ASCE Manuals and Reports on Engineering Practice No. 57

Management, Operation and Maintenance of Irrigation and Drainage Systems

AMERICAN SOCIETY of CIVIL ENGINEERS

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Management, Operation and Maintenance of Irrigation and Drainage Systems

Second Edition

Prepared by the
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ABSTRACT

Management, Operation and Maintenance of Irrigation and Drainage Systems (Manual No. 57) is a revision of the 1980 publication *Operation and Maintenance of Irrigation and Drainage Systems.* This manual presents significant new innovations and modifications of procedures that have been implemented throughout the irrigation and drainage industry, particularly in areas of management and maintenance strategies, environmental benefits and safety practices. It is intended to help irrigation and drainage districts to minimize costs while maximizing production with available resources. In addition, this revised manual should be of interest to anyone associated with irrigation and drainage systems throughout the world.

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Furthermore, material in this series, in distinction from a paper (which expresses only one person's observations or opinions), is the work of a committee or group selected to assemble and express information on a specific topic. As often as practicable the committee is under the general direction of one or more of the Technical Divisions and Councils, and the product evolved has been subjected to review by the Executive Committee of that Division or Council. As a step in the process of this review, proposed manuscripts are often brought before the members of the Technical Divisions and Councils for comment, which may serve as the basis for improvement. When published, each work shows the names of the committees by which it was compiled and indicates clearly the several processes through which it has passed in review, in order that its merit may be definitely understood.

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Preface

This manual replaces the American Society of Civil Engineers (ASCE) Manual No. 57, Operation and Maintenance of Irrigation and Drainage Systems, written in the 1970s and published in 1980.

This revision presents significant new innovations and modifications of procedures that have been implemented throughout the irrigation and drainage industry, particularly in areas of management and maintenance strategies, environmental benefits, and safety practices.

This updated information is intended to assist irrigation and drainage districts in the proper management, operation, and maintenance of agricultural irrigation water delivery systems in minimizing costs and maximizing production with available resources. In addition, the material presented in this manual is intended to command the attention of all persons associated with irrigation and drainage systems throughout the world.

This revision is a joint effort between ASCE and the Bureau of Reclamation. Special thanks to the International Irrigation Center, Utah State University, Logan, Utah, and Westlands Water District, Fresno, California, for their contributions to this manual. All contributing personnel have varied backgrounds and experiences that enhance this unique and functional document.

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Department of Interior

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SECTION I. THE MANUAL

1.1. PURPOSE

The purpose of this manual is to assist irrigation and drainage district personnel in the management, operation, and maintenance of agricultural irrigation and drainage systems. Throughout the world, there are thousands of irrigation systems that transport water from a source of supply to farmers for crop irrigation. These irrigation systems supply water to millions of acres of land through locally or regionally controlled organizations. Improving management, operation, and maintenance of these existing systems can produce significant economic, social, and environmental benefits, to farmers directly served by the systems, to the irrigation district, and to the populace who are directly and indirectly affected. This manual is intended to encourage and facilitate such improvements.

1.2. SCOPE

This manual describes state-of-the-art management, operation, and maintenance practices and procedures in general use by existing irrigation districts throughout the United States. The term "irrigation district" describes any agency, either public or private, regardless of the specific title of the organization, that provides the service of storing, conveying, and/or furnishing irrigation water, or providing drainage services to agricultural lands. The manual does not attempt to describe the development of a water supply, the planning, designing, or construction of a new irrigation project, or the use of water on farms.

Effective management of an irrigation district and the personnel who support the physical operation is essential for the success of an irrigation enterprise. Operation and maintenance of an irrigation system includes the physical operation necessary to deliver water to the farms. This manual focuses on relevant practices and procedures used throughout the United States, but this manual could prove useful throughout the world even though economic and cultural differences may require adaptation for such use.

1.3. SUGGESTIONS FOR USE

The material presented in this manual is a guideline for developing and formulating documents that outline rules, regulations, and policies to meet specific needs of an irrigation district. However, due to varied physical and economic situations in districts, this manual cannot cover all conditions. In small districts, the documents can be brief and simple. In larger districts with complex organizational structures, more detailed documents may be desirable. An irrigation district can improve its effectiveness by establishing appropriate rules, regulations, and policies with documents that set forth both goals and procedures.

Although most irrigation districts already have documents establishing practices and procedures, documents should be reviewed periodically and updated whenever necessary. A fixed schedule for review is recommended, typically from 1 to 3 years. The time frame to review various documents depends on the function and what, if any, changes or new ideas would be relevant. This manual can be used to assist in periodic reviews and to update the management of a district, particularly when changes have transpired in the magnitude or configuration of the irrigation district.

1.4. USER OF MANUAL

This manual has been focused on assisting officials in the United States having responsibility for and an interest in improving the effectiveness of their irrigation districts. These officials will more than likely be the principal users of this manual; however, this does not preclude others having an interest in irrigation and drainage systems from using the material presented. For instance, surveillance organizations, students, consultants, and possibly officials participating in irrigated agricultural industries in other countries might find this manual worthwhile.

Several organizations such as the World Bank, the United States Agency for International Development, and the United States Bureau of Reclamation are responsible only for the surveillance of irrigation districts. These organizations encourage the irrigation districts to facilitate and update their management practices and procedures to improve the management of irrigation systems. The information in this manual could serve as a guideline to assist irrigation districts in carrying out such programs.

Although this manual has not been prepared with the student in mind, students pursuing higher education in this field of study could use this manual as a useful reference or study document. The information in this manual could also serve students taking specialized short courses looking for general information about irrigation systems. This manual could be used by a consultant as a basic guideline when he or she is examining and evaluating the functions of an irrigation district. Even though there are economic and cultural differences in other countries, many of the practices and procedures presented in this manual could be adapted to meet the needs of irrigation districts in other countries.

SECTION 2. DISTRICT ORGANIZATION AND MANAGEMENT

2.1. GENERAL

Proper management of the organization established to carry out needed functions is essential to the effective operation and maintenance of an agricultural irrigation water delivery system. Management involves the effective use of available resources—funds, labor, materials, and equipment.

This section describes an organization and management structure for the operation and maintenance of an irrigation water delivery system. The organization and management are considered as important as the operation of the irrigation system (described in section 3) and maintenance of the facilities (described in section 4).

Presented herein are some generally proven approaches and suggestions that can be used, perhaps with modifications, to assist an irrigation district in establishing and/or improving its management and organizational structure. For practical purposes, specific examples to cover all situations could not be included.

2.2. IRRIGATION ORGANIZATION

There are many entities, companies, and districts with different names, such as irrigation, drainage, water, reclamation, conservancy, and water storage districts, mutual canal and ditch companies, both public and private, commercial companies, and others organized for various purposes. All of these organizations have one significant purpose—furnish irrigation water and/or drainage service to agricultural lands.

Three principal categories of such organizations are described in the paragraphs that follow. However, this manual covers the organization and management of an irrigation district even though much of the same setup can be established for any of the aforementioned organizations.

For convenience, the general term "district" or "agency" in this manual applies to any entity that handles the delivery of irrigation water or provides drainage service for agricultural lands.

2.2.1. Mutual Companies

Mutual companies are private cooperative organizations organized under state laws to provide water or drainage service at cost to the members. These companies offer a potential advantage in keeping operation and maintenance costs low. However, if the companies are not properly managed, the operation and maintenance functions may not be performed efficiently, with resulting long-range higher costs.

2.2.2. Commercial Companies

Commercial companies are organized under state laws for the purpose of constructing and operating irrigation and drainage systems for profit. These companies usually select beneficiaries and fix relationships by contract. Rates and services usually are subject to public regulations. These enterprises, unless effectively managed, may have difficulty showing a profit.

2.2.3. Districts

Districts are public agencies organized under state laws. These districts operate within legal boundaries and often provide services in addition to irrigation and drainage. The organization of a district is initiated by petition and majority vote. Districts have taxing powers, may issue bonds, may enter into contracts, may sue and be sued, may acquire property by condemnation, and may exercise other powers. Many districts have signed repayment contracts with the federal government to repay the cost of construction of all or a part of the systems.

Irrigation districts probably outnumber all other districts combined. Their primary purpose is to provide irrigation water for agriculture, and they may often provide other services as well. Drainage districts usually have as their primary purpose the furnishing of drains for agricultural lands. Conservation districts often encompass both irrigation and drainage and also may include beneficiaries other than those served directly by the project works. Districts are adaptable to large basin-wide, multiple-purpose needs and in some instances have broad taxing powers. There are other public agencies in this general category.

2.3. ORGANIZATIONAL STRUCTURE

For the proper management of an irrigation district, an organizational structure that clearly defines authority and responsibility should be established. The larger the organization, the more important it is that people know who is responsible for what, and who reports to whom.

The organizational structure usually includes an electorate, board of directors, general manager, division heads, workers, and in some cases, consultants. This section of this manual describes some of the more important aspects of an irrigation district, such as organizational and management structure, policies, management program, and functional activities.

2.3.1. Organizational Chart

An organizational chart outlining the interrelated activities of the organization is a very good way to illustrate the organization structure, and is an excellent management tool. No single chart can possibly fit all situations or show all lines of coordination and interaction. However, irrigation districts have enough similarity that representative charts can be presented to show primary lines of communication and respective levels of responsibility and authority.

A simplified organizational chart for a rather large irrigation district (with an average of 100 employees) is shown in Fig. 1. This chart is to be used for reference in connection with other material given in this manual. In actual practice, variations from such a chart will be necessary or desirable to meet specific local situations and individual organizations goals and objectives.

Several other organizational charts are presented in Appendix A to show alternative organizations for smaller and larger irrigation districts. In a smaller organization, these activities would be consolidated into a fewer number of segments. In a larger organization, specific detailed charts identifying a wide range of activities and staff might be beneficial.

2.4. MANAGEMENT STRUCTURE

Although the electorate and board of directors are responsible for overall management of the irrigation district, a management staff is needed to be responsible for the day-to-day management, operation, and maintenance of the irrigation district.

The primary goal of management is to organize and direct the staff, to make decisions, and to coordinate activities in a manner that will

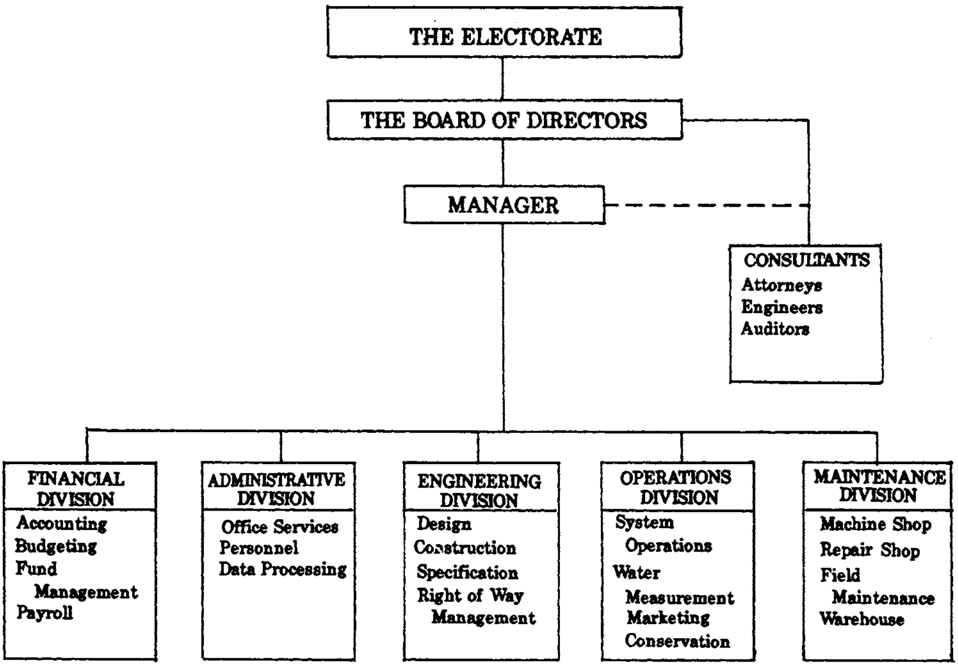


Fig. 1. Simplified Organizational Chart for an Irrigation District

encourage landowners, water users, district staff, and external agencies to work together to achieve the purposes of the district.

The primary purpose of an irrigation district is to deliver water from the source of supply to the water users (farmers) in an equitable and timely manner, within the limits of the resources available. This requires proper operation of the irrigation facilities along with appropriate maintenance and sound policies and procedures.

Some essential requirements for management of an irrigation district are the following.

- Develop an appropriate organizational structure.
- Adopt a well-defined management system.
- Establish clear procedures and regulations.
- Operate and maintain the facilities efficiently.
- Motivate personnel to work effectively.
- Provide an effective legal structure.
- Provide good internal and external communication.
- Maintain a good working relationship between staff and board of directors.

2.4.1. Electorate

Most irrigation districts are public agencies, organized under state laws. Those laws identify the electorate, which consists of landowners, water users, registered voters, or other designated groups. The electorate has the authority to form the district, elect a board of directors, and approve major proposals (such as bond issues) regarding the district.

The electorate can express its collective will by electing directors who represent their views or by voting on major issues that are presented. Having an electorate that is interested in and well informed about the district will improve the prospects for successful operation of the district. District management, therefore, will include an effort to provide opportunities for and encourage participation by the electorate in establishing policies, procedures, and programs.

Public hearings on important issues, open meetings of the board of directors (frequently required by state statutes), information programs, and efforts to develop an attitude of interested participation are some of the ways to encourage the electorate to play its proper role in district activities. That role, under favorable circumstances, is to provide effective community support for the programs of the district. However, if the electorate becomes dissatisfied with the functioning of the district, they can and should seek changes in policies, procedures, or programs through comments to the board of directors, election of new officials, or voting on important issues.

2.4.2. Board of Directors

The board of directors is the foundation on which most irrigation organizations rest. The board of directors should be accountable to the electorate for its actions and for adoption of policies and procedures that promote efficient and effective operation of the irrigation system. The directors are essentially the trustees of an important business enterprise and must see that the organization operates properly. The board members should be qualified leaders, representative of their community, who have an interest in and a knowledge of water, irrigation, agribusiness, public finance, and general public policy.

The board selects officers and establishes policies, generally as required by law. The board acts on information brought forth by its manager or consultants. The number of directors will generally vary from three to eleven. If possible, the directors should represent different interests or different areas within the extent of the irrigation system. The board must establish policy and set budgets. Individual board members should not interfere with the manager in regard to the handling of problems with water users, landowners, or staff members. The board must give the manager the authority and the freedom to use his or her own judgment to carry out board policy within budgetary constraints.

The board of directors is encouraged to review periodically how interested and well informed the electorate is on the affairs of the district. If there is apathy or dissatisfaction on the part of a significant portion of the electorate, special efforts should be made to determine the problem and to take appropriate corrective action. Regularly scheduled public information meetings are encouraged.

Annual Report

The board of directors should be encouraged to adopt a policy of preparing an annual report on district activities. This sometimes may seem a burden when the year is past, a new year is starting, and time to do the report is difficult to find; however, the preparation of an annual report can serve useful purposes and in the long run is worth the effort.

A typical annual report should include information on water operations for the year, information on crops grown, financial transactions, major improvements made to the irrigation system, major maintenance problems, major legal problems encountered, financial standing of the district, and other items worth recording for future reference. The process of preparing an annual report can be simplified by establishing a standard outline for use from year to year. The law frequently requires districts to have an annual audit of the district's financial records performed by an independent certified public accountant.

The annual report, if used properly, can help plan future operations, take into account past activities, and serve as a valuable historical reference. In many cases, the annual report can be provided to water users, the general public on a selective basis, and the news media as an effective public relations tool.

Accountability to Electorate

An irrigation district can be considered a social structure designed to perform a physical task. A democratic spirit and effective management must prevail if this social framework is to serve effectively. The purpose of the democratic process is best served when board members feel free to persuade and argue, and then are willing to abide by the majority decision without further airing of differences.

Public confidence is engendered in the local board of directors that defers bringing important matters to a vote until the issues have been clearly understood, both by the board members and by the electorate. The board should manage the affairs of the district effectively, but at the same time should keep in mind that it is accountable to the electorate and must have their support.

2.4.3. Officers of Board

The board of directors usually selects one of its members to serve as president and one to serve as vice president. These officers serve at the pleasure of the board, with normal terms of 2 or 3 years. If, for any reason, either of the offices become vacant, the board of directors selects another member to serve the unexpired term of office. Other officers of the board usually include a secretary, treasurer, and sometimes an assessor/tax collector. These officers may or may not be members of the board.

President

- Preside over all meetings of the board of directors.
- Call for public participation during meetings when appropriate.
- Rule on passage or failure of motions or resolutions brought before the board of directors.
- Vote on any motion, resolution, or ordinance involving a roll call.
- Ensure that all board members have an equal opportunity during board discussions (the president may discuss any matter, but his or her right to expression will be no greater than that of any other member).
- Appoint board committees and assign committee chairpersons.
- Set the time and place for special board meetings.
- Represent the agency at public ceremonies.
- Serve as public spokesperson for the agency.
- Sign checks for the agency, as authorized by resolution.
- Conduct the annual evaluation of the manager's performance.

Vice President

- During the absence of the president, perform all the duties of the president.
- Act in place of the president, if for any reason the office of the president is vacant.

Secretary

The secretary is appointed by and serves at the pleasure of the board, and may be an employee of the agency. The secretary performs important communication functions.

- Prepare minutes of the board meetings.
- Prepare and certify resolutions of the board.

- Prepare and post notices of special board meetings and of canceled meetings.
- File official board correspondence and maintain records.
- Act as custodian of the agency seal and records.
- Execute various licenses, agreements, permits, and contracts on behalf of the board.
- Call and schedule board committee meetings.

Treasurer

The treasurer is appointed by and serves at the pleasure of the board, and may be an employee of the agency, usually connected with the management of the fiscal division. The duties involve, but may not be limited as listed.

- Responsible for all of the agency's assets (such as receiving and crediting to the agency all of the money belonging to it).
- Responsibility for the disbursement and investment of all agency funds but is precluded from paying out funds unless authorized by the board.
- Providing consultation and advice to the board audit and budget or financial committee.

Assessor/Tax Collector

The assessor/tax collector is sometimes appointed by the board of directors and sometimes elected by the landowners or water users. The assessor/tax collector and treasurer may be the same person. The duties of the assessor/tax collector include, but may not be limited to the following.

- Establish the values on all land to be assessed.
- Recommend the annual assessment rate to the board of directors so that the funds collected will meet the budget requirements of the agency.

2.4.4. Committees

Even though a meeting of the board of directors is required to establish policy or take official action, much deliberation can and should take place through board committee activity. By working through committees, the gathering of information and presenting of recommendations on special problems can be handled efficiently without taking up the full time of the entire board, but still leaving the entire board the authority to take appropriate action. The structure of committees must be skillfully created to ensure that the board members not on any specific committee do not feel left out of important discussions and decisions.

In some situations in the United States, a quorum of a public agency board of directors cannot meet without a public notice. The board may close a meeting to the public to discuss litigation and personnel matters. Regardless of any legal requirements, it is good policy to announce meetings of the board and schedule open meetings whenever possible.

Committees of the board, having a membership of less than a quorum of board members, can meet as necessary to discuss the subjects assigned to the committee. The committees may also meet with the manager, staff members, consultants, or others to develop recommendations to the full board. It is important for management to take advantage of special skills of individual board members.

Properly functioning committees contribute significantly to the efficient operation of any board of directors. Committees can enhance communication between the staff and board of directors and assist the organization leadership in decision-making. In many organizations there are the following two types of committees.

- Standing committees that perform on a continuous basis.
- Special or ad hoc committees that analyze specific problems or functions for a given period of time.

Several standing committees are helpful in analyzing problems and recommending policies regarding the management, operation, and maintenance of the district. Common examples are executive, operation and maintenance, audit and budget, personnel, water policy, and nominating.

2.5. ORGANIZATION POLICIES

The board of directors is responsible for establishing policies. The board may wish to seek proposals from the manager or board committees in developing policies, but in the end, the board must establish district policy.

The policies will guide the manager and his staff in developing procedures and carrying out the functions of the district and will be the basis for the relations with the water users. Policies should be in writing in the form of policy statements, rules, and/or regulations to enhance the effectiveness of the district in meeting its goals. Policies should be carefully thought through and should be available for review by anyone who has an interest. Some of the more important subjects that should be covered by policy statements are identified in the paragraphs that follow.

Water Delivery and Use

The water users within the district want and need to know the conditions under which water deliveries can and will be made. District operators also need to know. Rules regarding the eligibility to receive water vary between different organizations. For instance, many organizations may require that all assessments be paid in advance of water deliveries. Ditchtenders must be made aware of the procedures and regulations governing water delivery and should be instructed to deliver water only to those deemed eligible.

Publication of Rules and Regulations

General rules and regulations should be published to keep all water users informed of their rights and responsibilities. In many instances, an annual or more frequent announcement may be necessary. Examples of the types of policies that might be considered for publication and distribution follow.

- The classes of lands to receive irrigation water.
- Water allotments for each class.
- Water charges.
- Procedures to follow to obtain supplemental water.
- Status of water account.

Water User Relations

Tact in dealing with water users is a necessity. The general relations with water users and the importance of treating all alike should be stressed. Agreements made between water users and the operating agency that constitute general operating policy may need to be revised or changed from time to time by mutual consent. All employees, ditchtenders in particular, should be kept fully informed of all changes, since their responsibility is to understand these agreements and to explain the changes to the water users.

Generally, complaints and inquiries relative to the rate of water delivery, location of turnouts, wastewater inlets, seepage, bridges, and crossings should be referred to watermasters or other authorities responsible for the formulation of policy. Inquiries as to why a farm unit is not eligible to receive water should also be referred to the headquarters office, which, in turn, should contact the proper officials as necessary.

Procedures should be established for installation of new water delivery turnouts. Important records that should be maintained include a set of written applications from farmers applying for a new turnout. A sample "Application for Water Delivery Outlet" is shown as Fig. E-13 of Appendix E. As-built data should also be maintained for installation and construction of each turnout. These data can be recorded on an "As-Built Data" form shown as Fig. E-14 of Appendix E.

2.6. MANAGEMENT PROGRAM

The method of formally managing an irrigation system can vary considerably, depending on the size of the organization and the local conditions. However, as a general pattern, the board of directors sets policy and hires a manager to implement policy. The manager will be supported by a group of division heads who direct the activities of the district. The manager and division heads are the primary management group. The staff that works under this primary management group is also essential to the success of the irrigation enterprise.

The manager should be compensated sufficiently to justify the responsibility and trust for overseeing the management of an irrigation system, which usually represents a large financial investment. The selection should not be based on who will work for the lowest salary, any more than one would make an important purchase on the basis of price alone.

2.6.1. Management Elements

The management elements that demand most from the manager and his staff are the following.

- Planning. Collection and analysis of water supply and demand data, estimation of probabilities and risks, and reconciliation of objectives and preferences of different interest groups (farmers, irrigation officials, agricultural officials, and representatives of other government agencies) to reach agreement on planning the operation of the irrigation system.
- Implementation. Adjustment of the district plan in regard to observed variations and actual changes in supply and demand. Provision of equitable water distribution and motivation of staff to resist pressures from water users that will misallocate water.
- Monitoring. Development of simple information and control systems with clearly defined criteria of performance and suitable objective indicators. Spot checking to ensure the accuracy of information being collected by staff to monitor performance. Spot checking to monitor the productivity of the staff in regard to attendance and record keeping. Identification of reasons for divergences between anticipated and actual work.
- Communication. Proper communication with water users, government officials, technical consultants, and other staff in regard to operation and maintenance plans and activities.

2.6.2. Manager

One of the most important responsibilities of the board of directors is the selection of the manager. The manager should be professionally trained in either a technical or administrative specialty. The larger the project, the more important it is to have a trained administrator as the manager because of the large number of diverse activities that must be coordinated.

Board-Manager Relationship

The relationship between the board and manager should be cordial, but businesslike, and should be one of mutual respect. The board and its members should show confidence in his or her judgment and grant the manager the prerogative to pursue his or her own methods. On the other hand, the manager should respect the board and its individual members, giving credit to the board for its policies, and recognizing that the board has the final responsibility for the success or failure of district operations.

The manager must never publicly assert a position contrary to the stated policy of the board. When the manager feels there is reason to change the policy, he or she should attempt to persuade the board to adjust. If the board does not choose to, then the manager should either accommodate the wishes of the board or resign.

Manager Duties

The manager must plan, administer, formulate, evaluate, and implement all aspects of the functions of the district. Some of these important tasks are the following.

- Setting short- and long-term objectives and priorities.
- Directing the annual planning and budgeting process.
- Directing the formulation of detailed work programs.
- Seeing that the staff is trained to implement agency programs.
- Supervising day-to-day activities (in smaller districts).
- Identifying problems and finding solutions for them.
- Monitoring project performance against objectives.
- Monitoring staff performance against agreed work targets.
- Seeking the opinion of water users about the quality of services provided.
- Identifying strengths and weaknesses in district activities and recommending remedies for the weaknesses.
- Communicating with other agencies on behalf of the district.
- Identifying and recommending policy changes.

Manager's Performance Review

An evaluation should be made periodically of how well the manager has been performing his or her duties. An annual performance review is normally considered appropriate. One possible procedure would be for the board of directors to meet in executive session to review both the strengths and weaknesses of the manager and develop suggestions for improving his or her performance.

The results of that meeting should then be discussed with the manager, either by the president of the board or by one or more of the board members. The manager should also be given the opportunity to comment on the evaluation and to express his or her views on ways in which the board could facilitate the management of the district.

2.6.3. Division Heads

In a typical irrigation organization, the manager will have several division heads to help conduct the affairs of the district. Fig. 1, presented previously, is a simplified chart identifying the principal divisions for a medium-sized irrigation district.

The responsibilities of the various division heads are similar to those of the manager, except that each division head concentrates on his or her own area of activity, rather than covering the entire range of activities of the district. Division heads should be given the authority and responsibility to manage their respective divisions within agency policies and budget limitations. The manager should review at least annually with each division head the strengths and weaknesses of the division, discuss his or her performance, and offer suggestions for improvements.

2.6.4. Staff

The staff under the manager and the division heads is the rest of the team needed to make the irrigation district function properly. The success of the organization will depend on the competency, skills, motivation, and dedication of the entire staff. Diversified experience and training should be encouraged, and educational programs made available. The members of the staff should be adequately trained to make proper decisions and given the opportunity to advance in the organization to the extent their abilities will allow.

2.6.5. Consultants

Most irrigation districts need to make use of consultants periodically or regularly to carry out their objectives. The various consultants hired by irrigation districts are attorneys, engineers, auditors, geologists, insurance and management advisors, and bond counselors.

The need for consultants usually arises for one of two reasons. The first is a need for professional services in a specialized field, usually when the irrigation district does not have sufficient activity in the field to justify the hiring of a full-time person. The second is when a special problem arises that is beyond the reasonable capability of the normal staff. Irrigation districts also need legal advice but usually do not have enough legal work to warrant the hiring of a full-time attorney. Frequently, districts will hire an attorney on a retainer and will arrange to have him or her attend board meetings whenever a legal matter is expected to come up and to do other legal tasks as the need arises.

Engineers and geologists most often are hired for large or specialized jobs that are beyond the capability of the regular staff. Sometimes they are hired on a retainer basis, so they are available on call when needed.

Irrigation districts should have their financial records audited annually and normally will hire an outside auditor to do the job.

Liability and other insurance needs seem to be increasing and are becoming more expensive. A consultant on insurance matters can often be of great benefit to the district.

As discussed elsewhere, good management is essential for the successful operation of an irrigation district. Hiring a management consultant to review management practices and arrange for management training can be worthwhile.

2.7. PUBLIC RELATIONS PROGRAM

Any irrigation district can improve its effectiveness with an effective public relations program. This involves a conscious effort on the part of irrigation district officials to inform appropriate groups what the district is doing and why. The public relations effort should be directed to three principal groups: employees, water users, and the local community.

Although an employee may know his or her job and do it well, he or she does not automatically know what is happening outside his or her immediate area of activity. Employees who are kept informed of district policies and programs will improve performance and have job satisfaction. These same employees "represent" the district in their personal contacts throughout the community; therefore, having well-informed employees is important for effective management and for improving community relations.

The format for keeping employees informed will depend on local conditions. For instance, a small district with few employees may only involve word of mouth, a large district may require a regular newsletter, or a combination of procedures may be beneficial. The most important factor, however, is that the district management make a conscientious and continuing effort to keep employees informed of what is happening.

Water users also need to be kept informed with respect to district policies, procedures, and activities. Even though this group is a little more difficult to reach, the important thing is to be conscious of the need to pass along information regularly. An avenue of communication can be through newsletters (perhaps delivered with monthly billings), annual reports, or newspaper releases.

Maintaining a good public relations program for the community at large is well worth the effort. The community is interested, and keeping them informed will improve community support for the programs of the district. Newspaper media should feel free to attend board meetings, since these meetings are public.

Press releases or radio or TV spot announcements should be prepared by the district whenever some significant activity is planned or carried out by the district. In a very large district, there may be a person assigned full-time as a public relations spokesperson. More typically, however, someone on the district staff will be assigned this responsibility as part of his or her normal duties.

2.8. SAFETY PROGRAM

Irrigation districts have an obligation to employees and a legal mandate under federal, state, and local laws to develop and carry out an effective safety program. A safety program is in the best interest of the district to maintain the well-being of its employees and to reduce the risk of liability.

The safety program can be classified under two general headings: employee safety and public safety. This program is not only important in maintaining the safety of the employees but protects water users, the public in general, and all facilities and equipment owned and operated by the organization.

Safety pays in many respects. Accidents can cause personal discomfort and monetary losses to the employee as well as monetary and productivity losses for the organization. Without exception, strict compliance with all applicable power system safety standards, construction safety standards, and technical standards is essential.

There sometimes is a tendency to reduce emphasis on safety activities because of time and cost; however, this attitude is known as "false economy." The value of the safety program is primarily in its long-term beneficial effects and long-range savings.

The board of directors has an important role in the safety program and should adopt general policies that will support an effective safety program. With these policies, the manager and his staff can develop specific procedures and regulations for assuring that the program is carried out. Examples of policies addressing employee and public safety are presented in Appendix F.

2.8.1. Employee Safety

Each organization should appoint a responsible employee as a part-time or full-time safety officer to oversee a safety program. All employees should be trained in the proper use of all equipment and tools, as well as various applicable regulations and laws.

Employees should not be required or allowed to work under conditions that are unsanitary, hazardous, or dangerous to their health or safety, as determined under construction safety and health standards promulgated by official regulations.

Personnel involved in the use of pesticides, herbicides, or any other hazardous material should be knowledgeable on the proper use of these materials. The individuals must be certified in the use of such materials when required by state or local statutes.

Safety Committee/Meetings

Office and field safety committees should be formed. These committees should consist of three members who serve for a limited time, such as 1 year, with a member rotating off the committee every 4 months. The committee should be responsible for conducting organization-wide (includes office and administrative personnel) safety meetings. These meetings should be held regularly (at least monthly) and last for about 1 hour.

For the organization-wide meetings, a safety expert could be brought in as a guest speaker, movies or slides could be shown on pertinent safety topics, and special training could be conducted. In the area of operation and maintenance, "tailgate" or "toolbox" safety meetings should be held regularly by each supervisor, for instance, every payday or every 2 weeks. The meetings should be informal, no longer than 15 minutes, and the subject of discussion should be limited to a single topic, such as safety equipment, use of hard hats, eye protection, working in the heat, crane signals, wearing safety shoes, or protection from insects.

A report of each safety meeting should be filed with the safety officer. The report should be short and should be written on a standard form (see Fig. F-1 of Appendix F) indicating the following.

- Job location.
- Number of employees present.
- Date.
- Accidents reviewed.
- Subjects discussed.
- Suggestions or recommendations by employees.
- Action taken or supervisor's comments.
- Signature of supervisor in charge.

Each worker should be encouraged to provide input and suggestions regarding how the topic discussed applies to his or her department or specific job.

In addition to regular safety meetings, each employee should receive annual instructions on the safe use of special tools or equipment used on the job. This training should be reported in writing on an "Employee Safety Training Report" (see Fig. F-2 of Appendix F) and filed in the employee's personnel file. A copy of all "Employee Safety Training Reports" issued to that employee should be in his or her file and signed by both the instructor and the employee to verify that the employee acknowledges receiving the training.

The minutes of the aforementioned meetings and any other safety meeting should be recorded on a specific form (see Fig. F-3 of Appendix F). Safety presentations and ongoing discussions on safety problems within the organization need to be recorded, and any recommendations made need to be noted.

The safety program should be ongoing, with various materials, such as posters and fliers, being posted and distributed continuously to emphasize to all employees the importance of safety.

Unsafe Conditions

Any unsafe condition should be reported by the first employee noticing such a condition. A sample form for this purpose is provided as Fig. F-4 of Appendix F.

Accidents

Good safety programs prevent accidents. However, when accidents occur, all employees should be prepared to act responsibly. A responsible employee should report any accident to his or her supervisor upon finding out about or witnessing an incident from which a potential liability claim could result. Whenever an accident is observed or discovered, a written report should be made and include the following.

- Date and time of the incident.
- Name of person(s) sustaining injury or a description of property damaged.

- Description of exact location where incident occurred.
- Description of how the incident occurred.
- Brief description of damages or injuries observed.
- List of names, addresses, and telephone numbers of all persons involved or witnessing the incident.
- Description of weather conditions (i.e., whether road surface was slippery).
- Sketch of incident, if appropriate.

A sample "Driver's Report of Accident" is shown in Figs. F-5 (*a* and *b*) of Appendix F. A similar report would be used to report any type of accident.

The following instructions should be given to all employees to minimize their liability and that of the organization.

- DO NOT MAKE ANY STATEMENT AS TO YOUR OPINION REGARDING CAUSE, FAULT, OR LIABILITY IN REGARD TO ANY ACCIDENT.
- If the person involved in the accident makes claims or overtures to you, you must advise that person that all claims must be made to your organization or to the organization's insurance company.
- If the person does not make a claim, do not volunteer anything.
- If contacted by your organization's insurance representative, you should furnish the requested information as accurately and as quickly as possible.
- Refer any persons seeking accident information other than persons from your organization to the insurance representative.

Supervisors should also be required to file a report when any subordinate is injured or involved in an accident. A sample "Supervisor's Accident Report Form" is shown in Figs. F-6 (*a* and *b*) of Appendix F.

Whenever there is damage to equipment or facilities owned or operated by the organization, the damage should be reported in writing as soon as possible after the damage is discovered. A typical form on which to make such a report is shown in Fig. F-7 of Appendix F. This report can also be used as a record of notification to any insurance carrier, of repairs of the damage, and of billing and collection for the repairs from an insurance company or person responsible for the damage, if appropriate.

2.8.2. Public Safety

The board of directors policy should be expressed in writing, supporting all reasonable means of promoting public safety with respect to the facilities of the district. This can include appropriate warning signs on facilities that are dangerous, public education programs on water safety, installation of protective devices, and in some cases exclusion of the public from the facilities. Exclusion of the public should only be used as a last resort in the most critical locations; otherwise, a feeling of resentment may develop that people are being excluded just for the sake of exclusion. In some instances, this could reduce the effectiveness of keeping people away. A sample policy (established by a federal agency) is provided in Appendix F.

The one item that probably causes management the most anxiety and trouble is the safety of the recreationists. Fishing and swimming in canals, especially near structures, can be extremely hazardous and has resulted in loss of life by drowning. Warning signs, protective works including barriers, and public awareness programs should be used to reduce and eliminate accidents. These problems are less acute when included in the original planning than when such usage is not anticipated.

To ensure public safety, roads subject to interference by work on the project should be kept open, or suitable detours should be provided and maintained. Necessary barricades should be provided, erected, and maintained, suitable and sufficient flasher lights, flagmen, danger signals, and signs should be used, and all necessary precautions for the protection of the work and the safety of the public should be followed. All work should be done in accordance with all applicable safety regulations.

Roads closed to traffic should be protected by effective barricades on which should be placed acceptable warning and detour signs. All barricades and obstructions should be illuminated at night, and all lights should be kept burning from sunset until sunrise.

Animal Safety

Lined canals can become death traps for wild animals, especially deer. Animals seeking drinking water enter the canal, fall in, and are trapped when trying to cross the obstruction that lies in their paths. Escape devices in the canals, bridges for game crossing, fences, and other improvements have been successful in saving the lives of many animals. In all cases, there is a certain amount of maintenance necessary to keep these devices in good working order, but they should be used wherever practical.

In 1989, the Bureau of Reclamation in cooperation with the California Department of Fish and Game evaluated the effectiveness of a new system of large mammal entry/escape steps in the Coachella Canal In-Place Lining Prototype, Imperial County, Calif. The steps are based on an idea from a California citizens group, Desert Wildlife Unlimited, Inc.

The steps are 1.5 in. (3.8 cm) deep, spaced every 18 in. (45.7 cm) from the bottom to the top of the canal sides. The idea is to form the steps continuously along the entire length of the canal to provide escape opportunity at any point where a mammal might enter the water (Photograph 1).

The mule deer that took part in this study was able to enter and escape from the canal with a water velocity of 2 ft/second (61 cm/second) and a 2-½:1 side slope. This concept warrants testing at steeper slopes and higher water velocities.

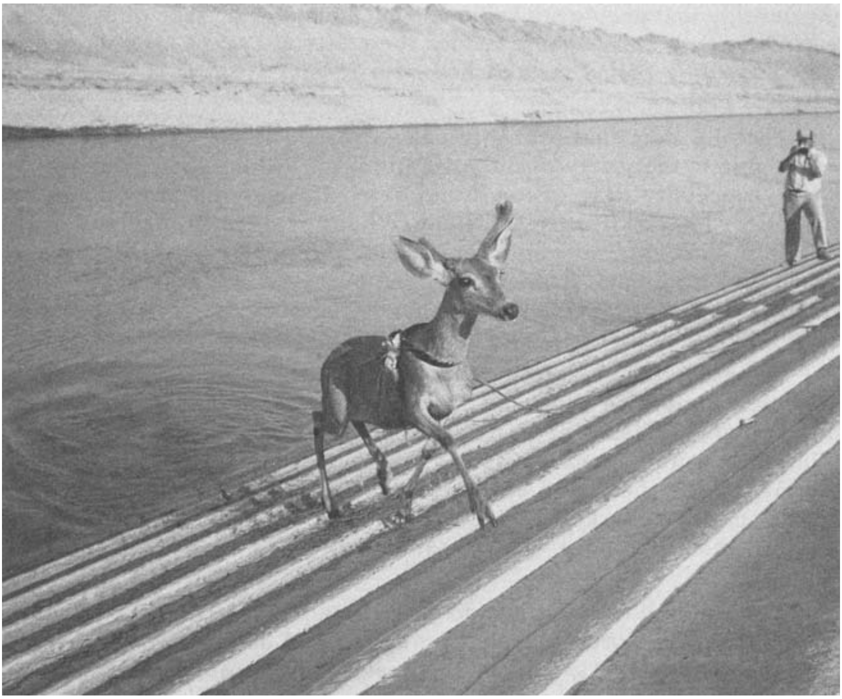


Photo 1. Deer gets good foothold on test entry/escape steps, Coachella Canal Inplacing Lining Prototype

2.9. LEGAL PROGRAM

An irrigation district should have adequate legal advice available to assure compliance with applicable laws for protection from adverse legal action. Large districts may find having a full-time attorney worthwhile; however, most districts will find an attorney on a consulting basis adequate and economical. Some of the important legal activities that need to be covered are listed here.

