions may vastly increase during flood and drought events, and most of them are made at the district level. Some division offices make real-time water management decisions for major projects. Some examples of principal functions required for real-time water management are:

1. Hydrometeorological data collection and processing.

2. Hydrologic, hydraulic, and reservoir modeling.

3. Inter- and intra-agency data exchange.

4. Water management decision making.

5. Instructions to project operators.

6. Reporting to higher authority.

7. Monitoring project effectiveness and preserving project integrity.

8.1.2.2. The real-time functions stated above are generalized and encompass many tasks, such as: information exchange, hydrologic and hydraulic forecasting, water data system management, application of computer models, briefings, and release scheduling.

8.1.2.3. Additional support activities, such as O&M of instrumentation and communication facilities in the office and in the field are also required. Routine activities include formulation of water control plans and "Standing Instructions to Project Operator," compilation or updating of water control manuals, development and adaptation of numerical models, database management, data archival, and the establishment of discharge ratings for streams and structures. A significant amount of work in the form of annual and post-flood reports is also required. ER 1110-2-1400, Reservoir/Water Control Centers, provides additional guidance on water management offices' roles and responsibilities.

8.1.3. Staffing. Water management staff in divisions and districts may include civil (hydraulic) engineers, meteorologists, environmental engineers, and hydrologic and civil engineering technicians. In addition, hydrologists, agricultural engineers, biologists, chemists, physical scientists, computer technicians, and mathematicians contribute significantly to water management in several offices. Key field personnel may also include streamgaging technicians, dam tenders, hydroelectric power plant superintendents, pumping plant operators, other water management structure operators, and park rangers. The responsibilities of water management staff are highly diversified, and much of the work leverages computer use from basic data collection to modeling water resource systems for multiple water management objectives. Most district and division water management elements use computer systems dedicated to water management activities. Responsibility for computer systems hardware and software is shared between the district, division, HEC, and the support organization that has immediate control over Corps hardware and software installation (currently ACE-IT). For more information on computer systems see Chapter 5 of this EM.

8.1.4. Role of Project Operator. Physical operation of water management structures for which the Corps has management responsibility is provided by the districts' operations divisions of the Corps, owners of non-Corps Federal projects, other Federal agencies, or by local interests. Project operators, which include dam tenders, power plant superintendents, lock masters, resource managers, and others, are furnished standing instructions for water management by the water management office. Section 9.4 discusses the information to include in the instructions. The hydraulic and hydrologic aspects of any operation plan in O&M manuals and similar documents are typically limited to the physical operation of structures, such as the manipulation of gates, placement or removal of stoplogs, and operation of pumps. Except for very small water management projects where little chance exists for mishap by incorrect operation, project operators are also furnished oral instruction and general information on a real-time basis by water managers. Clear and direct lines of communication and authority should be established between the water manager and the project operator. No delay in the communication between the water manager and the project operator should occur. Communication should be made directly with the project operator to best achieve water management objectives in a timely manner without confusion and error. In cases where direct lines of communication are lost, the "Standing Instructions to Project Operator" should be used until communications are restored.

8.1.5. Training.

8.1.5.1. Corps water management staff must be familiar with current technical procedures and computer programs. Although most colleges and universities offer training in the general disciplines involved in water management, regular programs at these institutions do not generally provide formal training focused on specific aspects of water management in the Corps. Many offices rely on mentoring by senior water managers to train new employees in water management.

8.1.5.2. Training directly related to the kinds of problems and situations involved in water management is available through selected short-term courses offered by the Proponent Sponsored Engineer Corps Training (PROSPECT) program of the Corps. In addition, workshops on these and other subject areas are conducted periodically by HEC, ERDC, and other Corps offices and organizations. Table-top exercises simulating potential operational scenarios are useful training tools as well.

8.2. Briefing Room Facilities.

8.2.1. General. Water management briefings may be held in division, district, or local area offices. Briefing facilities range from work areas equipped with whiteboards, static displays, and desktop computers, to specially designed briefing rooms equipped with a computer driven video projector, teleconferencing capability, and high speed internet connectivity to facilitate web meetings or live video teleconferences. Water management briefings are conducted daily or weekly in some offices, and only during floods or emergencies in others.

8.2.2. Purpose. A briefing room provides a setting to exchange information on field conditions and water management activities. Water management office staff should have priority use of the briefing room. A briefing room may be developed as an adjunct to a water management office to display data related to water management activities, to conduct briefings of current and forecasted conditions, and to present current and planned project regulation details. The facility should benefit not only water management office staff, but also other offices and agencies that depend on or are affected by water management decisions. The facility may be needed to brief the general public via the news media. During an emergency as described in Section 7.6, the briefing room may serve as a command center to direct not only water management functions, but also urgent related activities.

8.2.3. Design. A briefing room is planned and designed to be used for exchanging information and informing others of current and forecasted conditions and water management activities on a regular and systematic basis. The facility should provide for the display of visual aids to support description of water management problems, activities, and decisions. The scope and breadth of water management office activities, including an analysis of appropriate space to accommodate command personnel, office staff, and guests, should be a prime consideration in the design of a briefing room. The design should provide for adequate privacy, lighting, wiring, and display space. Additional features should include teleconferencing and web meeting capabilities.

Mobility of furniture and adaptability to the incorporation of new technologies are other design considerations. Experts should be consulted, as necessary, to achieve an effective design. All seating should be designed to provide clear lines of sight to information displays, and audio equipment should be considered, if necessary, to permit good sound quality throughout the briefing room and voice communication with others in remote locations. The primary video display should be the focal point in the briefing room. Space should be available to accommodate a projection screen, a large whiteboard, and maps or other printed figures.

8.2.4. Utilization.

8.2.4.1. The briefing room should accommodate water management office staff and others for water management-related meetings and briefings. Water management staff members are responsible for conducting the meetings, but support may be provided by other groups such as a NWS River Forecast Center (RFC) or hydraulic engineers who are specialists in hydrologic engineering, hydroelectric power, water quality, or other fields of water engineering. The briefings may be attended or remotely monitored by other Corps offices or by personnel from other agencies. These persons may also need to contribute to the discussions.

8.2.4.2. The frequency of briefings and attendance by staff members of a water management office and others depends on the scope of the water management activities, current conditions, and forecasted conditions.

8.2.4.3. Water management briefings are conducted under the supervision of the chief of the water management office or designee. For example, a briefing agenda may include:

1. Summary of current meteorological conditions and weather forecasts.

2. Summary of unregulated (natural) streamflow forecasts.

3. Summary of system reservoir regulation requirements for flood risk management, hydroelectric power generation, irrigation, navigation, fish and wildlife, recreation, or other functional uses.

4. Description of reservoir regulation and individual schedules of project operation in downstream order within the system.

5. Summary of outlook of water management conditions expected in the ensuing weeks or months.

6. Questions and discussions among participants.

The purpose of the briefings is to inform those not directly involved in the scheduling process of conditions and the rationale of current operations. The briefings provide a means to critically review current operations to ensure that the regulation is performed according to operating plans, and to achieve general coordination of water management activities. Specific input obtained from the briefings may guide future operations.

8.3. Administration of Water Management Data Collection Agreements.

8.3.1. Cooperative Data Collection. The Corps performs or supports the collection of most water data it uses. The USGS, NWS, and other agencies, through cooperative arrangements, provide services to the Corps to install, operate, and maintain the instrumentation for essential water data stations. The USGS/Corps Cooperative Stream Gaging Program (stage and discharge) and the NWS/Corps Cooperative Reporting Network (stream stage and precipitation) were established specifically to enable these agencies to assist the Corps. Arrangements to share the cost at stations are also made to best meet the needs and constraints of each organization. Arrangements may also be made with the USGS to measure streamflow or to process the data, including both collection (measurement and transmission) and handling (processing, archiving, and publication). Contractual arrangements for water data collection may be made by the districts, and the draft agreements are submitted to the divisions for review and approval.

8.3.2. Water Quality Data Collection. A significant amount of water quality data is obtained by contract for the Corps. The contracts may apply to physical, chemical, or biological parameters in water and sediments and may consist of everything from field survey to interpretative reports. All contract water quality data should meet the quality assurance/quality control criteria outlined in ER 1110-2-8154, Water Quality and Environmental Management for Corps Civil Works Projects.

8.4. Interagency Coordination and Agreements.

8.4.1. Types of Coordinating Groups. The following paragraphs discuss groups that have been formed to establish the working relationships necessary for coordinating water management activities.

8.4.1.1. International Boards, Entities, and Operating Committees. International boards, entities, and operating committees operate according to treaties for development or use of international rivers and waterways. These organizations consist of representatives of the United States and an adjacent country sharing a water body. Such groups may operate at national, regional, or local levels within the country. As such, the groups may be supervisory and meet infrequently to oversee water management operations to ensure compliance with treaty provisions, or they may be working organizations that meet frequently and communicate as necessary to schedule project regulation.

8.4.1.2. National Water Resource Coordinating Groups. National water resource coordinating groups are composed of representatives of Federal agencies at the national headquarters level. These groups coordinate the hydrologic and hydraulic data observation and acquisition programs, weather data acquisition and forecasts, satellite- and ground-based communication systems, radio frequency assignments for hydrologic reporting networks, etc., as needed for management of water systems.