Contract Review

Each contract should have legal review before the manager or board of directors enters into the contract.

Legal Advice

Districts will find it advantageous for their attorney to attend most, if not all, board of director meetings to ensure that legal advice is available on actions taken by the board. The objective should be to ensure compliance with all laws and to reduce the prospects for adverse legal action against the district.

Protection of Water Supply

Most irrigation districts rely on water rights or contracts for part or all of their water supply. The attorney for the district should work with district officials to ensure that rights and/or contracts are maintained legally sound.

Litigation

An appropriate role for the attorney is to anticipate possible legal problems and avoid litigation to the extent possible. Competent legal counsel is essential if a district finds litigation necessary.

Right-of-Way

The district should appoint someone, either on a full-time or part-time basis, to monitor activities in or adjacent to the district's right-of-way and to develop a permit or licensing procedure before allowing intrusions into that right-of-way.

2.10. FUNCTIONAL AND SERVICE ACTIVITIES

The activities to operate and maintain the district effectively can be divided into two general categories—functional and service. Functional activities associated with delivery of water to users are usually assigned to an operations division, while a maintenance division sees that the physical works are adequately maintained and ready for use. Under certain circumstances, these divisions will be included in a single organization unit. However, if the need warrants, additional functional divisions can be established.

In any event, the two groups must work closely together even though there may be some shifting of personnel from one division to the other as workloads of the divisions shift. Detailed discussions of these divisions are presented in section 3 and section 4, respectively.

To complete the organization, the service activities are yet another segment that is essential to meeting district goals and objectives. These activities include the administration support for both the operations and maintenance functions.

The service division consists of administration, finance, engineering, and any other support activities deemed appropriate. These activities, which are an integral part of the organization, are described in this section.

Written documentation must be maintained for continuity within the organization. It includes record keeping, data processing, issuing legal notices, and scheduling board meetings. Personnel procedures must be clearly stated and available in written form to assure fair and equitable treatment of employees and to maintain the morale of the organization.

Fiscal management involves identifying sources of income, preparing and adopting budgets, and managing income and disbursements. Many of these activities should be formalized in rules and regulations regarding financial management.

2.11. ADMINISTRATION

A competent administrative staff is necessary to coordinate office, operations, and maintenance activities. Some, but not necessarily all, of the services that may be provided are the following.

- Developing management policy and administrative procedures.
- Personnel management and personnel manuals.
- Data processing.
- Typing and filing correspondence and reports.
- Filing and maintaining current and historical records.
- Maintaining a reference library.
- Property management and purchasing.

2.11.1. Personnel Management

Good personnel management is of vital importance to the success of an irrigation district. All employees should know what is expected of them and what they can expect of the agency. The policies of the agency should be fair and impartial in establishing the relationship between the employee and the agency. Each employee should be furnished a written copy of all personnel regulations and a written copy of a job description that clearly outlines the function, distinguishing features, examples of work to be performed, and required knowledge, skills, and abilities necessary to perform the job.

Some of the more important elements of a good personnel management program are outlined here. In some cases, more details are included in appendices to this manual.

Personnel Manual

The personnel manual will provide the basis for personnel actions and will help assure that all employees are treated fairly. The manual usually will include general policies regarding personnel matters and the rules, regulations, and procedures for handling personnel matters. Appendix B includes more detailed suggestions regarding some of the general policies and procedures that should be included in the manual.

Selection and Hiring of Employees

The selection and hiring procedures for employees will significantly affect the quality of the staff of the irrigation district. Some suggestions regarding the selection process and the hiring procedures are presented in Appendix B.

Training

Some employees will need training before performing their jobs, and all employees would benefit from periodic training, which also would help improve district operations. A training program should be an integral part of the personnel management system. Ideas for a training program are described in Appendix B.

Employee Rights and Responsibilities

Employees have certain rights but at the same time also have a responsibility to their employer. These should be clearly stated in the personnel manual. Some of them are identified in Appendix B.

Job Descriptions

Job descriptions are useful tools in any organization where employees do different and varying jobs. This would be particularly true for an irrigation district. A job description is a formalized statement of duties, qualifications, and responsibilities of the job and should be based on information obtained by analyzing the job.

The purpose of the description should be to identify the job, define certain established limits, and describe scope and content. Information on special working conditions, tools and equipment used, and relationships with other jobs should also be included. Finally, the description should be accurate, concise, and complete. Every position in the organization should have a job description.

The development of job descriptions is usually the responsibility of the personnel department in most medium- to large-sized organizations. However, the actual writing of the specific job descriptions usually requires input from several levels of the organization hierarchy, such as top management, supervisor, and employee for which the description is being written, and finally, a job analyst (personnel officer).

Job descriptions written by management are costly and frequently regarded with some suspicion by the employees. Supervisors usually have the knowledge to describe the job accurately, but sometimes tend to inflate the importance of jobs supervised to make their own jobs seem more important. The employee and the supervisor can provide essential input to a job description, but as a rule, neither has writing experience or the specialized knowledge and skills required to prepare a description properly.

For these reasons, many agencies rely on specialists, either in-house personnel or consultants who have experience in preparing job descriptions. However, all job descriptions must be approved for completeness and accuracy by the supervisor and the department head or manager.

Appendix C contains job descriptions for some of the positions listed in the detailed organization chart and accompanying flowcharts for a large water district. The job descriptions are included to illustrate how the differences in the responsibilities of several levels of jobs can be described. Small districts will combine the duties and responsibilities of several of the listed jobs.

Employee Evaluations

A yearly performance review should be conducted with each employee. This is a valuable technique for assuring that the employee knows how well he or she is doing and how improvements in performance can be made. There should be a written procedure for conducting employee performance reviews. Some suggestions are contained in Appendix B.

2.12. FINANCIAL MANAGEMENT

The financial management of an irrigation district requires the participation of all segments of the organization. The board of directors and the manager in particular will find that they need to devote a substantial portion of their time and energy assuring that the financial integrity of the district is maintained. The finance division will have assignments relating specifically to the management of the funds of the district. Other segments of the organization will assist in budget preparation and in the careful expenditure of funds. The activities related to financial management can be organized for convenience into three major categories: sources of income, fiscal control, and budget preparation.

2.12.1. Sources of Income

Most irrigation districts will have the authority to collect money by one or more methods. Care should be taken in selecting the method, or methods, best suited to the particular district. Dependable, rather than widely fluctuating sources, are desirable to assure adequate funds each year for operation and maintenance of the irrigation system. Sometimes funds are obtained from more than one source to have a diversity of income. In some cases, water charges can and should be used to encourage more efficient use of water and generate income for operating purposes.

Those who are paying need to feel that equitable methods are being used to collect funds and that no group is paying an unfair share of the total cost of operating the district. The following sources of income are the ones most commonly used by irrigation districts.

Assessment

Assessments on the value of land and/or the value of improvements is one of the common methods of raising income. This is equivalent to a property tax.

Each parcel of land and/or each permanent improvement on the land is given a value, usually market value. A tax rate is then adopted by the board of directors. That rate multiplied by the value of the land and/or improvement determines the amount of money that each owner must pay. This method is favorable from the standpoint that it offers a relatively stable source of income under which the people pay in proportion to the value of the land and/or improvements that they own. The method is also often considered equitable for obtaining income to repay capital investments for irrigation systems, since the capital investments tend to increase the value of the land.

However, determining the market value of the land and/or improvements sometimes is difficult and can lead to controversy among some property owners, who may feel that the value of their property has not been determined fairly. Procedures should be established to assess property valuations on as uniform a basis as possible. Appeal procedures also are needed so that individual landowners can present their case to the board of directors for final determinations in the event of a dispute.

Water Charges

Another common method for obtaining income is for the district to make charges for the amount of water used. Reasonably accurate water measuring devices are necessary in the use of this method. Collecting through water charges divides costs to water users in proportion to the amount of water each one uses, and tends to encourage efficient use of water. Establishing a base charge for a minimum quantity of water and then charging higher rates as larger quantities are used can further encourage efficient use.

One possible difficulty in using water charges is that the water supply in some cases may vary in amount from one year to the next. In a dry year, there will be less water to deliver, so income may be reduced unless the water rate is increased. A variable water rate may be distressing to the water users, but it also can be a powerful tool for encouraging more efficient use of water in dry years. In summary, the use of water charges has many advantages, but it must be applied judiciously to be equitable.

Standby Charges

The use of standby charges, usually combined with one or more of the other methods, sometimes is an appropriate source of income. The standby charge is a payment that assures the user the right to obtain a fair share of water, whether or not he or she uses it. Then, additional charges often are made for the amount actually used.

Payment by Area or Crop

Some districts charge water users on the basis of the amount of land that is irrigated. This approach may be modified by making different charges based on the type of crop grown. These approaches have an element of simplicity that seems attractive. However, providing equitable service among different users is difficult, unless most of the district is devoted to the same type of crop.

Fees for Special Services

In some cases, districts may need to collect money for special services provided to some, but not to all, users. For example, if a farmer wants two turnouts to his land rather than one, he may be required to pay for the extra facility, or if a farmer causes damage to district facilities, the cost of repairing the damage may be charged.

The preceding discussion on sources of income is not intended to be comprehensive. Some of the more common sources of income were mentioned. The board of directors, in consultation with the manager and with water users, should consider the alternative sources of income carefully with the view of developing a source, or perhaps several sources, that will meet the financial needs of the district and will be considered by most to be equitable, not favoring one group of water users over another.

2.12.2. Fiscal Control

Procedures for the collection, receipt, safekeeping, and payment of district funds need to be established carefully. The board of directors must assume ultimate responsibility for assuring that proper procedures are developed and followed. The treasurer, appointed by the board, and the staff of the finance division will play important roles in establishing fiscal control.

Standard accounting procedures should be adopted, and a fiscal control manual should be prepared and used by all persons involved in fiscal matters. An annual audit conducted by outside auditors should be arranged and reviewed carefully by the board of directors to assure that fiscal control is being maintained. Cost-accounting procedures should be developed that will facilitate the correlation of records of actual costs in past years with budgets proposed for future years. Such a correlation will simplify both the preparation of the budget and the keeping of permanent cost records, which, in turn, can be used in future budget preparation.

2.12.3. Budget Preparation

Preparing the annual budget is an important task that takes considerable time and foresight. The budget should adequately project the financial needs of the organization and should be within the reasonable expectation of funds that can be collected. A standard procedure for budget preparation should be developed and used year after year, except for changes that experience shows will improve the process. Table 1 is an example of a budget preparation schedule that can provide adequate time to develop, review, and adopt a budget for the next fiscal year. However, it should be noted that the time required will vary from district to district, and the format must be adjusted to meet the local situation.

Examples of budget preparation guidelines, budget codes, and budget maintenance recommendations are presented in Appendix D. That information should only be used as a guide, because the items to be included in a budget will vary from organization to organization, as will the appropriate codes.

2.13. ENGINEERING MANAGEMENT

An engineering division is often established as a separate component of an irrigation district organization to provide technical support for operations, maintenance, and other divisions. The size of the engineering division will depend upon the extent to which technical activities are required and the extent to which the work is done in-house. Qualified engineers will be needed to provide a variety of services. If the workload is sufficient, one or more full-time professional engineers should be hired. However, the use of engineering consultants may also be needed to provide specialized technical assistance or to meet peak workloads that can-

TABLE 1. Budget Preparation Schedule

Number of months prior to new budget (1)	Action (2)
6.0	Finance division distributes annual budget forms to all other divisions, with cost data from previous years and guidelines for budget preparation.
5.0	Individual divisions submit completed budget requests to finance division.
4.0	Finance division distributes copies of "first cut" budgets to all divisions and to the audit and budget committee of the board of directors for review.
3.5	Manager holds meetings with division heads to review submitted budgets. Finance division revises budgets in accordance with decisions made at budget meetings.
3.0	Finance division distributes manager's proposed budget to all division heads and the audit and budget committee.
2.5	Board audit and budget committee reviews and recommends budget to the full board of directors.
2.0	Board of directors approves budget.
1.0	Finance division distributes approved budget to all divisions.

not be handled by the regular staff. Some of the significant assignments for the engineering division are discussed herein.

Design of Facilities

New irrigation facilities and major modifications or repairs of existing facilities normally should be designed by a professionally trained engineer. Engineers also should supervise the construction of the facilities.

Maintaining Rights-of-way

The land on which the irrigation facilities are located needs to be under the control of the irrigation district, either by ownership or easement. A record of engineering and legal descriptions for such land should be established and maintained. Periodic inspections should be made to make sure that there are no improper encroachments on such land.

Monitoring Facilities

Periodic examinations of the irrigation facilities should be made to ensure that the facilities have been maintained satisfactorily and are structurally sound. The details of such a program are described in more detail in section 4. The engineering division should play an important role in the process of evaluating the condition of the facilities.

As-Built Drawings

The engineering division should be responsible for maintaining a file of as-built drawings, which will include the design and construction drawings of all of the irrigation facilities. Those drawings should be modified whenever changes are made in the facilities. Such a file will be valuable in making future repairs and in making modifications to upgrade the system.

SECTION 3. OPERATION

The term *operation* encompasses many activities including storing, conveying, and delivering water, as well as disposal or reuse of drainage water. For the purpose of this manual, the subject of operations is treated through a discussion of the factors essential to good water management within an agricultural irrigation and drainage district. Some of the main items covered include: management of water supply, scheduling water delivery to users, water control, water measurement, operating procedures, and performance monitoring and evaluation. Each aspect can take on different forms depending on the complexity of the system, ability and qualifications of personnel, requirements of the farm system, and institutional limitations.

The irrigation system, as discussed in this manual, is the water conveyance and distribution system that brings water from its source to the agricultural users. The drainage system refers to constructed systems for the removal of excess surface and ground water when natural drainage is inadequate. In arid and semiarid areas, drainage is a necessary part of an irrigation system, whether natural or man-made. In semihumid and humid areas, drainage systems usually exist without a man-made irrigation component. The main focus of this section is on irrigation systems and combined irrigation and drainage systems, particularly since drainage systems require fewer day-to-day operations. Information in this section is intended to assist management personnel in developing and preparing policies and regulations for the operations and to aid personnel in understanding the requirements of the customers.

The main purpose of an irrigation district is to supply water to agricultural water users who in turn use this water for production of food and fiber. Drainage is usually required to remove excess water to maintain or enhance this production. The type and quality of water delivery service can have an influence on drainage requirements and on quality of production. Proper management of the water supply is needed to assure adequate water throughout the growing season or to control delivery when the supply is inadequate.

The supply, delivery system, farm irrigation system, soil/cropping system, drainage system, and weather are all interrelated in their influence on agricultural production. The irrigation and drainage system operations should be focused on improving productivity and management capability while maintaining the resource base to provide a sustainable agricultural system. Degradation of the soil and water resource base will ultimately lead to the failure of an irrigation project.

While farm irrigation systems and practices may not be the direct responsibility of the irrigation district, the system must be operated and managed in conformance with farming practices. The water supply system is generally designed for use with a particular type of farm irrigation system and associated farming practices and crops. Changes in farm practices, including cropping patterns and method of irrigation, from those anticipated in design may cause difficulty in operational procedures. However, such on-farm changes are sometimes needed to maintain the economic viability of all farming within the irrigation district.

For this reason, an irrigation district may wish to make changes in both its operational plan and its physical facilities in order to respond adequately to a changing agricultural environment. However, changes should not be made without careful consideration for the consequences in terms of user service and water control. Any changes should be made with the realization that improved on-farm management may be used to justify upgrading district facilities.

The district has some responsibility for the overall impact of farming operations that can have an influence on farming practices indirectly through water charges, fines, and water allocations. Such influence should be motivated by improvement in productivity and viability of farming within the district, as well as by simplification or streamlining of district operations.

3.1. Operations Management

The importance of delivering irrigation water to water users at the right time and at the proper rate and duration cannot be overemphasized. This should be the ultimate goal in regard to the operations of any irrigation system. In order to reach this goal, operating personnel are needed to regulate the water supply, operate control structures and pumps, and coordinate system functions with the water users. Some degree of automation is usually beneficial.

Operations personnel are generally the "eyes and ears" of the water delivery organization and persons with the most direct day-to-day contact with water users. System operators are, therefore, not only responsible for seeing that the irrigation system is operated properly by reporting all needed maintenance, but they also must be public relations persons with the water users. The operators of any irrigation system must rely on the support of engineers, maintenance, administrative, and financial personnel, as well as with management, including the board of directors, to carry out their work effectively.

The size of irrigation systems will vary from very small to very large. All personnel operating small systems may report directly to the manager or superintendent, whereas personnel operating large systems will more than likely report to various levels of operations supervisors, depending on the size of the system and staff.

In a large agency, the operations are usually headed by a chief of operations who reports directly to the manager. This type of organization is depicted in the organizational charts presented in Appendix A [Fig. A-3 (*b*)] and the appropriate job descriptions in Appendix C. The chief of operations is responsible to see that the following are performed.

- Written copies of District policies pertaining to water deliveries are made available to all farmers and these policies are followed equitably.
- Water is available to farmers and is allocated and delivered in a manner as equitable as possible.

- The irrigation system is controlled responsibly.
- Every farmer is informed of appropriate water management and conservation practices.
- Water is only delivered to land that has an entitlement.
- All farmers are informed in writing as to what is expected and what their obligations are in respect to receiving water service.

Except for the smallest districts, the chief of operations will normally have office and field help to see that all necessary operations work is conducted in a responsible manner.

3.1.1. Policies and Rules

Operating policies and rules pertaining to the irrigation system operations should be adopted by the board of directors and written copies should be made available to all water users. The policies and rules should provide for equitable service to all water users. Some examples of such rules are the following.

Control of the irrigation system should be the sole responsibility of the district. However, when appropriate, operation of various aspects of the system may be delegated to others, including farmers.

Rights-of-way along or across project land should be made available only with a revocable permit issued to adjacent landowners. Written permits should also be required for private improvements that are placed on such rights-of-way.

Turnouts from the irrigation system should only be constructed following submittal of a written request by the landowner. Turnout sizes should be designed and constructed to allow the delivery of a sufficient amount and rate of water to irrigate appropriately the parcel of land that the turnout is planned to serve.

Water should only be delivered to land that has an entitlement. Unauthorized water deliveries should be reported immediately to management so that proper remedial action can be authorized.

All water should be measured and accounted. Even if water charges are not based on the amount of water used, the amount of water used by individual water users and how the water is used should be recorded.

A procedure for apportioning water during times of shortage must be established. Various methods for apportioning water are available (Johnston and Johnston 1990). Water shortage allocation methods may take into account the user's normal water allocation, amount of historical water use, size of the irrigated area, and type of irrigated crop.

Water users should have as much notice as possible for all scheduled or planned interruptions in service. To maintain good relations between the farmers and district, farmers should be notified ahead of time whenever a system shutdown is planned. A postcard with a simple message does the job (see Fig. E-10 of Appendix E).

Unscheduled interruptions in service may occur at any time due to malfunctions in the water delivery system. Farmers should have no recourse for interruptions in service, providing the district makes diligent efforts to repair the system as soon as possible. Water service should probably be discontinued to any user for unauthorized use of water, wasting water, nonpayment of water charges, and nonpayment of any other charges due the organization.

Additional provisions should be developed to authorize penalties or interest charges if there are persistent unpaid charges. An appeals process should be established for any water user who believes he or she is being treated unfairly. The water user can appeal any management decision to the board of directors for a final ruling.

Every farmer should be expected to carry out appropriate water conservation efforts. In some cases, the district may advise the farmer about timing and amount of water used. The district should oversee that all water delivered through the irrigation system is used for beneficial purposes. The waste of water should not be tolerated. Regulations should be adopted that require water service to be discontinued to any water user who is wasting water until the situation causing the waste is corrected.

3.1.2. Terms and Conditions of Water Service

In general, furnishing water service to a water user is subject to terms and conditions imposed by the organization providing the service. These terms and conditions should cover the following.

- Allocation of water.
- How service should be requested.
- Method of service.
- Responsibility for use of water.
- Water quality.
- Payment for water.
- Penalties for nonpayment.
- Conditions under which water service can be discontinued or modified.

An example of "Terms and Conditions for Agricultural Water Service" adopted by the board of directors of a large water district can be found in Appendix E.

Water Ordering

Water-ordering policy statements must be developed and furnished to all water users in order to allocate and deliver water in a timely and fair manner. Farmers should be required to submit water orders in advance to ensure delivery. The required advance notice will depend on the system, and on the amount of time required to move water through the system. Farmers must be informed of and comply with written water-ordering procedures established to meet the needs of the irrigation system from which the water will be delivered. A typical set of such procedures is presented in Appendix E. The more flexible arranged and demand systems require less rigid control.

Good record keeping pertaining to water requests by farmers should be maintained by operations personnel. Data to be tabulated should include the following.

- Date that requests are received.
- Service area for which the requests are made, with a separate form used for each area served by the system.
- Water user's name.
- Specific geographical location of water user's water delivery outlet from which the water will be delivered.
- Water user's numerical code, if any.
- Type of order (i.e., on, off, increase, or decrease).
- Flow rate.
- Time the order will be changed.
- Description of service or where water will be used.
- Crop growing in service area.
- Crop planting date.

Fig. E-11 of Appendix E is a sample "Water Request Tabulation Form."

3.1.3. System Operation

Operations personnel should be responsible for the operation of all district facilities. Personnel should regulate the fixed water deliveries and coordinate the variable deliveries through the system, interpret and evaluate variations between actual and scheduled flows, and modify settings of control facilities as needed. Following is a list of specific operations functions that must be carried out by operations personnel to ensure delivery of water in a timely manner.

Check gates may be operated either by manual or supervisory control. Gate settings should be determined by using actual discharges as compared to assumed or target flows. Necessary check gate adjustments should be made at proper time intervals to allow the flow change to reach the next check structure in the system. Check gates should be operated in such a manner as to keep canals at the desired operating range. A tabulation of upstream or downstream limits for water surface elevations should be developed for each section of the canal.

Locks should be maintained on all canal side turnouts and should be unlocked as orders are placed. Turnouts not in use should be kept locked to prevent unauthorized use. Exceptions could be made for those users who request that their turnouts remain unlocked for stock or spray purposes or because their method of operation calls for intermittent use.

Users may be allowed to regulate their individual turnout gates as needed, but operations personnel should check and record flows daily, or more frequently, if necessary, to maintain control of the system. Gates or meters found turned off and unlocked during the collection of routine meter readings should be locked unless the water users have given prior notification of their desire to keep the turnout unlocked. Water users may fail to call in shutoffs and water orders that are carried beyond their applicable date, thereby disrupting operations.

Where gates are used to control water deliveries, readings should be done quite frequently, preferably twice a day, if possible. Standardized forms should be used to record gate readings, which can be converted to discharge rates and volumes of water delivered. Remarks should be placed on these forms regarding gate condition, unusual situations, and water users' requests or complaints.

Where meters are used, the meters should be read at least weekly and on the last working day of the billing period. Forms used to record meter readings should be completed to indicate the turnout number, the meter reading, and the time the meter was read. Routine calibration checks should be made on all meters. Notes should be made regarding meter condition or special situations. Additional meter readings may be required depending on water supply conditions and water user requests. An example of such a form is Fig. E-3 of Appendix E.

All meters should be routinely removed, inspected, and serviced. Where relatively clear water, free of debris, is delivered, water meters may need to be serviced less frequently than where turbid water or water carrying debris is metered. Continued variation in meter calibrations is an indication that the meter needs servicing. Worn or damaged parts can be replaced at this time. Leaking gates or meters not registering properly should be attended to as soon as possible. Gear changes on meters should be made when repeated tests indicate a discrepancy of over 2%.

Records should be kept regarding all gate or meter maintenance performed, indicating date, servicing, and any necessary parts. An adequate inventory of needed parts for gate or meter maintenance must be maintained. Gates and meters should be painted between irrigation seasons and equipped with cathodic protection where necessary. The maintenance process is described in section 4 of this manual.

The system should be patrolled daily to set check gates and lock and unlock turnouts and meters. Automation and/or use of pipelines may reduce workload. Information regarding daily activities should be maintained on a daily trip sheet. Daily visual inspections of all system facilities should be maintained noting malfunctioning gates or meters, seepage areas, cracks in concrete lining, sloughing of banks, and other irregularities. Upstream and downstream check elevations should also be recorded at each check site where applicable. Pressures and flows should be noted at all critical locations in pipeline systems.

All incorrect system conditions, improper water usage, and inappropriate daily activities taking place in each area of responsibility should be reported immediately. System conditions that should be reported are such things as alarms, trouble reports, gate or meter malfunctions, pipeline leaks, canal lining problems, and any other conditions that would affect operation or safety of the system.

System malfunctions should be corrected by originating a work order as described in Appendix G. Observations and incidents along the canal right-of-way, such as farmers or others encroaching on project property, parking equipment, storing tools, dumping debris or trash, vandalism, and trespassing should be reported immediately. Reports should be made regarding dead animals found in project facilities or along the right-of-way. These reports shall be made on a daily basis, and appropriate action should be taken to rectify the problem.

Trash screens should be cleaned and lubricated as frequently as necessary, and oil reservoirs on pumps used in the system filled as prescribed in standard operating procedures adopted by the district.

Emergency electrical power must be provided for certain facilities when regular power is not available. In that regard, operations personnel should maintain auxiliary power generators in proper working order in case of power outage.

Complaints reported to operators should also be reported in writing on a form such as the one shown in Fig. E-12 of Appendix E. This gives supervisors and management the opportunity to review organization policies and practices with dissatisfied customers or other persons unhappy with the organization.

All gate and meter readings needed to determine the volume of water use for the previous period, and used for water billing purposes, should be submitted to the finance division at the appropriate time.

3.1.4. Delivery Schedules

The delivery schedule refers to the method by which the irrigation district determines who will receive water from the district water distribution system and when they will receive it. A variety of delivery schedules has been used in various parts of the world. Often, a delivery schedule is in use because of historical development, rather than because it is the best schedule to use for a given area.

The purpose of this section is to present issues that are relevant to selection of a delivery schedule to match existing conditions within a district. The primary components of a delivery schedule are delivery *flow rate*, irrigation *frequency*, and irrigation delivery *duration*. These methods have been summarized by Replogle and Merriam (1980) and are presented with minor modification in Table 2. These delivery schedules are broken down according to degree of flexibility given to the farmer in terms of flow rate, frequency, and duration of application, and level within the delivery system at which irrigation delivery decisions are made. The types of major delivery schedules include demand, arranged, central system, and rotation.

These schedules can be viewed from two points of view. The first is from suitability at meeting crop water demands within limits of allowable soil moisture depletion while allowing for efficient use of water and labor. The second is from suitability for operation of the water distribution system. Since the farmers ultimately pay for the water distribution system through taxes, water charges, etc., the distribution system should provide for the most economical mixture of farm operation, delivery schedule, and distribution system design capability.

Schedules are delimited by the way in which the rate, frequency, and duration are determined. Several methods are available for specifying each of these basic components.

TABLE 2. Definitions of Delivery Scheduling Methods

System constraints schedule categories (1)	Frequency (2)	Rate (3)	Duration (4)
(*a*) Local control: Demand schedules			
Demand	U	U	U
Limited-rate demand	U	L	U
Arranged-frequency demand	A	L	U
(*b*) Intermediate Control: Arranged schedules			
Arranged	A	A	A
Limited rate arranged	A	L	A
Restricted arranged	A	C	C
Fixed duration arranged	A	C	F
Fixed rate/restricted arranged	A	F	C
(c) Central control: Central system schedules			
Central system	V	V	V
Fixed amount	V	F	F
(*d*) Rotation schedules			
Rotation	F	F	F
Varied amount rotation	F	F(V)	F(V)
Varied frequency rotation	F(V)	F	F(V)
Continuous flow	—	F(V)	—

U = unlimited, no restriction, under user control.
L = limited to maximum flow rate, but still arranged.
A = arranged between user and water authority.
C = constant during irrigation as arranged.
F = fixed by central policy.
V = varied by central authority at authority's discretion.
(V)= varied by central authority seasonally by policy.

The delivery *flow rate* can be set by administrative policy and fixed for the entire irrigation season. This represents the most rigid method for establishing the rate of flow, and possibly allows the flow rate to vary over the season to match crop consumptive use more closely. However, efficient operation of farm irrigation systems often requires a flow rate that is appropriate for the application requirements and field conditions. Drastically different flow rates are needed for trickle, sprinkler, or surface irrigation methods and for different-sized fields and soil types.

For surface methods, typically, higher flow rates are needed in the early season when soil infiltration rates are high. Thus, maintaining high efficiencies during the entire season would require greater flow rates at lesser duration and frequency early in the season, and the reverse later in the season. Strict rotation schemes are not capable of meeting these needs.

Many irrigation districts are able to arrange flow rates with a farmer so that the farmer can adjust for changing field conditions. A few districts with automated systems are capable of allowing flow rates to be changed during irrigation. Other districts hold to a strict delivery rate and allow frequency and duration to vary instead. Many districts have standardized delivery flow rates. This simplifies operations, since delivery system operators can speak in terms of the number of delivery heads or number of simultaneous deliveries rather than flow rate. Even where flow rates are arranged, the standard delivery rate is assumed unless otherwise specified. When systems are modified or upgraded, greater flexibility in varying delivery rates becomes more practical.

There is usually a limitation placed on the maximum flow rate that can be delivered. This is a practical structure capacity limitation; however, in most cases this is not a significant restriction. Some arranged schedules also place a limit on the minimum flow rate that will be delivered. This limitation is imposed because of the difficulty of managing small flow rates in a system designed for large flow rates.

In many cases, much water lost to an irrigation project is lost due to inappropriate *frequency* of irrigation. This is particularly true of rotation schemes with a fixed rotation frequency. Since crops usually have a varied need for water over time, water supplied on a fixed schedule is partially wasted. A fact well established is that both over-irrigation and under-irrigation tend to reduce crop yields. Thus, an inappropriate frequency both wastes water (from a project standpoint) and reduces yields.

In addition, frequency restrictions can also limit the types of crops that can be grown. For example, if the frequency is too long, shallow-rooted crops cannot be grown on low water-holding capacity soils. Frequency restrictions can also limit the type of irrigation system used. Trickle irrigation generally requires shorter irrigation frequencies than surface or sprinkler irrigation. Thus, a frequency set up for surface irrigation systems may be totally inappropriate for trickle or automated sprinkler irrigation methods.

Sophisticated methods of irrigation scheduling are being developed and used to provide better management of irrigation water. As more farmers use such methods and develop a better appreciation of good irrigation water management, frequency restrictions imposed by an irrigation project will be detrimental to the implementation of these techniques. In addition, fixed-frequency rotations (even when adjusted for seasonal changes) do not allow for the effective use of rainfall. This use is needed, since sufficient rain will effectively put all users in the same position in a rotation cycle, a cycle that does not have the capacity to shut down and then catch up.

Too much flexibility in frequency of irrigation can cause problems as well. Several districts have experienced the problem of low demands on weekends and holidays. This problem is difficult to handle without having increased spills unless sufficient storage is available or demand changes are known well ahead of time in order to permit adjustment of canal flows accordingly.

Under the more rigid rotation schedules, *duration* is tied to flow rate and frequency for a particular land area covered. When water is applied frequently, the duration will probably be too short for the efficient application of water. For demand systems, duration is not limited; however, duration becomes a significant factor for on-farm management of irrigation water with the intermediate (arranged) systems. The irrigation duration should be that needed to infiltrate the desired depth of water and no longer.

A fixed duration is the most common restriction (discussed under flow rate considerations) and can cause significant reductions in on-farm irrigation efficiency. In addition, a fixed duration can limit crop diversity. For example, if the irrigation scheme is set up to supply water at a given rate and given duration to a given land area (based on peak season consumptive use), the planting of different crops within this block of land (or irrigation of smaller blocks of land) becomes difficult. For even reasonable efficiency in regard to water use or labor, the farmer must irrigate the entire block at once.

Duration restrictions are often reinforced by the farmers desire to use fixed duration irrigations for labor convenience. In many cases, this is a result of highly labor-intensive irrigation methods (surface irrigation with siphon tubes). In addition, fixed durations of 8, 12, or 24 hr allow irrigators to limit nighttime irrigation operations, which are often undesirable. Under arranged schedules with arranged durations in nonautomated canal systems, efficient canal operation may require one farmer to take water as soon as a neighboring farmer is finished, even in the middle of the night. Automation and increased storage can be added to increase the flexibility of such systems.

If the on-farm irrigation changes can be made by pushing a button, opening a gate, or opening a series of ports, fixed durations may not be too unreasonable for middle-of-the-night changes. However, if setting siphon tubes or spills is required, this schedule is usually not desirable to farmers. When only daytime irrigations are used, some form of reservoir storage, either district or on-farm, is needed to hold the excess water, unless the canal system can be automated to pass upstream variations downstream for next-day use, or dumped as operation spills. An alternative is to shut down the canal at night (through use of downstream controls).

Water rights and allocations play a role in determining delivery schedules. Centrally controlled scheduling automatically takes these limitations into account. For the less centrally controlled schedules (demand and arranged), flexibility is often limited by the seasonal volume of water available or allocated. Flexible schedules can, in some cases, contribute to the inequitable distribution of water within a project. Proper controls must be established to limit water deliveries arranged in the project.

Rotation Schedules

Rotation schedules are the most restrictive of all irrigation schedules. The rate, frequency, and duration are fixed by policy of the central water authority and remain fixed for the entire irrigation season. Where proper administrative controls are lacking, a rotation schedule can be more equitable than a more flexible delivery schedule.

There are a number of possible variations on the pure rotation schedule that allow the schedule to meet farm and crop needs better. Several methods are discussed herein.

Continuous flow schedules are a special case of rotation systems, where the duration is the entire season and the frequency is once per year (see Fig. 2). Rotation and continuous flow systems are used in the United States in places where water is plentiful, the growing season is short, and the economics of efficient irrigation for maximum yield are not justified. Here, flow rates can be varied over the season to meet crop water needs. In many cases, while a constant rate is delivered to a farm, the water is rotated between fields or spilled when not needed for irrigation.

Varied-amount rotation schedules are one way of adjusting the volume of water delivered over different parts of the growing season. In general, the frequency remains fixed, while the duration and/or rate is varied to apply more or less water to a particular area. Adjustments in rate are fairly easily accomplished; however, adjustments in duration without adjustments in frequency are a little more difficult. One example would be to supply water one-half of the time to alternate rotation areas.

Varied-frequency rotation schedules are another way of adjusting for variations in crop water use over the irrigation season (see Fig. 3). Under these schedules, the frequency of delivery is varied. Again, it is somewhat difficult to accomplish without rate and duration variations, except in even multiples (for example, double the irrigation frequency during peak use periods of that in the early and late season). Another alternative is to drain water from the canal for part of the season if water can be stored for use when needed.

Demand Schedules

Demand schedules are the most flexible of all the irrigation schedules. In effect, they allow an unlimited amount of water to be taken from the system at user convenience. In many instances, such ideal systems are not practical and would be prohibitively expensive. The emphasis here is that the user decides when and how much water to take and when it will be

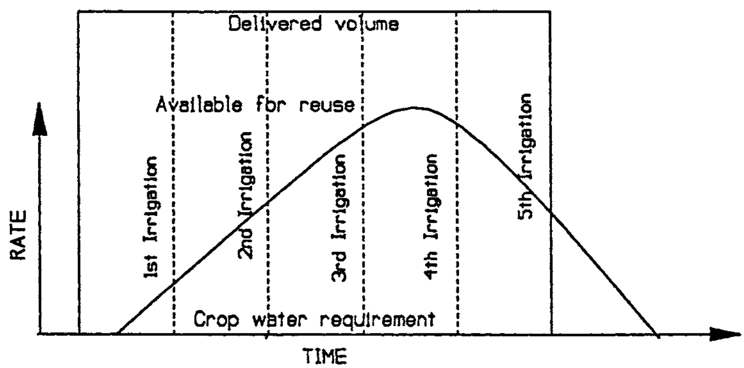


Fig. 2. Constant Amount-Constant Frequency (Rotation) Schedule

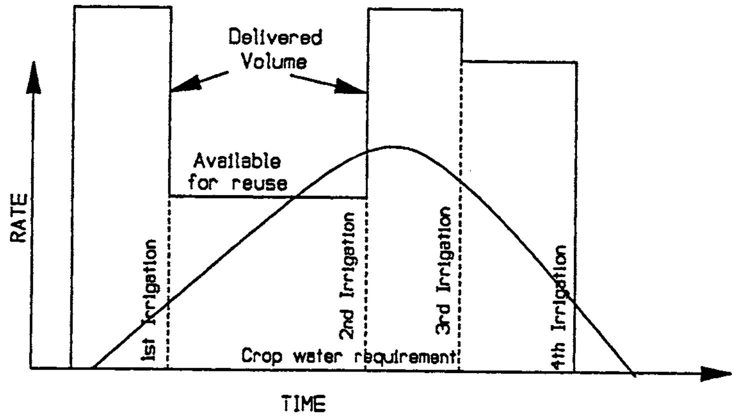


Fig. 3. Constant Amount-Variable Frequency Schedule (Variable Frequency Rotation)

taken. This is in sharp contrast to the aforementioned rotation schedules. Two of the most practical demand schedules are presented here.

Limited rate demand schedules allow the user to determine rate, frequency, and duration, but the flow rate is limited to a maximum amount. This allows considerable flexibility, while still being feasible. A number of such systems for surface irrigation are in practice through the use of reservoirs and level top canals. Pressurized water supply systems also operate under this type of schedule.

Arranged frequency demand schedules add a further restriction on water delivery when arrangements are made for an irrigation to begin, but once the irrigation begins, the user is in complete control of the water supply. Such a scheduling system is feasible for trickle or sprinkler irrigation systems. It is particularly suited to pressurized pipelines and surface irrigation methods where soil intake rates change.

Arranged Schedules

Under arranged schedules, rate, frequency, and duration are arranged between user (farmer) and water supply agency. Often, these arrangements are made on a local level, rather than on project level. This allows for more flexibility in arrangements (for example, last minute changes in arrangement).

The advantage of arranged schedules is that while flexibility is provided for farm operations, simpler delivery system operations rather than more complex demand systems are allowed. In fact, the delivery system operational capabilities have a direct impact on how flexible an arranged schedule can be for existing systems. The reverse should be true in the design of new systems. In essence, there is a continuum of possibilities from a pure demand system to a very restricted arranged system. The distinction between these schedules and rotation schedules is that in the latter, all decisions are made by a central authority.

The timing of arrangements is an important feature of arranged schedules and can have a significant impact on the success or failure of the arranged schedule. Some arranged schedules require a long lead time (3 to 4 days), while others require fairly short lead time (1 day). With an automated supply system, only an adequate water supply is needed. These differences can be significant, particularly for some irrigation scheduling methods. In addition, a change in duration (or even in rate) during the course of an irrigation could be necessary. This is easier to accomplish when irrigation durations are not fixed by policy, since it may just mean rearranging the start time for the subsequent user. Following are a number of commonly used arranged schedules.

Limited-rate arranged schedules are very flexible in that a restriction is placed only on the maximum flow rate, with frequency and duration arranged according to farmer needs. This schedule allows for changes in rate and duration during the irrigation, under direct farmer control, but within arranged limits.

Restricted arranged schedules are somewhat less flexible in that once they are set for an irrigation, rate and duration are agreed upon and unchangeable. This precludes any irrigator adjustments for conditions during the irrigation process, but any agreed restriction may be made.

Other schedules include the *fixed-duration arranged schedule*, where the irrigation duration is fixed and unchangeable even by arrangement, and the *fixed-rate arranged schedule*, where the flow rate is fixed and nonnegotiable. Other schedules are possible as well.

Central System Schedules

The idea behind this method, called system scheduling, is to improve the predictive ability of the project in estimating crop water needs several days ahead of time. Such schedules have not proven practical, but under limited circumstances, system scheduling may reduce errors in diversions of water while reducing lead time for ordering water. The idea is for the irrigation district to schedule all irrigations for farmers on a project-wide basis to allow the district an accurate forecast of future demand. This could be used to match crop water needs better within flow rate capacity restrictions of the delivery system. Early attempts at scheduling with this method found that farmers were unwilling to give up the important function of scheduling.

There are situations in which each type of scheme is useful. Using different schedules in different parts of the same district may be appropriate to minimize total cost of operations while still providing a satisfactory and equitable level of delivery performance. The rationale used here is that the farmer ultimately pays for the entire cost of collecting, storing, transmitting, and distributing water as well as on-farm water application and other on-farm water-impacted practices. Thus, it makes sense to provide a combined farm/project system that is most efficient and economical in totality. Flexibility and increased capacity increases costs, either in hardware changes (automatic gates, increases in system capacity, or additional reservoirs) or in software changes (more labor or more remote monitoring). This flexibility can often provide enough improvement in project operational efficiency and on-farm production and labor benefits to offset the added cost. However, the improvements and costs must be examined for each situation. Thus, it is important to select the proper degree of delivery flexibility that allows the farmer to operate reasonably independently, while still allowing for efficient, economical distribution system operation. A variety of reasons, both current and future, for using one schedule over another include the following.

Farm operational conditions:

- Types and capacities of irrigation systems in project.
- Types of crops grown.
- Types of soil.
- Size and complexity of farming operations.
- Level of farmer knowledge about irrigation and water management.
- Cost and availability of labor.

District operational conditions:

- Type of physical controls needed to operate district distribution canals and pipelines (automatic gates, remote monitoring, and instrumentation).
- Labor requirements and availability to operate project.
- Communication requirements.
- Level of technology required to operate and maintain project.
- Storage capacity on or off channel.
- System capacities.
- Effect of delivery schedule on overall project efficiency.

System capacity is viewed as a major limitation in increasing the flexibility of an irrigation water delivery system. While the benefits of improved flexibility vary from farm to farm, improving flexibility is normally desirable to insure the long-term future of irrigated agriculture.

3.1.5. Farm Irrigation and Drainage Systems

Farm irrigation systems can be classified into the following groups.

- Surface irrigation.
- Sprinkler irrigation.
- Micro- (drip or trickle) irrigation.
- Subsurface irrigation and controlled drainage.

The requirements of the water supply and distribution system vary widely for these different methods. In addition to the farm application method, farm water conveyance systems, particularly for surface irrigation, can also have a significant influence on water delivery requirements.

Surface Irrigation

There are a wide variety of surface irrigation methods and they vary considerably in their ability to apply irrigation water. The common feature of all surface irrigation systems is that water is conveyed from one part of the field to another by flowing over the land surface. Differences in infiltrated amounts of water in different parts of the field result from the time required for water to advance across the field and from differences in soil infiltration conditions. The water advance ratio is the ratio between the total time irrigation water is applied to the sloping field and the time needed for irrigation water to reach the lower end of the field.

Lower advance ratios for furrows and basins generally result in excess deep percolation at the upper end of the field, while higher advance ratios typically result in large runoff volumes. Thus, there is often a trade-off by the irrigator between the observable (and immediately reusable) surface runoff and deep percolation, which is more difficult to see or to recover.

Good water distribution uniformity is important for achieving good crop yields and avoiding excess deep percolation. High water application efficiency may be important where water is scarce or expensive, or where accumulation of excess drainage water is a problem. For any surface irrigation system, there is a relationship between application efficiency, distribution uniformity, and the soil moisture deficit at the time of irrigation in any specific field.

This relationship is governed by hydraulic properties of the system—field layout, soil infiltration conditions, crop resistance to flow, and delivered flow rate (per unit width or per furrow). During the growing season, the field layout usually remains fixed while infiltration and crop retardance change. Thus, adjustment in flow rate and application time are the controls the irrigator has to compensate for changes in soil moisture deficiencies, soil intake rates, irrigation hydraulics, and thus, efficiency and uniformity.

Irrigation applications on soils with a low soil moisture deficit will generally have high runoff and result in an inefficient irrigation. Early in the season, when crop rooting depth is shallow and soil infiltration rates are high, a great deal of water is generally lost to deep percolation. However, in order to irrigate at the proper soil moisture deficit (i.e., to optimize irrigation efficiency for some desired level of uniformity), the farmer must have control over frequency of irrigation.

Surface irrigation systems are very forgiving, in that regardless of the water supply constraints (except for having an insufficient supply), irrigators can successfully irrigate any given field, though probably not economically or efficiently, and since a farmer's main concern is profit and loss, application efficiencies can be quite low. If the irrigation district must handle the water returned as a result of low farm application efficiencies, consideration should be given to improving water control on the delivery side.

Use of Water

Farmers use water as a tool. Water is used to control temperature, reduce soil salinity levels, aid in germination, and reduce labor. Some of these uses are needed for long-term sustainability of the agricultural system, while others are simply for convenience or cost savings. Where water costs are low, more water will be used for management purposes.

Sprinkler Irrigation

In sprinkler irrigation, water is conveyed to the point of use in a pipe and released above the soil surface as a spray with a distribution uniformity comparable to surface irrigation methods. Sprinkler systems apply water at predetermined rates so the water depth applied is duration controlled. Rigid durations cause under-irrigation or over-irrigation regardless of uniformity. Frequency control is essential to match soil moisture requirements. Sprinkler systems are generally designed to apply water at a rate less than the soil infiltration rate so that there is little or no runoff. Greater or lesser amounts of water can be applied either by simply changing the set time (for fixed sprinklers) or by changing the rate of travel (for moving sprinklers).

Sprinklers can typically take better advantage of small water supply rates than can surface systems. Sprinklers can be used more easily on undulating land than surface methods, although elevation differences can cause non-uniform sprinkler irrigation. Sprinklers have particular advantages over surface irrigation where soils have very high infiltration rates and low water-holding capacities, which can cause large amounts of deep percolation, and where topography is steep.

Labor required for sprinkler irrigation can be less than or more than for surface systems, but more importantly, labor is typically not required during irrigation. Sprinklers can often be used for germination (for normally surface-irrigated fields), fertilizer applications, and temperature control.

Sprinkler systems usually require a high degree of control over the water supply. Supplying sprinkler pressure from a high-water source would be ideal. However, sprinkler pressures are generally supplied by pumping. Pumping from a water supply reservoir, ground-water, streams and rivers, or from a large canal is desirable in that water supply rates to the pumps are flexible.

The operation of sprinkler irrigation systems requires greater control of the water supply than does surface irrigation. Any changes in flow caused by changing operating pressures are easily accounted. Shutdowns due to moving systems becoming stuck or due to pipe breakage cause little difficulty for the district. However, when the water supply for a sprinkler system comes from a canal network (or an open-pipe network), changes in sprinkler water demand or sprinkler shutdown can cause operational difficulties. If water is pumped from a farm canal, water must be over supplied to assure proper pump operation. The excess water must then be directed to a drainage or return flow system.

Micro-Irrigation

Micro-irrigation encompasses a variety of techniques designed essentially to supply water to individual plants. Similar to sprinkler irrigation, water is supplied under pressure in pipelines, but rather than being broadcast with a sprinkler head, water is supplied to small areas near the plants.

Micro-irrigation systems have water supply requirements similar to sprinkler systems. Flow rates for trickle systems are much lower, and so are more frequent, than sprinkler systems. Micro-irrigation systems also require more physical and chemical treatment of the water than do surface and sprinkler systems. This can be a problem when water is supplied from canals where water quality is poor or varies greatly. Farm reservoirs are often used to supply trickle irrigation systems by storing canal water delivered at standard (for surface irrigation) rates.

Subsurface Irrigation and Controlled Drainage

Subsurface irrigation provides water to the soil within the plant root zone by raising the water table. After the soil becomes sufficiently saturated, the water table is lowered to allow oxygen to the plant roots. Subsurface and/or surface drains are used to raise and lower the water table. If surface water is supplied for subsurface irrigation, the quantity required may be unknown because of uncertainty concerning initial water table conditions. In addition, the amount of drainage water is also variable. These uncertainties may require some flexibility in operations.

Such irrigation is typically not done in arid environments where water is scarce, drainage water is saline, and drainage outlets are under close scrutiny. In more humid regions, such systems more often resemble controlled drainage.

Under controlled drainage, the water table is manipulated by adjusting the overflow level of the drainage outlets. This outlet can be a buried pipeline, canal, or natural stream. Water is supplied through rainfall, streamflow, or through ground-water flow from adjacent lands. Soil moisture for plant growth comes from capillary rise from the water table rather than through subsurface irrigation. Efficient operation of these systems usually requires close soil moisture and precipitation monitoring and forecasting.

Farm Drainage Systems

When natural drainage is inadequate, a man-made drainage system is necessary to assist the natural drainage process. There are several types of farm drainage systems. Surface drainage from fields resulting from excess rainfall or irrigation is usually handled by drainage ditches or canals that convey water to a natural water course or a larger collective drainage system. Subsurface drainage can be accomplished with subsurface drains that convey drainage water to a drainage outlet, deep surface drains that drain excess water through lateral ground-water flow, and ground-water wells that pump excess drainage water from the water table.

Farm drainage systems are generally small and work with shallow, local water table conditions. Frequently, drainage problems result from conditions that cover geographic areas larger than a single farm. As a result, collective drainage systems of a larger scale are needed. These then act as outlets for farm drainage systems.

3.1.6. Water Distribution

Conveyance and Distribution Systems

The purpose of an irrigation or combined irrigation-drainage system is to deliver water efficiently and equitably from source of supply to all users at the most economical cost considering the on-farm and project costs and benefits. This must be commensurate with the type of service that the water users are willing to support and consistent with sound water management practices and water conservation.

To maintain these objectives, the management agency must maintain the total irrigation-drainage system to the degree necessary to preserve the capacity and condition of facilities in a manner that avoids undue depreciation, store and deliver irrigation water as required by water users, hold seepage and operational waste to an economical limit, and be constantly alert to technical advancement by adopting new practices that will improve system operating efficiency and costs as well as on-farm operations.

The conveyance and distribution system will consist of a combination of diversion facilities, main canals and pipelines, lateral and sublaterals with associated water control structures, and regulating reservoirs.

Designation of Waterways

Some method of numbering canals, laterals, turnouts, drains, and wasteways is essential as a basis for reference on maps and in records. Main waterways are normally designated by names, letters, or numbers. On smaller systems, all may be given names. A key index map showing the numbers or names of all waterways should be available to all organizational personnel.

Water Orders

Some agencies issue a notice of eligibility for water service to the watermaster. This supplies the watermaster and ditchtender with names of users entitled to water over a specific period. Under rigid rotation and continuous flow systems, water ordering is essentially seasonal (e.g., indicating whether a crop is being grown). Some rotation systems allow a user to skip a turn in rotation. This refused water is difficult to manage and typically wasted unless storage is available. The ability of the operating system to handle changes in water orders varies with the operating system. More rigid operating systems (upstream control) require advance notice of changes in delivery.

Under more flexible arranged systems, changes are negotiated with the ditchtender in the field. Unless the operating system is designed to accommodate these changes, waste or impaired service to other users results. Under true demand systems, no water ordering is necessary. However, under the arranged-frequency demand schedule, a water order is required to start water delivery, but the user can then take water on demand for some specified period. The amount of record keeping on water order changes depends somewhat on how water deliveries are monitored (totalized flow or periodic rate measurements), and how the operating system handles these changes.

3.1.7. Water Supply

Sources of Water

Management of an irrigation and drainage system requires management of the water resource. This resource may come from precipitation runoff, storage reservoirs, irrigation return flow, or ground-water. Whatever the source, good management requires that an estimate of some type be made of the quantity of water available or handled annually, and possibly its quality. Quality is especially important where return flow or pumped water is involved.

Water Supply Forecasting

In the arid and semiarid Western United States, where a major portion of precipitation occurs during the winter months, water supply forecasts generally are made monthly by various agencies and organizations to determine the amount of surface runoff that can be expected. Water in storage, snow water content, and rainfall can be easily determined. Surface runoff and return flow can only be estimated from previous records, statistical analysis, and hydrologic modeling.

Ground-water availability can be determined by observing the effects of pumping on ground-water levels and by consideration of the depth to which pumping is practiced. None of the more sophisticated forecasting tools can fully replace the experience of operating personnel.

Storage

Water storage reservoirs facilitate the management of irrigation water supplies. Water produced by precipitation falling on the hydrologic basin can be captured and regulated for the most beneficial usage within the basin. Water captured and stored during periods of storm runoff or snowmelt can constitute the primary water supply for the irrigation season. On larger multipurpose projects, the reservoir storage may be used for added benefits of flood control or providing water supply for power generation, municipal and industrial uses, water quality maintenance, recreation, or fish and wildlife uses.

An irrigation system may include more than the main storage reservoir. Regulating reservoirs constructed on or beside the main canal are used for the purpose of regulating flows to maintain balance in operations. This is particularly beneficial in larger systems with lengthy canals. Offline reservoirs constructed off the main canal can serve the same purpose, but can also serve as pump storage facilities for power generation or be used to overcome delivery capacity constraints in the system. The various types and locations of reservoirs all serve to improve the overall efficiency and flexibility in managing the water resource.

Reservoir Operation

The operation of a storage reservoir for irrigation is a matter of regulating the available storage space. All dams and water control structures have certain limitations and operators must be thoroughly familiar with them. The simplest operation involves the scheduled release of water to meet the full or supplemental water requirements throughout the growing season. Refilling of the reservoir takes place during the rainy season or as the result of snowmelt runoff.

Snow survey data, weather and hydrological data should be used to prepare flood criteria for the reservoir. If a flood is predicted, reservoir storage must be made available, with discharge being regulated to keep downstream flows within safe operating ranges. After the flood season, releases of water must be made to meet vested water rights existing prior to construction of the reservoir, minimum streamflow conditions, and irrigation requirements of land dependent on reservoir storage.

The latter involves scheduling flows to meet the commitments of stored water allocation. The difficulty in managing reservoir storage is providing sufficient reservoir space for flood protection while trying to capture as much water as possible for irrigation.

Annual Planning

At the beginning of the irrigation season, system operations should apportion the total water supply to all those having water rights. Knowledge of the water supply is important to the manager and directors of the district and all water users who must depend upon the supply to grow a crop.

The operating organization should advise each farmer regarding the maximum quantity that he or she can expect to be delivered during the irrigation season, and to what flow each farmer is entitled when requesting his or her share of system capacity. With this information, the farmer should then be able to plan his or her cropping pattern and irrigation for the season on the basis of peak flow demand and total quantity of water available for the season. In the more humid areas, where supplemental rainfall is significant, such planning may be less critical.

3.1.8. Drainage

Drainage Requirements

The need to provide drainage to maintain the productivity of agricultural land has been demonstrated throughout history on every continent. The decline and disappearance of some civilizations can be attributed to the failure to overcome agricultural drainage and salinity problems.

Most farmers are aware of the importance of preserving the productivity of their land. Land lost because of water logging, seepage, or other problems caused by excessive water applications not only means loss of production to the farmer but reduces his or her ability to pay water assessments for operation and maintenance costs and taxes on capital investments made to construct irrigation systems serving the land. Both irrigated and nonirrigated land can be preserved with adequate surface and subsurface drainage.

Drainage systems must be provided in almost all irrigated areas where natural conditions are inadequate to remove water that is not used by crops or natural vegetation, or is not removed by natural means (i.e., runoff or deep percolation). Drainage facilities may become necessary to take care of excess surface runoff, melting snow, precipitation, canal seepage, artesian water pressure, or overapplication of irrigation water. Crop damage may occur from any of these situations if excess water accumulates and remains in the crop root zone too long or if salt concentrations build up in the crop root zone.

Negligence in the control of drainage water may cause seepage problems and possibly erosion and drainage system deterioration. Two kinds of drainage problems may develop—surface and subsurface. Every district should develop a policy in regard to the responsibility for the management of drainage water. The water user is usually responsible for management of delivered irrigation water. Normally, the district will only become responsible when reasonable care has been taken to manage the applied water, and some drainage water needs to be removed from the area.

Surface drainage water can usually be traced to its source. The responsible water user should not be allowed to waste water, thereby minimizing surface runoff of applied irrigation water. As it is generally much more difficult to determine the specific source of subsurface drainage water, the district may have to assume responsibility for managing such drainage problems, particularly if the problems develop because of the irrigation project.

Drainage Systems

The purpose of the drainage system is to control and remove excess irrigation and/or precipitation from cropped areas in a manner that protects crops and property. A drainage system may consist of natural channels, constructed channels, a subsurface collection system, water control structures, or any combination of these. Depending on the quality, water collected in a drainage system may be recirculated to augment the irrigation water supply, returned to a river or stream for subsequent use downstream, transported to an ocean or saline water body, or disposed of in cooling towers or evaporation basins.

"Drainage system" in this discussion refers to the system that collects drainage from farm drainage systems and provides a reliable outlet for disposal. Drainage systems can and do use various combinations of the following.

- Shallow surface drains for surface runoff.
- Deep surface drains for intercepting ground-water flow and subsurface drainage outlets.
- Shallow subsurface drains for lowering the water table (the typical farm drainage system).
- Deep subsurface drains for drainage of larger areas (typically with pumping to the surface).
- Shallow ground-water wells (dug open wells or sumps).

- Deep-pumped wells (deep by drainage system standards, not by water supply standards).

Diagnosis

Many irrigation system operators encounter the problem of seeped lands. Symptoms of the problem include rising ground-water, waterlogging, salinization, soil deterioration, poor crop response, and other natural indicators. When these symptoms are found or are anticipated, the next step is to find the cause of the problem. This might be canal and lateral seepage, excessive irrigation, poor water quality, inadequate natural drainage, or subsurface stratigraphic conditions.

Monitoring

In order to determine the nature of any drainage problem in arid areas, the responsible agency must have available such basic data as ground-water levels, salt content of soil and water, irrigation cropping practices, distribution system losses, and soil permeability and stratigraphy.

A general ground-water observation network should be installed prior to design or construction of any drain. The network should consist of observation wells to provide data on ground-water levels, and some wells to permit ground-water sampling for water quality determinations. From the data collected, drainage requirements should be appraised.

In humid areas, basic design data must include rainfall, runoff, evaporation, ground-water fluctuations, and soil permeability. This observation program is a necessary requisite for efficient operation. Stage and discharge data at control structures and pump stations also must be evaluated. An adequate network of rainfall stations is necessary to anticipate operational procedures. Operation of control structures and pumps should be systematically logged for operational efficiency and costing.

In arid areas, the continued collection of ground-water data should be collected at frequent intervals and compiled on water table maps. Discharge measurements and water analysis should be made of all drainage in order to check drainage efficiency and to determine whether a favorable salt balance is being maintained in the drained area.

Subsurface drainage systems are extremely important in controlling excess salinity in high water table areas, particularly in the arid west. In some instances, subsurface drainage systems may also be sized to carry some quantities of surface flood waters; however, sizing of subsurface drainage systems to carry this type of water is extremely expensive.

For subsurface drainage, an agency may provide main collector facilities to control the water table in an area. However, responsibility for installing on-farm drainage facilities to control subsurface drainage problems usually is the responsibility of the water user.

Regulations

Regulations for operation of drainage facilities comparable to those for distribution systems should be established. These regulations should prevent removal of protective levies, uncontrolled diversion of surface water into either open or closed drains, placing of obstructions in drains, or other actions that will interfere with the effective drain operation.

Reuse of Drainage and Return Flow

A drainage practice that may also serve as a water conservation measure is construction of sumps or small reservoirs in drainage systems for the collection of excess surface water. The water from conservation areas may be returned to the system or released to natural channels. However, the quality of all return flows must be closely monitored. Indiscriminant discharge of drainage water or return flows of unknown quality into any usable water should not be allowed.

Pumps are often necessary to evacuate impounded water. Such systems are typically constructed and operated by the farmer. Spills from district canals can also be collected in such reservoirs. In some areas, water is pumped for irrigation use from collective open drains that contain both surface and subsurface drainage water. Such water could contain chemicals from upstream users that could be detrimental, and so should be used with caution.

The return flow from drainage or any other excess surface water can be used to recharge ground-water supplies. In some areas, ground-water recharge may be accomplished by releasing excess surface water to natural channels. It may be beneficial to place check dams in streambeds to reduce the velocity of water to promote percolation downward to the ground-water table. Spreading basins operated separately or in conjunction with settling basins are also effective. Recharge wells may be drilled, but settling or filtering of water may be required to sustain efficiency of any well.

3.1.9. Water Conservation

Development Limitation

In view of current efforts being made toward water quantity and quality improvement, few persons associated with irrigation or drainage development need to be reminded that the supply of water is rapidly becoming the limiting factor in industrial, urban, and agricultural expansion. Therefore, proper management and conservation of the water supply becomes a paramount concern.

Numerous methods for increasing the water supply available to any given area have been used. These include transportation or conveyance from regions of plenty, increasing storage, increasing precipitation, and treatment of brackish or saline waters to upgrade quality. In addition there are ways in which currently available water supplies might be conserved. These include the reduction of seepage spills and evaporation from channels and reservoirs, better on-farm water management, and a reduction of evapotranspiration by nonagricultural plants; both constitute very significant losses each year.

Water Losses

The principal water losses from irrigation and drainage systems are mostly unavoidable, but are reducible. These losses include evaporation and seepage, normal operational spills, on-farm deep percolation, and tailwater runoff.

Water conservation efforts should include the use of all practical protective and corrective measures to overcome seepage and leakage from reservoir and canal systems. These systems should not be operated with the water surface higher than the designed normal water surface elevation.

The installation of concrete or membrane canal linings or closed conduit (pipelines) to replace unlined open canals and laterals will usually reduce canal seepage losses and improve operating characteristics of the system. Proper maintenance, including adequate weed control, is also important in attaining peak operating efficiency, and facilities should be kept in a satisfactory state of repair at all times.

Control of water is essential to water conservation. Operational spills should always be held to a minimum. Those with experience generally agree that operational spills on a well-managed irrigation system should not exceed 5% of total water diverted for each season. In practice, many irrigation water delivery systems exceed this percentage. Delivery of water to the water user in excess of that ordered or the delivery of water in excess of that required also will waste water. Such waste could be caused by inflexibility of the delivery schedule (e.g., fixed 24-hr delivery when only 21 hr are needed).

Every effort should be made to anticipate and adjust system operations to requirements of water users and weather conditions. Increases and decreases in system flows should be timed closely to minimize operational spills. This can be done by an alert and efficient operating organization, frequently with the help of automation. Water users should be notified of any planned system shutdown and should be required to provide sufficient advance notice of on-farm needs to allow for necessary system adjustments. This will minimize impact on the water users.

Wasting of water should not be permitted. The water delivered to each water user should be limited to the amount that can be beneficially used. If a user is found to be wasting water, the matter should be discussed with the user and a mutual plan worked out to avoid future unnecessary wastage. Many agencies have the right to discontinue service to a water user if water is wasted.

The excessive use of irrigation water by farmers may be corrected by an extensive educational program. In the United States, farm advisors and experts from the US Department of Agriculture are available to provide assistance in water management programs. However, conversion from existing irrigation methods to more efficient methods may require a change in the way water is delivered and may not be economically feasible in terms of water savings. Thus, improvements in farm water management may require substantial changes in the operation and physical control of water within an irrigation district.

The district can control, to some extent, farm wastes and deep percolation losses that occur on the farm. This can be accomplished by watching for excessive wastewater from the farm, having the power to regulate a water users headgate until the farmer can take care of the irrigation water, providing education on irrigation methods and practices, establishing annual water allotments, charging extra for water uses above the allotment, charging for tailwater runoff in excess of some allowable amount that enters district drains, and selling water to the users by volume.

3.1.10. Water Quality

Operating Organization Responsibility

Those responsible for operation and maintenance of irrigation and drainage entities must have an interest in and be knowledgeable of water quality, particularly in the United States where water quality laws are important and must be followed. With the need for better management and protection of water resources, it is incumbent on users of water to alleviate pollution. Federal and state water quality control regulations should be reviewed by irrigation or drainage agencies. Quality control standards have been established on all interstate streams in the United States, and every agency must determine its responsibility in water quality control. Water discharged to either public streams or ground-water aquifers must meet established water-quality standards.

The interest and responsibility in water quality will vary greatly by area. There may be little concern in an area that has a high-quality water supply and where return flows to the streams are small in proportion to streamflow. However, water quality control must be a major concern in an area where a poor quality water supply is used or where the disposal of saline subsurface drainage effluent is necessary.

Operating personnel must be made aware of the effect of water quality on operation and management of their irrigation or drainage system and on downstream water users. There are certain overall considerations in regard to water quality that are particularly important to operation and maintenance personnel.

Water to be used for irrigation must meet certain standards of chemical content, sediment content, and thermal conditions. Most districts should establish a water-quality monitoring program and may require measurement and sampling of flows at various locations, analysis of samples, and record keeping. Careful inspection and observation throughout the watershed and to the point of release of water from the irrigation or drainage system may be necessary.

Improvement of Water Quality

Water quality considerations and possible actions may be necessary in order to develop the best possible water supply. Watershed improvement programs to reduce sediment pollution and possible chemical contamination are sometimes necessary. In addition, any water supply agency may have to isolate and control flows of poor quality water from natural sources or urban and industrial waste that threaten the quality of the agency water supply. Where the water supply consists of some return flow, a joint effort with upstream users should be implemented to alleviate potential pollution problems.

Water that is low in quality because of high salts concentrations may be diluted with better quality water before use. A ground-water supply may be used for this purpose if its quality is better than that of available surface water. This may be especially needed if surface flows are badly polluted during a period of low water flow.

The quality of water may deteriorate while in storage due to evaporation, dissolution of salts in the substrata, settlement of sediment, and other factors. It may be necessary to develop operating procedures to alleviate these factors. For example, if water temperature is a problem, selective withdrawal from various reservoir levels may be beneficial. This procedure may also prove beneficial in managing sediment.

The most common means of controlling water quality is at the source of the contamination. This is accomplished with restrictions on waste discharges, recreational activities, industry, municipalities, mining, logging, and similar activities.

Factors that can contribute to a reduction of water quality are wastewater, herbicides, insecticides, sediment, farm waste, drainage from feed lots, industrial and municipal waste, and stagnant pools. The management of an irrigation district must inspect and control these factors, and legal action against individuals or organizations may become necessary.

The tailwater or runoff of water produced in irrigation of agricultural crops can be reused on the field to which it is originally applied, reused on a second down-slope field, or collected and re-regulated in a reservoir for later reuse on other fields. By so doing, a number of potential water quality problems will be eliminated. Reusing tailwater will eliminate the nuisance of having it standing in borrow pits or flowing onto adjacent property.

Districts should be aware of their water use for domestic and municipal purposes. The district should, by public notices or other formal means, warn citizens of an area against use of untreated canal or river water for domestic purposes, and warn them that water used for domestic purposes should be periodically tested for purity by proper authorities. Where water is furnished for municipal use and the district does not provide treatment, the district should assume no responsibility for the quality of furnished water nor guarantee its quality.

Return flows should conform to legal requirements, including treatment if necessary. Handling of surface or subsurface water originating outside or within the service area can be of vital importance, and all agencies concerned with public health should meet with local officials to determine whether all governing regulations are being met.

Humid areas present different water-quality problems in relation to operation of irrigation and drainage works. The serious problem of the salt content of irrigation return flows experienced in arid regions is of little consequence in humid regions. The meteorologic and geologic characteristics of humid regions shift the emphasis of water-quality-oriented problems away from irrigation supply and return water to concern for quality of excess storm waters handled by the drainage system, and its effect on intermediate and ultimate receiving water bodies.

Farming, as a whole, requires large amounts of supplemental nutrients and the use of various pesticides and herbicides to ensure economical agricultural production. Drainage water from developed agricultural areas may contain significant amounts of dissolved fertilizers or insoluble constituents attached to sediments. These materials may be introduced into either fresh or saline waters for storage, disposal, or both, resulting in fertilization of natural marshes and estuaries that have developed without significant levels of nutrients being present.

A substantial body of evidence is developing that these natural areas are not capable of accepting additional nutrients without becoming eutrophic. Not only is periodic quality sampling necessary to monitor runoff for degrading constituents, but if necessary districts must have the authority to enforce water quality controls.

3.1.11. Multiple-Use Projects

Competition for Available Water

The competition for water throughout the world is well known. Coordinating the various needs and demands with available water for various purposes is essential in the development of a good water-management plan. Irrigation, power generation, municipal and industrial purposes, fish and wildlife benefits, and recreation and navigational benefits are common uses of water.

Establishment of Priorities

Priorities for the aforementioned uses of water are generally established in every hydrologic basin. Water rights from a stream or a reservoir must be recognized, as well as instream flow requirements below a reservoir. In addition, the reservoir may also be required to provide flood control. Cooperation among federal, state, and local civic groups and individuals is of prime importance. All are entitled to voice opinions and show needs and requirements, even though the wishes of individual agencies may be in conflict. These differences must be reconciled, if possible, or at least understood.

Operating Plan

Overall planning can best be accomplished by consultation among all concerned and preparation of a detailed operating plan for the irrigation and drainage system.

Irrigation

In this manual, irrigation is assumed to be the primary purpose of construction and operation of storage and distribution systems. Many projects designed and constructed for irrigation use are being gradually converted to other uses. This often changes the objectives of the project and thus changes system operation. Recognizing when these changes occur is important so that appropriate changes in operation can be made in a timely manner.

Power Generation

The water release requirements from a reservoir for power generation are often in conflict with water-release requirements for irrigation. Power uses vary diurnally, while irrigation use typically does not. These short-term fluctuations can be handled by providing short-term storage in conveyance channels, particularly when water transmission times from storage and power generation facilities to water distribution facilities are longer than 1 day.

Power requirements in excess of average daily water release requirements are typically handled by use of other power facilities whose output can be regulated (coal, gas, or nuclear). Techniques for regulation of storage reservoirs for power and other uses is beyond the scope of this manual. Recognizing that benefits from water releases for irrigation are not simply related to the volume of water released but also to the timing and consistency of the supply is important.

Municipal and Domestic

Since water is so fundamental to human survival, domestic water use generally receives the highest priority for water. However, there is a wide variation in the amount of water use in different geographical locations. Considerable municipal water use is cosmetic and recreational (lawns, golf courses, sports fields, and man-made recreational lakes), as opposed to domestic. These uses are often the most highly scrutinized in times of water shortages. Even so, with population growth and movements of population from humid regions to more semiarid regions, where irrigation is practiced, these demands place increasing pressure on irrigation water supplies.

Some municipal areas receive irrigation water for lawns or for small fields and gardens, or even for small farm areas where farming is the second income. Water delivery to these small areas of non-full-time farmers can be significantly more difficult than delivery to larger agricultural areas. Scheduling for these smaller units tends to be more rigid, with fewer physical control structures because of the high cost of control relative to benefits.

Municipal use of water provides a potential water supply for agriculture in that a large portion of the water supplied for domestic use is returned as sewage effluent. Treated sewage effluent delivered to natural streams and rivers represents part of irrigation water supplies in many areas.

Ground-water recharge also provides a means of treating and recovering this water for irrigation use. Direct use of sewage effluent has not been highly successful to date, partially because of potential health problems and incompatibility of the timing of sewage water-supply and crop-water demands.

Industrial

Industrial use of water is usually small when compared to agricultural water use. Water use in some industrial applications can be diurnal, which can cause operational difficulty for the water-delivery system. This can be handled through the addition of storage facilities. Return flow water quality from industrial users can be a major problem.

Within the United States, environmental regulations are promulgated and enforced by the Environmental Protection Agency. These regulations require monitoring of waste discharges and control of sources of water quality degradation. The water delivery authority may or may not have control of waste discharge, but it certainly may have concern.

Fish and Wildlife

Support for the propagation and preservation of game fish and various species of wildlife may be desirable for irrigation and drainage districts as good public relations. Sometimes this may be accomplished without undue effort, but in some instances, quite the opposite is true. The procedures adapted to maintain or restore natural or near natural environmental conditions may require cooperative efforts among representatives of the irrigation or drainage district, conservationists, and to a degree, recreationists. Only a joint effort will satisfy, or at least partially satisfy, all concerned.

There are many innovations that may be followed to duplicate to a fair degree the natural conditions suitable for the propagation and preservation of fish. Keeping the fish out of pumps and turbines and preventing their release from the reservoir usually calls for added construction, and consequently added items of operation and maintenance. Dams prohibit migration of fish in streams. Fish ladders, passages, spawning basins, or other facilities may be necessary for fish passage or migration. Both gently sloping canal banks and carefully regulated water depths may be necessary to allow spawning of some fish species.

Perhaps the most common problem is operation and maintenance of fish screens at diversion dams. In some areas, these are required by law to prevent fish from entering the irrigation system. Usually these facilities are of such a nature that the weed and floating debris problem is greatly magnified, thus complicating operations.

Similar problems apply to the enhancement of wildlife such as birds and animals. Grassy areas along the right-of-way may provide a suitable habitat for wildlife. Normally, there are swampy or other wet areas in the project that can be improved and set aside for waterfowl. Nonagricultural lands within project boundaries may be planted with suitable vegetation and otherwise improved to provide habitat for small animals.

Recreation

Recreation is becoming an important facet in the management of reservoirs and streams. While irrigation and drainage organizations are not fundamentally recreation oriented, these organizations frequently have a responsibility and should support opportunities for recreation insofar as possible without jeopardizing the purpose of the project.

There is a tendency for recreation seekers to ask for facilities that cannot be provided within the revenues obtained from recreational uses of reservoirs and streams. Furthermore, people who use reservoirs and streams for recreational purposes frequently leave waste and litter to the point of becoming a nuisance and health hazard. These actions require maintenance by the operating agency.

Irrigation and drainage agencies are often called upon to provide cleanup and maintenance services far beyond the operational requirements of water management. These costs should not be borne by water users. Recreation beneficiaries and the general public should pay for these services.

Storage reservoirs or lakes above diversion dams provide opportunities for boating, swimming, picnicking, camping, and fishing. In addition, large canals may sometimes be used for fishing and other types of recreation. The present trend is to make these facilities available for such use. In fact, recreation is now considered one of the most important uses of some multipurpose reservoirs. It has been shown that large amounts of money spent by individuals for recreation can be important to the economy of an area.

There are three general procedures for handling recreation near an irrigation or drainage development. First, the operating agency may assume the entire obligation. Second, by agreement, some other organization, such as a county, state, or federal government, or a recreation district, may take over completely. The third is a combination of the previous two procedures whereby recreation at reservoirs (and perhaps other major facilities) is taken over by other organizations, while the operating agency assumes responsibility for recreation at other facilities. In either of the latter two procedures, agreements must be reached that clearly define the responsibility of each organization concerned.

Changing Conditions

Changes in land use resulting from urbanization, industrial development, construction of freeways, and other activities may be expected. Cropping patterns change because of marketing opportunities and for other reasons. Water may be converted to recreational use or used for fish and wildlife refuges. There may also be loss of irrigated acreage due to stream channel enlargement, construction of open drains, excessive rise in soil salinity, or retirement of poor-quality land from crop production.

There are many potential causes for change. These changes are of particular concern to operators whose systems are financed through the sale of water. Loss of acreage served affects finances. Small changes may necessitate alteration of the system, while major changes may call for major reconstruction. Management must be alert to signs of change and address these changes with proper planning.

3.1.12. Transition from Construction to Operation and Maintenance Status

Once construction of irrigation or drainage system facilities is completed, responsibility for care, operation, and maintenance passes from the construction agency to the operation and maintenance agency. This transition should be carefully planned.

Before the newly constructed facilities are transferred to an operation and maintenance status, structures and facilities should be carefully and thoroughly examined. This initial inspection should document any uncompleted work and construction deficiencies and establish responsibility for any corrective actions. The operating district should assure that needed information is available to prepare a detailed operation and maintenance manual for the system (see section 3.4.2).

3.2. CONTROL STRATEGIES

A water control strategy for irrigation can be fairly complex. The control strategy normally represents interactions between irrigation district operations and farm operations. Irrigation district operations are affected by the type and location of physical control structures, the logic according to which the system is to be controlled, and the operating plan. The operating plan represents the means by which control logic can be carried out with existing structures and personnel. The combination of these items is referred to as the control strategy. As discussed earlier, this strategy should address the needs of farm operations if district operations are to be successful.

3.2.1. Physical Control Structures

Canals

Irrigation canals are constructed with a series of check structures that control waterflow in the canal. This control frequently allows water to be diverted to other, lower-level canals by gravity. For large main and secondary canals, radial gates are the most common control structure. Where upstream water levels are being controlled, short-crested adjustable weirs are often used in conjunction with the gates.

In other cases, long oblique weirs can be used without gates for upstream control. For smaller canals, vertical sluice gates are more common than radial gates. Radial gates are typically used for automatic control. For automated (gate) upstream or for downstream control, weirs are not used in check structures.

Vertical sluice gates are common for lateral, tertiary, and quaternary canal turnouts. Such turnouts commonly have a short pipe section between the source and destination canals to allow for a canal access road. Such turnout gates then are frequently submerged orifices. As discussed under the section on flow measurement, these are frequently poor measuring devices.

Various types of weirs and flumes are currently the most practical style of measuring structures in open canal systems. Weirs and flumes can provide a degree of control in that conditions are isolated upstream and downstream of a structure. Movable or adjustable weir turnouts are not common in the United States.

Whether canal sections are lined or unlined can play an important role in canal regulation. Unlined sections lose water through infiltration. Such infiltration alters the transmission of water along an intermittently used canal, causing significant delays and unpredictable performance. Unlined canals are typically larger and thus require a larger volume of water during filling. Diurnal changes in infiltration can also alter canal flows, which makes management difficult.

Sedimentation in canals can be a major problem in some areas. In some cases, sediment movement through the system and deposition on fields is possible; however, in other cases, sediment must be removed from the distribution system. Slow-moving water will tend to deposit sediments that can be periodically sluiced to drainage canals or can be removed mechanically.

Open Pipelines

Open pipeline systems are generally low-pressure systems (see Fig. 4). Pipe risers are used inline to open the pipeline to the atmosphere. The presence of the riser reduces maximum possible pressure in the pipeline. A weir within the riser is used to regulate pressure in the pipeline upstream from the riser.

Turnouts are typically sluice gate openings on the upstream side of the weir. Such systems operate very much like open canals with check gates. The presence of frequent risers and low operating pressures reduces the need for surge suppression valves, although air release valves or vents are needed because air entrainment can occur downstream from risers.

Open pipelines are an attractive alternative to open unlined canals. However, these pipelines provide no advantage over open channels, and in many cases, flow is more difficult to measure and divide properly. This is particularly true when a series of turnouts exists between risers (as opposed to having all turnouts located adjacent to the riser). Any flow that is not taken off by a turnout is passed downstream.