8.4.1.3. Regional River Basin Interagency Committees, Compacts, and Commissions. Regional river basin interagency committees, compacts, and commissions coordinate water management activities within a major river basin or regional area of the country. These organizations consist of representatives of Federal and state government agencies concerned with project planning and construction and management of water resources within the region. The groups may be formed voluntarily, by legislative action, or through river basin compacts. Although the primary concern of these organizations may be related to planning and construction for river basin development, an additional focus may be to improve coordination of water management activities for an existing system. These organizations may have subcommittees that deal with the specific problems of coordinating data and river forecasts and with the technical problems related to multiagency river regulation objectives in general accordance with agency policies and objectives. These organizations are not generally concerned with day-to-day scheduling, but with monthly or seasonal regulation.

8.4.1.4. Operating Committees for Water Use. Operating committees for water use are formed to coordinate project operating input, as established under contractual agreements with cooperating agencies or utilities for coordinated operation of water management facilities. These committees consist of representatives of the water users, utilities, or government agencies (including the Corps) who are parties to the contract. The representatives generally work at the organizational operating level and have technical expertise in the scheduling of water or power to meet the contractual requirements. These committees are informed of current operations on a weekly or monthly basis and provide input to water managers for specific needs. This guidance is coordinated with other project needs to modify project schedules. A supervisory committee may be included to periodically oversee the operating committee activities and to ensure that project authorities and contractual commitments are being met.

8.4.1.5. Working Groups.

8.4.1.5.1. The preceding paragraphs described four formal types of coordinating groups that reflect overarching political, geographic, and functional factors affecting Corps projects, often at the administrative or project management level. A fifth type of group consists primarily of Corps field office personnel and corresponding members in other agencies that may be in frequent contact with each other, by voice or text, to manage water. Such frequent contact may normally occur throughout the year, or may instead occur mostly during periods of flood, drought, or other events requiring close coordination. The Corps members of the group may be field office engineers, forecasters, technicians, or other personnel with hands-on duties. Working groups may be formal or informal, have irregular periods of greater or lesser activity, and may have varying numbers of members over time.

8.4.1.5.2. Formal working relationships may be formed to coordinate and divide responsibilities between Corps water management offices and other Federal agencies, states, counties, cities, tribal groups, local drainage and flood risk management districts, operators of water management projects owned by navigation companies, commercial or industrial organizations, etc., which are affected by river or reservoir regulation. An annual water management meeting is an example of a recommended formal relationship and that can include representatives from national, regional, and local agencies, as applicable, to share information and to address current water management needs and challenges. Another example of a formal relationship is that relationship between the TVA and the Corps, which permits TVA operational control of multipurpose reservoirs during normal (non-flood, non-drought) times, but which cedes operational control to the Corps during flooding and severe water shortages. The hour-by-hour coordination between the Corps and TVA is often accomplished by a working group that includes Corps personnel stationed in different districts or divisions. A third example is a formal relationship with a drainage district that operates a pumping station or other structure according to Corps protocols. A fourth example is an agreement with an entity, such as the U.S. Coast Guard, to provide security for Corps vessels during an authorized flood fight. A final example of a formal relationship is an agreement with a county or municipality to assist in the warning of persons that live downstream of a reservoir in danger of failure. Formal relationships should be pursued as needed to prevent critical operational delays that can risk public safety or have unintended results and diminish public confidence.

8.4.1.5.3. To some extent, an informal relationship is characterized by persons taking the initiative to contact people in other organizations. Quite often the tone or setting of communication is also informal, through voice and text transmissions or meetings in the field. Informal working relationships provide an additional source of information and coordination to support water management decisions and should be pursued and maintained as needed to maximize water management effectiveness, enhance public relations, and engender public confidence. It is essential to establish and maintain informal relationships with applicable Federal, state, and local agencies in advance of flooding or other emergencies to support and coordinate critical water management decisions.

8.4.2. Types of Water Management Agreements. The functions and responsibilities of the above coordinating groups, except informal working relationships, may be formalized by Congressional legislation, by written agreement, or both. The agreements are usually in the form of MOUs signed by the agency heads at the national, regional, or local levels. These agreements, which include such areas as hydroelectric power generation, fish and wildlife resources, and water supply, form the basis for coordination of water management activities by water managers. This type of arrangement may also be made for coordinating the flood risk management and navigation regulation of non-Corps projects that are subject to Section 7 of Flood Control Act of 1944. Even though much freedom may be given to another agency with regard to meeting a desired water management objective, the agreements explicitly state that the Corps is ultimately responsible for the overall achievement of water management objectives, whether complementary or conflicting. Many such agreements exist concerning water management. All such agreements should be reviewed for approval by the appropriate water management center or water management element before completion, and the agreements normally require signature by the Division Commander. The following sections provide three examples.

8.4.2.1. Data Exchange. Agreements are made with Federal or state agencies regarding the exchange of hydrologic and hydraulic data to be used in making forecasts and project regulation in general. These arrangements may be made at the national, regional, or local level. The need for coordination is usually associated with scheduling project regulation. The requirements for coordination of data gathering and exchange and forecasts and/or forecasting activities must be specifically addressed in each river basin. Actions taken to coordinate these activities may range from simple exchange of data between agencies to a coordinated data and forecasting center with joint staff participation.

8.4.2.2. Hydrologic and Hydraulic Forecasting. The NWS is responsible for the forecasting of hydrological and meteorological events, and for disseminating this information to the public. As part of the Corps responsibility for water management, NWS forecasts are often supplemented with Corps internally determined project inflow and local flow forecasts. Also, the Corps may routinely develop separate internal hydraulic and hydrologic forecasts to consult with the NWS, and to support project construction, operation, and navigation.

8.4.2.3. Hydroelectric Power Generation.

8.4.2.3.1. EM 1110-2-1701, Hydropower, discusses the relationship between a Corps project and the Administrator of a regional Power Administration Office of the DOE. Such an agreement is supplementary to a water control plan and manual and may be explicit regarding some aspects of coordination and very general in regard to others. Reasons for the DOE to seek such an agreement are to clarify the DOE role in the use of Corps projects, and to express the DOE objective to maximize hydroelectric power generation. Reasons for the Corps to enter into such an agreement are to clarify the overall Corps responsibility for water management and to limit adverse impacts to other authorized project purposes to the extent permissible.

8.4.2.3.2. In the interest of multipurpose water management, the Corps requires a signed MOU with the licensee for non-Federal hydroelectric power construction at a Corps project, which specifies that the operational procedures and power guide curve be used and be consistent with overall project management objectives and efficient system regulation.

8.4.3. Coordinating with Operating Entities and Other Public and Private Water Use Organizations.

8.4.3.1. General Considerations.

8.4.3.1.1. The Corps seldom works alone in the field of water management. The regulation of a major river system involves many other organizations that have an interest in the daily and seasonal water regulation from an operational or forecasting point of view. The coordination of activities may stem from many years of effort in working with others in the planning, design, and construction phases of project development. In the operational phase, coordination of all phases of project regulation with various interest groups may be needed. Water control plans, particularly regulation schedules and AOPs, are usually developed in concert with other agencies as expressed in contractual arrangements, formal operating agreements, or informal accords to ensure that various multipurpose water use functions are achieved to mutual satisfaction. These basic efforts for coordination extend beyond the planning and design stages into current operations, usually through interagency coordinating groups, operating committees, or working relationships established with individual agencies. Most of these arrangements are not legally required, although some are based on commitments made in the planning and design phases of project development. The water management activities may require coordination on an international, national, regional, or local basis, involving countries adjacent to the borders of the United States as well as Federal agencies, regional or state water or energy authorities, public or private utilities, local water-oriented agencies, or public interest groups.

8.4.3.1.2. Certain water management coordination requirements directly affect project regulation schedules. Examples are coordinated system regulation required under operating agreements for hydroelectric power generation, water use agreements and commitments set forth in international treaties, and flood risk management and navigation requirements established for projects subject to Section 7 of the Flood Control Act of 1944. These firm commitments, which must be incorporated into project regulation schedules, require coordinated efforts among the operating agencies. This requires exchange of operating data and communication to achieve project regulation that complies with the water control plan. Where several operating agencies are involved, the coordination may be achieved under the authority of an operating committee, the membership of which includes representatives of each of the cooperating entities or under the authority of a single operating agency, by direct communication with that agency.

8.4.3.1.3. Some elements of water management coordination involve agencies that do not own or operate projects, but that represent water interests concerned with project regulation. These may include Federal, state, or local entities involved in environmental protection, fish and wildlife, navigation, irrigation, water supply, recreation, and local boards concerned with land use in the operation of diversion and by-pass facilities. The needs for coordination with these individual entities are usually met by periodic contacts with the water management center or other water management office of the Corps.

8.4.3.1.4. A final element of water management coordination is related to streamflow and river level forecasting. This function may involve a daily exchange of data and associated coordination, such as providing Corps daily and forecasted reservoir outflows to the NWS to improve the estimation of river stages affected by the reservoir releases. Clear coordination and good working relationships are important to create a level of trust and confidence between the interacting agencies, and to produce the best forecasting estimates. The particular requirements and methods for coordinating the water management activities described above with other agencies vary widely from region to region within the United States. The needs and desires for achieving coordination depend on the local conditions. Although no set procedure exists to achieve such water management coordination, annual water management meetings and other interagency cooperative efforts should be considered to share knowledge, which can support the ultimate objective of effective water management.

8.4.3.1.5. Regional or river basin water management coordinating groups may be used to institutionalize coordination of water management activities. As noted previously, coordination may be achieved through voluntarily formed committees or groups, or by an operating committee formed as an adjunct of formal operating agreements to implement the regulation plans involving two or more agencies.

8.4.3.1.6. The water manager should be responsive to all types of river users and have an "open door" policy to local interest groups, as well as to other operating agencies, to consider special requests or to explain operating procedures. Infrequent interactions of this type can be addressed informally on a case-by-case basis. Establishment of formal working relationships should be considered in circumstances that require a continuing need for exchange of data or consideration of special operating requirements.