Semi-Closed Pipelines

Semi-closed pipelines are an alternative to open pipelines. They have several advantages over open-pipeline systems (Merriam 1987). Float-controlled pressure-regulating valves are used to keep a relatively constant downstream pressure within the riser. The riser is open to the downstream reach to allow operation without surges or water hammers. Pressures within the pipeline are similar to those in an open-pipeline system, but the nearly constant head is maintained downstream rather than upstream. Heads are seldom as high as in a closed pipeline. The advantage of the semi-closed pipelines is that water that is not delivered through turnouts remains in the system, as in a closed pipeline. Variable flow rates

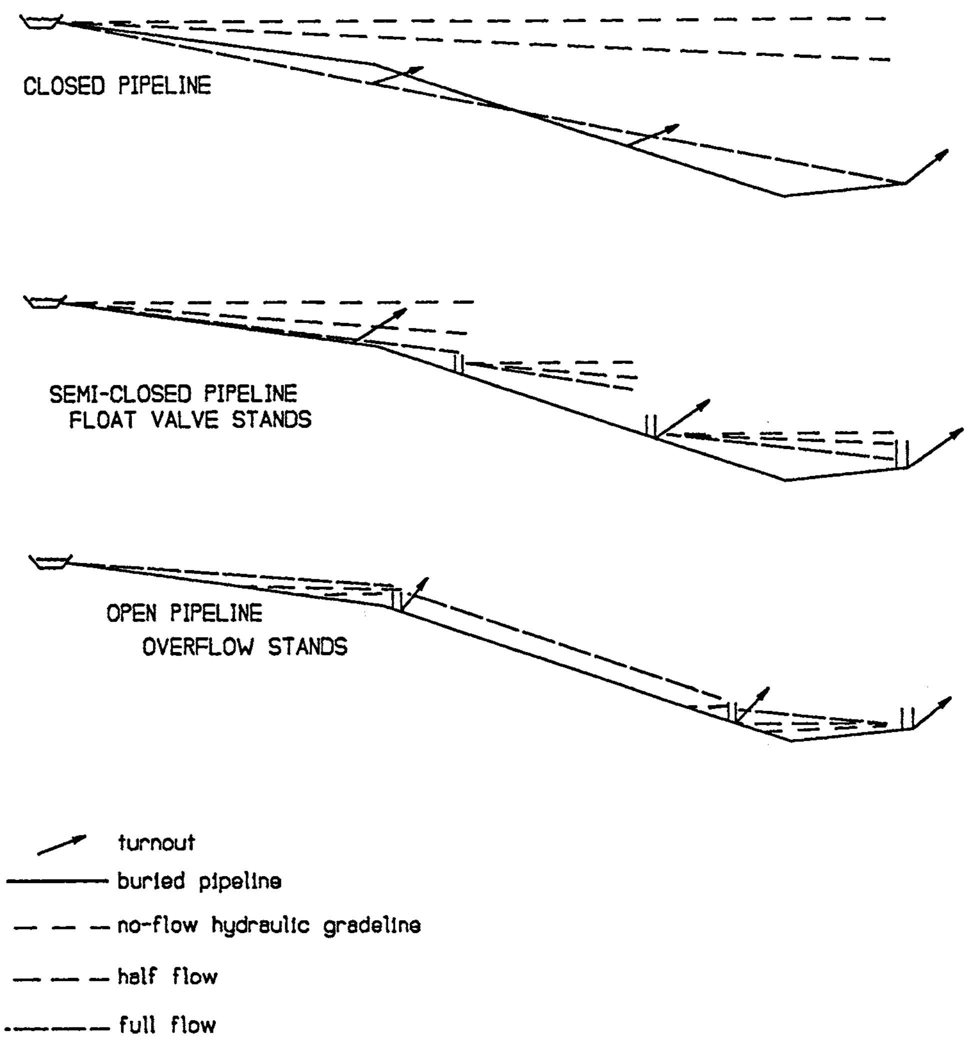


Fig. 4. Pipeline Classification by Hydraulic Gradeline (Adopted from Merriam, 1987)

are automatically adjusted back to the source, making the system adaptable to flexible scheduling like a closed pipeline, but at more stable heads.

Debris entering open pipelines can be a problem. In addition to keeping debris out of the pipeline entrance at its source, the system must keep debris out of open risers. Debris can cause problems with valve closure, can get stuck on propeller and turbine-type meters, or can clog the pipeline, causing overtopping. Low-pressure pipelines typically are constructed with inexpensive low-pressure pipe.

Closed Pipelines

Closed-pipeline systems typically function at high pressures. They are not open to the atmosphere at any point, except at the upper end where they may terminate at an open tank, reservoir, or canal. Valves generally are installed at all bifurcations and turnouts to allow shutting off of the flow for repairs, adjustments, or regulation of flow.

Flow is typically controlled by pressure or flow regulation at outlets and bifurcations. This keeps the operating pressure in the pipeline at a maximum. Sudden valve closures can cause surges in the pipeline. Air-relief valves are used to remove air from the system during startup, and vacuum release valves are used to let air into the system during a negative surge or draining of the pipeline.

In some cases, surge chambers are used to reduce pressure surges. These surge chambers can be closed, pressurized tanks, open tanks, or open tanks with one-way valves. When open tanks are used, the system can resemble an open pipeline. The main difference is that open tanks in a closed system are used to dampen surge pressures and are not used to regulate pressure. Open tanks are generally inline, as in an open pipeline, while the others are not inline.

Surge suppression can also be achieved with surge anticipator valves, which allow pressure surges to open to the atmosphere temporarily when a high-pressure surge follows a low-pressure surge. A variety of water meters is available for pressurized pipe systems, which are discussed in section 3.3.3.

Pumping Plants

Irrigation or drainage pumping plants vary in size from very large installations, which lift water from rivers or reservoirs to supply water to an entire irrigation district, to small pump stations at the end of small laterals. Pumping plants may employ different sizes, numbers, and types of pumps in order to operate effectively for given conditions. Five types of pumps are commonly used in irrigation and drainage works—propeller, mixed flow, vertical turbine, horizontal centrifugal, and vertical centrifugal.

The required pumping head dictates the type and number of stages in the application of vertical turbine pumps. Single-stage pumps of the propeller or mixed-flow type are used for low heads. Multistage vertical turbine pumps are used in deep wells. Propeller, mixed-flow, and turbine pumps operate with the pump suspended by the column in an open sump or deep well. Water from the pump is discharged through the column.

Horizontal centrifugal pumps are basically of these types: split-case, side-suction or close-coupled, end-suction pumps. Pumps are normally installed so that the suction inlet is flooded and no priming is required. Split-case, bottom suction pumps are equipped with a flared suction tube extending down to an open sump or pit and do require priming. In the design of all pumping stations, the equipment must be located so that accidental flooding of motor and control equipment is avoided.

Vertical centrifugal pumps usually have intake tubes and elbows leading from the plant forebay to a pump. The pump casing may be set above or below the normal water surface, on a floor in an enclosed plant, or on a deck in an outdoor plant. Large units with casings may be embedded directly in the concrete pad.

Propeller-type vertical pumps are unsuitable for installations where throttling of the pump is required. These pumps are generally used for comparatively large capacities at low pumping heads, and operate most satisfactorily with a short discharge line with only a flap valve at the end. If regulation of the pump discharge is desired, it is accomplished by bypassing part of the discharge back to the sump, rather than by throttling.

Centrifugal and turbine pumps, on the other hand, can be throttled to provide the desired discharge rate. These pumps can be started against a closed discharge valve, thus simplifying the startup procedure when two or more pumps are manifolded into one discharge line. Vertical turbine pumps are well suited for small pumping plants where extensive regulation of discharge is desired. These pumps have been used in small sizes at pumping heads as low as 10 ft (3 m) and in sizes up to 30 cu ft/sec (0.8 m^3/sec) at pumping heads as high as 300 ft (90 m).

Booster pump stations are used to increase the pressure in a pipeline. These stations may also increase the discharge in the pipeline, depending upon conditions upstream and downstream (the affect on source). Centrifugal and turbine pumps are the most common.

Canal systems often have lift stations where flow is lifted from a lower to higher elevation. Because of difficulties in matching pump discharges with canal inflows, some canal storage must be provided. This may cause difficulties in canal operations, unless turnouts within the vicinity of the lift stations are automated. Canal sections immediately upstream from a lift station must have emergency overflows to protect the canal from damage in the event of a power outage.

When pumping plants are used to lift water from a canal or stream, then it may either be throttled to regulate the flow or some of the water may be returned to the canal or stream. Pumped turnouts must frequently be handled more as a demand system, since pump discharge is not dependent on canal flow. The canal system must also be able to handle the water not pumped in the event of a pump failure.

Regulating Reservoirs

Regulating reservoirs are an important tool in canal and low-pressure, open-pipe system regulation. These reservoirs can be used to minimize effects of accumulation of flow errors in the system or to buffer sudden unexpected changes in flows. Reservoirs are also useful for dividing the canal network into manageable subunits that can be controlled independently. Downstream control is easier to manage in smaller units. Downstream control requires control of the water source, which is practical with a regulating reservoir.

Closed high-pressure pipe systems also use reservoirs for regulation of flow. If multiple lifts are required, reservoirs provide a convenient means of regulating pressure and storing excess water. On large systems, these reservoirs may be an alternative to having booster stations at each farm turnout, as they provide sufficient head pressure to operate on-farm sprinkler systems.

Farmers sometimes construct farm reservoirs to collect water delivered from an irrigation district. The water can then be used by the farmer according to the needs of the farm irrigation system. In the extreme case, a rigid rotational delivery of fixed duration and flow can be transformed into a demand system.

Such reservoirs are used in surface irrigated systems, to increase the rate of flow available (a means of reducing labor), and in sprinkler and drip irrigation, to reduce the rate of flow to match the operating system. Such ponds should be large enough to handle storage requirements for mismatches in flow rates and durations, or to handle an entire irrigation volume for later use.

3.2.2. Control Concepts

The focus of most control methods is on control of energy level or head. In the case of open channels, head translates to water level, while pressure is representative of pipelines. Flow-rate control is frequently given secondary consideration; for example, it is frequently assumed as result of head control. Controlling both head and flow at each location may not be necessary, but both must be controlled by the system as a whole (Clemmens and Replogle 1989; Zimbelman 1987; Dedrick and Zimbelmen 1987; Rogers 1988).

The focus of control methods is usually on an individual or single line (a canal or pipeline), while irrigation districts are networks of canals and pipelines. Thus, control methods must address the interconnectedness of the system.

Upstream Control

Most canal check structures are generally not accurate measuring structures and, therefore, are not used for control of flow rates, but rather are used to control canal water levels. Under upstream control, the check structure (gate or weir) is adjusted to maintain a constant water level in the canal upstream from the check structure (see Fig. 5).

Canal turnouts to laterals or smaller canals are generally located immediately upstream from the check or control structure. This location will usually provide the most stable head relative to the land surface. Once a turnout gate is set, a constant upstream water level will mean a relatively constant turnout discharge.

Open (low-head) pipelines are frequently controlled with the same method, where control of the water level in an open pipe riser is done with control structures. Upstream control is typically not used with closed pipeline systems, since intermediate control structures are not provided to control pressure.

Water that enters a section or reach between two control structures and is not distributed to turnout will pass through the reach to the next lower reach. Once water is released from the source, it must pass through

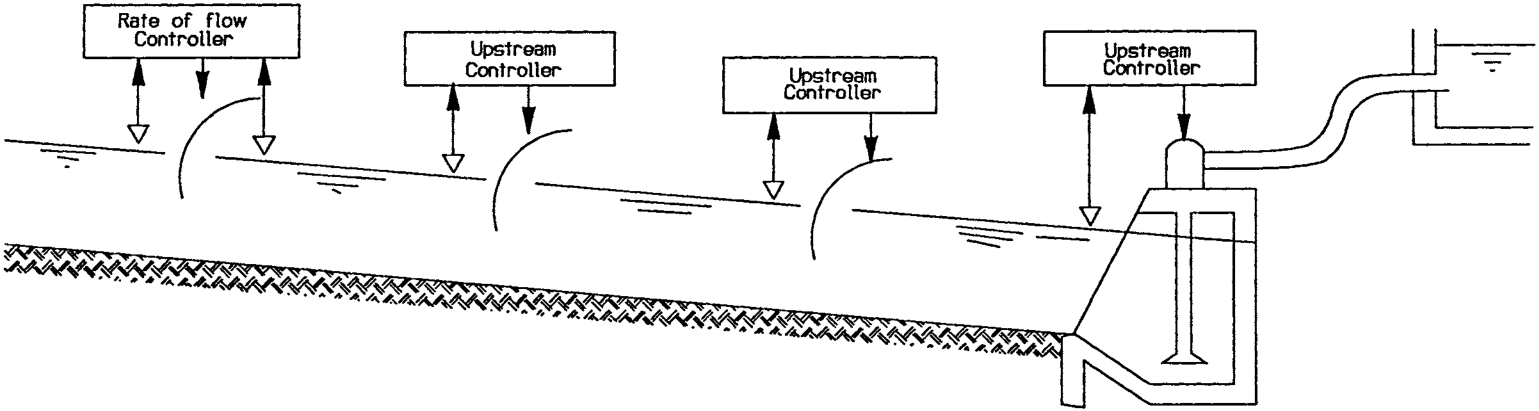


Fig. 5. Upstream control—Supply operation

an upstream controlled system. Inaccuracies in control, poor flow measurements, flow transients, and long travel times result in surpluses and shortages throughout the distribution network.

In addition, turnouts not adjacent to a control structure may experience fluctuations in flow rate. These fluctuations are due to changes in water surface elevation resulting from flow rate changes in the line and a corresponding change in water surface slope. Thus, even automated upstream control throughout a system may not be totally effective. In many cases, water is guided rather than controlled (Burt and Lord 1981; Clemmens and Dedrick 1984).

Upstream control is the most commonly used method for several reasons. It can be operated manually with no automatic or remote controls, it is supplier oriented, making it easy to operate by district personnel, and it is the most appropriate for systems with rigid delivery schedules.

For systems with more flexible delivery schedules, upstream control is more difficult. Most such systems require from 1 to 5 days lead time, for inflow to match demand, depending on the length of the canal system. Shorter lead times are possible if intermediate storage is available, or if excess water flowing through the irrigation supply system is returned to the river system. Upstream control can be implemented with manual, remote, or automatic gates, with duckbill weirs, or with a combination of these structures.

Downstream Control

Pressurized semi-closed and closed-pipe systems are examples of downstream control allow for flexible operation, since water is available on demand as long as sufficient pressure is available. Under these systems, control of flow rates are made at farm turnouts. For open pipelines, downstream control can be accomplished with Harris float valves (Merriam 1987). These valves essentially close off the entrance to a riser and provide constant pressure within the riser and can be used in line or for individual turnouts. These valves convert an open pipeline into a semi-closed pipeline.

Downstream control of canals represents an attempt at supplying the same level of service from canals as that available with closed and semi-closed pipelines. Downstream control is far less common than upstream controls because downstream control is difficult to implement. This is partially due to control structure requirements and partially because it implies control of the water source. In many irrigation projects, control of the water source close to the point of distribution is difficult, but can often be corrected with imaginative engineering.

Downstream control of a control structure uses the water level downstream from the structure to indicate the need for either more or less water from the upstream reach. This control is most effective when the water level to be controlled is immediately downstream from the gate.

A number of *local* automatic gates can be used to control the water level immediately downstream from a canal gate. These include hydraulically controlled gates as well as electronically controlled gates (Littleman controllers), which can be used to control inline or turnout canal water levels (Replogle and Clemmens 1987).

Local automatic controllers that control the water level immediately downstream from a gate are appropriate *only* at canal turnouts or when placed in series with sections of level-top canals (or pipelines with control gates on the upstream side of the riser).

Level-top canals are often used with downstream control to facilitate shut off (zero flow) from the downstream end. A series of level-top canals is used where the height of the level top on the upstream side of one check is above the controlled level on the downstream side of next check upstream.

Thus, the water level on the downstream side of the check remains constant, while the level on upstream side changes with discharge. Further, in order to maintain a constant flow rate to a turnout, the turnout must be placed immediately downstream from the check or automated for a constant discharge. Locating turnout gates immediately downstream of a check gate is generally undesirable from an energy standpoint (the canal top may be below ground surface). However, closed or semi-enclosed pipelines can take off below such structures, since they are not appreciably affected by small head variations.

A number of computerized techniques have been developed to control the level at downstream end of a pool between two checks from the gate at the upstream end of the pool (or the level on the upstream side of one check controlled by the next check upstream). This allows the use of downstream control on sloping canals. When the control level is far from the gate that is doing the controlling, control becomes more complex because of the lag time involved between the time at which the gate is adjusted and the time at which the water level at the control is influenced by the gate adjustment (see Fig. 6).

The schemes used to control water levels in canal reaches at some distance downstream from the gate doing the controlling can be placed in three categories: (1) Control of the water level immediately downstream from the gate; (2) control of the water near the downstream end of a reach; and (3) a combination of the first two categories. EL-FLOW (Ploss 1987), CARRD, and Zimbelman's technique (Zimbelman and Bedworth 1983) all use feedback of water level at the downstream end of the reach to keep a constant level at that point. CARRD requires measurement of water levels at intermediate points as well. These techniques are intended to be applied on in-line main and lateral canals, where the flow rate to turnouts is at the downstream end of a canal reach. The turnouts are typically not automated, so that maintaining a constant water level on the upstream side of the turnout gates is desirable.

Another technique, BIVAL, uses information on water levels at both ends of the reach and attempts to keep a constant water level at some intermediate point, typically the middle. Such a system is typically applied to large canal and river systems, where precise control of water levels at the downstream end of a reach is not crucial.

Controlled volume control attempts to maintain (near) constant volumes of water in the canal reach. This method is also applied to large canals where all canal turnouts are automatically controlled. Thus, maintaining constant water levels is not highly important. Controlled volume

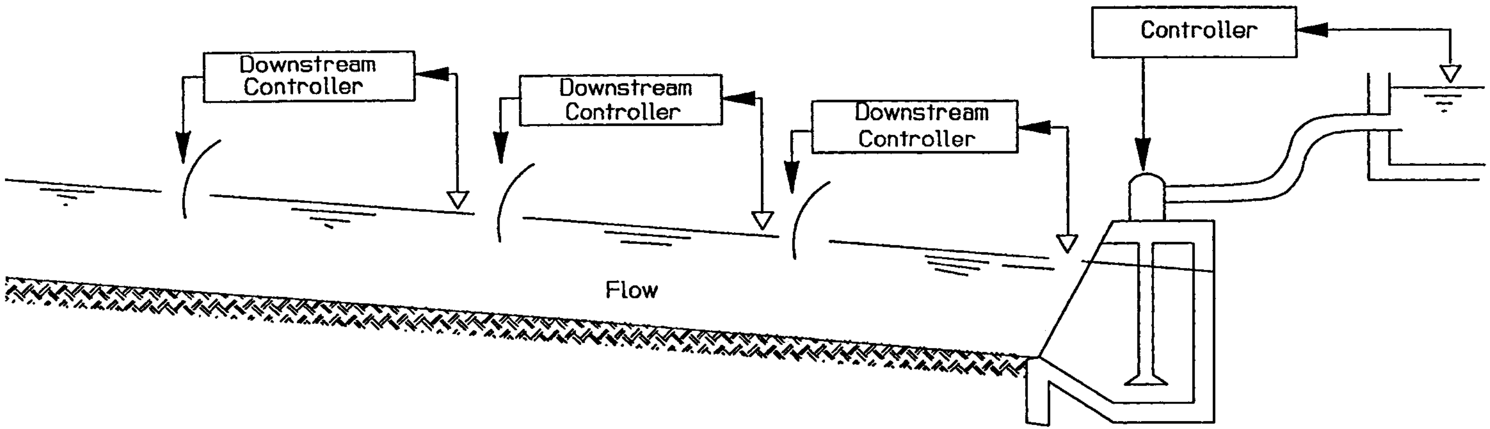


Fig. 6. Downstream control—Demand operation

control and BIVAL canals typically have level tops over the lower half of each canal reach (see Fig. 7).

All these methods in one form or another require feedback of actual water surface elevations plus some information about water surface response to changes in flow rate. In some cases, the latter is simply a delay time or a weighting coefficient. These coefficient values often are determined by simulating water flow in the canal with a canal hydraulic model.

Gate stroking, one method of implementing controlled volume control, attempts to use the canal model to predict flow and water surface conditions exactly. All the other methods rely entirely on feedback of actual water levels. Because of continual changes in canal roughness and gate discharge coefficients, hydraulic modeling of conditions is at best inexact. Thus, in actual operation, gate stroking must use feedback of existing conditions to provide satisfactory control.

The potential advantage of gate stroking is its ability to predict future conditions. Thus, to effect a control, a series of gates can be manipulated simultaneously. The gate stroking concept works best with prearranged schedules. Any changes from prearranged schedules are handled manually. The notion of gate stroking was extended by including the observation of water surface elevations in a feedback control loop based on feedback regulator theory (Balogun et al. 1988). This method shows significant promise.

Another control scheme, dynamic regulation, attempts to supply water on demand in sloping canals. Water is delivered from the source for anticipated demands, rather than known demand, with continuous adjustments. Just as in gate stroking, dynamic regulation requires somewhat more detailed engineering studies than the other approaches. However, control algorithms have been developed from extensive modeling to allow control decisions to be made quickly.

CARRD, BIVAL, Zimbelman's method, and EL-FLOW can all be operated as a series of local controllers with local feedback. Dewey and Madsen (1976) indicated that hydraulic transients are reduced if all gate changes are made simultaneously. This requires remote control of the entire canal from a central station centralized control (Fig. 8), as is typically done with gate stroking, dynamic regulation, and manual supervisory control.

All these systems require the use of electrically operated motorized gates. The centralized control methods are likely to be too complex and expensive for all but large main canals. Several of the local control methods are being used on smaller main and lateral canals. Currently, all these methods appear to be workable for their respective purposes, provided the method selected is custom-fitted to the application.

Most of the emphasis on these methods has been the control of large, slowly changing canals. When control of small, steep, and highly transient lateral canals is required, control requirements will become more stringent, and some modification to the aforementioned methods will probably be necessary.

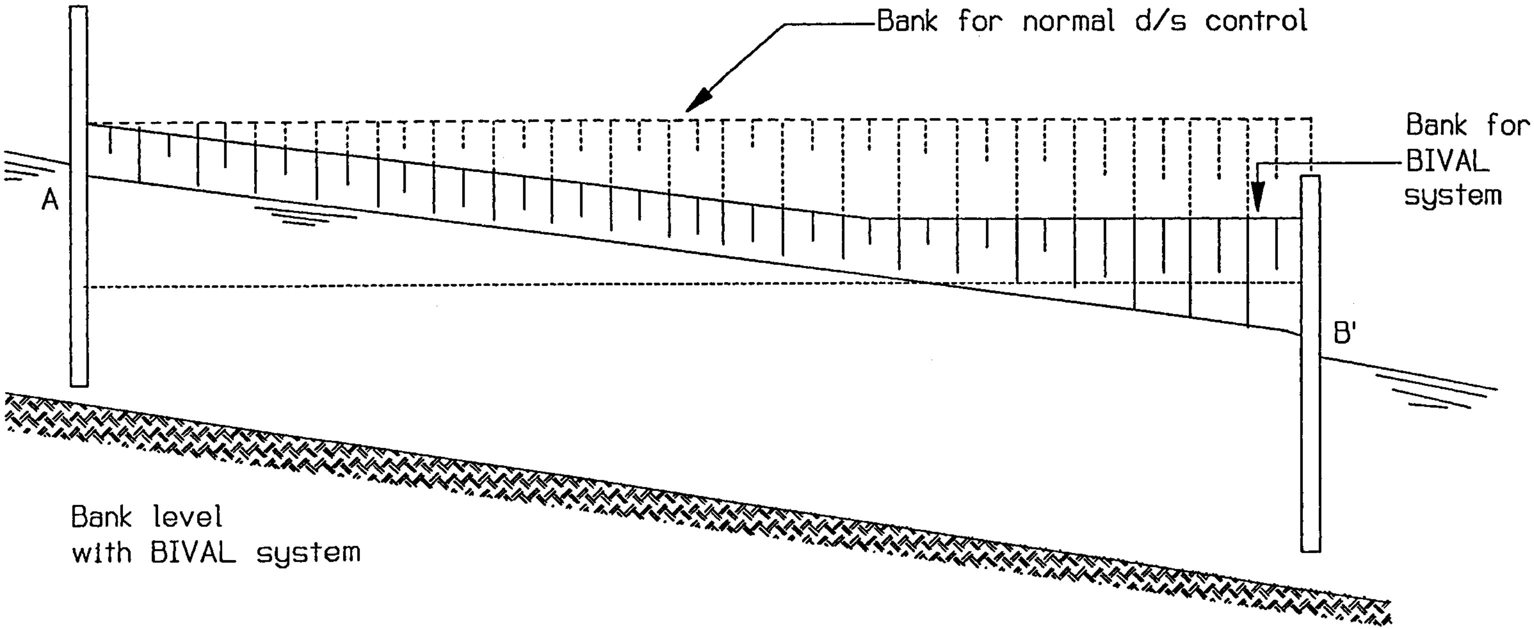


Fig. 7. Characteristics of the BIVAL system

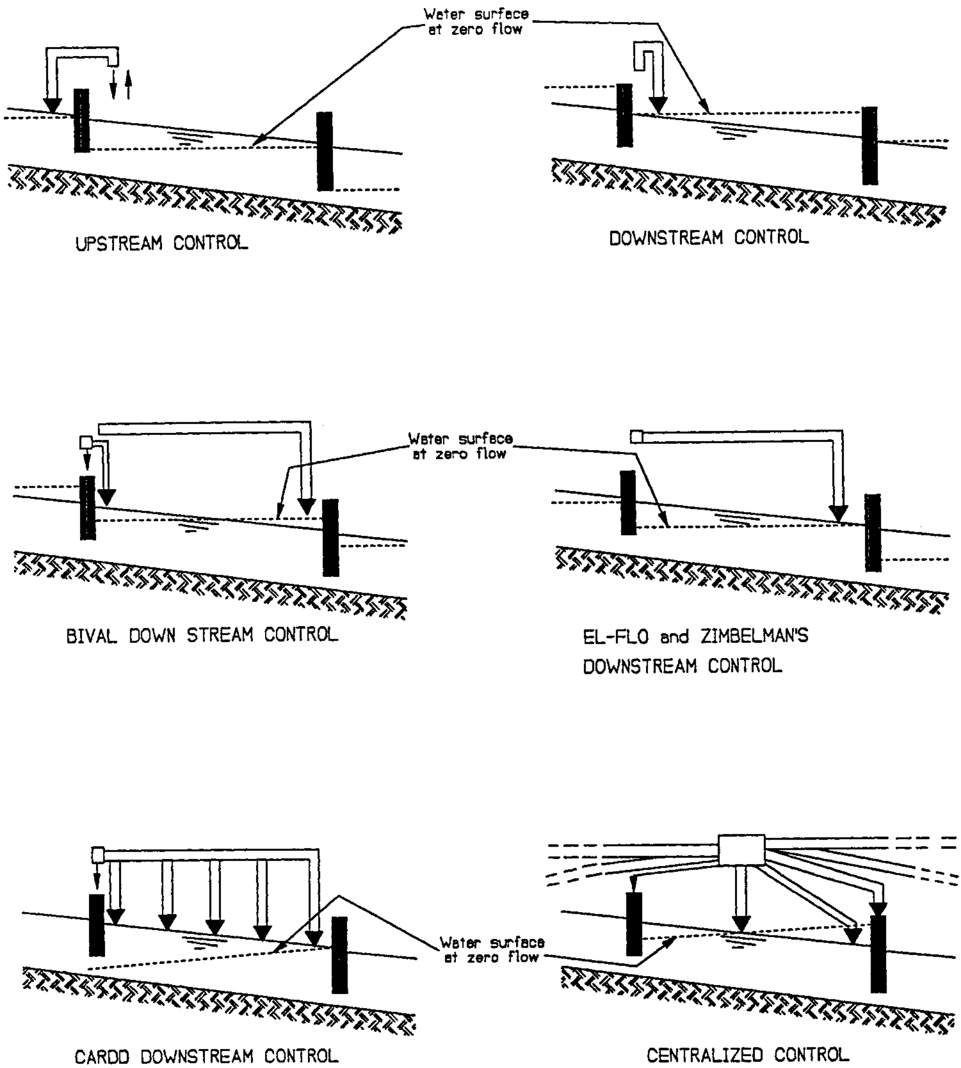


Fig. 8. Types of Control on Sloping Canals

3.2.3. Control at Bifurcations

The success of a control scheme, to a certain extent, is determined by how well water is delivered to users. In passing from the source through the canal network to the user delivery point (the farm turnout), the flow may pass through many bifurcations or divisions in flow. Thus, success of the control scheme often depends on how water is controlled at these bifurcations.

Under manual upstream control, turnout flexibility, F, is used to determine the operational nature of the bifurcations (Bos et al. 1984). The flexibility is defined as the rate of change of turnout discharge with upstream head divided by rate of change of continuing canal discharge with upstream head.

If $F=1$, any change in discharge will be proportionally divided between the structures. If $F<1$, a higher proportion will remain in the continuing canal. For example, if the turnout is an orifice with a high head and the check structure (continuing supply) has a wide weir with a low head (or combination orifice and weir), then F will be small. This is a common check structure arrangement that keeps most of the regulation errors in the continuing canal.

If $F>1$, then proportionally more flow will pass through the turnout than will remain in the continuing canal. An example is an emergency overflow weir with a low head and a check gate with only an orifice and a high differential head. Equitable distribution of water (including fluctuations) would favor $F=1$. Constant deliveries (at least in upper end of system) would favor $F<<1$. However, this may cause extremely large fluctuations at the lower end. Water disposal or canal protection would favor $F>>1$.

Thus, at least for manual upstream control, turnout flexibility plays an important role. For check structures with both an overflow weir and an orifice (gate), flexibility is not fixed but changes with gate settings and flow rate. Thus, the operator potentially has an additional degree of control though it may come with the drawback of added complexity.

Proportional Division

One of the first concepts developed for irrigation development was known as water spreading. The idea was to divide available flow proportionately to the area serviced, thus spreading whatever supply was available equally among users. Divisors have often been used for this purpose, particularly where water falls over a rectangular weir.

Since at critical flow over a level weir, flow rate and depth are uniform, equal widths will receive equal amounts of water. Thus, division walls that divide the weir into sections also divide flow proportionately to the width of those sections. In the western United States, such structures are common in higher mountain areas, usually at the tertiary or quaternary canal levels. In other parts of the world, such structures are also common at the secondary and main canal levels.

Other fixed structures can be used to proportion the flow at a given discharge, such as fixed orifices and weirs. Usually such divisions are not proportionate at other flow rates unless the structures have been very carefully designed and constructed. Such structures are very difficult to design for a flexibility value of unity over the entire range.

Adjustable divisors are in use in some parts of South America. There, a broad-crested weir is used to measure flow rate and a movable divisor is placed at the downstream end of the weir. The pivot for the divisor is a considerable distance downstream, so that the change in angle or divisor does not significantly affect flow. Variation in division is possible only over a narrow range. Such devices are very good at regulating flow, but may not give the flexibility needed. Manually adjustable gates are not as good at apportioning flow, but give considerable flexibility.

Flow Rate Control

Most of the automatic devices for canals are aimed at the control of water levels in continuing canals. In some cases, control of flow rate is needed. It should be recognized that flow rate control is possible only at bifurcations and at outlets from storage reservoirs. A constant downstream level can be converted to flow rate when a critical depth device such as a flume or weir (or a free-flowing orifice) is placed downstream from the controlled level. Broad-crested weirs and long-throated flumes are recommended because of their high accuracy, low construction cost, and low head loss requirements.

The Neyrpic modules (see Fig. 9) are constant flow devices with no moving parts that operate in a transition zone between weir and orifice flow. These modules can maintain an accuracy of 10% over a fairly wide head range. A number of modules are placed in parallel when different flow rates are desired since modules are either fully open or fully closed. Significantly better control (±5%) can be obtained by placing an automatic downstream level control device immediately upstream from the flow module. Most of these devices can be configured to provide flow rate control within ±10%. Some can provide control at better than ±5%. Such flow rate control devices are not currently in common use on canals (Replogle and Clemmens 1987).

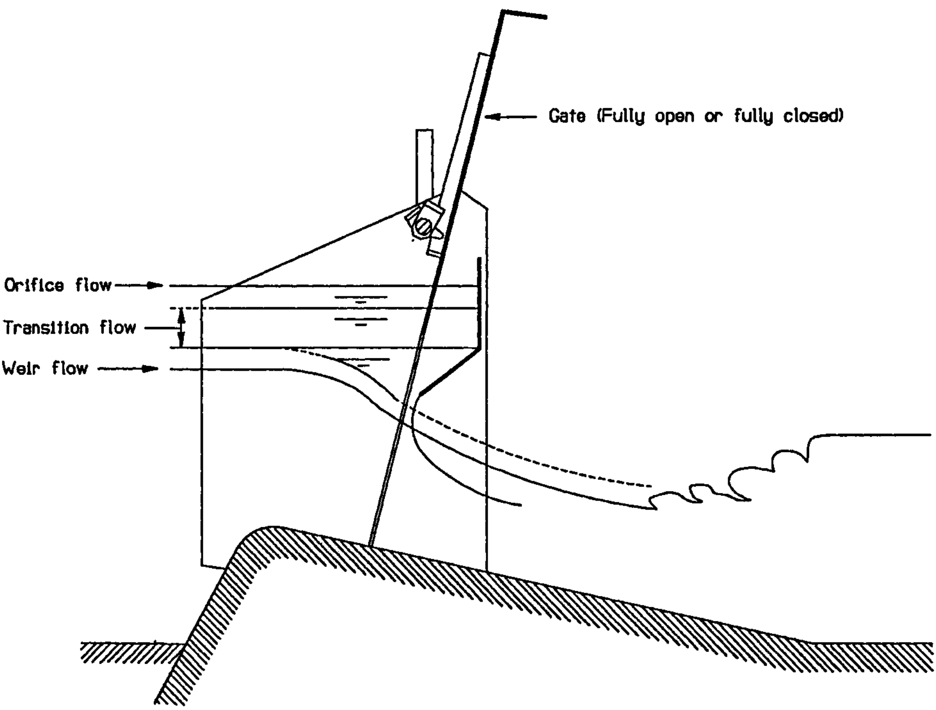


Fig. 9. Neyrpic module Type XI Meter

Control of flow rates in high-pressure closed pipelines is usually accomplished with pressure regulating devices. Flow-regulating devices are available for flows up to about 27 cfs (750 L/s) as well. For open pipelines, flow rate control is much more difficult. Pressure control can be translated to flow control only when a weir or free-flowing orifice is present at the outlet. Even for downstream control with semi-closed pipelines, flow control must be handled by the user at his outlet. In the case of pipe application systems (sprinkler, micro), pressure control may be sufficient for flow-rate control.

For moving sprinkler systems with large elevation changes, such regulation may be needed along the moving system to maintain proper pressures. For surface systems, manual regulation of individual outlets can provide the needed flow rate control.

3.2.4. Operating Techniques

There are a number of methods to operating a series of check or control gates in canals and open pipelines. After the inflow to the canal has begun, gates can be adjusted sequentially as the change in flow reaches them, all gates can be controlled simultaneously, or only selected gates can be controlled independently from other gates. Under upstream control, gates are typically adjusted sequentially.

Downstream control methods for small and/or steep canals (CARRD) also adjust gates sequentially (although not in a coordinated fashion). Most of the techniques developed for large, slowly changing canals (controlled volume control) use simultaneous gate controls. Local automatic controllers use selected control, as do most closed pipe distribution systems. With semi-closed pipeline systems, changes back to the source are made automatically.

Upstream Control

With sequential control in canals, the ditchtender generally waits for a flow change to reach the gate to be controlled. The wave caused by a change in an upstream gate setting is dampened by the time it reaches the next gate. To avoid overtopping of a canal reach as a flow rate change gradually builds up, the check gate is changed prior to the arrival of the full discharge rate.

The gate setting is estimated for conditions that are expected when the full wave arrives. Usually, the ditchtender will have to return to the site to readjust flows after several hours of operation. Thus, control is not very precise and requires a good deal of experience. Where turnout deliveries are not taking place, precise control of upstream level is not needed.

Timing is a very important factor in avoiding unnecessary changes in water surface elevation in canals or pipeline risers. In canals, necessary adjustments can be accurately timed through the evaluation of wave travel times. These travel times can be determined from observation (experience) or from modeling (theory). This will give ditchtenders an aid in knowing when to adjust downstream gates. In earth canals with small water-surface gradients, travel times between check gates can be very long.

On steeper canals, travel times can be very fast. Pipelines have no surface storage, so that changes in discharge are reflected almost immediately throughout the system. In an open pipeline, three gates (the main turnout, the lateral turnout, and the farmer delivery valve) typically have to be adjusted to add a delivery to a lateral. Gate adjustments must be made almost simultaneously if operational spill is to be kept within reasonable limits.

Changes in delivery patterns require even more extensive gate adjustments. In canals, it is sometimes necessary to preset downstream gates before the furthest gate upstream is adjusted. This keeps the ditchtender from having to race the water down the canal (or pipeline). However, it may temporarily affect other users on the system.

Depending on the type of control structures in place, changes in water level or head that occur during the addition or subtraction of a delivery flow can have a significant impact on delivery to other users within the canal or in open or closed systems, but a negligible one with a semi-closed system. Upstream control thus encourages use of steady flows and discourages frequent changes in discharge.

Balancing inflow and outflow can be a problem with upstream control. Typically, the individual at the tail end of the system gets whatever is left over from upstream users, which is frequently less than the desired amount. Ditchtenders typically deliver more to a lateral than the amount ordered (if available) to assure that the end user gets enough water.

Large excesses caused by flow changes upstream sometimes occur for short durations. These flow imbalances can then cause overtopping of one or more of the open stands in a pipeline system or overtopping of banks in an overloaded open canal. Hydraulic control of these types of systems is extremely important.

Under manual control, main canal flows are typically controlled by a single ditchtender, while control of lateral flows and delivery turnouts may be accomplished by several persons. When changes in flow are made in the system, coordination of these different individuals is necessary, as operations by one affects the other.

If check structures that contain both an underflow gate and an overfall are used, then proper operation of these structures is important to proper flow control in the canal. It is typical for the check to be set such that water is flowing at a low rate over the overflow weirs—for example, heads over the weir of 0.05 to 0.20 ft (0.02 to 0.06 m). Flow changes that come down the canal pass through the structure with a minimum influence on upstream head on the structure and, thus, minimal influence on turnouts at that location. However, this also causes all flow errors to be accumulated downstream.

Check structures in the canal system are designed and constructed to maintain particular water surface elevations during normal operation. If excessive elevations are maintained, unnecessary loss may occur through seepage and spills. This also tends to encourage water weed growth. An observant ditchtender will remove and replace check boards as required to maintain proper water surface elevations.

Gravity drainage systems often operate only with control sufficient to minimize bank erosion. Pumped drainage systems in arid areas usually operate by simple rules of thumb concerning water levels at which pumps are automatically turned on and off. All pumps can be automated, but for systems where flow fluctuations are small and infrequent, automation is usually not worth the investment. The levels at which sump pumps turn on and off are determined by the amount of drainage flow, volume of sump storage, and size and type of pump.

Downstream Control

The operation of a closed-pipe system approaches that of a municipal-type water supply system. The control of flow takes place completely at the delivery points. These points may be opened or closed as necessary, similarly to opening and closing the water faucet in a home. Semi-closed pipe systems provide the same results at low stable pressures.

Pipe systems have many advantages, but unless there is an inexhaustible instant water supply, it is necessary to carefully schedule deliveries and create a discipline among water users to spread the demand over reasonable time periods, as is done with arranged schedules. If not, a pipeline will be no more satisfactory to the customer from a service standpoint than an open canal or lateral. In addition, the pipe system could give even poorer service.

Operation of a pipeline must be such that pipelines are filled slowly, valves are operated slowly, and the system is shut down slowly. Air should be removed during filling of the pipeline. Sand and silt in the channel above the pipeline should not be pulled into the pipeline. Automatic valves should be checked for proper functioning.

Canal systems operating under downstream control must include some form of automatic controls to be effective. Ditchtenders should monitor canals to assure proper operation of the control system and to discourage unauthorized water deliveries.

Under an arranged scheduling system, the ditchtender is responsible for making deliveries, arranging minor changes, and recording actual water delivered. However, under more flexible schedules some controls are left up to the farmer. Under a demand scheduling system, the ditchtender simply records water delivered. No actual control actions are needed, except for adjustment of delivery gates.

In arid areas where subsurface drainage problems can be controlled by pumping the ground-water table during the irrigation season, automation is not required. The rate of water application through irrigation can usually be anticipated, so drainage pumps are usually run continuously through the end of the irrigation season. If the quality of water is acceptable, such drainage water can be used as a supplemental water supply by discharging the drainage water into the irrigation system.

In humid areas, control of ground-water levels may be a little more complex, because the operator must rely on his or her anticipation of precipitation influence on the water table. The ground-water aquifer essentially acts as a storage reservoir, but with delays because of variable water movement rate through the soil.

Water levels can be controlled in open drains with adjustable weirs, standpipes, or inflatable check dams in open drains or streams. Most such structures are manually operated, but they can be automated to open under flood conditions and then be manually reset.

3.2.5. Remote and Automatic Controls

Remote and automatic controls of one kind or another have been installed in many water supply and drainage systems to control operation of pumping plants, bifurcation works, diversion works, canal checks, and other facilities. In most cases, complete automation is neither feasible nor desirable. Providing remote monitoring with human judgment and control or automatic control of individual components of the system is often more cost-effective.

Definition of Terms

There are two functions that must be performed by the water delivery control system: *monitoring* of conditions (pressure, level, and flow) and *control* of regulating devices (gates and valves). These two functions can be performed *manually* or *automatically* and *locally* or *remotely.* Local and remote control should be differentiated from *central* control, where a number of devices are controlled in coordination, and *distributed* control, where each individual device is controlled separately. Centralized control is always remote, while distributed control can be done locally or remotely.

Automatic control schemes or devices perform both monitoring and control functions automatically without supervision. Such control schemes include an automatic gate that maintains a constant water level or a pressure regulating device that maintains a constant pressure. These are examples of distributed local automatic control. Dynamic regulation is an example of centralized remote automatic control, which, for safety, should include monitoring for district personnel.

Supervisory control is basically a system for remote monitoring and control. System status is displayed on a control panel and allows the operator to view a schematic of the entire system at once. Control decisions and adjustments are made by the operator.

A supervisory control system is defined as a system in which all supervisory control, indicating and telemetering devices in a master station, and complementary devices in the station(s) use a single common interconnecting channel or link for transmission of control or indication signals between these stations. Supervisory control systems for main canals within an irrigation district are becoming more and more common.

Telemetering provides a means for making measurements at a distance or at a remote location, and transmitting the metered information to a master or local station.

Canal Gate Control

The two main types of mechanized gates in use are electrically motorized gates and hydraulically actuated gates. Most remote control schemes, either manually or computer-operated (automated), use motorized gates. Although vertical sluice gates are sometimes used, radial gates are normally installed, since these gates require a nearly constant force to cause gate movement regardless of canal stage.

Analog gate control devices (original EL-FLOW and Littleman controllers) must be located near the gate being controlled (i.e., they must be local). Digital control systems can be either local or remote.

Because of costs involved, supervisory control systems are typically used only for main canals. Control of the rest of the distribution network remains as local distributed manual control. In many cases, supervisory control of a main canal has no noticeable influence on the operation of lateral and tertiary canals and farm turnouts. The influence of automating or remotely monitoring one portion of the canal network on the remainder of the network should be considered. Supervisory control of main canals is very important for safety reasons (overflow protection, canal breeches, and dewatering).

Local control methods can sometimes be used in conjunction with remote control. Here, remote control can provide a setting for local controller (the desired flow rate) or can be used to keep the local controller within its operating range. For example, when a large canal control structure with several parallel gates is locally automated, only one gate needs to be automated. The rest can be operated manually to keep the single gate within its operating range.

In some areas, electrical power is either unavailable, too expensive to install, or unreliable. A number of mechanical gate devices are available for maintaining a constant level either upstream or downstream of a control gate. One type (the Neyrpic gates) uses a large float on the gate and a balance of forces to keep a near constant level.

Another type (the controlled-leak system) uses a float in a float chamber to move a radial gate up and down. A counterweight is used to balance the gate. Water-level changes in the float chamber are used to move the gate up and down. Leakage rates in and out of the float chamber are controlled by error in water level.

Pipeline Controls

Closed and semi-closed pipelines rely on control at the turnout valve for control of flow rate or pressure to users. For closed pipelines, pressure control within the pipeline, even at branch points, is typically not necessary. Openings to the atmosphere (reservoirs or surge tanks; see Fig. 10) are used for water storage and surge suppression and not for pressure regulation. Frequently, the water level in such reservoirs is used as an indicator of when pumps should begin and stop operating.

Pressure regulating valves at turnouts are common in high-pressure pipelines, particularly when pipeline pressures are very high. In some cases, the user is entitled to water at a certain pressure. Controlled pressure is not always a good indicator of flow rate, particularly if the back pressure from the farm system changes.

A totalizing water meter is needed if either source or back pressure at the valve is allowed to vary during the irrigation event, unless a flow control device is used that will maintain a constant flow with a variable differential pressure. If fluctuating pressures and flow affect the perfor-

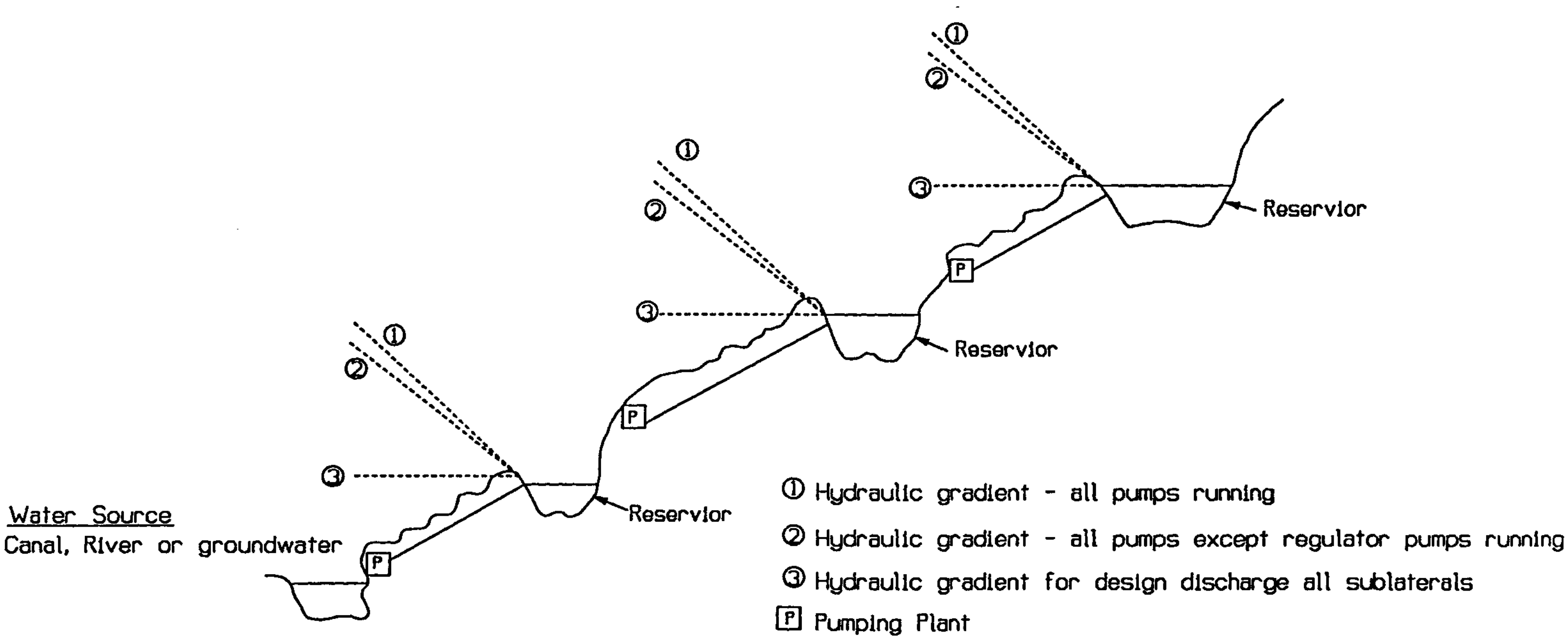


Fig. 10. Three-lift. Reservoir System

mance of the on-farm system significantly, then some form of flow or pressure regulation should be used.

The major problem with pressurized pipelines is supplying sufficient pressure for all potential users along the lines. If pipeline capacities are limited, pressure can be maintained only by limiting use of the pipeline—for example, by limiting the number and type of users at any given time. In addition, controls should be used on pumping plants that supply the water at the desired pressure.

In semi-closed pipelines, short reaches of the pipeline are controlled by inline control valves that regulate pressure on the downstream side of the valve. Water is typically discharged into open pipelines, into open channels, or directly into fields. Some form of flow rate control at these outlets is essential to ensure proper operation of the system. If pressure control at the turnout is adequate, then weir or orifice outlets can be used to regulate flow. Turnout controls for both closed and semi-closed pipelines are nearly always manually operated.

Pumping Plant Controls

If the flow rate supplied by a pumping plant is required to vary over time, it is usually economical to have a number of pumps in parallel. Thus, controls are needed to turn on pumps when pressure or flow is too low and turn off pumps when pressure or flow is too high. If the pumping plant is discharging into a canal or an open pipeline, then flow into the system is controlled by selected pumps. Generally, this does not give very precise control.

Finer control is achieved either by throttling the outlet with a valve or by using a bypass line to return water to the source. The selection of which control to use depends primarily on the pump curve characteristics. Manual throttling is most often used when the outlet is into a canal or open pipeline.

If the pumping plant is discharging into a closed or semi-closed pipeline, a balancing of flow rate is sometimes achieved by changes in pressure; that is, when pressure increases, flow decreases according to pump characteristics. For larger changes in pressure, addition or subtraction of pumps is needed. This can easily be done automatically with either level switches in an open riser or, to a limited degree, with pressure switches. Turning pumps on and off and the use of a bypass line are more common than throttling in closed pipeline applications, since these can be done more successfully automatically.

When the pumping plant is a booster station within a closed pipeline system, a line for bypassing the booster station should be installed with a one-way check valve (see Fig. 11). The check valve opens when the booster station pump stops and momentum of flow creates a higher pressure on the suction side of the pump than what exists on the discharge side. This helps eliminate water hammer (pressure surges) in the event of pump failure or shutdown. The check valve should be a slow-closing type to prevent a pressure surge as flow begins to reverse (Beieler 1988). The choice of manual or automatic operation depends on type and facility size, reliability needed, safety, cost, and efficiency desired.

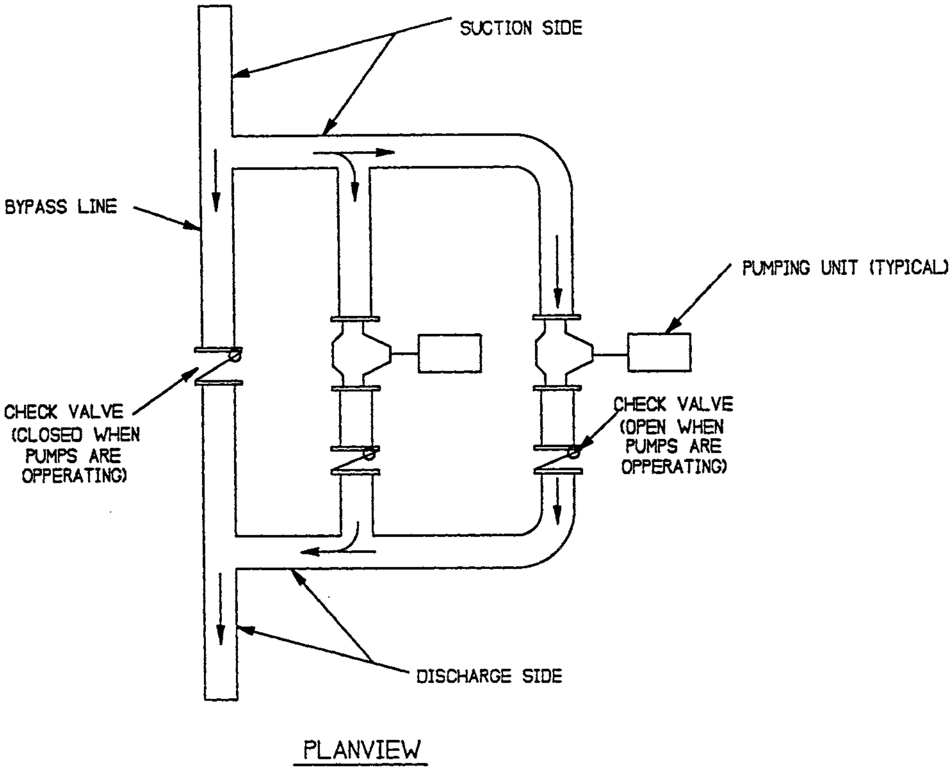


Fig. 11. Check Valve in Booster Station Bypass Line

Supervisory Control

Supervisory control allows for coordinated manual operation of canals and pipelines. The control system should include sufficient displays for the user to have a clear picture of system operation. The most simple supervisory control systems include displays of water levels (or pressures) and gate (valve) positions and allow gates and valves to be adjusted.

More advanced supervisory control systems include control panels with warning lights to indicate when a level or pressure is outside the desired control limits, lights to indicate pumps that are on or off, and a wall map of the system with key display information on system functioning. One of the major advantages of supervisory control is the coordinated control of operations. Errors in flow can quickly be adjusted through the system by near simultaneous control of gates and valves.

A major advantage of supervisory control is in the control of emergency situations such as canal breaks or large flood flows entering a canal. A centralized view of these conditions can help to minimize further damage to facilities.

Supervisory control is also useful when combined with computer canal control. In many cases, computerized controls are limited in their applications, making manual overriding necessary. Manual observation of computer-automated operations is essential as a safety measure, particularly on large systems. Supervisory control is adapted to flexible farmer-varied schedules.

Telemetering

If the system chosen involves remote operation or indication, a means of communication is required. This may be a buried cable (twisted wire or fiber optic), VHF (very high frequency) or UHF (ultrahigh frequency) radio channel, microwave channel, or power line carrier. Buried cable circuits may be leased from the local telephone company or constructed as a part of system facilities where commercial facilities are not available at reasonable cost or where suitable service cannot be assured.

VHF-UHF and microwave radio would be more appropriate in difficult terrain or where considerable distances may be encountered, or both. A power line carrier normally would be the least likely available means of communication on most irrigation developments.

Because of cost considerations, use of supervisory control equipment is generally considered for systems having a large number of functions or stations, or both, while remote control and telemetering equipment are generally considered for smaller systems. Accordingly, the choice of the transmission system is defined by size of irrigation or drainage development and amount of information that must be transmitted.

The cost of communication channels varies greatly. A microwave communication channel is the most expensive and is usually difficult to justify solely for use with an irrigation or drainage development, because channel requirements would rarely approach the capability of even a small microwave system. The major cost of this type of system lies in the radio frequency equipment, houses, towers, power supplies, and access roads. Thus, the initial cost is not proportional to the number of channels being used.

VHF and UHF radio channels are relatively economical, as are leased open-wire telephone lines. The foregoing considerations should provide the potential user of electronic equipment for irrigation system control with some of the factors to be weighed in selecting equipment tailored to his specific requirements.

A major consideration in choice of telemetering systems is system reliability. For example, weather conditions that cause implementation of emergency procedures may also cause communication system failure, thus nullifying a major benefit to supervisory control.

Justification

The first step in examining the possibility of developing an automatic or remote control scheme is to define the purpose of doing so. In some cases, remote or automatic controls can be used to reduce labor requirements of district operations. However, frequently such systems result in better water control than is feasible with human control alone.

In fact, some canal downstream control schemes are not feasible without some form of automatic control. It may be that one scheme can inexpensively reduce labor costs while another slightly more expensive scheme will provide better water control as well. The challenge is to find an efficient mix between control method, remote monitoring and control, automatic control, and human control.

An economic analysis of proposed improvements should consider capital cost of new hardware, maintenance cost including need for specialized skills and labor (electronic technicians), design life of electronic and mechanical equipment, savings in operational labor, improvement in water control, and any benefits to users resulting from improved control. The last factor is somewhat difficult to evaluate and difficult to recover without some change in water charging.

3.2.6. Integrating Measurement and Control

Water measurement should be an integral part of the control scheme. When upstream control techniques are used, water measurements at all divisions in flow are necessary to supply water in a reliable, equitable fashion. When downstream control techniques are used (as in a closed or semi-closed pipeline system), water measurement is essential only at farm turnouts. However, measurement of flow into the pipeline or lateral is a good check on the amount of water being delivered.

Reversing Control

It may be desirable to reverse the control scheme at a particular location from upstream to downstream control or vice versa. Upstream control can be converted to downstream control by use of a storage reservoir. Excess water released from upstream and not requested downstream can be bypassed to the reservoir. Similarly, additional water needed downstream can be taken from the reservoir.

It is often possible to locate such regulating reservoirs so that water flows by gravity with no pumping required. In this case, the reservoir isolates the downstream controlled canal or pipeline from the upstream controlled canal or pipeline.

Another alternative for converting to downstream control is simply always to release excess water and return what is not needed in the canal downstream to another canal, reservoir, or river. If excess water is returned to the system for downstream projects and canal capacities can accommodate this excess, this method offers a simple means for improving control. However, this could be at the expense of lost potential energy and lost instream flows.

In this case, return flow isolates the upstream controlled supply to the canal from the downstream (or flow rate) control to turnouts. This method is preferred to delivering this excess water to users, since the flow returns with less water-quality degradation and less negative effect on yields. Similar methods may also be available.

Downstream control can usually be converted to upstream control more easily. Any time the effects of downstream water level are not transmitted upstream, upstream control results. A steep canal section with no artificial feedback (electrical signals or a stilling well tap) of water levels at the downstream end of a reach (the canal section between control structures) is automatically converted to upstream control, provided that the backwater curve does not reach the upstream end of the reach.

A critical depth-measuring structure, free-flowing orifice, or free-overfall structure will result in upstream control downstream of the structure, regardless of the control scheme used upstream. A submerged orifice with a high differential head relative to downstream water-level changes will, for practical purposes, produce a similar effect.

Isolating Control

Most preceding parts of the section have dealt with in-line controls. Reservoirs and free overfalls can be used to isolate control schemes in different parts of the same canal. The important implication of this is that different parts of a distribution system can be controlled and managed independently.

This further implies that different parts can be controlled and managed differently (that is, with different objectives, control schemes, and operating procedures). For large projects, this can be used to significant advantage in that conditions tend to be nonhomogeneous.

It may also be important to isolate the control of adjoining canals from each other (isolating control of a lateral canal from that of a main canal). Flow rate control and downstream control on the turnout (lateral) canal effectively isolate control of two canals.

Manual upstream control schemes attempt to do this by maintaining a constant level in the main canal. Often, this isolation does not exist, and turnout canal conditions actually affect conditions in the continuing supply canal. These effects are more pronounced for farm turnouts from relatively small canals, where little head is available.

One method that has proven effective in isolating adjoining canals that operate under upstream control is to install critical-depth, flow-measuring devices at the head of a lateral canal and downstream of all turnout gates on turnout or farm canals. The devices must be designed to maintain critical flow; otherwise, no isolation exists.

Another advantage of this scheme is that flow measurement is made simple with wall-mounted gauges and is, in many cases, more accurate than many existing measurement methods (measuring head drop across the gate and gate opening). In some canal systems, significant improvements in control could be made with this scheme without the cost and complexity of automation. However, with such controls flexible scheduling cannot be done.

Another very effective means of isolating control is the use of regulating reservoirs. In some irrigation projects, farm reservoirs are used to collect water delivered by the water authority according to a rigid supply schedule, and to remove the water according to farmer needs. In this case, a considerable amount of land is taken out of production. In addition, flow-rate control is frequently needed at farm reservoir outlets if farm canals are gravity-fed (i.e., there is no pump).

An alternative is to place the regulating reservoir further up the canal system—for example, at the head of a lateral canal. This would then isolate the lateral canal and its users from the rest of the project (although other locations along the lateral canal may be more desirable). Such a lateral regulating reservoir would facilitate flexible deliveries, with the amount of flexibility dependent upon downstream controls.

Selection of Control Schemes and Structures

The main factors in selection of control schemes and structures are cost, flexibility of service, controllability of system, consistent and equitable water distribution, water accountability and safety, not necessarily in that order.

With the wide variety of control schemes available, the goal of efficient, flexible, equitable water distribution encourages a mix of control strategies within a project rather than a single uniform policy. For all but very simple canal systems, the most appropriate control scheme will consist of a variety of control methods and structures.

The pertinent question is not which control method to use, but rather, where to use various control methods. For example, at the head of a surface-irrigated field, it is most desirable to have upstream control with flow rate control at the farm source, or finally at the field delivery point.

Turnout flow rate control works best when in-line structures use downstream control. With in-line upstream control, turnout flow-rate control will result in flow-rate mismatches and associated tail-ender problems. Sprinkler and micro-irrigation essentially require some form of demand operation (downstream control).

Appropriate control options can be selected by working back up the system from farm to project source. However, many large canal systems begin necessarily with upstream control. This is often dictated by long transmission distances and correspondingly long travel times. The difficulty in selecting canal controls is in making the transition from supply constraints (upstream control) to farm irrigation needs (downstream control). This problem is minimized when water is pumped from its source into closed pipelines.

It is probably not feasible for all structures within a large project to be remotely controlled from a central location. Manual control and local automatic control will likely be most common. Central remote control is probably only a viable option for project main canals and key bifurcations. One of its biggest advantages over local automatic and manual controls is the rapid detection of storm inflows or canal breeches or failures, and the ability to isolate the appropriate canal reach rapidly.

Downstream control is more dangerous in that it tends to supply additional water downstream to feed the breech, unless special safety features are implemented. The reaction of the system to any failures of automatic control devices should be carefully considered.

3.3. WATER MEASUREMENT

3.3.1. Need for Water Measurement

The purpose of an irrigation system is to deliver water in a specified quantity and at a specified time and place for irrigation. Considerable emphasis must be placed on measurement and control of water both in storage and in transit through the system. Adequate control and accurate measurement of waterflows from storage to delivery are necessary for successful business management to do the following.

- Meet legal obligations concerning water appropriations.
- Conserve water.
- Ensure an equitable distribution of water to those served.
- Establish and maintain a cordial relationship among owners, operators, and water users.

Day-to-day management of water requires that daily water use be known and compared to system inflow reserves and demands. This can be accomplished only by knowing with reasonable accuracy the amount of water being diverted, withdrawn from storage, and delivered. Considerable quantities of water can sometimes be accounted for merely by upgrading existing measurement devices or by properly installing, operating, and maintaining new devices.

Points of Measurement

In many irrigation developments, a storage reservoir is provided to regulate seasonal runoff of the stream that supplies water for the district. Here, the water is held until needed. Downstream from the storage reservoir, a conveyance system transports stored water to the irrigated area. This system may consist of a combination of natural watercourses, canals, laterals, pumping plants, pipelines, and wasteways.

If water is conveyed in a natural stream channel to the irrigated area, a diversion dam and headworks are usually necessary to divert the water into the principal conveyance or distributaries. A sketch of a typical system is shown in Fig. 12. In an ideal arrangement, flow would be measured at storage outlets, canal headworks, strategic points in canals and laterals, all lateral headings or bifurcation of flow, points of delivery to users, and all wasteways.

Under certain circumstances, water may be released directly from storage into the district conveyance system. The water then flows through a canal and/or pipeline system for conveyance to the land. In some cases (see Fig. 12), water is released from storage and flows through a natural watercourse to a point near the irrigation area before it is diverted into the district system.

At point of diversion, measurement is again necessary because stored water could be mingled with water belonging to others who have rights to use the water from the stream. Measurements are also necessary at this point for determining conveyance losses and proper water administration.

The farm turnout, constructed for the ultimate consumer, is probably the most important point of measurement in an irrigation system. Measurement must be made here to ensure an equitable distribution of water supply and provide a basis for charges. There may also be points of law, such as rights to the water, to be considered.

The responsibility for water measurement at the farm turnout should lie with the irrigation district. However, measurement of water is also important for the irrigator in the management of the farm.

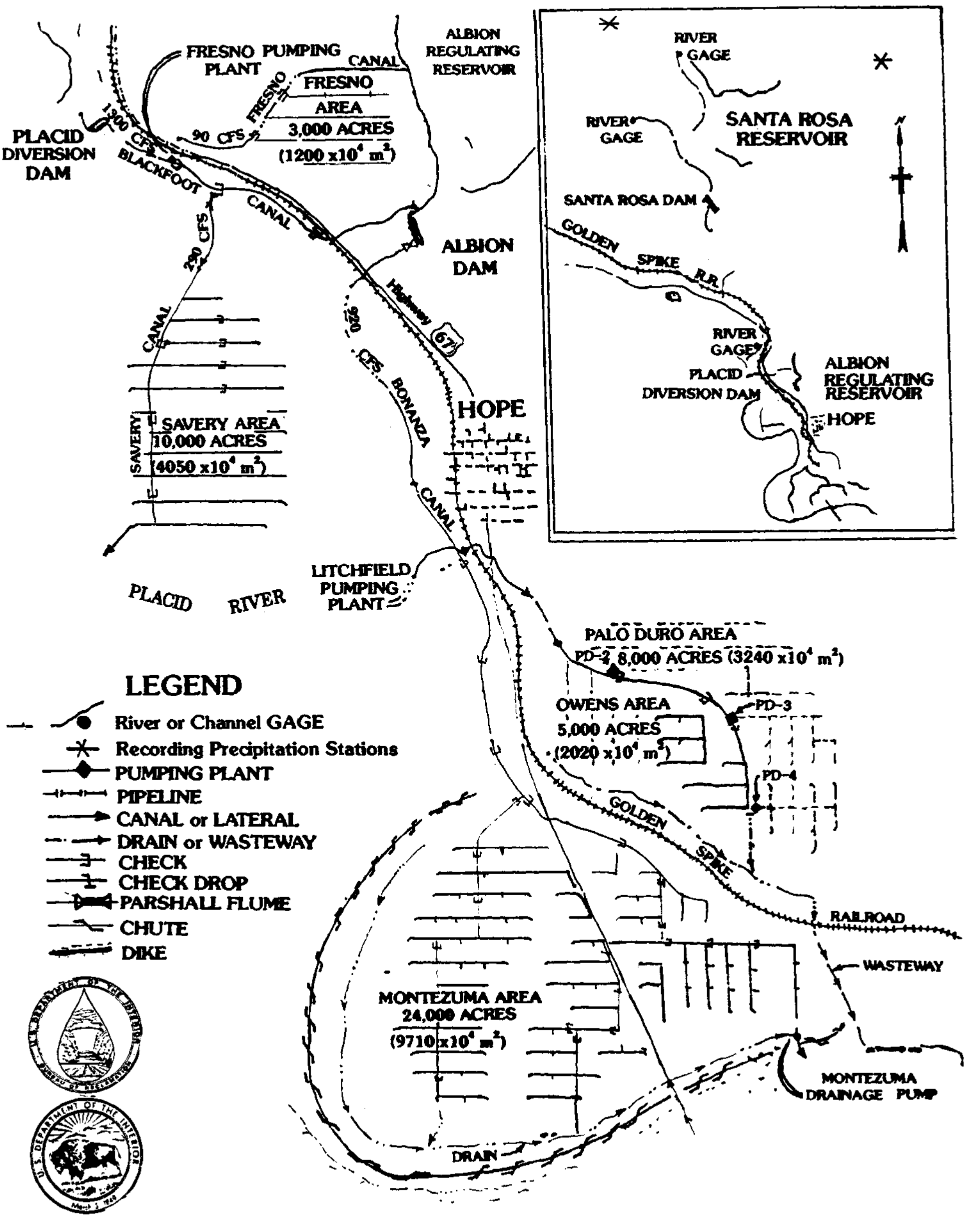


Fig. 12. Typical Irrigation System (1 acre = 4,047 m^2; 1 cfs = 0.028 m^3/s

If district measuring devices are not accessible to the farmers, the farmer may install their own measuring device for on-farm water management. This type of situation is becoming more common in districts with canal delivery systems and has been brought about in part by poor district water measuring structures and lack of easy verification by farmers.

Conflicts can arise when district and farmer flow measurements do not agree, or if the district measuring device is not understood by the farmer. Such a situation is avoided by cooperation between the irrigation district and farmer in providing a single device that will serve both purposes.

Fluctuations of water surfaces both upstream and downstream of the point of measurement may normally be anticipated. The means of measurement at the farm turnout must be selected to meet exacting conditions. For instance, a small loss in head may be very important at a turnout serving land adjacent to the canal or a lateral, particularly when the water is delivered by gravity flow.

The cost of the measuring device at the farm turnout is of primary consideration, particularly where the farm units are small or the economic return is low. A shutoff is required at a farm delivery in most instances because the farm operator may not desire water or may not have legal entitlement at all times when there is flow in the canal or lateral.

Installation can be economically obtained in open-canal systems if the shutoff at the farm delivery (a sluice-type gate) also serves as a means of measurement. This provides measurement right at point of turnout, rather than at some distance downstream. This approach has been successful in many places; however, two problems exist with this approach. First, unless gate and site conditions are set up specifically for measurement, measurement accuracy can be poor, particularly where head is limiting. Second, this approach does not allow an easily made independent check by irrigators for their management.

Permanent measurement structures downstream from the turnout gate would generally be on-farm property and might be deemed unacceptable for district use. However, this situation exists in pipeline turnouts, where the measuring structure is at some distance downstream from the valve and is totally acceptable. These differences lie in policies made by the district that are influenced by farmers and the history of development.

Basis of Measurement

In the United States, water is usually distributed on the basis of flow rate. Flow rate or discharge is defined as the volume of water that passes a particular reference section in a unit of time. The unit of discharge now in general use in irrigation practice in both humid and arid regions is the cubic foot per second, also known as second foot. Other units still in use are gallons per minute, miner's inches, acre-inches per hour, and millions of gallons per day. The most common metric units are cubic meter per second and liter per second, with megaliters per hour and cubic dekameters per hour in use in some locations. The most common metric units with conversion to cubic feet per second will be used here to discuss flow rates. A conversion table for the various units is given in Appendix I.

The flow rate combined with time may be used to give a volume as a basis for charges. The unit of volume commonly employed in irrigation practice is acre-foot—the quantity of water required to cover 1 acre of land 1 ft deep. Cubic meters and cubic dekameters are the common metric units for volume.

The measurement of water is a difficult problem in many areas where irrigation is practiced. Gradients of the conveyance system are normally low, which causes a deficiency of head for accurate measurement. Water requirements on farms vary from day to day, causing increases and decreases in flows in the conveyance channels, which are of fixed dimensions. This results in a varying water surface, varying velocities, or both, depending on the control structures used. Also, the presence of weeds and silt, the difficulty of maintaining close tolerances during construction, and many other factors are present to reduce the accuracy of flow measurements.

3.3.2. Measurement-System Components

Water-measurement systems are composed of several components. These include a primary device, which has some physical contact with the water, and any number of secondary devices, which condition output of the primary device and display this output in a desired form.

Thus, when considering any water-measurement system, the user must select a combination of primary and secondary devices that will accurately measure the desired range of flows, result in an output in usable form, and not be prohibitively expensive.

A distinction should be made between accuracy and precision. Accuracy is an absolute measure of the relationship between the actual rate or volume of waterflow and the rate or volume determined from the measuring system. The most accurate means of measuring waterflow is by gravimetric (or weighing) and volumetric methods. These are the primary standards of flow measurement. The accuracy attainable is generally better than ±0.1%. Most other measuring devices are compared to these standards; however, gravimetric and volumetric methods are not generally used for routine field use because the devices needed are cumbersome and for large flow rates would have to be quite large. Precision is primarily a measure of how accurately small changes in flow can be detected and of repeatability of the measurements. High levels of precision do not imply high levels of accuracy. For example, a device can be repeatable to within ±0.1%, be able to detect changes of ±0.01%, and only be accurate to within ±1%.

The two types of measurement errors are systematic and random. Systematic errors for any particular device are errors that do not change over time. Manufacturing and construction errors cause systematic errors in measurement. For example, a series of devices intended to be identical will usually differ in discharge measurement, even if by a very small amount. Such errors can be corrected if identified.

Random errors, on the other hand, represent the inability of the measuring device to repeat itself. Visual reading of staff gauges usually results in random errors. Some random errors result from not including measurement of a factor that affects discharge, for example—temperature. The expected value of a measuring system random error is computed as the square root of the sum of squares of all the sources of random errors.

For many devices, the percentage error of the primary device varies little throughout the flow range. Thus, the errors are usually given as a percentage of the reading. Other devices may have a relatively constant level of uncertainty, such as reading a scale, that becomes more significant at a small discharge. The errors for these devices are usually given as a percentage of the full scale. The percentage error at half scale is likely, but not necessarily, twice the percentage error at full scale.

Errors for secondary and tertiary devices can be analyzed in a similar manner. There may be any combination of error types, both percentage of reading and percentage of full scale. Thus, the expected percentage error will usually vary with discharge rate.

3.3.3. Types of Measuring Devices

Primary Measuring Devices

The array of measuring devices that can measure flow is virtually unlimited. Any number of these devices can be made to work at high degrees of accuracy, especially when they are calibrated in place. However, many are impractical, cumbersome, expensive, and generally not suited to usual conditions of irrigation flows. Most are not well adapted to variable flow rates associated with flexible schedules. Totalizing meters are best.

Thus, this discussion will concentrate primarily on those devices that can reasonably be expected to be used in irrigation and drainage systems. The two basic groups of devices that are common for irrigation flows are quantity meters and rate meters.

There is a variety of physical principles that are exploited in the measurement of flow rate in either group, including head differential across known contraction, variable head and area, which primarily exploit knowledge of critical flow, tracing of flow particles to estimate velocity, calibration of force, momentum and displacement, and various other fluid properties. Some meters are a mix of quantity and rate meters depending on the application, e.g., propeller and turbine meters (see Figs. 13 and 14). Table 3 gives categories of various meters in use.

Volumetric meters directly measure either weight or volume of water accumulated over a given period of time. Examples are weigh tanks, volume tanks, propeller and turbine meters of many configurations, as well as the mechanical-chamber types that are characteristic of many household water meters.

Rate meters infer an instantaneous readout for a continuous flow. The flow moves through or by the primary element. Some type of interaction on the primary element in contact with fluid is monitored by a secondary device. This interaction of fluid and primary element depends on one or more physical properties of fluid as previously mentioned. The secondary device indicates changes in these properties that are related to flow rate. The different types of rate meters are discussed next.

Volumetric Meters

Propeller and turbine meters may be considered quantity meters because these meters basically accumulate the passage of volume when equipped with revolution counters. Piston, or positive-displacement pumps separate the volumes, while propellers are continuous. The mechanical-chamber types, gear pump, bellows, and piston-pump styles are

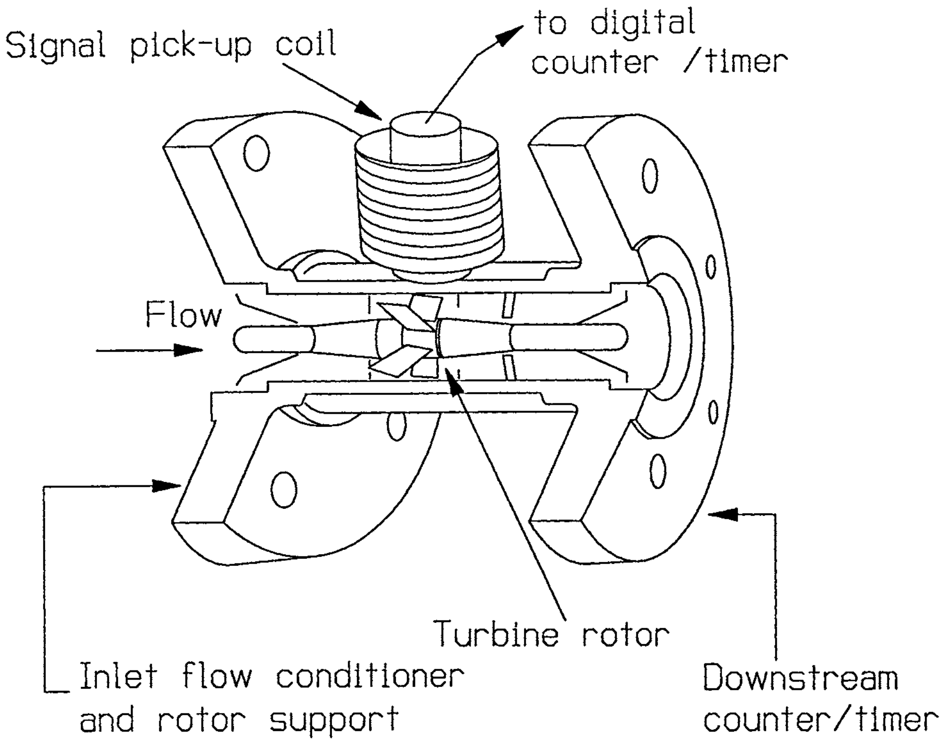


Fig. 13 Turbine flowmeter

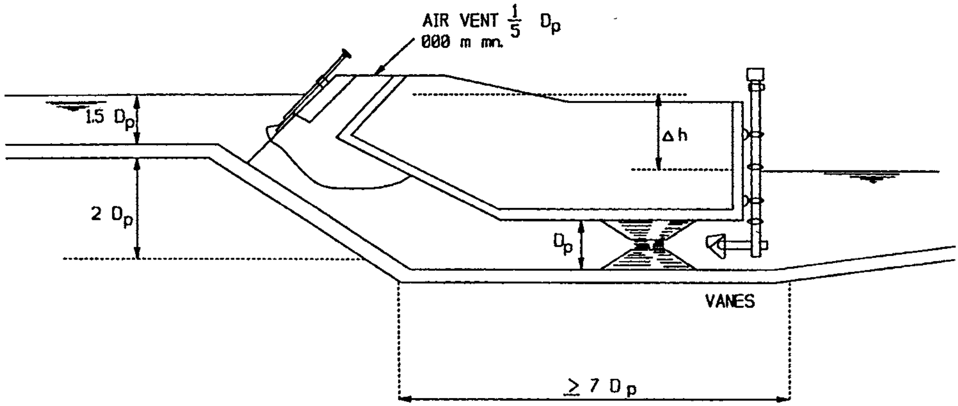


Fig. 14 Typical propeller meter installation

Table 3. Characteristics of Primary Measuring Devices (Replogle 1987)

Meter type (1)	Potential accuracy (2)	Ratio of flow max:min (3)	Remarks (4)
(a) Volumetric (Quantity)			
Propeller	1% of reading	15:1	Can be a rate meter (in pipe).
Paddle wheel turbine	3% of reading	15:1	Can be a rate meter (in pipe).
Turbine	0.5–1% of reading	15:1	Many blades for accuracy (in pipe).
Dethridge meter	2–5% of full scale	4:1	Currently in limited use (open channel).
(b) Differential Head (Rate)			
Venturi	1% full scale	5:1	Low head loss; can be used with slurries (pipe).
Orifice (in pipe)	0.5–1.5% full scale	5:1	High head loss; many shapes in use.
Orifice (in channel)	3–5% of reading	5:1	High head loss.
Elbow	3–10% full scale	3:1	Adds no further losses if already in line.
Constant head orifice	5–10% of reading	5:1	Accuracy limited by head differential.
Pitot tube	2% of reading	3:1	Accuracy limited by velocity distribution.
(c) Variable Head and Area (Rate): Accuracy Limited by Head Detection Method			
Short-throated flumes			
Parshall	2–5% of reading	75:1	Must be carefully constructed according to specifications.
Cutthroat	"	75:1	
H-Flume	"	100:1	

Table 3. (Continued)

Meter Type (1)	Potential accuracy (2)	Ratio of flow max:min (3)	Remarks (4)
***(c)* Variable Head and Area (Rate): Accuracy Limited by Head Detection Method**			
Long-throated flumes			
Rectangular	2–3% of reading	35:1	Calibrations computable, construction deviations usually can be accomplished by recomputation. Flow range depends on shape (rounded or gradual approach).
Triangular	"	350:1	
Trapezoidal	"	250:1	
Palmer-Bowlus	"	250:1	
	"	200:1	
Broad-crested weir			
Sharp-crested weirs	1–2% of reading	25:1	Subject to wear, approach velocity conditions.
Cipolletti weir	"	25:1	
***(d)* Force-Velocity (Rate)**			
Chemicals, salts/dyes	1–2% of reading	20:1	Indicates flow velocity.
Floats	5% of reading	10:1	Indicates flow velocity.
Ultrasonic doppler	5–10% full scale	10:1	Clamp-on, nonintrusive; needs suspended particles for motion detection.
Propeller meter (channel)	5% of reading	5:1	Current meter sampling in channel. Accuracy varies widely.
***(e)* Force-Displacement (Rate)**			
Vane deflection	1–2% full scale	5:1	Field accuracy in channels is poor.
Target meter	1–2% full scale	5:1	Seldom used for irrigation flows.
Rotameter	0.5–10% full scale	10:1	Useful for chemical injection monitoring.