8.4.3.1.7. In some respects, the needs and desires for interagency coordination are interrelated. The desires for coordination may reflect long-standing working relationships between the organizations, which over a period of time build confidence in and respect between individuals and organizations involved in attaining the water management objectives. However, no prescribed method exists to foster such relationships or to determine the effort required. Inasmuch as many of the procedures are based on voluntary actions between the agencies, the decisions on these matters are based on the initiative and judgment of all parties with the goal to best serve the public interests.

8.4.3.2. Conflicts in Water Use. In formulating operating strategies for water management, conflicts may arise reflecting differing interests of water users. The conflicts may arise in connection with interpretation of operating rules and agreements for carrying out the authorized project functions by user groups (e.g., navigation, power, irrigation, or flood risk management interests), or they may arise in areas related to the achievement of environmental or social goals in conjunction with the economic and authorized regulation requirements. These conflicts may encompass local or regional problems that have major impacts on various and diverse segments of society with regard to social and economic well-being and perceptions of the importance of the contested issue(s) to the public good. Although many of these types of problems are resolved in the planning and design phases of project development, other problems of water utilization often arise in the operational phase. Furthermore, changes in public attitudes may occur with regard to water management procedures, and these changed attitudes should be taken into account in project regulation. The conflicts may involve a wide range of impacts, varying from minor effects in formulating regulation schedules to accommodate a limited water use requirement, to major effects on regional power supplies and employment, fishery resources, flood regulation, environmental impacts, or other impacts related to water use. These issues may be considered to the extent the currently authorized water control plan permits, or to the extent that a deviation or revision to the water control plan may be pursued as described in ER 1110-2-240.

8.4.3.3. Efforts to Resolve Conflicts through Coordination. Efforts to resolve conflicts in water management are initiated at the working level through coordinated operation described in the preceding sections. Initially, a thorough exchange of data and information is required pertaining to the current operation, together with an explanation of the scheduling requirements between the operating office and the individual water user groups who have an interest in the project's functional use. These discussions often clarify operating requirements and interpretations of project regulation schedules and serve as a basis for a better understanding of the overall requirements for multipurpose regulation. From these discussions, relatively minor conflicts may be resolved by negotiation to adjust project schedules and accommodate special requirements without significantly jeopardizing other water use functions. Recording the resolution of such conflicts should be considered through an MOU or similar document.

8.4.3.4. Public Meetings. Communication with the general public should follow the public involvement process outlined in ER 1110-2-240, Water Control Management. The purposes of the meetings are to inform local interest groups and the general public about issues related to the water management and river regulation activities in the project area, to exchange views on the impacts of alternative methods of regulation, and to seek input that could be considered in formulating operating decisions. The content of public meetings could include the effects of the operating decisions on the general public, with particular emphasis on public use functions such as fishing, boating, recreation, and aesthetics, combined with the effects on the local economy, employment, safety, environment, and general well-being of the people.

8.4.3.5. Involvement with Elected Public Officials. Elected public officials, particularly congressional representatives and governors, should be informed in cases where water management decisions may be of significant interest to their constituencies, and the Corps should be responsive to public concerns. Informal contacts by the District or Division Commanders can alert these public officials to potential problems that may have political significance.

8.5. Water Management Reports on Prevailing Conditions.

8.5.1. General. Much of project and real-time water data are stored in a data system, as discussed in Chapter 5. The data are used to regulate projects and to prepare reports. The following sections describe reports prepared from real-time water data to assist in water management decisions.

8.5.2. Project Operator Reports. In addition to reporting water management actions, dam tenders often monitor water data, as specified in the "Standing Instructions to Project Operator" (see Section 9.4), and furnish the data directly to the appropriate water management element in the district or division. The requirements for monitoring and reporting are usually more intensive during flood and drought events; reference ER 1110-2-8156, Preparation of Water Control Manuals.

8.5.3. Water Management Morning Reports. Water management morning reports are used to evaluate watershed and project conditions and are the principal means of informing in-house staff that have a need to know prevailing conditions. These daily reports are generated from project and hydrometeorological data that have been entered into a database management system in a water management office. The information in the reports may include observed water data, hydrologic and hydraulic forecasts, release schedules, power generation schedules, and other relevant information such as inflows and current constraints.

8.5.4. Special Advisories.

8.5.4.1. Potential and actual emergencies of any nature that have a significant impact on water management decisions associated with Corps projects should be reported immediately by telephone or other designated form of communication to the appropriate division water management element who will then notify CECW-CE. If the district deems the information to be critical, the report can go directly to CECW-CE and be copied to division. Chapter 7 of ER 500-1-1, Civil Emergency Management Program, describes the circumstances in which such a project information report that is compiled by the district RCO is required. The RCO role is to pass information between Planning and Policy Division at HQ (CECW-P) and the district. An example of a special advisory is a project information report related to an imminent threat of unusual flooding that is forwarded by the district through the division to CECW-P. Examples of other special advisories are:

1. Severe weather warnings.

2. High runoff potential advisories.

3. Flash flood warnings.

4. Emergency condition alerts concerning the quantity of streamflow, water quality, and ecology.

5. A report of an unsafe condition connected with water management that could impact streamflow conditions or the integrity of a water management structure, considering both Corps and non-Corps projects.

8.5.4.2. These advisories are required to keep the division commander and the Chief of Engineers apprised of critical events. Reports made by telephone are followed immediately by a concise narrative summary (special advisory) of the event. The follow-up advisories are reported by the most rapid means available, often by emails and briefings. ENGLink is the recommended form of communication because it is a good command and control tool that helps eliminate multiple emails on the same subject.

8.5.5. Discharge Data. During flood events, discharge measurements at critical sites should be made and preliminary results should be promptly reported to the water management office to support real-time water management decisions. Any adjustments of the preliminary discharge results should be immediately provided to the water management office. Discharge measurements are often made by the Corps, the USGS, and state offices.

8.5.6. Flood Damages. On request, the districts provide flood damage estimates of designated areas, potential and actual, to the division water management elements during prevailing flood events. Complementary maps depicting areas of inundation and land use may accompany the basic data and may be furnished as computer graphics. These reports are prepared according to ER 500-1-1.

8.5.7. Reports for the Media, Local Entities, and the Public.

8.5.7.1. Water data at projects and at control points on streams are furnished to the news media, local entities, and the public. Automated reports may be made available to the public and disseminated via district and division Internet web pages in bulletin or plot format. These reports may include observed water data, hydrologic and hydraulic forecasts, release schedules, and power generation schedules.

8.5.7.2. Caution should be exercised to avoid furnishing river stage forecast information to the press or organized interest groups since dissemination of official river stage and discharge forecasts is the authorized responsibility of the NWS. ER 1110-2-240 gives further information regarding communicating river forecast information to the public, and working with the NWS.

8.6. Documents, Reports, and Records. Standard types of water management documents and reports are prepared to guide regulation of water resources projects, to support administration at the division and HQUSACE levels, and to provide a permanent record of project and control point conditions.

8.6.1. Water Management Documents. ER 1110-2-8156, Preparation of Water Control Manuals, states the basic requirement for preparation of water management documents. The contents of these documents, which are discussed in Chapter 9, consist of:

1. Standing instructions to project operators.

2. Water control plans.

3. Water control manuals (for individual projects and for water resources systems).

8.6.2. Annual Operating Plans and Other River Basin Committee Reports. AOPs and other river basin committee reports commonly address the achievement of water management objectives during the previous year and the operating plan for the current year for certain project purposes of interagency (joint) interest. AOPs are based on long-term runoff projections. Navigation, hydroelectric power generation, flood risk management, and water supply are the primary project purposes reflected in these reports.

8.6.3. Annual Water Management Reports. Annual water management reports are prepared by the districts, consolidated for the division by water management elements, and submitted to CECW-CE. The reports include project accomplishments, flood risk management activities, and status of water management documents, with a schedule for preparation and revision. The report is required by ER 1110-2-240.

8.6.4. Annual Report on the Cooperative Stream Gaging Program. The annual report on the Cooperative Stream Gaging Program concerns the funding of water data collection (stage and discharge) provided to the Corps by the USGS. ER 1110-2-1455, Cooperative Stream Gaging Program, discusses this activity and the report in further detail.

8.6.5. Annual Billing for the Cooperative Reporting Network. The annual billing transaction for the cooperative reporting network consists of a reverse billing procedure between CECW-CE and the districts to fund water data collection provided to the Corps by the USGS and the NWS.

8.6.6. Annual Budget Request. Construction funding is the preferred funding source for the required preliminary and final water management documents related to new Corps projects. O&M funding is normally used to revise and update water management documents. Water managers in the districts prepare budget requests 2 years in advance for water management activities. The requests are prepared in the March through June timeframe according to annual budget guidance provided by Programs Division, Directorate of Civil Works.

8.6.7. Summary of Runoff Potential. Seasonal reports on hydrometeorological conditions include the outlook for floods resulting from snow accumulation and for droughts, with supplemental reports as the situation progresses. These reports help inform the chain of command and support organizations on potential issues and reservoir operations.

8.6.8. Post Flood Reports. Water managers contribute significantly to the preparation of post flood reports (see ER 500-1-1). Project regulation effects, including evaluation of stage reductions at key stations and estimates of damages prevented by projects, are determined and included in the report. These are historic documents; water managers should invest sufficient resources to properly document the flood event. Funding for this documentation should be acquired from Flood Control and Coastal Emergencies (FCCE) funds to the extent available and then from O&M funds.