Table 3. (Continued)

Meter Type (1)	Potential accuracy (2)	Ratio of flow max:min (3)	Remarks (4)
	(f) Special Metering Methods (Rate)		
Electromagnetic (pipe)	1% full scale	20:1	Conductive liquids only.
Electromagnetic (channel)	5% of reading	5:1	Conductive liquids only. Velocity sampling.
Ultrasonic	1% full scale	20:1	Only clean liquids.
Vortex-shedding	1% of reading	100:1	No moving parts.
Chemical dilution	2% of reading	100:1	Can be difficult to use (rarely used).

sometimes called positive-displacement meters. Also included in this category are nutation-type disk household watermeters and other household styles.

The high head losses and small flow rates usually associated with these positive displacement meters limit their use for most agricultural deliveries. Such meters are more common for low flow rates typical of on-farm application methods, tile drainage flows, or agricultural chemical injectors.

Propeller and turbine meters can measure larger flows, but when these meters do so, the meters typically cover only part of the flow area and become very effective rate meters. The Dethridge meter is a quantity meter that can measure relatively large flows (3.5 to 10 cfs or 100 to 300 L/s) in open channels.

These are in use in some parts of Australia and have met with limited success and enthusiasm elsewhere, perhaps because Dethridge meters are basically paddle wheels, which are heavy and bulky.

Differential-Head Meters

The most common types of differential head meters are the orifice (see Fig. 15) and venturi meters. These are very common for pipeline flows and can be accurate primary devices because their results are so repeatable. Entrance flow conditions can have a significant effect on the accuracy.

Laboratory calibrations are used to establish calibrations for orifice plates. These are available for many standard sizes from 1 in. (25 mm) to several feet (1 m). The biggest limitation is the high amount of head loss required to get an accurate measurement with standard secondary head measurements. There is a wide variety of orifice tap locations, and they all have different published calibrations; therefore, the user should be sure that the correct tables are used.

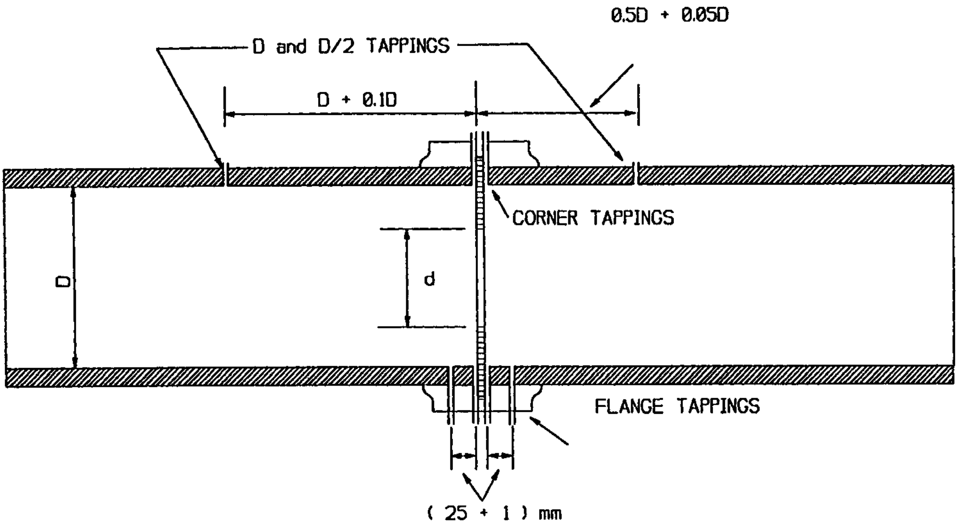


Fig. 15. Orifice plate with standardized tappings

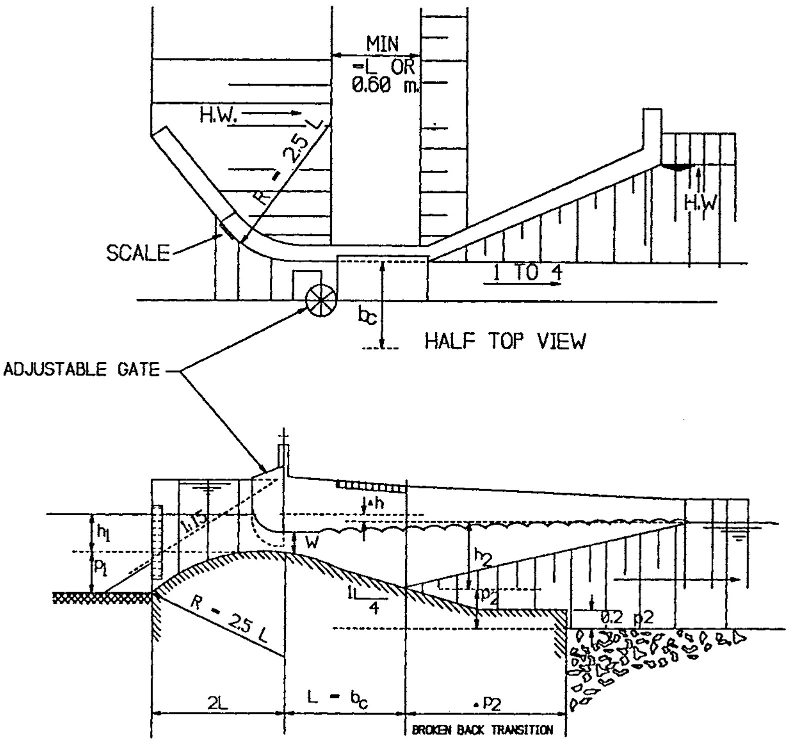
Recent international standards now advocate using so-called "diameter" taps at fixed ratios of the pipe diameter (one diameter upstream and one-half diameter downstream). Venturi meters are generally more reliable and less subject to wear, but they are more expensive, and thus are not in common use for irrigation. Calibrations are available in *Fluid Meters, their Theory and Application* (American Society of Mechanical Engineers1972).

Fixed orifices are sometimes used with open-channel approach and exit conditions. Here, calibrations can be obtained from handbook values (USDI 1984; Bos 1989), but these are not as accurate as pipe calibrations because of the wide variety of approach conditions possible in open channels. Accuracy suffers if the orifice edge is not accurately constructed and maintained.

Adjustable orifices (gates, see Fig. 16) are also in use as measuring devices. Several examples of differential-head orifices include meter gate (see Fig. 17), constant-head-orifice, submerged vertical-sluice gates (see Fig. 18), and submerged radial gates. Such installations can give reasonable accuracy provided that special care is taken to assure that approach and exit conditions are exactly as existed during calibration, the opening can be accurately measured, the full range of backwater conditions was tested during calibration, and the gate lip or seals are exactly as used during calibration. These requirements are frequently ignored in field situations.

Sedimentation and erosion at the approach to such meters can cause significant errors in flow measurement. The biggest problem with this style of measuring device as used in open-channel systems is the low head differential under which the meters are used (typically less than 6 in.or 15 mm). The accuracy automatically suffers because of the inability of commonly used secondary devices to accurately measure these small heads.

Adjustable orifices that are free flowing and have no backwater require only a single head measurement. These orifices are generally more



NOTE:
ON STANDARD STRUCTURES p_1 = bc and L = bc

Fig. 16. The Crump-De Gruyter Adjustable Orifice Dimensions as a Function of h_1 and b_c

accurate than differential head orifices since the heads are much larger and flow properties are less affected by deviations in flow conditions from those existing during calibration. Orifices that change from submerged to free flow are difficult to use since the transition between free and submerged flow is not consistent with rising and falling heads (a hysteresis loop exists).

Fixed orifices in channels are generally located several orifice diameters from channel bottom so that standard orifice equations can be used. Gates are generally located at canal bottom, thus, it is considered a half orifice with the canal bottom as the center of the orifice. If the bottom of the gate is above the canal bed when closed, the flow conditions are somewhere between a full and a half orifice. Flow conditions are less predictable than those for either full or half orifice, and thus, discharge relations are more difficult to predict. Some orifice calibrations can be found in *Water* (USDI 1984), Bos (1989), and from manufacturers.

The pitot tube can be considered as a differential head meter. The head difference is a measure of the velocity head, which can be converted

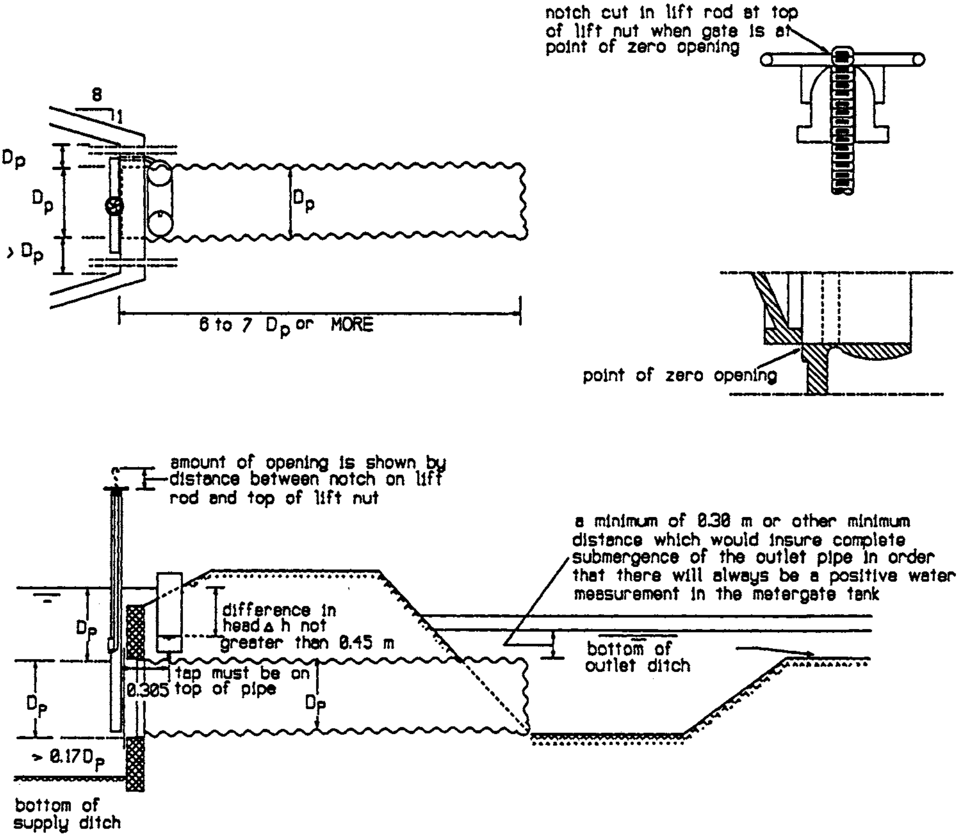


Fig. 17. Metergate Installation (Courtesy of ARMCO)

to velocity. For a well-developed velocity profile (20 pipe diameters from elbow), the pitot tube can be positioned to give an accurate repeatable reading. If the velocity profile is not well developed, the pitot tube can be moved across the pipe to sample velocity at various locations. This can be rather time consuming if done on a regular basis. The range of flows for a pitot tube is fairly narrow.

The newer developments in connection with these meters concern secondary devices that exploit microprocessor technology to integrate flows to provide both instantaneous rate and totalized flows. These devices have a fairly restricted flow range (5:1).

Variable Head and Area Meters

This is a particularly important group of rate meters for irrigation and drainage in agriculture because this group contains weirs and flumes used extensively for open-channel flow measurements. These devices in-

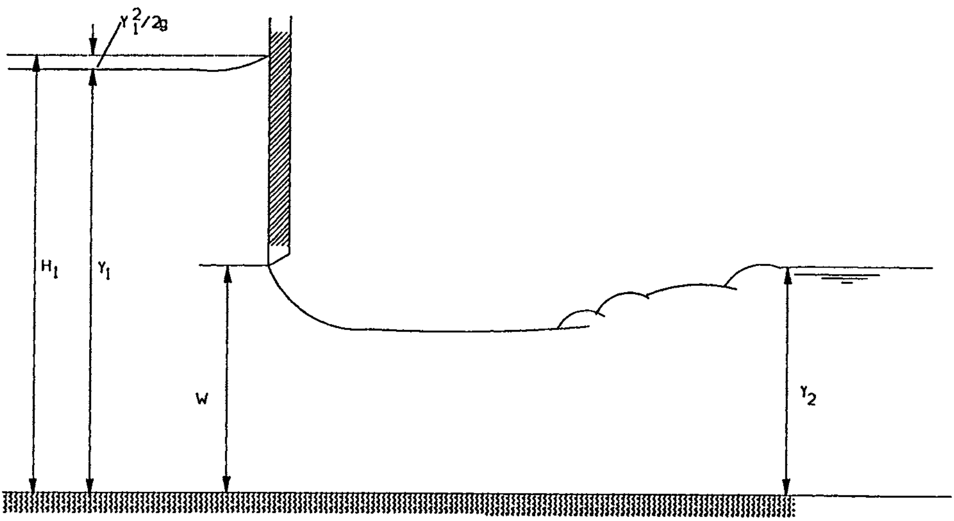


Fig. 18. Flow Below a Sluice Gate

clude sharp-crested weirs, short- and intermediate-throated flumes, and long-throated flumes (Ackers et al. 1978; Bos 1989; Bos et al. 1984).

Sharp-crested weirs have changed little over the past several decades. Major advantages are low cost and extensive documentation. Disadvantages include the need for high head loss and poor passage of sediments. These weirs can tolerate no back pressure from the tailwater channel; that is, the limiting submergence ratio (modular limit) is zero. Actually, most references suggest a margin of at least (2 in.) (50 mm). Inaccuracies result when the weir crest becomes dull, dented, or pitted, or when the structure has settled.

Flumes of short and intermediate variety are those in which major streamline bending occurs in the contraction or throat region of the flume. This affects the hydrostatic pressure distribution and limits ability to accurately predict discharge from theoretically derived relationships. It also affects tolerance to the downstream backwater. The sharp-crested weir could be considered the limiting case of short-throated flumes.

The older and more familiar short-throated flumes are Parshall, Cutthroat, and H-flumes (Ackers et al. 1978; Brakensiek et al. 1979). All depend on laboratory-derived calibrations. All should be installed with careful attention to duplicating the calibration situation as closely as possible (Bos 1989; Ackers et al. 1978). These flumes have a higher tolerance to downstream water levels than sharp-crested weirs and commonly tolerate 60 to 65% of upstream flow depth in downstream tailwater depth before corrections are needed in the calibration, which are determined by a second depth reading made on downstream water elevation.

The long-throated flumes and related broad-crested weir (see Fig. 19) have experienced several recent technological advances for measuring

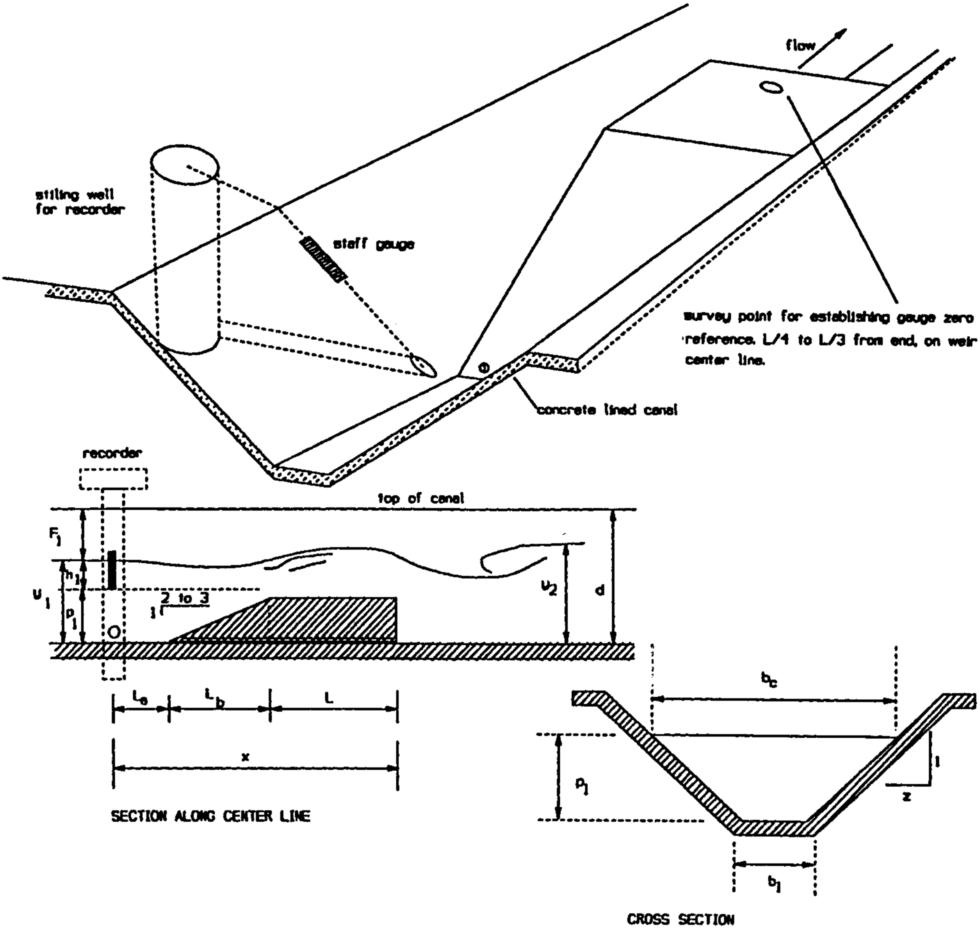


Fig. 19. Broad-crested weir in Concrete-lined canal

open channel flows (Bos et al. 1984). In these newly designed flumes and wiers, throats are proportioned to be at least as long as the measured head, and preferably twice as long, so that hydrostatic pressure conditions prevail at the control section.

Application of fundamental fluid flow characteristics related to fluid friction and flow velocity distribution in channels permits accurate computations of flow for a wide range of channel shapes and flume throat shapes. These "computables" are becoming the standard for most new open channel installations and are usually good candidates for retrofitting older canal systems because of high accuracy, low head-loss requirements, and simplified construction details (Bos et al. 1984).

The computer calibrating procedures are available (Replogle 1975). Submergence ratios exceeding 90% with a single upstream depth reading are usually practical and will provide maximum head recovery. The well known Palmer-Bowlus flumes (Wells and Gotaas 1958) have configurations that allow calibrations to be computed as long-throated flumes.

Among flumes and weirs, "computables" have the following advantages.

- Weir or flume can be shaped in such a way that all practical ranges of discharge can be measured accurately.
- For any weir or flume, a rating table can be calculated with an error in listed discharge of less than 2%.
- The required head loss over the structure is low.
- Head loss requirement of each combination of structure and channel can be calculated.
- Under similar hydraulic and other boundary conditions, the computables are usually the most economical for accurately measured flows.

The largest broad-crested weirs installed to date can measure 1765 ft^3/s (50 m^3/s). The required head loss is only about 0.33 ft (0.1 m) (Bos et al. 1984). The smallest in routine use measures 0.09 ft^3/s (2.5 L/s) at maximum capacity and 0.004 ft^3/s (0.125 L/s) for its low rate with a required head loss of less than 0.04 ft (12 mm).

For the usual small field ditches with concrete linings, precomputed ratings have been prepared and published by Clemmens and Replogle (1980) and by Bos et al. (1984). The usual configuration is a trapezoidal, broad-crested weir with an approach flow ramp.

Dimensionless ratings for average roughnesses and profile lengths were presented for partly full circular culverts fitted with similar sills (Clemmens et al. 1984). However, direct computation by the computer model (Clemmens et al. 1987) for specific construction materials and lengths provides a slightly more accurate equation for specific configurations that can be used for portable drain outlet flows.

A majority of field errors result from construction errors (particularly a problem for throatless and short-throated flumes), improper approach conditions, and improper zeroing of head detection equipment (secondary device). Submerged or non-modular flow, which requires a differential head reading, should be avoided since accuracy can be extremely poor (in excess of 10%) even under well-controlled conditions. Errors also occur when structures settle with time.

For all variable head and area meters, flow rate is nearly proportional to throat or crest flow area. Thus, flow area at the crest or throat should be closely controlled.

Force-Velocity Meters

For force-velocity meters, flow pushes the primary detecting device along at fluid speed. Injected salts or dyes, floats, suspended particles, and tiny bubbles are all in this class. One may also reclassify turbines and propeller meters (which are included with quantity meters when detecting total revolution count) into this group when rate of spin is detected. The blades are responding to the force component of flow much as a float would respond.

Sonic doppler flowmeters are relatively new but are really secondary devices used to monitor floating bubbles, turbulence interfaces, or silt-sized inclusions being pushed along in all but the cleanest flowing waters. The devices are primarily suited for nonintrusive surveys of pipe flows.

Propeller and turbine meters can be very accurate for measuring pipeline flows. If the meter is downstream from a valve or bend in the pipe, then meters that cover a high percentage of cross sectional area should be used as opposed to meters that sample flow in only in a small portion of the pipe cross section.

The biggest problem associated with propeller meters in pipes has been bearing wear, a significant problem for well flows that contain sand. Generally, these meters are good for totalizing flow (magnetic pickup as revolution counter as secondary device). Instantaneous flow-rate readings with a speedometer-type gauge are generally not very accurate. Electronic readout devices should provide better rate measurements.

Propeller meters are also used for measuring culvert flow at transitions from pipe to open channel flow. Generally, these are not left in place but installed for each measurement. These are sufficiently accurate, provided that the meter does not cause a significant head loss (more than 10%), a problem for low-head installations.

When used to sample velocities in streams, rivers, and canals, propeller meters are often called current meters, since these meters measure the velocity of the current. Measured velocity times the cross section of the area through which the flow is occurring should give an estimate of flow rate. Since velocity in an open channel is not uniform, a series of velocities at different depths and transverse positions is necessary to characterize flow profile (Herschy 1985). This method requires a well-defined metering section with proper approach conditions and skilled operators with well-maintained equipment to get reasonable accuracies (less than 5%).

Force-Displacement Meters

Vane deflection meters (penvane) have been used to measure open channel irrigation flows. These meters require a well-defined, cross-sectional area and a smooth water surface. These meters have a fairly narrow flow range, but can be accurate under ideal conditions. The accuracy of commercial versions for open channels (no longer available) was limited by the precision of the secondary device and was significantly affected by wind.

Force-displacement devices have also been used for pipeline flows. These generally fall under the category of target meters and are not commonly used in agricultural applications.

The glass-tube rotameter, often classified as a variable area meter, can be considered a force displacement meter. A ball or float is placed in a vertically mounted, tapered glass tube. Increasing flow rate causes the ball to rise (American Society of Mechanical Engineers 1972). These are common for injection of chemicals at low-flow rates and are sometimes used in trickle irrigation.

Special Metering Methods

Chemical dilution techniques use a known volume and concentration of dye, other chemical, or radioactive tracer added to a flowing stream and tested for final concentration. From this concentration, the amount of water diluting a tracer chemical can be calculated. This can be a cumbersome, time-consuming process and is not well suited to routine measurement of irrigation flows.

Magnetic flowmeters are available for measuring flow in pipelines. The velocity of flow distorts a magnetic field generated by the meter and received by a transducer. The standard magnetic flowmeters sample the entire profile, and therefore are less affected by the velocity profile.

Manufacturers still recommend 3 to 5 diameters of straight pipe on either side of the meter. Magnetic meters are accurate but fairly expensive. Smaller, wall tap-style magnetic flowmeters are also available. With smaller meters, only a part of the cross-sectional area of flow is sampled because the source and detector are located physically close together. Thus, these meters are more sensitive to changes in the velocity profile.

Magnetic probe flowmeters have also been used to measure velocities in open channels. These meters work well even with fairly dirty water and can be used as current meters in place of propeller meters or can be mounted on channel walls for more permanent installations. An insulating blanket is necessary in areas that have other electrical interference. The biggest problem with these meters in open channels is the same as with any velocity measurement: readings must be translated to average velocity and area must be accurately known.

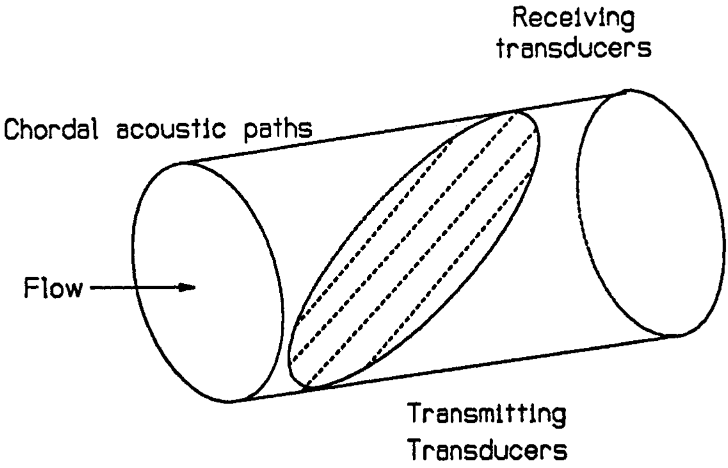
Multiple path ultrasonic meters (see Fig. 20) have been in use since the 1970s. These meters have been too expensive for measuring all but very large flows in large (3 to 9 ft or 1- to 3-m diameter) pipes. Results have been mixed. The biggest problem appears to be proper installation and alignment of sending and receiving units. While many have worked well, most have had extensive field verification and calibration. The biggest advantage is that the meters are nonintrusive, have essentially no head loss, and have a reasonably good flow range. The biggest drawback has been cost.

A relatively inexpensive single-path ultrasonic meter was developed in the mid-1980s for smaller flows, typical of large irrigation deliveries (15 cfs or 425 L/s). This meter uses battery power with solar panel recharging and is microprocessor controlled to allow a sleep/wake-up mode to conserve power.

There are two lead crystal diode (LCD) displays, one three-digit display for flow rate, and another of six digits for totalized flow volume. There are two totalizers, one is nonresettable and is displayed continuously. The other totalizer can be temporarily displayed in its place and can be reset to zero, which is useful for irrigation management. The single path units have experienced widely varying flow rate measurements (±10 to 15%) when installed downstream from a partially open sluice gate.

The errors appear to be random so that multiple rate measurements will give the correct accumulative volume. More details on this meter can be found in Replogle (1987). This is a good example of the type of meter output that can be used by both farmers and irrigation districts.

Three different meters using oscillatory principles have been developed and marketed: vortex precession (Swirlmeter), Coanda effect (wall



Transducer arrangement of multi-path ultrasonic flowmeter

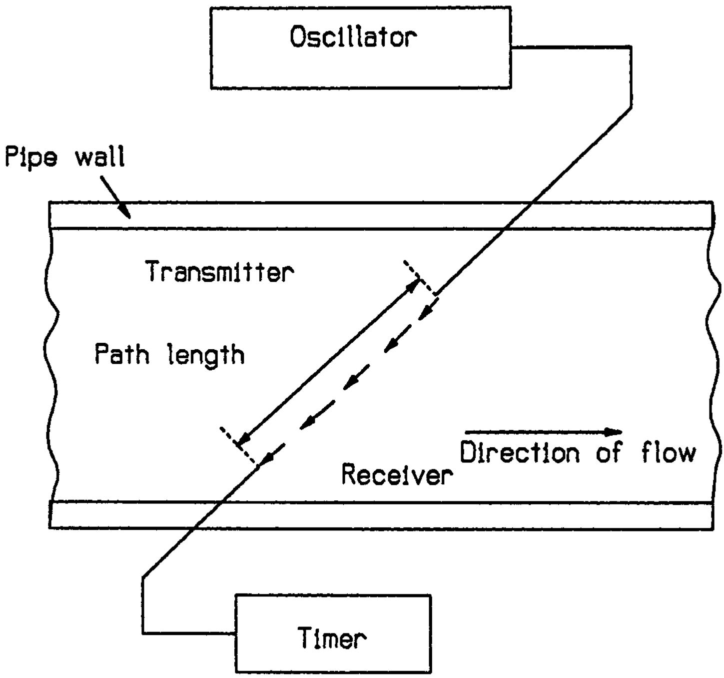


Fig. 20. Principle of Ultrasonic Flowmeter

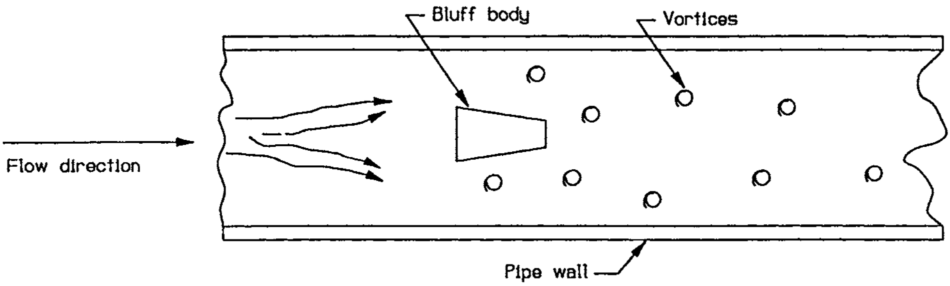


Fig. 21. Principle of Vortex—Shedding Meter

attachment or fluidics), and Von Karman Vortex Street (vortex shedding). Of these, the vortex-shedding type (see Fig. 21) has been the most widely applied. The readout is usually digital and claims an accuracy of ±1%. The vortex-shedding meters are suitable for liquids and gasses, including steam, over a wide operating range of about 100:1 (ratio of highest flow to lowest flow for a particular device) with calibration, and 10:1 independent of calibration.

The vortex-shedding meters are commonly available in sizes from 25 to 1 to 8 in. (200 mm) but large versions measure smokestack discharges. Portable versions for large bore pipes designed as probes have also been built. Most developments in vortex-shedding meters have been in the improvement of secondary devices. Although design of these meters has been good, there have been problems in regard to vibration immunity, sensor reliability, and sensitivity to low flows and densities.

Oscillatory flowmeters are a good alternative to orifice meters. These flowmeters have the following advantages.

- Wider flow range detection than most orifices.
- Electronics that can totalize flow.
- All fluid is kept in the main pipeline, which may be important in freezing conditions or for hazardous fluid.
- Consistent performance is maintained because shedding-body edge is not as critical as that for a sharp-edged orifice.
- Low installation cost.
- Pressure drop is usually lower than for an orifice.
- Output flow rate, within limits, is independent of fluid density and viscosity (volume meter) (Harrison 1980).

On the negative side, there are no easy manual readout methods such as manometer, and electric power is needed from a battery or powerline source.

Secondary Devices

For some meters, most of the cost associated with the meter is in the secondary device. The more an irrigation or drainage system depends on automation or automatic data collection, the more important (and more expensive) are the secondary devices.

Secondary devices for meters which read head or water level include manometers, point gauges, staff and wall gauges, weir sticks or rules (measure weir head plus velocity head), float-operated chart recorders, float-operated potentiometers, submerged pressure transducers, float-operated optical scanners, and pressure transducer-bubbler systems. The last four all have the potential for electronic data collection and digital totalization.

Of the nonelectronic devices, point gauges and manometers are probably the most accurate head detection methods (±0.3 mm or 0.001 ft), with weir sticks, wall and staff gauges the least accurate, and float-operated recorders somewhere in between. With the electronic devices, accuracy is generally related to cost. Electronic devices tend to be temperature sensitive and can drift with time. Compensating for these factors can be costly. Optical readers are not temperature sensitive but are somewhat cumbersome and have a limited increment or range.

To date, the electronic secondary and tertiary devices have frequently cost more than the primary devices. Thus, orifices, weirs, and flumes are typically read manually. Advances in these secondary devices have been and continue to be made. With the increasing value of water, such devices are becoming more and more common. Data loggers and portable computers are now available for direct connection to these secondary devices for easy collection of flow data.

Some of the mechanical flow-rate devices such as propeller and turbine meters are now available with electronic digital readouts as well as mechanical odometer-style totalizers. Such devices, thus, are adaptable to data transmission and collection.

Many of the electronic primary devices have built-in secondary devices for digital readout. Some can be interfaced with data loggers or other electronic equipment for data storage or totalization of flow. The ability of a meter to provide such an interface will be increasingly important.

3.3.4. Considerations in Meter Selection

Standard and Nonstandard Devices

A truly standard device is one which has been fully described, accurately calibrated, correctly installed, and sufficiently maintained to fulfill the original requirements. Standard discharge tables or curves may be relied upon to provide accurate measurements. However, a waterlogged boot partially blocking the flow in the ditch can be a measuring device if properly calibrated (Schuster 1980).

Certainly the boot would be a nonstandard device because no discharge tables or curves are available from which to determine the discharge. Many other devices including certain weirs and flumes may also be nonstandard if not installed correctly and, therefore, do not produce standard discharges. Like the boot, the other devices must be calibrated to provide accurate measurement and calibration tests can be quite costly when properly performed. Ratings must be made at fairly close discharge intervals over the complete operational range and curves or tables prepared. Standard devices are less costly and usually not too difficult to install and maintain in good condition.

For pipe flow, there are generally a variety of standard devices that can be chosen that will match flow conditions in the pipe. In open channels, which are virtually unlimited in size, shape, and flow conditions, selecting from the published standard devices is much more difficult. Another option is to custom design the measuring structure to match channel conditions. Calibrations can be developed from theory with 2 to 3% accuracy (Bos et al. 1984).

Typical Errors

While most of the devices in Table 3 have potential accuracies which are sufficient for irrigated agriculture, in practice, most of these accuracy numbers are much higher. As field accuracy values for these devices vary so widely, the devices are not given in the table. Most devices, if properly designed, installed, and constructed, will be accurate enough. However, there are so many ways to misapply these devices that the list is too long to include here.

Accuracy of water measurement is a prime importance in operation of any water distribution system. Many closed-pipe measuring devices when left in a rundown condition or when improperly installed usually underrecord the actual water deliveries. The very nature of these measuring devices makes delivering less water than indicated impossible. Channel obstructions upstream from open channel devices typically cause the device to deliver more water than indicated by the device; while downstream obstructions, which cause partial submergence, will typically cause devices to deliver less water than indicated.

In addition to the devices, other factors upstream and downstream from the measuring device also will control its accuracy. To understand these factors, it is necessary to understand the basic flow principles involved and to know how each factor can influence the quantity indicated (Schuster 1980).

Many open-channel devices require measurement of the head or water level. This water level must be properly referenced to the crest of the measuring device. Failure to properly zero or reference head measurement can lead to extremely large errors in flow measurement. When current meter velocity measurements are made in channels, accurate measurement of flow area is also very important in determining flow rate.

Approaching Flow

Many factors which adversely affect accuracy are visible on the open-flow-type devices but are invisible on closed (pipe) system devices. However, many facts and principles established for such open-flow devices as weirs and flumes also apply to other water-measuring devices.

In inspecting a water measuring station to judge or evaluate its probable accuracy, it should be determined whether the device is a head or velocity measuring station. This is the key to the order and importance of other observations. In either case, the first observation should concern visible flow conditions just upstream from the measuring device, because extremely large errors in discharge indication can occur from poor flow conditions in this area. Any deviation in the approaching flow from a normal horizontal or vertical flow distribution, or presence of water surface boils, eddies, or local fast currents, is reason to suspect the accuracy of the measuring device.

Sand, gravel, or sediment bars submerged in the approach channel, weeds, or riprap obstructions along the banks or in flow area can cause unsymmetrical approach flow. Such obstructions as well as turbulence, rough water surface, poor flow patterns, and velocity of approach are all factors that contribute to errors in measurement.

All visible signs of turbulence should be eliminated. To eliminate this turbulence, use of specially constructed wave-dampening devices may be necessary to obtain a smooth water surface. These wave suppressors have been successfully used in large and small channels. Causes of excessive velocity head may include a pool upstream from the measuring device that is too shallow. Also, there may be poor lateral velocity distribution upstream from a weir. To correct poor flow patterns, deepening, widening, or introducing baffles or other spreading devices in the approach channel may be necessary.

Exit Flow Conditions

Exit flow conditions can cause as much flow measurement error as some of the approach flow problems. Differential head, open channel meters are particularly sensitive to exit flow conditions since these conditions can change the velocity distribution of flow and head loss across the meter. For free-flowing weirs and flumes, it is sufficient to be sure that backwater does not submerge a device to a degree that affects the upstream head discharge reading.