8.6.9. Water Data Records. Records of stage, discharge, water quality parameters, and other information that define water management events are compiled and stored using various media, including the use of national paper archives and on the Internet using websites hosted by the Corps, U.S. Environmental Protection Agency (USEPA), USGS, NWS, and other entities.

8.6.10. Federal Register.

8.6.10.1. A list of Corps and non-Corps projects authorized by Federal laws and directives is published in Part 222.7, Title 33 of the CFR. The list is maintained by CECW-CE with input from the division and district offices. ER 1110-2-240 details related policy.

8.6.10.2. Section 7 of the Flood Control Act of 1944 requires the Corps to prescribe regulations for the use of storage allocated for flood risk management, or for navigation at all reservoirs constructed wholly or in part with Federal funds provided on the basis of such purposes. (TVA projects are special cases.) Part 208.10 applies to small (<12,500 acre-feet) local flood risk management projects that are turned over to local interests for physical O&M after completion. The requirements in Part 208.10 address O&M, but do not address the regulation of water management projects. When appropriate, documents entitled “Standing Instructions to Project Operator” are prepared by water managers and furnished to local project operators. Part 208.11 applies to all other projects subject to Section 7 that are not included under Part 208.10. The Corps prepares water control manuals for projects listed under Part 208.11, including water control plans and standing instructions.

8.6.11. Annual Report on Project Benefits. Monetary benefits are determined annually for project purposes that produce tangible benefits. The economics team collaborates with engineering and operations personnel to routinely compute the benefits attributable to flood risk management, navigation, hydroelectric power generation, water supply, and recreation. The information is then provided to HQUSACE for preparation of the Annual Report of the Chief of Engineers, Civil Works Activities. When appropriate, benefits are also determined for water quality and fish and wildlife enhancement, streambank and beach erosion control, and restoration of the environment (e.g., terrestrial, wetlands, and aquatic plant control). An annual flood damage report, which includes damages prevented and damages incurred in each state, is prepared by CECW-CE with significant input from partner agencies. The report is submitted to Congress according to House Committee Report 98-217, Energy and Water Appropriations Act, 1984.

8.6.12. Annual Water Quality Report. A water quality report should be prepared annually by each division and submitted to CECW-CE to ensure that adequate information on Corps water quality management activities is available to HQUSACE, division and district water management elements, and other interested parties. The report should summarize the water quality management program for the past fiscal year and highlight specific project information, planned activities, and other pertinent information, issues, and proposed solutions. ER 1110-2-8154 contains guidance on this report.

8.6.13. Periodic Inspections and Reports. Water managers should participate in annual and periodic inspections, periodic assessments, operational condition assessments, and review prepared reports for each project to avoid problems that might impact project regulation. The inspections should include gage verification and redundancy to assure stakeholders of properly functioning streamgages. A periodic inspection is held every 5 years. A periodic assessment includes a semi-quantitative risk assessment that supplements every other period inspection (every 10 years) and a Potential Failure Mode Analysis (PFMA) and evaluation of downstream consequences. The periodic assessment essentially confirms or reassigns a project’s DSAC.

# CHAPTER 9

## Preparation of Water Management Documents

9.1. Basic Documents.

9.1.1. Types of Documents. The basic water management documents for projects or systems of projects include:

1. Water control manuals.

2. Water control plans.

3. Standing instructions to project operators.

4. Initial reservoir filling plans.

9.1.2. Types of Projects.

9.1.2.1. Table 9-1 defines and categorizes all water management projects according to size and complexity to identify the appropriate amount of documentation needed. These projects may include culverts, floodwalls, weirs, lakes and reservoirs, locks and dams, controlled channels and floodways, gated saltwater and hurricane barriers, backwater projects, and large pumping plants. Table 9-1 also lists the categories of projects and the associated characteristics and structure types.

9.1.2.2. The level of documentation needed for water management projects has been scaled to match the types of projects listed in the above table. Type I projects should seldom need any water management documentation due to the simplicity of these projects. Any documentation should be provided by the engineering group within a district or division for inclusion in an O&M manual or Emergency Action Plan. To clearly distinguish water management objectives and requirements from physical operation procedures, only Type I projects include water management documentation in O&M manuals. Water management documentation for Types II, III, and IV projects are discussed in the following sections.

9.2. Water Control Manuals.

9.2.1. Project Water Control Manuals.

9.2.1.1. Purposes. Water control manuals are typically prepared for only Type III and IV projects. The main purposes of the manuals are to document the water control plan and to provide a reference source on project issues, authorities, data, schedules, and all other information necessary to regulate a project. A manual is generally prepared for a project within 1 year after the project is placed in operation. The primary reason for preparing a separate manual or an appendix to a master manual for a water management project is to facilitate the use of specific information such as instructions, plates, tables, diagrams, and charts; and to execute the water control plan.

Table 9-1. Categories and Characteristics of Water Management Projects.

| Project Type | Description | Examples | Water Management Documentation |
|---|---|---|---|
| Type I | • Small structures<br>• Operation by opening and closing water passageways<br>• Engineering provides water management requirements<br>• Operations division operates and collects data | • Culverts<br>• Floodwalls<br>• Uncontrolled Weirs<br>• Pumping stations<br>• Gated structures<br>• Fuseplugs | • Not required |
| Type II | • Small structures<br>• Operation by opening and closing gates or pumping<br>• Operation dependent on hydrometeorological conditions<br>• Operation limited to fully opened or fully closed positions | • Culverts<br>• Pumping stations<br>• Gated structures | • Standing Instructions to Dam Tender |
| Type III | • More complex structures<br>• Timely reporting of project conditions important<br>• Water managers responsible to monitor project | • Reregulating structures<br>• Locks and dams<br>• Completely uncontrolled projects | • Water Control Plan<br>• Water Control Manual when part of a system<br>• Standing Instructions to Dam Tender |
| Type IV | • Major structures<br>• Require complex water management procedures<br>• Usually require attendants during unusual hydrometeorological conditions | • Reservoirs<br>• Lakes<br>• Major diversion structures<br>• Pumping stations<br>• Floodways | • Water Control Plan<br>• Water Control Manual<br>• Standing Instructions to Dam Tender<br>• Initial Reservoir Filling Plan |

9.2.1.2. Contents. ER 1110-2-8156, Preparation of Water Control Manuals, contains the preparation requirements for water control manuals. A manual should contain information to assist water management regulation, and should consider all foreseeable conditions that may affect a project or system. All chapters and exhibits in a water control manual should focus on providing a full understanding of the project and water control plan. The water control manual should include descriptions of structures and water management conditions that constitute an integral part of a project such as reregulation, pumpback, or diversion facilities. The water control plan for a separate neighboring project within the same system should be presented in a separate manual. The scope of certain chapters or topics in water control manuals for individual projects may be less extensive for those projects within basins or systems for which water control master manuals are either available or planned for the near future. For example, consider a water control master manual that documents operation of a system of locks and dams with respect to forecasted flows. The water control manual for one of the locks may refer to the master manual for operation based on forecasted flows in lieu of presenting an unnecessary duplication of the information contained in the master manual.

9.2.2. Water Control Master Manuals.

9.2.2.1. Purpose. Similar to project water control manuals, water control master manuals are prepared to document the overall system water control plan to facilitate regulation. A master manual should be prepared when the scope and complexity of a system of interrelated projects are significant. Aspects to consider whether preparation of a master manual is necessary are whether the reservoir operations are based on system criteria, general hydrometeorology, network data collection, common forecasting points, complexity and objectives of the system water control plan, and management responsibilities shared by multiple districts, divisions, or other requirements. For example, a system of reservoirs with a common control point could have a water control master manual.

9.2.2.2. Contents. ER 1110-2-8156 contains the preparation requirements for water control manuals, including master manuals. Appropriate cross-referencing between a master manual and appendixes (individual project manuals or plans, as required) can serve to reduce the duplication of information regarding specific subjects. All charts, graphs, diagrams, and other items pertaining to individual projects should be presented in the individual project manuals as appendixes to the master manual.

9.2.3. Revisions. ER 1110-2-240, Water Control Management, provides guidance on update intervals for water control plans and water control manuals. As a minimum, Chapter 7 of the water control manual should be updated following any change to the water control plan. Complete updates should be made at regular intervals to incorporate additional hydrologic data as well as any other new information.

9.3. Water Control Plans.

9.3.1. General. The water control plan guides water release decisions for a project. As outlined in ER 1110-2-8156, the water control plan is contained in Chapter 7 of the water control manual. An interim water control plan is required for the construction phase of a project; a preliminary water control plan is required once full-scale operations begin and before the approved water control plan is authorized; and an approved water control plan is required within 1 year after operation begins. If operations are desired outside the flexibility the plan provides then a deviation may be requested.

9.3.2. Interim Water Control Plan during Construction. To ensure that water resource projects perform safely and effectively during construction or modification, an interim water control plan is required for Type III and IV projects before the alteration of the watercourse or when the construction site becomes subject to flood damage. Interim water control plans remain in force until the project is formally accepted for full-scale normal operation under the preliminary water control plan. The interim plan should include, but is not limited to:

1. A description of hydraulic features provided to protect the project during each phase of construction, including compliance with ER 1110-2-8152, Planning and Design of Temporary Cofferdams and Braced Excavation.

2. A plan for water control management during each phase of construction with references to the maps and plates and identification of all water data collection stations, measured parameters, and data transmission modes, and an explanation of the method used and time needed to forecast streamflow at the construction site during a flood event.