Rectangular throated flumes without a raised sill (Parshall flumes) in trapezoidal channels are more likely to become submerged at low flows than at high flows. Bottom-contracted weirs and triangular-shaped flumes are more likely to become submerged at high flows. If a flume becomes submerged, then either downstream obstructions should be removed or flume altered to provide more obstruction through the range of flows where submergence exists. This can be done by either raising or narrowing the throat. Gates calibrated for free discharge at partial openings should not be submerged nor should eddies interfere with the jet of water issuing from the gate.

As previously stated, the underside of sharp-crested weir nappes should be ventilated sufficiently to provide near atmospheric pressure beneath the nappe. An easy test for sufficient ventilation is to part the nappe downstream from weir plate for a moment with a hand or shovel to allow a full supply of air to enter beneath the nappe. After removing the hand or shovel, if the undernappe profile remains the same as it was while fully ventilated, the weir has sufficient ventilation.

Transition Between Pipes and Open Channels

The unknown flow area in open channel flow makes flow measurement more complicated. Thus, measurement methods which have a fixed area are generally easier. In irrigation delivery systems, there are frequently short sections of pipe flows in open channel system (and vice versa). In many cases, these pipe sections make logical measurement stations. Meters that obstruct the flow, such as propeller meters, are not very suitable for permanent measurement at these locations unless the inlet is well screened to keep debris out of the pipe. Most pipe devices require some distance of straight pipe flow both upstream and downstream for accurate measurement.

For pipe turnouts, a partially closed gate causes swirling in the pipe. Thus, a meter that integrates the entire pipe area should be used. If partial-area meters are used (single path ultrasonic, wall-mounted paddle wheel turbine), then instantaneous flow-rate measurements can be considerably in error (±10%). The total volume accumulated from a series of measurements should still be accurate since the swirling tends to be random.

When an open channel meter is placed downstream from a gate or pipe outlet, there must be ample distance to allow the flow pattern to adjust to approximately that for an infinitely long channel. This usually requires a distance of 10 to 30 times the flow depth.

Poorly Constructed Devices

Poor workmanship in construction or installation of measuring devices can result in a nonstandard device. Such constructed or installed devices may be out of level, out of plumb, skewed, out of alignment, have leaking bulkheads with flow passing beneath or around them, have been set too high or too low for existing flow conditions, have inaccurate weir plate lengths or Parshall flume throat widths, or have incorrect zero setting of the head or staff gauges.

Pressure readings are needed to determine discharges through certain types of meters. Pressure taps or piezometers must be installed with care and with a knowledge of how these meters perform. Openings should always have the smallest diameter necessary to eliminate the possibility of clogging by foreign materials and must be installed perpendicular to the pipe. Rough edges or surfaces in the pipe in the vicinity of the piezometer can also result in measurement errors, in that water is deflected into or away from the piezometer opening. The higher the pipe velocity, the greater the error will be (Schuster 1970).

Poor Measuring Techniques

Inaccurate discharge measurements from regularly maintained equipment properly installed in an ideal location are possible if poor measuring techniques are used by the operator. In short, it is desirable that each operator understand the measurement he or she is trying to make; then, each operation should be critically examined by the operator to be sure what is being measured is what is supposed to be measured. The operator should try to improve his or her techniques whenever possible.

It should be recognized that head or velocity measurements may only represent the discharge at the moment of measurement. Therefore, water deliveries can be accurate only if enough measurements are made to establish the fact that discharge did or did not vary over the period of time that water was being delivered. In many systems, measurements are only made once a day or when some physical change in the supply or delivery has been made. If the rate of change is erratic, frequent readings may be necessary. When a great many readings are necessary, a recording device may be justifiable.

3.3.5. Water Records

Necessity in Operation

Good water records are a necessity as are good water measurements. Any organization needs good water records to permanently document what has been accomplished in the way of water delivery. There are a number of reasons why good water measurement and water records are desirable, necessary, and of great value to any operating agency. First, records may be needed to provide information relative to available water supply and to deliver water equitably to users in accordance with their proper share. This is especially true when water supply is a limiting factor or when capacity to deliver becomes a limiting factor.

Second, it is important to deliver as near as possible the amount of water requested. This becomes of major importance when an irrigator is using sprinklers or siphon tubes. Generally, a small surplus is necessary to avoid the problems that delivery fluctuations might make.

Third, good measurement and records can help locate excessive system losses. Information on the location of leaky areas in channels is very necessary if repairs to or rebuilding of the system is attempted. There are other methods of locating losses that are more precise than inflow/outflow measurements. Nevertheless, inflow/outflow measurements over weirs and checks in the channel adjusted by outflow through various deliveries are very useful in initially locating areas of suspected excessive loss.

Fourth, measurements are frequently relied upon for revenue. Without measurement of water and adequate records, proper charge to any user cannot be established.

Fifth, as discussed next, measurements and good records are essential for legal protection.

Type of Records

Careful thought should be given to the type of records that will be useful. In some applications, flow rates are measured periodically (several times a day). These rate measurements are then used to estimate the volume of water delivered, typically assuming flow-rate changes are linear between two measurements. Where flows are variable or the user takes water on demand (closed pipeline), totalizing flowmeters are necessary for an accurate indication of volume. Flow totalization is fairly simple with many pipe meters and is fairly difficult or expensive with most open channel meters.

Water delivery records are frequently kept by personnel responsible for supplying or distributing the water, e.g., reservoir superintendents, gate tenders, ditchtenders, and other operating employees as a part of their operating duties. The type and frequency of measurement depend upon meter type, records kept, and local conditions. Hydrographers (water measurement specialists) are frequently used to monitor flows within the system, check meter accuracy, and other hydrologic measurements related to seepage, drainage, and return flows.

In record keeping of water deliveries and related data, adhering to the use of standard units of measurement and standard record forms is not only desirable but practical. Several forms used in recording reservoir storage, water orders, water measurement, and related data are included and discussed in section 3.4, Operating Procedures, and illustrated in Appendix E..

Daily water delivery records should be kept for all important distribution points and especially for each farm turnout. The ditchtender's daily water report is essential. His records should include diversions from main canals and laterals, and diversions to wasteways, in addition to his daily deliveries to farm units.

All records should be as simple as possible and readily understandable. The three following general principles should be observed.

- Original field records of the ditchtender, including arithmetical computations, should be filed in the agency office where records will be available for examination and checking.
- A journal or daily record should be kept showing in detail quantities of water delivered to each water user.
- A ledger account of water delivery to each water user should be kept so that quantity used can be quickly ascertained at any time.

Water records should include a summary of water furnished each individual user for the season and a summary of agency water use or delivery operations for the year. The yearly report should contain a monthly summary of diversions from source of supply, amount delivered to farms, canal losses, operational waste, and system efficiency. Computerized recordkeeping systems can be of great assistance in generating these various reports.

3.3.6. Calibration and Maintenance of Water Meters

Water meters need to be properly calibrated in order to convert measurements of head or velocity to quantities of flow or volumes of water. The initial calibration usually will have been accomplished when the meter is selected and installed. However, all water meters will tend to deteriorate with use. Regular maintenance procedures should be established and followed rigorously to ensure continued functioning and accuracy of each meter.

Maintenance procedures and frequency of maintenance checkups should be available from the designer or manufacturer. However, if written maintenance procedures for a particular metering device are not available, the operations supervisor should see that such instructions are prepared and furnished to personnel using the meters.

In many cases, a meter should be recalibrated periodically to assure that continued readings from water flows or volumes can be computed with reasonable accuracy.

A schedule should be set up or criteria adopted for determining when meters should be recalibrated. Even under the most favorable circumstances, measurement of water quantities is difficult and subject to some error. Those errors can and should be kept to a minimum with a sound program for calibrating, maintaining, and recalibrating all water measuring devices on a regular basis. Maintenance procedures are discussed in section 4.

3.4. OPERATING PROCEDURES

3.4.1. Planning Operations

Meeting the purposes of an irrigation system requires proper timing, control of water releases, and long-range operating plans sufficiently flexible to permit rescheduling of releases and deliveries as changing conditions of weather, cropping, and supplies necessitate.

A general plan must be developed. It must cover consideration of existing and potential water rights, state laws, compacts, treaties, and other related factors such as agreements with other agencies for flood control, conservation of fish and wildlife, and operation of recreational facilities. Responsible operating officials should familiarize themselves with the operation plan and then formulate necessary regulations and instructions to ensure the system purpose is realized.

General Plan

Before system operating plans can be completed, the basis for the design of the system must be understood. Planners, designers, and construction organizations can and should provide the operating organization with this information in a generalized operational plan. The operating criteria established by the designer may be combined in a single volume and include all or part of the following.

- Design criteria.
- Designer operating instructions.
- Final as-built drawings.
- Logs of drill holes to show geology and water tables.
- Other documents such as photographs, inspection, and reports.

Members of the operating organization should study and become thoroughly familiar with this operational plan.

Two main features underlying the generalized operational plan are water delivery scheduling and water control strategy. The yearly operational plans should be consistent with these two planning and design assumptions. For instance, if the system is designed and built for capacity of the conveyance system to deliver water only on a rotation basis, the operating organization should not try to operate the system on a demand basis.

Similarly, if the system is designed and built assuming that water users will apply water to the land by sprinklers, radical changes may be necessary if flood irrigation is used. That is, if the design assumptions are no longer appropriate, changes in the delivery scheduling method, water control strategy, physical structures, and operating procedures may be necessary.

3.4.2. Standing Operating Procedures

The district should have standing operating procedures (SOPs) establishing complete, accurate, and current structure-oriented operating instructions for each component within the system such as storage reservoirs, distribution system, and associate structures.

These SOPs should include operating procedures for different situations that may occur such as normal operations, critically low flow conditions, potential flooding conditions, and emergency conditions. The need for SOPs is usually brought about by changes incorporated in the irrigation and drainage system over the years, lack of designer operating criteria, or need for special instructions not normally covered in the designer's operating criteria.

The purpose of SOPs is to ensure adherence to approved operating procedures over long periods of time and during changes in operating personnel. These instructions will also permit responsible persons knowledgeable in operations, but unfamiliar with conditions at a particular facility, to operate the system during an emergency situation and at such other times when the regular operator cannot perform his normal duties.

SOPs are prepared primarily for use by the person or persons performing day-to-day operations and immediate supervisors who are assigned the responsibility for the physical operations and maintenance of the system. SOPs should contain, as a minimum, all information and instructions necessary to perform duties correctly. These instructions should be written in a form that is easily understood, and capable of being revised from time to time to keep pace with changes made in the system and organization.

The extent to which data and instructions should be included in the SOPs will vary considerably. This will depend mainly on circumstances relating to the particular system such as complexity of operation and locations and responsibility of various operating offices.

On more extensive and complex systems, the instructions should be divided into more than one document; for instance, separate storage reservoirs from distribution system. The SOP and any supporting documents such as designer instructions and manufacturer instructions should establish complete operating and maintenance procedures for all levels of responsibility, regardless of the plan selected for grouping of instructions.

The SOPs generally provide definite lines of communication and instructions in safe, efficient, and effective operation of irrigation and drainage facilities during normal and emergency conditions. It is generally specified that the operating procedures shall not be changed without the approval of the person responsible for the system.

Procedures and instructions are usually based on directives from the manager or designer of the system, operation and maintenance concepts visualized during design and construction, and available hydrology. Where the need for deviation or revision develops during emergencies, approval is required at the lowest appropriate level of authority through the most expeditious means of communication.

Information and instructions contained in SOPs for either storage reservoirs or distribution systems should follow a standardized format and include, but not be limited to, the following.

- Preliminary pages including Emergency Preparedness Plan (EPP) and communication directories.
- Chapter One, "General," containing information and instructions concerning administration of the system and distribution and revision of the SOP's.
- Chapter Two, "Structural, Mechanical, and Electrical Information," containing detailed instructions for operation and maintenance of the system and its appurtenant structures and equipment.
- Chapter Three, "Operations," containing detailed instructions and information on all aspects of system operation.
- Appendix, containing maps, drawings, photographs, copies of selected operating documents, and other related material.

As a definitive guide on how to operate and maintain the system during emergency and normal conditions, each SOP should give detailed, understandable instructions. An operator should be able to follow the instructions in the SOPs without having to determine the function of each switch or valve by making a detailed study of the system.

In powerplants, pumping plants, power generating plants, and various operational control centers, use of posted operating instructions, marked photographs, color coding, and numbering to identify valves and switches mentioned in the operating instructions are recommended as a supplement to step-by-step instructions in the SOPs. The use of these aids simplifies the operating instructions considerably and reduces the chance of error.

SOPs for individual field structures are improved when diagrams and photos identifying components and demonstrating proper procedures are included.

The preparation of SOPs for a system requires a detailed review and analysis of the operating and maintenance procedures. Because of the appreciable investment of time and effort this entails, effective management dictates the desirability of making certain reviews in conjunction with preparation of SOPs. This includes the following.

Review of Designer's and Manufacturer's Operating Instructions

Questions may have developed or conditions at a facility may change so that portions of the operating instructions are no longer applicable. The designer should be contacted if possible to clarify intent of criteria or to make changes in criteria to meet changed conditions.

Review of Attendance, Access, Standby Power, and Communications

Management of the organization should establish requirements for attendance, access, standby power, and communication necessary at a facility under normal operations, and more importantly, under emergency conditions such as adverse weather or floods.

Review of Wall-Mounted Operating Instructions

The installation of durable operating diagrams and instructions adjacent to controls for gates and valves logically forms a part of the program to provide complete operating instructions. Status of posted operating instructions should be reviewed while preparing SOPs. When posted instructions are considered inadequate, corrective action should be initiated at that time. SOPs should include wording and drawings of all instructions and diagrams that are to be posted and should specifically state posting requirements. SOPs should require that operating personnel replace these instructions before they become illegible.

Review of Identification of Valves, Pipes, and Equipment

Preparation of structure-oriented operating instructions for SOPs require identification of valves, levers, and piping used during operation of equipment. Installation of nameplates and color coding of pipes is one of the suggested identification methods.

Review of Performance of Facility at Meeting System Objectives

It is important that all facilities and structures be operated in ways that are consistent with objective of the irrigation and drainage enterprise. Since objectives and requirements of the users change over time, the ability of current facilities and operating procedures to accomplish these objectives should be periodically reviewed.

Throughout the SOP preparation process, input and involvement from personnel responsible for the operation and maintenance functions is essential to provide the author a full understanding of the system. Of great importance is feedback from those individuals who are intimately familiar with the system response and who carry out these instructions. These individuals can provide insight into improvements and must be able to understand changes or corrections.

Following completion of SOPs, a careful review should be coordinated with operations personnel. The best means of doing this is to follow the SOP's step-by-step during actual operations.

Periodic review of the SOP by knowlegeable employees should be made to reinforce the instructions and correct any instructions or methods to reflect changed conditions. SOPs can also be used to train new operators.

3.4.3. Operational Considerations

Delivery of water to district farms must accomplish two sometimes apparently opposing goals. The district system must be operated efficiently and simply, yet water must be delivered in such a manner to allow effective and efficient on-farm use.

From the administration standpoint, the simplest and most effective operation of an irrigation system is accomplished when the amount of water delivered and frequency and duration of its delivery to each user are definitely established. When the amounts of water required for delivery along all portions of the system are definitely known in advance and are not subject to change, the system can be operated at minimum cost and with minimum water wasted in and from the system.

However, these advantages of operation cannot be fully enjoyed without rigid scheduling of deliveries by the operating agency. Unfortunately, such a rigid schedule is rarely in the best interest of farm production, farm efficiency, and water conservation. The arranged flexible delivery schedules allow a compromise between the on-farm requirements for an adjustable schedule with the district requirements for a known schedule. Even so, short-notice changes in delivery requirements do take place.

If operating policies allow these changes to take place, benefits to farm operators will take place. Whether the cost of this increased flexibility is offset by farm benefits is case specific. A general rule used by many operating agencies is that all canals, structures, gates, and other agency property are under exclusive control of the agency and its officials, and that nondistrict personnel are not permitted to interfere with canal operations or adjust any gates. This rule may be invoked even when the intention is to permit changes by users under certain conditions.

A daily water report should be made to include a ditchtender report of accomplishments for the day and his instructions for the following day. This and other records, many of which are initiated by ditchtender reports, are discussed in detail in a subsequent section of this manual. Forms similar to that shown in Appendix E may be used for recording deliveries made to a turnout.

These forms may be either carried by the ditchtender or kept in a small box at the turnout for review at any time by the water user. Keeping a copy of the record at the turnout is especially useful when the flow delivered is necessarily less than that requested by the water user, and where the ditchtender has not had an opportunity to notify the water user of the change. Posting of a wall chart or providing a computer display showing water flow at the head of the system, delivery to farms, operational waste, loss, and efficiency can allow both agency employees and water users to observe what is taking place in the system.

There will undoubtedly be times when demand for water exceeds either the available supply or capacity of one part of the system. Decision rules established by the board of directors should determine how to allocate available supplies in these cases. Short-term, localized (single lateral), temporary capacity limitations are typically handled on a first-come, first-serve basis. However, season-long or district-wide capacity restrictions require a policy of equitable distribution and sufficient measurement and control to carry this out.

Without such a policy, the lower end of a district will typically receive less than their fair share of available water. The board and district manager have the responsibility to establish such a policy, and the watermaster has the responsibility to develop operating rules to carry out the policy.

Deliveries from Open Channels

District personnel should watch to ensure that any structures built by the farmer will not affect measurement and regulation, nor interfere with the maintenance of facilities. There is generally no objection to attaching a farm structure to an agency structure if the farm structure in no way interferes with the operation and maintenance of the agency structure.

When the canals carry water intermittently, or where a check is used for only a few days per month to make certain deliveries, less freeboard may be needed than in canals that are maintained full and where banks are under continuous strain. On the other hand, danger from breaks on intermittent use banks (due to the activity of burrowing animals) is greater than on those where water is held at a constant elevation. However, checks should not be operated above normal control water surface on any canal without the approval of the watermaster or other supervisor.

Energy or "head" is needed for both the control and measurement of water within the canal system. Distribution systems are usually designed to provide water with at least some minimum head above the maximum farm field elevation. Because of the costs associated with raising a canal above the natural ground surface, the tendency is to design such canals with as little head as is absolutely necessary.

However, changes in backwater from farm canals (from changing irrigation sets) change the available head across the measurement or turnout control structure. Orifice-type turnout devices (gates, constant head orifice, meter gate) require about 0.5 ft (0.15 m) to obtain reasonable measurement accuracy. And while they minimize the impact of changes in supply canal water level, these devices do not isolate delivery flow rate from farm backwater influences.

Weir or flume turnouts (or a flume following a submerged gate) can be designed with less head loss (typically 0.2 ft [0.06 m] or less). Weir turnouts are more sensitive to canal level changes, but isolate farm canal backwater effects. Flumes with fixed crests designed with minimum head loss at high flows are sometimes submerged at low flows when backwater is high or restrict flow when supply canal levels are low. Thus, minimum amounts of head available at turnouts compromise the requirements for both measurement of flow and control of delivery. Such conditions apply both at farm turnouts and at other bifurcations within the canal network (lateral canal turnouts).

It is most desirable to have a check or head regulation structure adjacent to each farm (or lateral) turnout. However, this may be too costly when turnouts are spaced uniformly along a canal at close intervals. The discharge at turnouts not located adjacent to a regulating structure will not be controlled as well unless turnout gates are automated or frequently adjusted.

Canal deliveries are generally associated with surface irrigation, which simply accepts whatever supply is available. If the irrigation method requires control of the supply (pumped sprinkler irrigation), special measures must be taken to assure that supply meets demand. For example, the pump can draw water directly from a continuing canal, a reservoir can be built to supply water to the pump, excess flow can be supplied with the excess returned through a surface drainage system, or the system can be automated to react to changes without human intervention.

Pipe System Deliveries

Pipe deliveries eliminate some of the problems associated with open channels. Available head is as important an issue for open pipeline system as it is for open channels. Insufficient head, and in many cases insufficient head control, causes significant problems in regulation of water in open pipelines. Equitable division of water to multiple outlets within an open (or even semi-closed) pipeline reach between risers can be very difficult.

As a result, open pipeline systems are frequently operated with rather rigid daily schedules to avoid changes in system pressure. Semi-closed and closed pipelines require greater head for operation, which is relatively easy to achieve. For closed pipelines, equitable distribution is controlled by outlet pressure or flow regulation. In some instances with closed systems, outlets can be operated by the water users and monitored by the district operators.

Designers stress that operation of the closed-pipe system must be such that pipelines are filled slowly, valves are operated slowly, and the system is shut down slowly. Also, filling the pipeline should be done with all valves open until the air is exhausted. Sand or silt in the channel above the pipeline should not be pulled into the pipe, except when there is maximum flow through the pipeline, and automatic release valves must work and function properly. When designed and operated properly, pipe systems can provide a large amount of flexibility in the delivery of water to on-farm users.

Pumping Plants

The performance of all pumping apparatus generally will be warranted for a limited time by the manufacturer. The manufacturer may supervise the installation and conduct such starting tests as are possible, usually under full operating conditions. A pump is ready to be put in service after it has been properly installed, all necessary precautions have been taken to ensure alignment, and the pump has been checked for proper direction of rotation.

The steps necessary for starting a pump depend upon its type, use, and installation. Some require steps that are totally unnecessary in others. For this reason, SOPS should either be posted or be made easily available to an operator. Because of the wide variation in types, sizes, parts, and design of irrigation pumps, manufacturer instruction books should be carefully read and studied before attempting to start, operate, or service any given unit.

In large attended pumping installations, an hourly record should be kept of the equipment. Card files may be maintained so that any change in unit characteristics can be easily and readily found. However, most irrigation pumping plants require only periodic inspection, typically consisting of an operator, ditchtender, or watermaster visiting the plant once or twice daily.

Particularly in unattended plants, there is a need to watch lubrication, fittings, or oil reservoirs on the main pump bearings. Attention should be given to cause and control of vibration, such as that which can result from excessively throttling of a pump or from imminent bearing failure. Pump motors should be kept clean and free from an accumulation of spider webs, dirt, bird nests, and other debris.

Overheating of a pump motor should be brought to the attention of maintenance personnel; however, it should be noted that some motors are designed to run hotter than others. A sudden rise in the temperature of a bearing or stuffing box is more indicative of trouble than one that constantly runs warm. Loose electrical connections can cause excessive heating and complete failure. Normal vibration will cause connections to loosen, and the ditchtender should be alert to such possibilities.

Thorough inspections are generally made of all pumping plants semiannually or annually by an experienced mechanic. At least once each year, the operator should review operating procedures with the mechanic at each plant. When a different operator or ditchtender is assigned during the operating season, he or she should be instructed as to proper operating procedures for each pumping plant by the mechanic and watermaster prior to assuming responsibility.

Motor and pump controls and relays all have important functions that are mainly of concern to the mechanic. However, operator or operating ditchtender should notify the mechanic or watermaster immediately of any malfunction encountered, giving full and complete information.

Special precautions to avoid freezing damage to pumps located in wet sumps should be considered by operation and maintenance people in colder climates. In some instances, considerable effort may be required to assure that no damage occurs.

Damage to pumps from ice in the sump pump is often limited to breaking of the oil line to the lower bearing. The repair of this line is usually a relatively simple matter; however, a general feeling exists that maintenance cost savings results from permitting the pumps to remain in place during the winter.

Because pumps are not specifically designed to withstand stresses that might result from freezing, pumps left in wet sumps during freezing periods should be inspected (lower bearing oil line) prior to operation.

Operational Spills

Wasteways serve two principal purposes: They provide relief in case of a canal break below the wasteway, and they regulate the water supply carried in the channel. Wasteways should be located above vulnerable sections of canal to enable flow to be turned out quickly in case of breaks or other emergencies. For operational reasons, wasteways or spillways should be located just below the point of diversion at ends of canals and laterals to provide an outlet for unused water and at points within the system where outlets can be secured.

Emergency and operational wasteways should be operated only as needed. The use of wasteways should be carefully controlled by operating personnel and should not be operated as a convenience for water users or ditchtenders. One test of good management is the ability to operate a project with a minimum of waste. An operational or regulation waste of over 5 to 10% for most systems is considered excessive.

In actuality, most regulation losses result in excess delivery of water to users rather than as operational waste or spills. This excess delivery is not as easily observed as operational waste, but in fact can have a detrimental effect on ground water levels and return flow quality. Operational waste may be justified in rare instances if it means less overall regulation loss and improved return flow quality.

Some wasteways are designed to act automatically, with control devices opening when the canal either rises or falls below certain limits. Such devices, if not tested frequently, may fail when needed. For canals with unstable sections, it may be desirable to have low- and high-water alarms connected with ditchtender or patrolman quarters so either one can be called at any time. Since wasteways are used infrequently, there may be encroachment into the wasteway channel. It is important for the districts to make periodic inspection of the wasteway channel to ensure that encroachment into the channel does not impede its use and operation.

3.4.4. Communication Systems

There are two communication systems that must be established in the operation of an irrigation district. The first is communication between farm operator and district. This can be accomplished through television; radio; newspapers relating to available water supplies, emergency conditions, public meetings; and telephones and mail for water orders, complaints, water duties, special notices, water bills. Communication plays a significant role in the successful operation of an irrigation district.

The second is communication within the district operations. Telephone, radio systems, and networked computers can be used to communicate person to person, person to equipment (remotely), and in some cases, equipment to equipment. Written documents are also an effective means of district communications.

Telephones and radios are used to connect field personnel with each other and with supervisory personnel. This communication network must be dependable and maintained in the best working condition. In many instances, radio systems have proven more dependable than telephone systems, especially where fixed stations are properly located throughout the area served, and cars and trucks of operating and maintenance personnel are suitably equipped with dependable communication units.

Operating roads on the canal and lateral bank are an important part of any agency communication system and have often been overlooked in design and construction of a canal and lateral system. These roads have proven essential for economical operation and maintenance.

3.4.5. Water Ordering and Record Keeping

Water records on rate of flow and volume should be kept on water diversions of the district (including ground-water pumping); water distributed to main, secondary (lateral) and tertiary canal; water losses through wasteways and drains; and water delivered to users. In addition, records should be kept on water levels in storage and regulating reservoirs. These records are important in accounting for water and its distribution in the district.

Demand systems either require no request for water or may require starting day and time for delivery to be arranged. For demand systems, it is very important that actual volume delivered be automatically recorded, since rate can vary at user discretion. Water billing on volume and management of the supply require this information. Continuous flow and rotation systems require no water ordering. Since the supply is under the control of the district, less frequent monitoring is required.

Most irrigation districts within the United States use arranged delivery scheduling methods of one kind or another. Lead times for water orders range from 1 to more than 5 days. Water ordering consists of filling out a water request card which is given to the ditchtender or a phone request to a dispatcher. From these water requests, the ditchtender and watermaster determine a schedule for water deliveries for the day in question.

Canals or laterals with demands in excess of capacity are identified. Water delivery rates may be limited or orders for one or more users must then be moved forward or back a day, with notification to the affected users. Water supply conditions should be checked to ensure that requested water is available. A plan is then initiated to assure that water can be moved through the system to supply water at times and rates requested.

Ditchtenders should record start time and flow rate for each delivery made in accordance with the water delivery schedule. Some districts have a policy that a ditchtender will not start a delivery unless an irrigator or user representative is present. Some districts leave a record of this information at the site. This is useful for relief ditchtenders and other operations personnel who also play a role in regulating flows, particularly when the regular and relief ditchtenders do not have access to a mutual location.

To a certain extent, these policies depend on ditchtender schedules and other operation characteristics. At the end of delivery and at intermediate times as deemed necessary, the ditchtender should record the flow rate and time.

Changes in flow are handled differently in different districts, and sometimes differently in different parts of a district. Some districts require all changes be cleared through the watermaster prior to execution. Other districts allow the ditchtender to adjust water delivery rates and durations to a limited degree, but with notification of significant changes to the watermaster. These differences result from differences in type of water control within the system. In any event, all changes should be recorded in the ditchtender records.

Ditchtender records on water delivery are then turned over to the watermaster and used for keeping account of water allocation. These records are then passed to accounting and become the basis for billing.

There are two areas related to water ordering and accounting where computers are playing an increasingly important role. Larger districts often use multiple-user minicomputers for many of their operations.

Smaller districts can use fewer microcomputers to provide the same type of results. Ditchtender records, water orders, and accounting can easily be entered into a computer database.

Once data are in a computerized data base, user water record reports can easily be generated, providing data on actual deliveries, volume used to date, and available volume of remaining allocation. Such reports can be mailed to users periodically or can be generated on request. Interactive user-friendly computers can be used to provide such information on screen for immediate review.

Similar records should be kept on water delivered to lateral canals and water diverted to wasteways and end-of-canal spills (Appendix E, Figs. E-1 and E-2, respectively). With these, the ditchtender and watermaster have a complete record of water handled, except for system losses that may occur through seepage.

These records can be used to determine lateral and canal efficiency as well as to provide a log of water handled in a given period. Such records are important for evaluating system operating characteristics. Again, with a computerized data base, such comparisons can be programmed to be generated automatically on a preselected schedule or generated upon request. If the records are entered in a timely fashion, these comparisons can be used to assist in day-to-day management and scheduling, as opposed to after-the-fact evaluations.

Computer entry of water orders also can speed the process of identifying conflicts in requests versus canal or pipeline capacities, and in checking user water allocation limits. Phone requests to a central dispatcher (with or without computer assistance) can speed scheduling of water and potentially reduce required leadtimes. Of course, better water control within the distribution system may also be needed to reduce these leadtimes (regulating reservoirs). It should be noted that this discussion on use of computers assumes that the required software is available. Software to accomplish all functions must either be created by district personnel or consultants, or off-the-shelf software can be adapted to the district's needs.

Some districts can accommodate water requests 1 day ahead even though canal travel times from reservoir storage to user turnouts are on order 3 or 4 days. Some modern canal control techniques for large canals require computer input of information on water requests for both main or lateral canal diversions.

Forms such as water delivery, individual water user ledger, abstracts of all water ledgers, and an individual report of water used (Appendix E, Figs. E-3 through E-6) are typical forms used to maintain water use or delivery records.

3.5. PERFORMANCE MONITORING AND EVALUATION

A recommended activity for the district board and manager is to regularly monitor and evaluate water operations with the view of determining whether performance has been satisfactory and whether improvements can be made. Monitoring and evaluation should usually be considered from a seasonal or long-term viewpoint as distinguished from procedures for control of water operations on a shorter time frame (day, week, or month).

Monitoring should be based on realistic parameters that are relatively easy to evaluate. Such monitoring will depend mainly on water measurement data, most of which should be available from information gathered in connection with normal operations. However, some estimating and some additional measurements may be needed.

3.5.1. Establishing a Monitoring Program

Each irrigation district should establish an appropriate regular monitoring and evaluation program. It is advisable that the board and management compare district performance from year to year. Operations supervisory staff should establish a monitoring program for frequent evaluations. The information gathered can be used for identifying areas of either high or low performance, determining cause of low performance and weighing changes, and rewarding superior performance. Monitoring should then continue to ensure that changes have produced the desired results and that high standards of performance are being maintained.

The monitoring and evaluation program will vary from district to district, depending on the size of the district and the complexity of operations. A minimum program to evaluate water user performance should include: record of crops grown and area devoted to each crop; estimate of crop water requirements (evapotranspiration); estimate of water needed for crop-related purposes, such as for temperature control and leaching of salts; measurements of the amount of water delivered by the district to farm turnouts; measurements of the amount of water delivered from main canals and pipelines into each lateral; measurements of the amount of water entering main canals and pipelines at the head of conveyance system; changes in surface storage within the system and also, where appropriate, changes in storage water in underground aquifers; and, volume of water leaving the district through drains or spill channels.

With the foregoing information, water budgets can be developed through water balance equations. A water budget is similar in concept to a financial budget—total of inputs must equal total of outputs. However, in the case of the water budget, there is a complicating factor in that often there are gains or losses from the system that cannot readily be measured. These can include the amount of precipitation, evaporation from water surfaces (reservoirs and canals), seepage and/or leakage from canals or pipelines, canal operational spills, theft of water, and farm operational losses.

The procedure for developing the water budget is to make use of an equation in which amount of water entering the system must equal amount leaving the system, with appropriate adjustments for changes in storage in the system. Measured quantities and quantities that can be estimated with reasonable accuracy are used to the maximum extent possible. Losses that cannot be measured directly or cannot be estimated closely are computed to make the equation balance.

3.5.2. Monitoring the Conveyance of Water

An irrigation district has a responsibility to convey water from its source of supply to the farm turnout efficiently, avoiding undue waste. Success of the district can be monitored and evaluated through use of the following water balance equation:

(Measured inflow at head of conveyance system)
minus (measured deliveries at farm turnouts)
equals (estimated conveyance system losses) (1)

Adjustments for changes in storage in the system and other components may also need to be introduced into the equation to make it balance.

The overall conveyance losses can be computed from Eq. 1. Each district should make such a computation at least annually and perhaps monthly as part of its water monitoring program. The overall conveyance losses computed as described above may include evaporation, seepage, operational spill, errors in water measurements, or other components. The data thus gathered should be analyzed to determine the magnitude of conveyance system losses and used as a basis for identifying problems and taking corrective action when losses appear excessive or as a basis for recognizing above average performances.

It is recognized that in some cases conveyance losses through seepage may be acceptable, or even desirable, where water seeps to underground and then later is recovered by pumping from underlying aquifers. Similarly, if canal spills are recoverable and reusable, the spills may be acceptable. These and similar special situations need to be evaluated as appropriate for the particular district involved.

If losses from canal systems exceed about 10% or losses from pipeline systems exceed about 5%, efforts should be made to identify the problem and find appropriate solutions or justify whether or not such losses are appropriate or reasonable. Even lower losses should be sought where water supplies are especially limited.

For larger and more complex irrigation district systems, water balance equations similar to those described should be made for various subsections of the district. The equations will help identify problem areas and may reveal inefficiencies in certain localized operations or facilities that should be corrected.

3.5.3. Monitoring Water Use

Monitoring and evaluation of farm irrigated efficiencies in the irrigation district can be accomplished in a manner similar to that described above using the following equations:

(Farm turnout deliveries) equal
(farm crop water requirements) plus (farm losses) (2)

$$\frac{\text{(Farm crop water requirements)}}{\text{(Farm turnout deliveries)}} = \text{(Farm irrigation efficiency)} \qquad (3)$$

In these equations, farm water requirements will include crop consumption (evapotranspiration) and may include other crop uses such as water for temperature control and for leaching of salts. The farm turnout deliveries may also need to include water from other sources such as precipitation or pumping by farmers from the underground. Farm losses and farm irrigation efficiencies can be computed from these data.

Irrigation districts may not want or need to make evaluations using Eqs. 2 and 3 on a farm-by-farm basis, unless the district sponsors an on-farm water management program. However, the equations may be useful on a district-wide basis, or on a lateral-by-lateral basis. The results of such an evaluation will be useful in determining whether farmers in the district are conducting their irrigation operations in a manner consistent with generally accepted, good irrigation practices. By reviewing published literature, irrigation district managers can get an idea of the range of irrigation efficiencies that are considered acceptable.

If the farmers appear to be using excessive quantities of water, the district may wish to encourage better farm irrigation practices through educational programs or through operating rules. Any resulting improvements will assist in a more equitable distribution of water to various parts of the district and more efficient use of water. As competition increases for use of limited water supplies, irrigation districts need to make sure that water is used as efficiently as is reasonably possible by both districts and farmers.

3.5.4. Project Efficiency

Overall project efficiency can be computed, if considered desirable, by combining results from the computations given for monitoring conveyance of water and farm use of water. Some districts also may find it useful to use other parameters for monitoring and evaluating the effectiveness of water operations. For example: Determine the ratio of intended deliveries (or ordered amounts) to actual deliveries, which in some cases may indicate how effective the operators are in meeting farmer water needs; and, compare records of the number of valid complaints from farmers regarding water deliveries with actual performances to determine the success of operators in meeting their goals.

3.5.5. Monitoring Drainage Performance

From the district perspective, drainage is adequate if the water table is sufficiently low to not impair crop production and soil salinity is kept at reasonable levels. However, many irrigation districts will encounter a rising water table, which commonly leads to waterlogging, soil deterioration, poor crop yields, salinization, and other ecological degradation. In that situation, the irrigation district should establish a monitoring program with respect to drainage (Tanji 1990).

Usually, the basic approach will be to compare crop water requirements and irrigation water applications and to gather data on ground-water levels, salt content of soil and water, permeability and stratification of soil to be drained, and measurements of quantity and quality of drainage water.

Water balance and salt balance operations for drainage can be developed. Generally, the total amount of water leaving the area through crop use and outflow should equal the inflow. Similarly, the total amount of salt leaving the area should equal inflow of salts. If a water and salt balance is not maintained, the area eventually will become useless for agriculture.

The monitoring and evaluation program for drainage should be established as soon as there is any indication of a potential problem and should be continued until enough data is gathered to provide a basis for finding a solution to the problem.

SECTION 4 MAINTENANCE

4.1. INTRODUCTION

The subject of maintenance in this manual is treated through a discussion of factors essential to keeping the facilities of an irrigation and drainage system in good condition, the staff necessary to accomplish the work and their responsibilities, and common practices and procedures used for maintenance of structures and facilities pertinent to such systems.

4.1.1. Maintenance Objectives

Maintenance of an irrigation or drainage system may be concerned with storing, conveying, delivering, or removing water, or with all of these activities. The objectives should be: to keep the system in top operating condition at all times through proper maintenance; to obtain the longest life and greatest use of system facilities by providing adequate maintenance and replacement; to achieve the foregoing two objectives at the lowest possible cost; and, to avoid interruption in water deliveries, particularly at times when crop damage would occur.

The history of irrigation and drainage is replete with examples of the folly of neglecting maintenance. The best constructed system will eventually fail if maintenance is neglected.

Maintenance activity should begin the day the system is placed in operation, or under some circumstances, before construction of a system is completed and the system as a whole is placed in operation. Keeping maintenance work current on all facilities in a system is the keystone of any successful irrigation or drainage enterprise. Preventive maintenance is most important. It not only pays dividends in economical operation, but maintaining a smooth-working system or plant also means uninterrupted water service for the water users or the delivery of water at minimum cost.

4.1.2. Maintenance Program

All structures and facilities are subject to deterioration in varying degrees. Constant vigilance is necessary to identify and correct potentially unsafe or unsatisfactory conditions as deterioration develops. Seepage below a dam, cracks in concrete, general erosion, or settlement of an embankment can result in major failures if not corrected or repaired without delay. Many problems that develop may not be of a serious nature when first noticed.

In water conveyance channels, weed and pest control, bank erosion, water seepage through the banks and bottoms, aggradation, degradation, and alignment may seem less serious, but are problems that must also be given attention. Frequently and over the years, what appear to be less serious problems are more time-consuming and costly. Many problems common to irrigation canals are common to drains as well. In addition, both surface and subsurface drains must be kept open.

The use of proper materials for repair or replacement is important. This can include adequate attention to suitability of concrete aggregate and cements used, characteristics of protective coatings to meet environmental requirements, or use of cathodic protection in addition to or in lieu of coatings for protection of metal surfaces.

Irrigation or drainage system managers and maintenance personnel should always be alert to the development of new procedures, materials, and products and possible adaption to maintenance activities. Asphalts, plastics, epoxies, chemicals, and automation equipment are typical examples.

There was a time when hand labor was inexpensive and horsepower was plentiful. This period was followed by one in which draglines, power shovels, and trucks were used in much of the maintenance activity. Dozers and scrapers then appeared, and all of these items are used to some degree in present-day maintenance.