3. Identification of any special conditions during construction that may cause operational constraints.

4. A description of the impacts of overtopping cofferdams, diversion dikes, or embankments at the project site, of flooding borrow areas, and of high stages and high streamflow velocities not associated with overtopping.

5. Safety precautions and appropriate warning systems for potential hazards to upstream and downstream properties or residents, and plans for minimizing the adverse effects associated with partially completed relocations or incomplete flowage rights.

6. Map(s) showing each construction phase, and plan views and cross-sections of diversion dikes.

7. Discharge rating, stage duration, and flow frequency curves for natural and modified conditions, and degree of flood risk management provided during each construction phase (discharge, stage, and freeboard).

8. Instructions to protect operators during the physical operation of completed or partially completed water control features of the project for interim regulation and for acceptance testing.

9.3.3. Preliminary Water Control Plans. The preliminary water control plan should be prepared to provide an initial plan of regulation before preparation of an approved water control plan (see ER 1110-2-240, Water Control Management). A preliminary water control plan, pertinent data, filling schedule for storage projects, and standing instructions to project operators are required at least 60 days before completion of construction. The preliminary water control plan should be prepared using the outline and format detailed in Exhibit A for Type III projects or in ER 1110-2-8156 for Type IV projects or Type III projects that are part of a water resource system. The preliminary water control plan should explain the relationship to any neighboring water resource projects, and the plans for storage projects should always include drawdown requirements. Sufficient tables and graphs should be included to support understanding of the preliminary plan.

9.3.4. Interim Risk Reduction Measure Water Control Plans. Any changes to an approved water control plan related to IRRMs must follow the guidance outlined in ER 1110-2-1156, Safety of Dams – Policy and Procedures.

9.3.5. Initial Reservoir Filling Plans. The initial reservoir filling plan should include the interim and preliminary water control plans and should cover the broad needs of project operation during the construction and initial filling phases.

9.3.5.1. New Corps Reservoir Projects.

9.3.5.1.1. A design memorandum on initial filling plans must be developed during early construction stages for all new reservoir projects. As a minimum, the report should address the following:

1. Interim water control plan.

2. Preliminary water control plan.

3. Project surveillance.

4. Cultural site surveillance.

5. Flood emergency plan.

6. Public affairs.

7. Safety plan.

8. Transportation and communications.

9.3.5.2. Existing Corps Reservoir Projects. At existing Corps projects that have exceeded the top of the flood pool, reviews should be made to verify compliance with requirements outlined in Section 9.3.5.1. For projects with undocumented contingency plans that have a potential danger from filling or impounded storage, a report should be developed outlining the contingency plans. The document may be titled "Emergency Action Plan," provided that revised initial filling requirements are determined to have minimal potential impacts on the safety of the structure. However, such a determination does not preclude the emergency action plan from citing appropriate references to water control plans, project surveillance, cultural site surveillance, safety plan, transportation, communications, etc. A review should be made of reservoirs that have been filled or nearly filled to determine any problems that occurred during the initial filling stage. A filling plan should be developed for any reservoir that exhibited a problem during initial filling that would likely recur during subsequent fillings.

9.3.5.3. Interim Risk Reduction Measure Pool Restriction Removed. An initial filling plan may also be required after an IRRM reservoir pool restriction is removed. This plan could designate filling targets that pause at an intermediate elevation to assess the project's structural integrity and to evaluate instrument readings. A good communication plan among the different elements at the district, division, and HQ levels (i.e., water management, dam safety, environmental, office of counsel, and public affairs) is extremely important in successfully refilling a reservoir. Automated real-time data collection benefits a filling operation by allowing conditions to be monitored continuously. One difference between a refill and an initial fill could be the significant volume of water already in the reservoir at the time when an IRRM restriction is lifted; there would be much lower incremental increases of total hydrostatic pressure on the structure as the reservoir fills during a refill than as the reservoir fills during an initial fill for a new project.

9.3.6. Approved Water Control Plans.

9.3.6.1. A final approved water control plan for Type III projects or a water control manual in final form for a Type III or IV project, as appropriate, should be prepared within 1 year after the project is placed in operation. The water control plan should be prepared using the outline in Exhibit A for Type III projects, or in ER 1110-2-8156 for Type IV or Type III projects that are part of a water resource system.

9.3.6.2. The initial water control plan and subsequent updates should be developed in close coordination with other agencies, such as local county emergency managers, city representatives, recreational interests, and applicable state departments. Development of the water control plan must also have a public involvement process. Appendix B to this manual contains partial lists of Federal Water Resources Management Laws. The developed plan must be reviewed by the appropriate division and headquarters offices before submission to the division commander or designee for review and approval.

9.3.6.3. IRRMs that require modifications to the Water Control Plan should follow the process outlined in ER 1110-2-1156, Safety of Dams – Policy and Procedures.

9.3.6.4. A deviation request from the approved water control plan must be submitted to the division commander or delegated party per ER 1110-2-240 for review and approval. If deviations are required because of permanent situations, the water control plan should be modified to reflect the necessary change.

9.3.7. Revisions. See Section 9.2.3 for information on revising water control plans.

9.4. Standing Instructions to Project Operators for Water Management.

9.4.1. General.

9.4.1.1. Standing instructions to project operators for water management are essential to ensure efficient and safe operation of the project at all times. The instructions apply to dam tenders, power plant superintendents, lock masters, resource managers, etc. Any physical operating constraints should be clearly outlined to ensure that water control features are operated in a safe manner and within design limitations during all phases of project life, including the construction phase. Particular care should be exercised during initial acceptance testing of the project's regulating features. The standing instructions must be kept distinct and separate from O&M manuals and are required for all Type II, III, and IV projects. However, the instructions should be referenced within O&M manuals and water control manuals, as appropriate.

9.4.1.2. The instructions and project release orders guide the regulation of projects for water management. Therefore, the hydraulic and hydrologic aspects of any operation plans in O&M manuals and similar documents must be limited to the physical operation of structures, such as the manipulation of gates, placement or removal of stoplogs, operation of pumps, etc. Thus, the operation plans will apply to physical operation and not to water management.

9.4.2. Format. Exhibit B provides an example of the format and summarizes the information to be included in standing instructions to project operators.

9.5. Related Water Control Documents.

9.5.1. Deviation Requests. Occasions may occur that require a deviation from the water control plan. ER 1110-2-240, Water Control Management, covers the process for deviating from an approved water control plan.

9.5.2. Situation Reports. Situation reports may be prepared and submitted to the district management on a regular schedule or as events warrant the need to provide information regarding current watershed conditions and pending water management operations. A situation report detailing conditions and potential flood damage locations should be provided to the RCO office once a threat of major flooding is identified.

9.5.3. After Action Reports. After action reports should normally be prepared after major weather events that result in extreme periods of low water drought, high reservoir pool levels, high river flows downstream of reservoirs or other water management structures, or other significant flooding. The after action reports should document the meteorological and hydrologic conditions leading up to the event and all reservoir and structural operations related to the weather event. After action reports are normally coordinated by the RCO office.

9.5.4. Drought Contingency Plans. A drought contingency plan should provide a basic reference for water management decisions and responses to water shortage induced by a climatological drought. The drought contingency plan may address the operation of a single isolated reservoir or other water management structure or a system of reservoirs or structures. As a water management document, the plan should be limited to drought concerns related to water management actions. Additional information on drought contingency plans is provided in ER 1110-2-1941, Drought Contingency Plans.

9.5.5. Cultural Resources Documents. Developing guidance to address water control effects is essential to meet legal requirements and cultural resources objectives. All Corps activities should develop guidance related to the evaluation and protection of cultural resources at the district level, in collaboration with district cultural resources professionals following objectives outlined in the District Cultural Resources Management Plan. Guidance should address issues such as inadvertent discoveries (including human remains) in compliance with the Native American Graves Protection and Repatriation Act (NAGPRA); site protection and mitigation for ongoing impacts according to the National Historic Preservation Act (NHPA); and required consultation with Indian Tribes (Executive Order [EO] 13175), State Historic Preservation Offices, other affected agencies, and the public (36CFR800.2); and the potential of looting and theft as a result of erosion caused by water management operations and the Archaeological Resource Protection Act (ARPA).

9.5.6. Federal Register. Changes or proposed changes in the rules or policies relating to the regulation of Corps reservoirs may be published in the Federal Register for public notice.

9.6. Coordination of Water Management Documents.

9.6.1. Responsibility. MSC Commanders, who normally delegate this responsibility to the division water management office, are responsible for approving water control plans and related manuals. See ER 1110-2-240.

9.6.2. Coordination. All water management documents should be prepared by or under the direction of water managers within the districts or divisions. All documents must be coordinated within the district and/or division offices and, when appropriate, with local, state, and Federal agencies. Water managers must maintain a close contact with water management divisions throughout the development and revisions of all water management documents. Meetings with all entities involved may be appropriate throughout the development and updates of these documents. Preliminary documents should be reviewed by cooperators, project personnel, and any other agencies that are affected by the project operation before the technical review.

9.6.3. Agreements. All interagency water management agreements proposed by a district must be submitted to the division office or appropriate water management element and office of counsel for review. Some examples are: MOUs, field working agreements, power and water supply contracts, biological opinions, compacts, etc. All agreements should be reviewed on a regular basis to ensure that current requirements are addressed and that the documents are still valid.

9.6.4. Review. On completion of a draft water management document, the review process should begin following the requirements of EC 1165-2-217, Civil Works Project Reviews (or successor document). Additionally, the following general policy guidance is suggested:

9.6.4.1. The National Programmatic Review Plan for Routine Operations and Maintenance Products, reference 1.d, is applicable to all routine O&M products that only require District Quality Control (DQC). At a minimum, all routine O&M products require DQC review. The Programmatic Review Plan is applicable to revisions to Water Control Manuals that are administrative or informational in nature, that do not change the water control plan, and that do not require public meetings in accordance with ER 1110-2-240.

9.6.4.2. Each update must be evaluated against EC 1165-2-217 (or successor document), to determine whether an Agency Technical Review (ATR) and/or an Independent External Peer Review (IEPR) is required. Water Control Manual Updates that include changes to the operation of the project or revisions to Chapter 7 of the manual must have a separate individual review plan prepared and submitted for approval, and will undergo ATR as a minimum.

9.6.4.3. Updates to Water Control Manuals would generally be categorized as "other work products" in EC 1165-2-217 (or successor document). Authorities for allocation of storage and regulation of projects owned and operated by the Corps of Engineers are contained in legislative authorization acts and referenced project documents. These public laws and project documents usually contain provisions for development of water control plans, and appropriate revisions thereto, under the discretionary authority of the Chief of Engineers. Some modifications in project operation are permitted under congressional enactments subsequent to original project authorization.

9.6.4.4. Water control manuals may also be required to undergo IEPR under certain circumstances, based on a risk-informed decision, as described in EC 1165-2-217 (or successor document). A deliberate, risk informed recommendation whether to undertake IEPR on updates to water control manuals which include revisions to Chapter 7 shall be made and documented in an individual project-specific review plan. Depending on the scope and nature of the changes, some revisions to Chapter 7 of water control manuals may trigger IEPR.

9.6.5. Approval. After all the review requirements for water management documents and related manuals are completed, the finalized documents will be forwarded to the MSC Commander and, if required, to headquarters for approval. The finalized document package will include all signed agreements, review certificates, and any other related documents. On approval, documents will be made available as outlined in ER 1110-2-1400, Reservoir/Water Control Centers.

9.7. Vertical Datum Reference. All new and revised water management documentation should follow the vertical datum policy in ER 1110-2-8160, Policies for Referencing Project Elevation Grades to Nationwide Vertical Datums.

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# APPENDIX A

## References

33 CFR 208.11, Part 208, Flood Control Regulation, Use of Storage Allocated for Flood Control and Navigation Purposes, Published in Federal Register, 47184, 13 October 1978, as amended at 46 FR 58075, 30 November 1981; 55 FR 21508, 24 May 1990; 79 FR 13564, 11 March 2014.

EC 1165-2-216, Policy and Procedural Guidance for Processing Requests to Alter U.S. Army Corps of Engineers Civil Works Projects.

EM 1110-2-1201, Reservoir Water Quality Analysis.

EM 1110-2-1406, Runoff from Snowmelt.

EM 1110-2-1412, Storm Surge Analysis.

EM 1110-2-1413, Hydrologic Analysis of Interior Areas.

EM 1110-2-1417, Flood-Runoff Analysis.

EM 1110-2-1420, Hydrologic Engineering Requirements for Reservoirs.

EM 1110-2-1602, Hydraulic Design of Reservoir Outlet Works.

EM 1110-2-1603, Hydraulic Design of Spillways.

EM 1110-2-1605, Hydraulic Design of Navigation Dams.

EM 1110-2-1611, Layout and Design of Shallow-Draft Waterways.

EM 1110-2-1613, Hydraulic Design of Deep Draft Navigation Projects.

EM 1110-2-1701, Hydropower.

EM 1110-2-4000, Sedimentation Investigations of Rivers and Reservoirs.

EM 1110-8-1(FR), Winter Navigation on Inland Waterways.

EP 1130-2-540, Environmental Stewardship and Maintenance Guidance and Procedures, Change 2.

ER 10-1-53, Roles and Responsibilities, Hydroelectric Design Center.

ER 500-1-1, Civil Emergency Management Program.

ER 1105-2-100, Planning Guidance Notebook.

ER 1110-2-240, Water Control Management.

ER 1110-2-249, Management of Water Control Data Systems.

ER 1110-2-1150, Engineering and Design for Civil Works Projects.

ER 1110-2-1156, Safety of Dams – Policy and Procedures.

ER 1110-2-1400, Reservoir/Water Control Centers.

ER 1110-2-1454, Corps Responsibilities for Non-Federal Hydroelectric Power Development under the Federal Power Act.

ER 1110-2-1455, Cooperative Stream Gaging Program.

ER 1110-2-1941, Drought Contingency Plans.

ER 1110-2-8152, Planning and Design of Temporary Cofferdams and Braced Excavation.

ER 1110-2-8154, Water Quality and Environmental Management for Corps Civil Works Projects.

ER 1110-2-8156, Preparation of Water Control Manuals.

ER 1110-2-8160, Policies for Referencing Project Elevation Grades to Nationwide Vertical Datums.

ER 1110-8-2(FR), Inflow Design Floods for Dams and Reservoirs.

ER 1130-2-540, Environmental Stewardship Operations and Maintenance Policies

ETL 1110-2-584, Design of Hydraulic Steel Structures

# APPENDIX B

## Water Management-Related Legislation

| Name | Key Items |
|---|---|
| Flood Control Act of 1928 (P. L. 70-391) | This Act authorized comprehensive flood control plan for the Mississippi River and tributaries |
| Flood Control Act of 1936 (P.L. 74-738) | Section 1 declares flood control as proper Federal activity, and that improvements for flood control are in the interest of the general welfare. Federal government should improve or participate in the improvement of navigable waters or their tributaries for flood control if the economic benefits exceed the costs (33 USC 701a).<br>Section 2 sets forth the jurisdiction of Federal activities and prescribed among other things, that the Corps Chief of Engineers would have jurisdiction over, and supervision of Federal investigations and improvements of rivers and other waterways for flood control and allied purposes (33 USC 701b).<br>Section 3 requires local interests to: (a) provide without cost to the United States all lands, easements, and rights-of-way necessary for the construction of the project, except as otherwise provided herein; (b) hold and save the United States free from damages due to the construction works; (c) maintain and operate all the works after completion according to regulations prescribed by the Secretary of Army (33 USC 701c). Requirement (b) was modified by Sec. 9 of the Water Resources Development Act of 1974 (Pub. Law 93-251). |
| Section 7 of the Flood Control Act (FCA) of 1944, (33 USC 709) | Section 7 of the FCA of 1944 specifies that the Secretary of the Army shall prescribe regulations for the use of storage allocated for flood control or navigation at all reservoirs constructed wholly or in part with Federal funds, including those of the Tennessee Valley Authority (TVA) when the lower Ohio or Mississippi Rivers are in danger of flooding. This law therefore creates a specific requirement for Corps regulation of reservoirs that include flood control or navigation storage, and that are operated by Federal agencies other than the Corps or by non-Federal agencies. All U.S. Bureau of Reclamation projects constructed after (and some before) 1944, where flood control is one of the project purposes, are included in the provisions of this Act. Projects that come under the authority of this legislation are generally referred to as "Section 7" projects. |
| Section 4 of the Flood Control Act of 1944, as amended (16 USC 460d) | Section 4, as amended, grants authority to the Corps to construct, operate and maintain recreational facilities at Corps reservoirs, and to permit local interests to do the same. Storage was not allocated |
| Water Supply Act of 1958, as amended (43 USC 390b) | The Water Supply Act of 1958, as amended, grants general authority to the Corps to include storage for municipal and industrial (M&I) water supply in Corps reservoirs upon agreement by State or local interests to reimburse the Government for the costs, including reallocation of storage that is compatible with other project purposes. |
| Fish and Wildlife Coordination Act (FWCA) of 1958 (16 USC 661-664) (amending Act of March 10, 1934 and August 14, 1946) | The FWCA requires coordination between Federal agencies and the U.S. Fish and Wildlife Service (USFWS) in the planning of Federal water resources development projects to evaluate impacts to fish and wildlife species, with a view to the conservation of wildlife resources and the development and improvement of such resources. Storage was not allocated. |

| Name | Key Items |
|---|---|
| Sections 401 and 404 of the Federal Water Pollution Control Act (FWPCA) of 1972, as amended (33 USC 1341 and 1344) | The FWPCA establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters. Sections 401 and 404 require the Corps to obtain from States water quality certifications when planning water resources development projects that involve the discharge of dredged or fill material in the waters of the United States, to the effect that the proposed projects will comply with applicable pollution standards. The FWPCA provides certain exceptions to this requirement. |
| Section 306 of the Water Resources Development Act of 1990 (33 USC 2316) | This Act provides that the Secretary of the Army shall include environmental protection as one of the primary missions in the planning and operating of Corps of Engineers water resources projects. |
| Section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 USC 1536) | Section 7 of the ESA states that each Federal agency shall, in consultation with and with assistance of the Secretary of the Interior, ensure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered or threatened species, or result in the destruction or adverse modification of critical habitat. |
| Executive Order 12088, *Federal Compliance with Pollution Control Standards* (October 13, 1978) as amended by Executive Order 12580 (January 23, 1987) | This Executive Order provides that the head of each executive agency is responsible for ensuring that all necessary actions are taken for the prevention, control, and abatement of environmental pollution with respect to Federal facilities and activities under control of the agency. |
| Executive Order 13693-Planning for Federal Sustainability in the Next Decade (March 19, 2015) | This Executive Order provides that Federal agencies shall propose targets for agency-wide reductions in greenhouse gas emissions from agency facilities, and promote measures to meet those targets. . |
| Section 6 of the Flood Control Act of 1944 (33 USC 708) | This Act authorizes the Secretary of the Army to make agreements with States, municipalities, private entities, or individuals, for domestic and industrial uses of surplus water at Corps reservoirs at such prices and terms as he deems reasonable. |
| Fish and Wildlife Conservation Act of 1980 (16 .USC §§ 2901-2911) | This Act encourages all Federal departments and agencies to use their statutory and administrative authority, to the maximum extent practicable and consistent with each agency’s statutory responsibilities, to conserve and promote conservation of non-game fish and wildlife and their habitats. |
| Federal Water Project Recreation Act of 1965, as amended (16 USC 460l-12 et seq.) | This Act provides for the inclusion of recreation or fish and wildlife enhancement as project purposes in the pre-authorization planning of multiple purpose projects, subject to cost sharing agreements with non-Federal public bodies. |
| Magnuson-Stevens Fishery Conservation and Management Act of 1976 as amended (16 USC § 1801 et seq.) | This Act promotes the protection of essential fish habitat in the review of projects conducted under Federal permits, licenses, or other authorities that affect or have the potential to affect such habitat. |
| Migratory Bird Treaty Act of 1918 as amended (16 USC §§703-712) | The Act states that it is unlawful to pursue, hunt, take, capture or kill; attempt to take; possess, offer to or sell, barter, purchase, deliver or cause to be shipped, exported, imported, transported, carried, or received any migratory bird, part, nest, egg or product, manufactured or not, included in the treaty. |
| National Environmental Policy Act (NEPA) of 1969, as amended (42 USC §§ 4321-4347) | NEPA requires that all Federal agencies prepare detailed environmental impact statements for “every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment.” This Act also stipulated the factors to be considered in environmental impact statements, and required that Federal agencies employ an interdisciplinary approach in related decision making and develop means to ensure that unquantified environmental values are given appropriate consideration, along with economic and technical considerations. |

| Name | Key Items |
|---|---|
| North American Wetlands Conservation Act, as amended (16 USC 4401 et seq.) | This Act encourages partnerships among public agencies and other interests to protect, enhance, restore, and manage an appropriate distribution and diversity of wetland ecosystems and other habitats for migratory birds and other fish and wildlife. |
| Wild and Scenic Rivers Act of 1968, as amended (16 USC 1271 et seq.) | This Act protects the environmental values of free-flowing streams from degradation by impacting activities, including water resources projects. |
| Executive Order 11988, Floodplain Management (May 24, 1977) as amended by Executive Order 12148 (July 20, 1979) and by Executive Order 13690 (January 30, 2015) | This Executive Order directs Federal agencies to evaluate the potential effects of proposed actions on floodplains and to avoid undertaking actions that directly or indirectly induce growth in the floodplain or adversely affect natural floodplain values. |
| Executive Order 12962, Recreational Fisheries (June 7, 1995) as amended by Executive Order 13474 (September 26, 2008) | This Executive Order states that Federal agencies shall evaluate the effects of Federally funded, permitted, or authorized actions on aquatic systems and recreational fisheries and document those effects relative to the purpose of this order. |
| National Historic Preservation Act (NHPA) of 1966, as amended (16 USC 470 et seq.) and implementing regulation 36 Code of Federal Regulations Part 800 | The NHPA directs Federal agencies to establish programs to identify and evaluate historic properties located on public lands. Section 106 requires any Federal agency having direct or indirect jurisdiction over a proposed Federal or Federally assisted undertaking to consider the effects of that undertaking on historic properties, and to consult with the appropriate agencies on those effects. |
| Archaeological Resource Protection Act (ARPA), as amended (16 USC 470aa-mm) | ARPA establishes civil and criminal penalties for the willful destruction, removal, or trafficking of archaeological resources from Federal or Tribal managed land. This Act also provides a mechanism for Federal agencies to issue permits to persons having a legitimate interest in conducting archaeological excavations on Federal lands. |
| Native American Graves Protection and Repatriation Act (NAGPRA), as amended 25 USC 3001 et seq.) | NAGPRA directs Federal agencies to return cultural items described as human remains, associated funerary objects, sacred objects, and objects of cultural patrimony, to Native American Tribes and Native Hawaiian organizations having an established lineal descent or cultural affiliation with the remains. |
| Section 8 of the Flood Control Act of 1944, as amended by Section 931 of WRDA 1986 (43 USC 390) | This Act authorizes the Secretary of the Army to determine, upon recommendation of the Secretary of the Interior, that a Corps reservoir may be used for irrigation purposes, after which the Secretary of the Interior may seek authorization form Congress for construction and use of facilities for irrigation pursuant to the reclamation laws. Section 931 authorizes the Secretary of the Army to temporarily allocate M&I water supply storage to irrigation purposes until the storage is required for M&I water supply purposes. |
| Section 103(c)(3) of WRDA 1986 (33 USC 2213(c)(3) | This provision establishes a 35% non-Federal share of construction costs for Corps projects authorized for agricultural water supply. |

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# APPENDIX C

## Acronyms and Abbreviations

| Term | Definition |
|---|---|
| AAR | After-Action Report |
| ACE-IT | U.S. Army Corps of Engineers–Information Technology |
| AGC | Automatic Generation Control |
| AIS | Automated Information System |
| AMO | Atlantic Multidecadal Oscillation |
| AO | Arctic Oscillation |
| AOP | Annual Operating Plan |
| API | Antecedent Precipitation Index |
| ARPA | Archeological Resources Protection Act (of 1979) |
| ATR | Agency Technical Review |
| BLM | Bureau of Land Management |
| BMP | Best Management Practice |
| BPA | Bonneville Power Administration |
| CD | Compact Disk |
| CECW | Directorate of Civil Works, U.S. Army Corps of Engineers |
| CFR | Code of the Federal Regulations |
| CHPS | Community Hydrologic Prediction System |
| COOP | Continuity of Operations |
| CoP | Community of Practice |
| COTS | Commercial off-the-Shelf |
| CPC | Climate Prediction Center |
| CWA | Clean Water Act |
| CWMS | Corps Water Management System |
| DBMS | Database Management System |
| DCP | Data Collection Platform |
| DO | Dissolved Oxygen |
| DOE | U.S. Department of Energy |
| DOI | U.S. Department of Interior |

| Term | Definition |
|---|---|
| DQC | District Quality Control |
| DRGS | A Direct Readout Ground Station |
| DSAC | Dam Safety Action Classification |
| DVD | Digital Video Disk |
| EAP | Emergency Action Plan |
| EC | Engineer Circular |
| EDL | Electronic Data Logger |
| EM | Engineer Manual |
| ENSO | El Niño/Southern Oscillation |
| EO | Executive Order |
| EP | Engineer Pamphlet |
| ER | Engineer Regulation |
| ERDC | U.S. Army Engineer Research and Development Center |
| ERDC-CRREL | Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory |
| ESA | U.S. Endangered Species Act |
| ETL | Engineer Technical Letter |
| FCCE | Flood Control and Coastal Emergencies |
| FEMA | Federal Emergency Management Agency |
| FERC | Federal Energy Regulatory Commission |
| FIA | Flood Impact Analysis |
| FOA | Field Operating Activity |
| FR | Federal Register |
| GDM | General Design Memorandum |
| GOES | Geostationary Operational Environmental Satellite |
| GSU | Generator Step-Up |
| HA | High Availability |
| HAB | Harmful Algal Bloom |
| HDC | Hydroelectric Design Center |
| HEC | Humphreys Engineer Center |
| HEC-FIA | HEC Flood Impact Analysis |

| Term | Definition |
|---|---|
| HEC-HMS | Hydrologic Engineering Center – Hydrologic Modeling System |
| HEC-RAS | Hydrologic Engineering Centers – River Analysis System |
| HH&C | Hydrology, Hydraulics and Coastal Community of Practice |
| HQ | Headquarters |
| HQUSACE | Headquarters, U.S. Army Corps of Engineers |
| IEPR | Independent External Peer Review |
| IM | information management |
| IRRM | Interim Risk Reduction Measure |
| ISO | Independent System Operators |
| IT | Information Technology |
| IWR | Institute for Water Resources |
| IWR-HEC | Institute for Water Resources, Humphreys Engineer Center |
| LAN | Local Area Network |
| LAN/WAN | Local Area Network/Wide Area Network |
| LOS | Line of Sight |
| LRD | Great Lakes and Ohio River Division |
| LRIT | Low Rate Information Transmission |
| M&I | Municipal and Industrial |
| MCX | Mandatory Center of Expertise |
| MOU | Memorandum of Understanding |
| MSC | Major Subordinate Command |
| NAGPRA | Native American Graves Protection and Repatriation Act of 1990 |
| NAS | Network Attached Storage |
| NASA | National Aeronautics and Space Administration |
| NEPA | National Environmental Policy Act |
| NESDIS | [National Oceanic and Atmospheric Administration] National Environmental Satellite, Data, and Information Service |
| NEXRAD | Next-Generation Radar |
| NHC | National Hurricane Center |
| NHPA | National Historic Preservation Act of 1966 |
| NOAA | National Oceanic and Atmospheric Administration |

| Term | Definition |
|---|---|
| NOHRSC | (National Weather Service) National Operational Hydrologic Remote Sensing Center |
| NPS | National Park Service |
| NRCS | Natural Resources Conservation Service |
| NWD | Northwestern Division |
| NWS | National Weather Service |
| O&M | Operations and Maintenance |
| PDO | Pacific Decadal Oscillation |
| PFMA | Potential Failure Mode Analysis |
| PI | Periodic Inspection (report) |
| PL | Public Law |
| PMA | Power Marketing Administration |
| PROSPECT | Proponent Sponsored Engineer Corps Training |
| QA/QC | Quality Assurance/Quality Control |
| QPF | Quantitative Precipitation Forecast |
| RCO | Readiness and Contingency Operations |
| RFC | River Forecast Center |
| RR&R | Repair, Rehabilitation, and Replacement |
| RTO | Regional Transmission Organization |
| SAR | Safety Assurance Review |
| SCADA | Supervisory Control And Data Acquisition |
| SCSI | Small Computer System Interface |
| SEPA | Southeastern Power Administration |
| SES | Senior Executive Service |
| sftp | Secure File Transfer Protocol |
| SHEF | Standard Hydrologic Exchange Format |
| SNOTEL | Snow Telemetry |
| SWE | Snow Water Equivalent |
| SWPA | Southwestern Power Administration |
| TMDL | Total Maximum Daily Load |
| TVA | Tennessee Valley Authority |

| Term | Definition |
|---|---|
| UOC | USACE Operations Center |
| UPS | Uninterruptible Power Supply |
| USACE | U.S. Army Corps of Engineers |
| USBR | U.S. Bureau of Reclamation |
| USC | United States Code |
| USDA | U.S. Department of Agriculture |
| USDA-NRCS | U.S. Department of Agriculture-Natural Resources Conservation Service |
| USEPA | U.S. Environmental Protection Agency |
| USFS | U.S. Forest Service |
| USFWS | U.S. Fish and Wildlife Service |
| USGS | U.S. Geological Survey |
| WAPA | Western Area Power Administration |
| WFO | Weather Forecast Office |
| WMES | Water Management Enterprise System |
| WRDA | Water Resources Development Act |

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EXHIBIT A

# WATER CONTROL PLAN
# (largest bold type)

## STRUCTURE OR PROJECT NAME
## (large bold type)

Stream

River Basin

Appendix _____

to the

Water Control Master Manual

For

(Parent Project Name, If Applicable)

District Office

U.S. Army Corps of Engineers

Date

l. Outline for Type III project Water Control Plan

Minimum Requirements for

WATER CONTROL PLAN

(PROJECT NAME)
Type III Project

TITLE PAGE

PHOTOGRAPH OF ALL WATER CONTROL STRUCTURES

TABLE OF CONTENTS

PERTINENT DATA

– Information in Concise Summary Form –

1. INTRODUCTION. State the requirement for the Water Control Plan (ref ER 1110-2-240, ref Part 208.10 of CFR, Title 33, when applicable, and state as Type III project) , project authorization, purpose, location, description, and completion date of the principle and related projects.

2. PROJECT FEATURES. Description of all water passageways (discharge facilities, inflow and outflow channels, etc.), related water resource projects, and all public use facilities.

3. HYDROMETEOROLOGY AND WATER QUALITY. Watershed description, climate, runoff, table showing average monthly precipitation in inches and average monthly runoff in both inches and cfs, water quality, design conditions, water passageway characteristics, data collection stations and maintenance of instrumentation, data collection procedure and reporting (refer to exhibit on Standing Instructions to the Project Operator), method of preparing hydrologic forecasts if done in-house, and source, access procedure and overall suitability of forecasts if obtained from NWS.

– Detailed Information –

4. WATER CONTROL PLAN. Overall summary of the water control plan, including objectives and major constraints, followed by: specific objectives, the regulating procedures, and the beneficial effects of regulation for each water control objective. Address the following objectives, as appropriate: flood risk management (include regulation for design flood), navigation, water supply, water quality, fish and wildlife, hydroelectric power generation, recreation, and any other water control objectives and incidental achievements. The discussions should include examples of regulation and any constraints.

5. PROJECT MANAGEMENT. Project owner, role of the regulating office (water control managers, and summarize requirements for the water control morning report for the subject project); role of the Project Operator (refer to exhibit on Standing Instructions); communication between the District office and project operator; coordination with local, state and other Federal agencies, if required, and future changes to the project and the impact on water control.

6. PLATES (using 11-inch binding edge, label tables not in text as plates).

a. Map and plan of project area with vicinity map insert.

b. Plan and profile of structure clearly showing all discharge facilities.

c. Data collection network map (designate auto-recording, auto-reporting and key control point(s)).

d. Water Control Diagram (guide curve), with release schedule and explanatory notes, when applicable.

e. Discharge rating curves with rating table insert (designate important related elevations).

f. Hydrograph examples of water control regulation (inflow and outflow), with hyetographs (for floods of record and the design flood).

g. Frequency and duration curves for headwater or pool and control point or tailwater (discharge and stage).

h. Other plates as required for the project.

7. EXHIBITS

a. Detailed Pertinent Data.

b. Other Exhibits, as appropriate.

c. Memorandum of Understanding or other Agreement.

d. Standing Instructions to the Project Operator for Water Control (see Exhibit B).

1. This format applies only to Type III projects where the scope of water management does not require preparation of an individual water control manual. However, the water control plan should be appended to the water control master manual when the project is in a water resource system. The plans and standing instructions for water control structures in the system may be prepared and submitted for approval prior to the master manual, if desired, to expedite the most essential documentation requirements. Include project name and project type in heading.

2. Detailed presentation of these topics in the system master manual is preferred when one is prepared.

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EXHIBIT B

STANDING INSTRUCTIONS TO THE PROJECT OPERATOR[1,2]

# FOR WATER CONTROL
# (largest bold type)

## STRUCTURE OR PROJECT NAME
## (large bold type)

STREAM

River Basin

Exhibit _________2

to the

Water Control Plan (or Manual)

For

(Parent Project Name)

District Office
U. S. Army Corps of Engineers
Date

[1] Required for all Type II, III and IV projects (see Section 9.4.1).
[2] Omit for Type II projects that are not in a water resource system.

Information to be included in

STANDING INSTRUCTIONS TO THE PROJECT OPERATOR FOR WATER CONTROL1

(PROJECT NAME)

Type Project

PHOTOGRAPHS OF ALL WATER CONTROL STRUCTURES (TYPE II PROJECTS ONLY)

TABLE OF CONTENTS

PERTINENT DATA

1. BACKGROUND AND RESPONSIBILITIES.

a. General Information.

(1) Reference compliance with Section 9.4 of EM 1110-2-3600 and ER 1110-2-240, and state that a copy of these Standing Instructions must be kept on hand at the project site at all times, and that any deviation from the Standing Instructions will require approval of the District Commander.

(2) Identify authorized project purposes and all water control objectives.

(3) Identify chain of command and the entity to which the project operation is responsible for water control actions.

(4) State project location and brief description of water control structures.

(5) Describe constraints on physical operation of the water control structure.

(6) Include a statement as to whether O&M is by the Corps or by local interests, and a statement as to whether it is a local flood risk management project. Reference the Code of Federal Regulations (CFR Title 33, Part 208.10) when it applies.

b. Role of the Project Operator,

(1) Normal Conditions (not dependent on day-to-day Instruction). Applies to all Type II and some Type III projects.

Include the following statements ... "The Project Operator is responsible for water control actions during normal hydrometeorological conditions (non-flood, non-drought) without daily instruction. However, the water control manager should be contacted any time conditions are such that consultation or additional instruction regarding water control procedures is needed."

OR. … Normal Conditions (dependent on day-to-day instruction). Applies to some Type III and most Type IV projects. When appropriate, state that. ..“The Project Operator will be instructed by water control managers on a daily basis for water control actions under normal conditions”.

(2) Emergency Conditions (flood or drought). Same as above, as appropriate, during flood events and other emergency conditions.

2. DATA COLLECTION AND REPORTING.

a. Normal Conditions. Instructions for collecting water data under normal hydrometeorological conditions, and instructions for reporting the water data to the District office.

b. Emergency Conditions. Same as the above during flood events and other emergency conditions. Specify more intensive requirements when appropriate.

c. Regional Hydrometeorological Conditions. State that “The Project Operator will be informed by the water control manager of regional hydrometeorological conditions that may/will impact the structure.”

3. WATER CONTROL ACTION AND REPORTING.

a. Normal Conditions. Specific step-by-step instructions for water control action under normal hydrometeorological conditions, taking into account any constraints on water control or physical operation, and specific step-by-step instructions for reporting the action and any unusual conditions to the water control manager.

b. Emergency Conditions. Same as the above during flood events and other emergency conditions.

c. Inquiries. State that... “All significant inquiries received by the Project Operator from citizens, constituents or interest groups regarding water control procedures or actions must be referred directly to water control managers.”

d. Water Control Problems. State that... “The water control manager must be contacted immediately by the most rapid means available in the event that an operational malfunction, erosion, or other incident occurs that could impact project integrity in general or water control capability in particular.”

e. Communication Outage. Specific step-by-step instructions for water control action in the event a communication outage with the water control manager occurs during either normal or emergency conditions, considering constraints.

4. PLATES (to support the above, use 11-inch binding edge).

a. Map of the project area showing the water control structures, streams, levees, dikes, channels, water data stations and parameters measured, with a vicinity map insert depicting the drainage area above the project.

b. Schematic drawing of the project facilities, including a plan and profile of water control structures which show key water levels (headwater and tailwater), and other pertinent information.

c. Forms for collecting water data, reporting water data, and reporting water control actions.

d. Discharge rating curves, if appropriate, with key elevations identified and a rating table inserted on the graph.

e. Water control diagrams and release schedules, if appropriate, for normal and emergency conditions, and for communication outages.

f. List of points of contact in District and/or Division office.

g. Other supporting plates, if needed.[1]

[1] Required for all Type II, III and IV projects. Include project name and type in heading. Include water management office symbol in upper left corner, and date in upper right corner of each page.