However, high labor costs and the need for even more efficient equipment has led to the use of more mobile and more easily transported equipment with self-contained locomotion capability. This, of course, has changed the type of personnel required. Skilled workers and fully equipped shops are necessary for operation and maintenance of equipment and facilities.

4.2. MAINTENANCE STAFF AND THEIR RESPONSIBILITIES

The number of maintenance personnel and type of positions necessary will depend primarily on system size, method of water delivery and removal, and period of operation. On smaller irrigation systems, only the nucleus of a crew may be required if the operation is seasonal. In this case, the operating staff can be used for maintenance after the close of the irrigation season. Where water is managed all year, a separate maintenance staff must be employed.

On larger systems, numerous maintenance personnel will be required. A large maintenance organization is generally headed by a maintenance manager with basic responsibilities to oversee that include the following.

- All facilities are maintained in good order within the rules and regulations of the organization and within budget.
- The preventive maintenance program is administered properly, minimizing breakdowns and unplanned shutdowns.
- Adequate engineering advice is provided, and specifications for facilities and equipment are developed to allow all other maintenance personnel to keep all facilities operating in an efficient manner.
- The purchasing of supplies and materials are made in a timely manner.

Other key personnel for a large maintenance organization could include maintenance planner, assistant chief engineer (maintenance), supervisor of preventive maintenance, supervisor of general maintenance, purchasing agent, warehouse supervisor, maintenance clerk, and maintenance workers. See Appendix C for an example of several job descriptions and Appendix A for a representative organizational chart showing placement of these personnel.

These positions may be combined in several different combinations, depending on organization workload, and unique qualifications of individuals in the various positions. The point to remember is that if the organization is to have a good maintenance program, all work must be done regardless of how many persons are involved.

An organization that operates and maintains a system in which the water is used for various purposes other than irrigation must also adjust to fit that particular circumstance. The technology of irrigation and drainage systems is being improved to the point where automatic devices and communication networks will permit operations and maintenance decisionmaking from a central location. Even though much progress has been made to this end, there will always be a need for competent maintenance people to maintain automatic devices; the communication network; storage, diversion, and pumping facilities; and open or closed conveyance systems that transport water, as well as structures that control these systems.

4.2.1. Field Crews

Field repair crews generally may, depending on the type of facilities in the system, consist of a working foreman, electricians, mechanics, electronic technicians, laborers, and equipment operators. The latter may be dragline or backhoe operators and their helpers, tractor operators, and truck drivers. In addition, each system may need special field crews for operation of equipment such as that needed in weed and pest control.

Some of these crews, particularly those used for weed or pest control or electrical work, may need extensive training and local or state certification and licensing. Weed control workers, for instance, must be trained and certified in most states in the identification of various noxious weeds, various types of herbicides, how and where herbicides can and cannot be used, and dangers that may exist in their improper use.

Ditchtenders or patrolmen that are responsible for control, delivery, and accounting for water can also be used to perform minor maintenance work and assist maintenance crews during the nonirrigation season. Another important function of a ditchtender is to monitor the system and identify potential maintenance needs as well as operational improvements, and then notify the appropriate personnel.

Good maintenance and equipment operation are closely related. A conscientious operator will insist that equipment be maintained in good condition, and if he is unable to make repair and adjustments, he will call for qualified assistance.

A good maintenance supervisor will quickly recognize when operators need training and will see that those operators are adequately trained, or if necessary, replaced. Mechanical aptitude and experience should be a large factor in choosing operating personnel for dams, pumping plants, and other similar locations. Those selected should be closely supervised for a time to assure not only that operating instructions are understood, but also that the operators are capable of making minor repairs of equipment.

4.2.2. Shop Crews

On larger systems, a full-time shop crew may be desirable to maintain and repair equipment. Shop crews generally include a foreman, mechanics, welders, electricians, helpers for these specialists, and equipment servicemen. Frequently, shop personnel may perform in a dual role by also operating equipment or helping equipment operators.

On large systems, there may be enough work to keep a mechanic-electrician-type employee busy with the care of small motors, pumps, and water meters. Such an employee should be capable of reading drawings and electrical diagrams as well as understanding system operating criteria. Each organization should determine the economics of contracting part or all of the equipment maintenance and repair work.

4.2.3. Seasonal Operations

It is necessary to have some full-time, well-qualified maintenance people to operate earth-moving machines and perform emergency maintenance. Weed control also is a job that requires maintenance personnel throughout a large portion of the year.

A major concern on many systems that are operated on a seasonal basis is keeping the number of full-time employees at a minimum in order to retain and fully utilize operating personnel during off-season. A good manager will examine this matter very carefully and endeavor to postpone maintenance work for the off-season. If operation personnel are used to perform off-season maintenance, a stable workforce can be maintained.

Earthmoving, canal cleaning, riprapping, and similar activities often can be carried on nearly all winter; however, concrete work can be performed only until cold weather (frost or freezing) makes it impossible. Accordingly, it is recommended that an employment arrangement be developed wherein crews can be directed to take most of their annual leave during off-peak periods, thus keeping them on the payroll.

4.2.4. Special Maintenance Personnel

There is a need for specially trained personnel in large irrigation and drainage systems, especially where failure of equipment might result in serious flooding or failure to deliver water in a timely manner. Under these conditions, a maintenance force may be needed on a standby basis. Such personnel should use their skills for routine preventive maintenance during nonemergency periods.

4.3. MAINTENANCE PLANNING

Obtaining the longest life and greatest use of irrigation and drainage facilities can best be accomplished by providing good maintenance and a program of systematic improvements and replacements. Planning is essential to the success of an adequate maintenance program. Elements of planning must include those preventive, recurring, and routine activities that arise on a continuous basis. In addition, contingency plans must be developed to meet emergency situations. Appendix G describes a general maintenance management plan.

All facilities must be maintained in proper condition to serve their intended purpose. If a structure or facility does not perform in the manner for which it was designed, the designer should be consulted to determine the appropriate changes. In this connection, experienced operation and maintenance personnel can assist by having an opportunity to review system designs before a facility is constructed. In making reviews, the operations and maintenance personnel can recommend designs and construction that will require minimum maintenance.

Maintenance needs of a facility depend on such variable factors as topography, geology, size, and purpose served. Some maintenance items may be critically important for one structure in a given system but less important for another similar structure in the same system. Geographic location also plays a role in establishing a maintenance program. As an example, facilities susceptible to winter freezing require dewatering during the nonirrigation season.

4.3.1. Types of Maintenance Encountered

A universal task is control of terrestrial and aquatic weeds, followed by necessary cleaning of waterways to remove silt, debris, and weeds to maintain system capacity. Weed control and cleaning operations are generally required at least annually; however, maintenance activities on most irrigation systems as well as on some drainage systems composed of open waterways are required continuously.

Another routine task is the periodic painting of metalwork and woodwork. New coatings have been developed, and many previously used have been improved. Other previously used coatings have been banned for environmental or health reasons. The cathodic protection of submerged and buried metalwork on irrigation systems is being used to an increasing extent.

As systems attain maturity, seepage from canals may cause problems of waterlogging and sometimes salinization of farmland. Periodic rehabilitation is necessary for older systems by replacing wooden, concrete, and metal devices or structures as the systems deteriorate through weathering erosion and general aging. Routine recompaction of certain reaches of earthen canals may also be necessary.

Routine maintenance of operating roads and drainage channels must be attended to on a periodic basis. On irrigation systems that usually traverse a number of natural drainage basins, facilities to handle cross drainage must remain free of debris and functional.

Repairs will be required on electrical and mechanical operating equipment of the irrigation or drainage system, such as maintenance of water measurement devices to ensure continued service and accuracy. Maintenance of electrical and mechanical equipment should be of a preventive type, since failure and repair would result in a lapse of service to customers. In order to continue a maintenance program on the irrigation and drainage system, it is equally important to maintain mobile and service equipment and structures.

4.3.2. Development of Program

Types of maintenance are very diverse. Means for accomplishing the work are being constantly improved. New equipment and materials manufactured for other purposes have been successfully adapted for repair and rehabilitation of irrigation and drainage systems. Management personnel should be alert to these new, often time-saving, and more durable products.

Obtaining the longest life and greatest use of irrigation and drainage facilities can best be accomplished by providing good maintenance and a program of systematic improvements and replacements. In many instances, the point at which good maintenance ends and replacement begins is sometimes difficult to determine. Good maintenance, for example, may necessitate replacement of a gate leaf; later, a gate stem; and perhaps still later, a lifting device. A system of structure identification or numbering and canal stationing is important to monitor required maintenance and records on maintenance actually performed.

As irrigation works advance in age, a program to replace worn and obsolete structures is essential to extend the useful life of an irrigation or drainage system. Improvements or betterments such as additional control structures, canal lining, or replacement of unlined laterals by pipe will provide for better service, reduce seepage losses from conveyance channels, extend the system's period of usefulness, and reduce overall operation and maintenance costs.

4.3.3. Participation of Directors

A long-range maintenance and improvement program that will accomplish the preceding objectives should be developed. The operating agency governing board should take part in the planning of such programs and participate in periodic inspections and examinations of system facilities. This will help the board to understand problems and assist them in developing a rational program to meet the needs. The planning should include budgeting for normal operation and maintenance, development of major equipment replacement, and emergency repair funds. Carefully designed financial plans are necessary in order to insure that reserve funds are adequate to deal with nonroutine or emergency repairs.

4.3.4. Inventory of Needs

Identifying structure-by-structure maintenance needs is necessary in planning, budgeting, and scheduling an effective maintenance program. The designers of the system can help prepare a program of maintenance tailored to fit each of the works. Manufacturers' manuals for electrical/mechanical equipment can be very useful in developing a maintenance program.

This maintenance program should be as detailed as necessary to identify all needed items of maintenance and to specify the means for accomplishing this program. The program should be prepared well before the system is placed in operation, but then modified as district personnel become familiar with system needs.

Setting up a maintenance program including an adequate funding mechanism should begin with an inventory of all structures and facilities in the system, including storage and regulating reservoirs and dams and embankments involved in creating the impoundment; diversion dams; all river, canal, lateral, drainage, and relift pumping plants, whether inside or outside type; wells and pumping facilities; and carriage facilities, including canals, grassed waterways, pipelines, tunnels, flumes, siphons, pump discharge lines, canal linings, and bridges.

Lateral distribution facilities, surface and subsurface drains, and other significant features such as levees, river channels regularly maintained by the agency, roads, buildings, safety devices, and fences must be maintained to serve or protect agency beneficiaries and the general public.

4.3.5. Review of Maintenance

The key to good maintenance is frequent inspection. Although this applies to many situations, it is especially important in care and maintenance of irrigation and drainage systems. Inspection followed by proper care of water conveyance channels, structures, and especially mechanical and electrical equipment will avoid major maintenance later.

Proper maintenance demands close and continuous examination of system facilities by experienced personnel, followed by timely repair and replacement programs. Maintaining a system in a structurally sound and functional condition can be accomplished only by preventive maintenance, timely repair, and programmed replacement throughout its life.

The timing for some recurring maintenance needs can usually be predicted with reasonable accuracy. For example, vegetation on some canal banks or berms may be expected to need an annual spraying for weeds and periodic mowing during certain seasons. In some instances, a fertilizer application may be needed until the vegetative cover is well established. Spraying vegetative growth around structures may be needed more than once annually. Other maintenance needs can be determined only by a careful onsite observation; therefore, it is necessary to arrange for periodic inspection of the system facilities.

Inasmuch as untreated or uncorrected minor maintenance needs can grow rapidly into major and costly maintenance problems, inspections should be made frequently beginning immediately after the structure or facility is completed and placed in service. The interval between subsequent inspections may be lengthened as performance dictates.

Frequent inspections also should be carefully made for some time after problems develop or after an unusual event such as flooding or an earthquake. Conveyance channel facilities, for instance, should be inspected after unusually heavy runoff from storms.

There are three procedures that might be useful in development of an inspection program.

Initial Inspection

When construction is essentially completed, a formal inspection of all work is made and any uncompleted work and deficiencies listed. This defines work remaining and transfers responsibility for the system from construction organization to operating agency. In addition, it provides an opportunity for all concerned to be better informed on the condition of system features at the time the agency assumes control. The inspection should be made by a team representing design, construction, and operating agency.

Operation and Maintenance Instructions and Criteria

A detailed manual for operation and maintenance on major structures should be prepared, covering at least all important features in the operation and maintenance of system facilities. Frequently, designers and equipment manufacturers publish documents to explain the technical operations of equipment and structures and technical requirements of maintenance. This information helps to ensure that the facilities will be operated as the designer intended, thus avoiding damage and extending the life of the facilities through proper maintenance practices.

As an example, consider an apparent cavitation noise in the butterfly valve of the outlet pipe at a dam. An air vent valve is located immediately downstream. The operators have no knowledge of the manner of setting the air vent to minimize cavitation. The designer had a reason for installing the air vent valve and knowledge of how it should function. The documents furnished by the designers and equipment manufacturers should explain how to operate the air vent valve to minimize cavitation in the butterfly valve.

Periodic Reviews of Maintenance

These reviews should be in the form of a thorough inspection of all facilities. For a dam, an inspection team should include at least one engineer with design experience, one individual experienced in operation and maintenance, and someone from the operating agency, preferably the agency manager. Key operating personnel should also be included.

The combined knowledge of this team should take in all equipment and features that make up the system to be inspected. The principal purpose of reviews is to verify the safety of the structures; disclose the level of maintenance and conditions that might cause disruption or failure of operation; note the extent of deterioration as a basis for planning maintenance, repair, or rehabilitation work; and obtain operating data for improvement of future design, construction, maintenance, and operation practices. Each employee should cooperate in maintaining serviceability and safety of the facilities in accordance with his assigned duties and opportunity for observation.

4.3.6. Frequency of Examinations

All structures and facilities can be classified by the interval when each should be formally examined to determine its condition and state of repair. This interval may vary from 2 to 6 years. Each storage dam, principal pumping plant, diversion dam, or other structure deserving individual consideration is examined in detail and reported on separately.

It is not expected that each lateral, drop, check, farm turnout, or other minor structure in the system will be examined during the periodic review of maintenance inspection. Only a sufficient number of such features and structures are examined to assure personal knowledge of general operating condition and sufficiency of maintenance being performed.

At least once each year when there is no water in the canals or drainage channels, maintenance foreman or other supervisory personnel should accompany each ditchtender or patrolman over his part of the system. This examination should include all minor structures. Special attention should be given to unsatisfactory conditions disclosed in earlier reviews to ensure that adequate action has been taken. Reports of the examinations should then be made. The reports can be brief in outlining the maintenance required but should include sufficient data to form the basis for necessary work orders.

4.3.7. Review of Maintenance Reports

Written documentation should be prepared on all maintenance examinations. This documentation will provide a historic record of the conditions of each structure and its operating performance. Such records are important to the maintenance manager for preparation of the annual budget and an annual work plan.

In-depth written reports should be prepared covering periodic formal examinations. These reports should include current findings, comparisons with previous examinations, and a summary of conclusions and recommendations. The report should also contain a section on operating practices being followed at the time of the examination and any recommended changes.

To provide guidance in planning and performing repairs, the reports should also include adequate photographs and drawings to illustrate conditions found. Recommended repairs and operating procedures should be grouped into categories according to importance of problems involved.

Category 1

Recommendations involving matters of great importance where immediate action is required to ensure the structural safety and adequate functioning of a facility.

Category 2

Recommendations covering a wide range of important matters where action is needed to prevent or reduce further damage or preclude operational failure.

Category 3

Recommendations covering matters of less importance, but believed to be sound and beneficial to the operation of a project or project feature.

The intended purposes for including formal recommendations within a report are to place emphasis on the necessity to accomplish a corrective action to remedy a deficiency; document a concern noted as a result of field conditions observed during the examination for future reference and examinations; provide a means of tracking the accomplishment of recommended or suggested work activities; suggest means of accomplishing a current operation and maintenance activity in a more economical or efficient manner; remind operating personnel to perform or monitor an operation and maintenance activity not critical at the time of examination, but which could develop into a matter of concern before the next examination; and, provide justification for budgeting of funds to accomplish necessary or desired operation and maintenance activity.

See Appendix H for a list of items that should be in an examination report and a checklist for review of operation and maintenance examinations.

4.4. MAINTENANCE ACCOMPLISHMENT

Responsibility for initiating corrective action with respect to defective structures, facilities, or operating practices usually lies with operating officials and the operation and maintenance organization manager. The manager should review periodic maintenance reports, program work for execution, and upon approval by agency directors, initiate action for work accomplishment. As a followup, the manager should be required to report the status of work until work has been completed.

The manner of performing maintenance work should be carefully considered and a method selected that will best fit agency resources, desires, and capabilities. If the operating organization has the equipment and a qualified work force, it may wish to perform its own maintenance work. This is frequently done on large systems or where several smaller systems are maintained by a board of control, and personnel and equipment of several smaller systems can be pooled.

On smaller systems, some or most of the maintenance work can be done by contract or by agency personnel with rented equipment. This method enables a small agency to operate with reduced outlays for costly equipment. On the other hand, use of an agency's operating forces to perform maintenance in the off season makes it possible to maintain experienced crews. If major maintenance can be completed during the nonirrigation season or, in the case of drainage systems, nonoperating seasons, the operating forces can be used as the maintenance crews.

4.4.1. Maintenance Publications

The operating agency should subscribe to and maintain a library of publications and manuals dealing with maintenance of facilities. Excellent sources for such publications are governmental agencies such as Bureau of Reclamation, Corps of Engineers, Soil Conservation Service, and local land-grant colleges and universities.

Most manufacturers provide manuals dealing with operation and maintenance of their equipment. The various publications and manuals include operating procedures, electrical and mechanical maintenance, new maintenance equipment and products, and many suggestions for operating personnel.

4.4.2. Maintenance Shop

The size, complexity, and arrangement of the maintenance shop will be governed by number of units serviced and repaired, extent of repair, and availability and capability of commercial facilities that can render service.

This may vary from a typical roadside one-man repair garage to a multiplicity of special purpose shops, one of which would be classified as a machine shop. The layout and facilities of the shop will depend a great deal on the climate in which it is located and purpose for which intended.

Shop space requirements will depend upon the nature and allocation of work to a shop. A well-arranged shop building will contribute to efficiency and labor saving and should be given careful study. Adequate space should be allowed for an office; spare parts and toolroom; toilet; battery and tire service machines; welding and blacksmith shops; painting; washing and steam cleaning operations; engine overhauling; generator, starter, magneto, and injector repair; heating plant; lift for greasing service; and general repair spaces, depending on the number and size of units that may normally be expected to be in the shop for repairs.

Particular attention should be given to selection of locations for washing and steam cleaning racks and for a grease lift. Access to or location of either of these items should not interfere with normal operation of other phases of shop work.

Equipment supplied in the shop will depend on the degree of work performed. If the agency elects to perform complete engine overhauls, amount and type of equipment, as well as space, will be greater than if this work is contracted to others.

Fuel storage and mobile tanks will be a necessary item in any equipment servicing facility. It is important that the interior of the tanks be kept clean and free of water and rust. The type and size of mobile tanks will be dictated by state or local safety standards or motor vehicle codes. Consideration should be given to leakage monitoring of storage tanks. Recent environmental concerns for leakage from underground storage tanks dictate that a monitoring program be established.

4.4.3. Budgeting for Work

The board of directors of the agency have the responsibility to see that an annual operation and maintenance budget is prepared. The board must also see that sufficient reserve funds are available for emergencies. The maintenance manager or maintenance supervisor must prepare the budget estimate for review and approval. Maintenance reports should be supplied throughout the year for review at each board meeting.

State and/or local statutes and codes under which an operating agency has been formed may dictate what type of accounting procedure is used. Appendix D provides a detailed example of budgetary procedures.

All supervisors must be made aware of actual maintenance expenditures. Each maintenance department should monitor differences between actual maintenance costs and budgeted costs. Maintenance cost is a function of maintenance severity work requested. If facilities or equipment fail for various reasons such as overload, operating errors, and design problems, repairs must be made.

The maintenance department cannot control all these causes and has little authority over usage and care of the facilities and equipment. Therefore, it is strongly recommended that the true budget responsibility be transferred to specific operations departments. The maintenance department should, however, give maintenance advice regarding optimum preventive maintenance, good performance rate, and try to minimize maintenance, labor, and material costs. Maintenance should recommend preventive maintenance repairs, general alterations, and corrections for improper design, if any are needed, at the scheduled weekly meetings. If these types of problems are not corrected in a timely manner, they could cause additional damage to other facilities and interruptions in service.

4.4.4. Rehabilitation and Modernization

As a part of the maintenance effort, there may be a time when rehabilitation, betterment, or modernization of an irrigation or drainage system becomes necessary. This could occur when the ravages of time make it difficult to repair a structure, or more often, when mechanical, hydraulic, or electrical equipment parts and services are no longer available.

Other facilities become obsolete and uneconomical due to changing water and land use such as the method of irrigation differing from what was originally planned, or a change in the type of crops raised.

Some systems may suffer from inadequate initial design, including some new or modern systems that probably would benefit from major revisions to increase operation efficiency, possibly in both monetary and resource terms.

The need for rehabilitation may be the result of economic constraints. The rising costs of labor, materials, supplies, and construction and maintenance equipment, coupled with the recent economic plight of agriculture, have been detrimental to management in the orderly maintenance of existing works.

Recent environmental constraints have also complicated historical operational procedures and have tended further to imbalance the economic position of the typical irrigation and drainage operation.

Finally, national expectations in the United States are for the irrigation and drainage industry to operate at higher efficiency in regards to resource utilization. Probably at no time in the history of irrigation and drainage has the industry been confronted with such a myriad of problems imposed by all levels of government and the environmental sector.

In considering rehabilitation, betterment, or modernization program, management of an operating agency should assess the condition of the physical works in terms of economy of operation and efficient use of resources. The rehabilitation, betterment, or modernization of an existing facility should use the latest technological advances in methods, materials, and equipment, provided economy of operation or efficient use of resources is enhanced. Liaison between operating agency and designers to accomplish a desired betterment or modernization program is important in order to take advantage of new materials, equipment, and techniques as developed.

Good operating records, both fiscal and resource, coupled with a good assessment of the economic position of the operating agency and irrigation or drainage system beneficiaries are invaluable for intelligent appraisal and consideration of a rehabilitation, betterment, or modernization program.

Since these programs represent large capital investments that must be paid by beneficiaries over an extended period of time, beneficiaries should have a voice in the matter and must be intelligently informed as to need and economic benefits that will accrue as the result of program implementation. Without good operating records, it is difficult to prepare a reasonable rationale for presentation to the beneficiaries.

In time, much can be done toward modernization or rehabilitation during normal maintenance activities, but large programs usually require funds over and above those normally available. Once a tentative decision is made for a rehabilitation, betterment, or modernization program and the scope of the program has been generally determined, the best method of financing must be selected.

There are a number of alternatives to this problem. There are governmental agencies in the United States, both federal and state, that have financial assistance programs for rehabilitation and betterment funding. Finally, an agency in good economic position might issue bonds or secure conventional bank loans. All of the aforementioned loans will require that the borrowing agency supply information and assurance of current and future economic stability.

4.4.5. Records

Good maintenance record keeping cannot be over emphasized. The importance of records is emphasized because of the need to have costs to develop maintenance budgets and to establish a system for routine inspection, servicing, replacement, and maintenance.

Records should be kept to a minimum, with specific uses for each. Daily, weekly, monthly, or annual summaries should be used as needed. Modern bookkeeping and data processing machines can greatly reduce personnel costs in maintaining the necessary records.

Records begin with design and construction of structures or installation of equipment, and continue with regular inspection. A consistent record of inspections, together with specifications and record of installation, provides a crucial history for proper maintenance of any structure or piece of equipment. Only such a record makes it possible to determine whether or not the proper techniques are being used to provide the greatest overall economy.

The first record should be a note when the structure was constructed or the equipment was installed. Ideally, each major structure should be permanently marked with date of construction. In addition, safety and equipment marking tags are desirable for all equipment and structures. Such tags can be dipped in a 40% glyptal solution and remain legible and durable as a record of construction or maintenance activity.

Proper servicing of irrigation and drainage facilities requires that data be kept. Data cards attached to a facility are in the most ideal location for consistent field use. Information in the headquarters office is also essential in order for management to know that proper maintenance is being accomplished.

4.5. MAINTENANCE EQUIPMENT

Maintenance equipment needs will vary with each organization. The two basic types of equipment required are mobile and stationary. Mobile equipment includes motor vehicles and heavy equipment, and stationary equipment includes machinery to maintain mobile equipment, structures, and equipment of stationary installations.

Any piece of equipment that moves or has a moving part must be maintained. Cleaning, lubricating, and replacement of worn parts should be accomplished on a regular schedule. In this regard, manufacturers' manuals can be of great assistance. Extensive and major overhauls should be performed as needed, or in cases of seasonal work, immediately after or prior to scheduled need.

Every piece of equipment should be accounted for in the records of the organization and inventoried at regular intervals, at least annually. To that end, if possible, a major piece of equipment should be assigned to one person who should be responsible for its safety and maintenance.

4.5.1. Mobile Equipment

Almost all irrigation and drainage entities will have some mobile equipment. The motor vehicles may be automobiles, pickups, or light trucks. The heavy equipment may include cranes, rock crushers, road graders, loaders, concrete mixers, weed mowers, crawler tractors, wheel tractors, trenchers, trucks, weed sprayers, weed burners, backhoes, excavators, and compaction equipment.

When the need for a unit of equipment has developed, a determination should be made as to whether its need is sufficient to warrant purchase or if the equipment should be rented. This will depend largely on location relative to rental agencies, amount of time needed each year, and if needed on an emergency basis. Many agencies find that high rental costs make ownership of equipment more economical. Others make primary use of rental equipment during emergencies. Less common items often rented are boats, diving suits, pile drivers, snowmobiles, well drilling rigs, and well point systems.

Economic and efficient equipment use depends to a great extent upon proper unit selection. Equipment efficiency includes such things as work unit versus fuel consumption and time expended versus work unit. Selecting types and models of equipment that will be most economical in operation requires a knowledge of types of service in which the unit will be used during the greater part of its economic life; operation and maintenance costs of similar units in comparable service (fuel and oil, servicing, maintenance, repairs); and final sale or salvage value.

Accurate records on cost, number of hours used each year, and interest on invested money for each unit will provide factual information of significant value and should be available to the officials responsible for selection of equipment.

The use of standard production models, purchased and serviced locally, has many advantages—ready availability of parts and accessories from local sources, necessity to stock fewer fast-moving parts, requirement for fewer special tools in maintenance shops, ease and facility of training operators and mechanics, and availability of a broader market upon disposal by sale or transfer.

Standard models should be used to the greatest extent possible, but at the same time should not prevent acquisition of special or heavy-duty equipment justified by job requirements. Most manufacturers have optional equipment available such as special axles, transmissions, and radiators, which may be specified for factory installation. These can usually be obtained at far less cost both in dollars and time out of service than it would cost to modify standard equipment after delivery.

Many irrigation and drainage entities are public agencies and, therefore, are required by law to purchase most equipment through specifications and bids. Others simply find the practice advantageous. Much care must be taken when preparing specifications for vehicles, machinery, and equipment. Purchase of items that are required almost annually, such as pickup trucks, can become more or less routine. However, experience has proven that care must be taken even in these cases; otherwise, the agency finds itself with a piece of equipment that has unwanted features or, more likely, that has wanted features lacking. In larger and more expensive items that are very rarely purchased, much detail should be taken when preparing specifications.

Advice should be sought from vendors, other entities using the same or similar equipment, and particularly the person operating and maintaining the equipment. Mobile equipment maintenance can be divided into the following four categories.

Daily Preventive Maintenance

Performed each day by the driver or equipment operator. This includes checking engine and driver train fluids, battery and cable connections, hoses and belts, lights, brakes, and tires. Extra care should be taken by equipment operators as specified in manufacturers' manual.

Scheduled Preventive Maintenance

Performed in conjunction with periodic servicing. Many of the same items as during a daily checkout are performed, but in greater detail and by a qualified vehicle or equipment mechanic.

During scheduled preventive maintenance, safety features will be given a thorough test. Some agencies may wish to perform inspections and tests in the presence of an agency safety representative. In addition, separate safety inspection records may be required. Brakes, audible warning devices, emergency equipment, load testing of cranes and hoists, and safety devices on personnel hoists should be tested.

Shop Repair and Overhaul

Covers any repairs or replacement within capabilities of shop personnel or shop equipment and includes installation of such major items as new or rebuilt engines, transmissions, or axles.

Commercial Repair and Overhaul

Covers any repairs or replacement beyond the capabilities of shop personnel or shop equipment and usually includes such items as engine rebuilding, wheel alignment, and air-conditioning equipment repair. For heavy equipment, probably includes work on injectors in the heads of diesel engines and crankshaft buildup and grinding.

Repair or replacement of parts to continue an assignment must be done immediately. Many equipment manufacturers specify servicing and maintenance at hour or mileage intervals such as 100 hr or 2,000 miles (3,200 km). Other agencies specify inspections at 6-month intervals. One procedure used requires vehicles be retired when accumulated maintenance costs, including gas and oil, reach a predetermined percentage of purchase cost.

Records and reports on mobile equipment should be sufficient to inform the shop foreman, superintendent, and manager as to which equipment received what maintenance, when, and at what cost. Examples of records are as follows.

Title or Record of Ownership

This is required by law for those vehicles that are licensed to use public highways, and necessary when ownership of the vehicle or equipment is being transferred. The state or federal government usually prescribes the necessary form. For heavy equipment not licensed to travel on public roads, the form is merely a vendor's invoice or bill of sale.

Accident Report

This report can be relatively simple, as exemplified by the form usually required by insurance companies. A more detailed report may be required by the operating agency safety program (see section 2.8 and Appendix F on safety).

Daily Use Report

A report submitted at the end of each day of heavy equipment use is the simplest way to keep a record of equipment performance and its operator. The form should show time spent traveling, working on each job, under repair, and waiting for parts. Quite often, this form is combined with the time report for the assigned operator or crew. See Appendix G for a sample of an equipment usage report.

Shop Repair Order

This is required on each vehicle and piece of equipment so that shop personnel are informed as to what work is to be performed; also, when the work is completed, the form provides a record of time, material, and cost. See Appendix G for a sample of an equipment repair order. Automatic data processing is becoming more commonly used for this type of record.

Monthly and Annual Equipment Report

This use and cost report is a consolidation of daily use reports on heavy equipment or monthly reports on motor vehicles. This report is for recording mileage, hours used, fuel usage, and parts and labor costs for each calendar month with an accumulative cost for the year up through that month. Thus, the report for the last month of the fiscal year is also an annual report. This annual report can provide valuable information to management for equipment and budget planning.

Equipment Historical Record

This is a record of use, repair, and costs of an individual piece of heavy equipment. This is usually in jacket-file form and should contain copies of all work reports and shop repair orders pertaining to that piece of equipment. A summary should be kept and brought up to date annually, showing pertinent information for each year. A historical record is not necessary for use with motor vehicles because of short life span; however, an annual equipment report can usually give sufficient detail for a decision on replacement. See Appendix G for more information on equipment histories.

4.5.2. Automatic Data Processing Equipment

Automatic data processing (ADP) equipment ranges from programmable pocket calculators costing less than one hundred dollars to extremely complex computer equipment costing hundreds of thousands of dollars. There is probably an application for ADP equipment in practically every irrigation or drainage operation.

The consideration and selection of this equipment should be carefully tailored to the individual operation with the objective of increasing efficiency and reducing costs. Representatives of ADP manufacturers may be found in virtually every city of any size, and these representatives can be used for technical assistance in the consideration and selection of equipment.

4.5.3. Communication Equipment

An essential requirement for maintenance of an irrigation or drainage system is an adequate means of communication. In addition to vehicles and roads, there must be a means of immediate personal contact—telephone and radio.

Maintenance of the radio system can be performed by employees of the operating agency or through contractual services by approved specialists and perhaps subsidized by the equipment company. Even with a large number of units, contract type service has been found to be more economical than hiring an employee. This is an important issue that should be agreed upon when purchasing a radio system.

Maintenance of a leased telephone system is performed by employees of the owning company. If an irrigation or drainage agency operates in an area where it must own its telephone lines and equipment, then of course, system maintenance must be provided by its own employee specialists or by obtaining contract services.

4.6. SAFETY FOR MAINTENANCE PERSONNEL

4.6.1. Public Contact

All maintenance personnel should develop a close working relationship with water users, farmers, and landowners within their area of responsibility to ensure a congenial operation of the project and to keep users informed as to the ability and operational requirements of their section.

Maintenance personnel should inform fishermen, swimmers, and other trespassers along the canal right-of-way of canal hazards and request that trespassers leave restricted areas for their own safety. If necessary, supervisors should be contacted to enforce trespass regulations.

When maintenance personnel are confronted with the news media, the individual should respond to general questions with a common sense approach. All controversial questions must be referred to the maintenance manager.

If possible, maintenance personnel must notify his or her dispatching office by radio when confronted with emergency personnel (policemen or firemen) along the right-of-way. In the event that a supervisor or management person is not available, personnel will assist in whatever manner requested by the emergency personnel in attendance.

4.6.2. Maintenance Shutdown Procedures

Again, safety of maintenance personnel cannot be overemphasized. A typical procedure for safely shutting down and recharging an irrigation system or a part of a system should be described in some detail in the SOPs (see section 3.4.2).

4.6.3. DO NOT OPERATE Tags

All operation and maintenance personnel must be provided with a supply of "DO NOT OPERATE" tags. Each tag should be marked permanently with the persons name and identification or radio call number so that person can be contacted whenever there is a question. These tags should be made of durable plastic to withstand bad weather conditions (see Fig. G-46, Appendix G).

When maintenance of facilities or machinery must be performed and a portion of the system must be taken out of service, a "DO NOT OPERATE" tag must be affixed to the facility to show who tagged the facility, when, and why the facility was shut down. The tag owner must also notify a dispatcher or maintenance clerk who keeps a log on the status of each of these tags that is in use. This eliminates confusion in the field because anyone can immediately determine the status of any facility (see Fig. G-47, Appendix G).

After repairs are complete and the facility is returned to service, the tag is removed, a dispatcher or maintenance clerk notified that the facility is back in service, and the tag is returned to its owner. It is essential that procedures for use, removal, and return of tags be followed precisely to maintain the integrity of the tagging procedure.

Operations personnel are usually part of the planning process in regard to deciding on when any part of the system is taken out of service. In fact, operations personnel are usually in charge of initiating the shutdown procedure. However, if operations personnel are not involved, it is essential they be continuously informed about status of any part of the system that is out of service.

4.6.4. Safety Locks

Additional safety precautions are essential when maintenance personnel must work inside a facility that is normally charged with water such as a pipeline, underground control structure, pump sumps, tanks, siphons, or other such structures. In order to perform maintenance repairs on such facilities, it is necessary to lock the facilities off-line.

This should be done with a multiple lock clip which will hold a separately keyed safety lock or padlock from each crew that will be working inside the facility needing repair. These separately keyed locks are placed on the clip prior to doing any work in the facility and are removed from the clip by each crew only after each crew is clear of the facility to be recharged with water. A diagram of a safety clip is shown in Fig. G-48 of Appendix G.

As indicated earlier, operations crews normally will take a system out of service and dewater the facility to be repaired. Therefore, the operation crews lock will usually be the first lock on and last lock off the clip. As an added check on the work, the operations supervisor also maintains a maintenance clearance checklist (see Fig. G-49, Appendix G). As each maintenance crew completes their work and removes their lock, the operations supervisor is notified and he checks the operations crew off the maintenance clearance checklist.

When all repairs are complete, all locks are removed, all repair crews are checked off the maintenance clearance checklist, and the operations crew then removes its lock and returns the facility to service.

4.7. RESERVOIR MAINTENANCE

Most irrigation developments depend upon reservoirs to store and regulate their water supply. While some developments in a river basin share a common reservoir, many operate one or more storage reservoirs as an integral part of their project operation. There are many problems including numerous hazards connected with the operation of reservoirs.

4.7.1. Watershed

Periodic inspection of the contributing watershed should be made. There are many factors involving upstream land use and developments that affect the quantity and quality of water reaching the reservoir. These include but are not limited to overgrazing, timbering, industrial and municipal return flows, and construction of numerous small reservoirs for water spreading and stock ponds.

Reservoirs constructed in canyons with precipitous slopes are subject to serious problems in the event of earthquakes or saturation of slope material by heavy rains. A major catastrophe with the attendant loss of hundreds of lives occurred at Viant Dam in Italy when a rain-saturated slope slid into a reservoir, causing a water wave to overtop the dam and flood the valley below.

4.7.2. Sedimentation and Vegetation

Periodic sedimentation surveys should be made to assess the loss of reservoir storage capacity due to sediment. These surveys may be routinely made by the range method on smaller reservoirs or by the contour method on larger ones. It is important to monitor this accumulation so that the useful life of the reservoir may be predicted and changes, if any, and rate of sedimentation may be noted.

Management of vegetation in the uninundated portions of the reservoir is an important consideration. After only a short period of low reservoir stages, phreatophytes will establish in sediment beds that provide an optimum environment for their growth.

If not controlled, these plants will consume large quantities of water, choke off channels carrying water to the storage pool, create hazards to recreational use when the areas are again covered by water, and accelerate unequal sediment accumulations that may cause serious aggradation problems at the upstream end of the reservoir. Good vegetative management and control in reservoir areas will yield many dividends in economy of resources.

4.7.3. Recreational Use

Recreational use of irrigation reservoirs by the public is practically universal. This use, if not strictly controlled under guidelines and regulations, may cause serious problems. The district or operating agency should be concerned with liability, vandalism to adjacent facilities, littering, and degradation of water quality.

If the public use of a reservoir is significant, the recreational responsibility is often turned over to a state, county, or federal recreation entity for supervision and administration. These entities are generally better equipped to handle such an activity.

However, some common hazards and corresponding warning or corrective measures should include marking of submerged rock or sand bars near the surface; marking of turbulent water or its isolation by log booms, nets, screens, or fencing, if on shore; marking or fencing of landslides and high bank areas; elimination or marking and barricading of abandoned roads and trails leading into reservoirs; and placement of signs, fencing, and possibly floating booms, to protect swimmers from sharp or shallowly covered rocks and deep water. Floating debris or logs should be removed from the reservoir or confined in areas that are clearly marked. When covered with ice or snow, dangerously thin ice areas should be marked or barricaded.

4.7.4. Water Quality Considerations

Federal and state environmental laws now require the consideration of water quality standards in the operation of most reservoirs. These may include standards for salinity, dissolved oxygen (DO), biochemical oxygen demand (BOD), temperature, and turbidity for stored water as well as water released from the reservoir. These requirements must be considered in the reservoir operation and maintenance plan.

4.8. MAINTENANCE OF DAMS, EMBANKMENTS, AND LEVEES

4.8.1. General Responsibility and Inspection

Storage dams, diversion dams, levees, and embankments are fundamentally necessary structures in an irrigation and drainage system, and failure or malfunction of any of these structures could constitute an emergency situation.

It is mandatory that, for efficient operation as well as responsibility to the public, these primary storage, diversion, and distribution facilities be periodically inspected, carefully maintained, and operated in strict conformance with applicable operating rules and regulations.

Definite arrangements should be made for periodic inspection and report by a responsible person who is educated in regard to potential hazards for the facilities being inspected. For more important structures, inspections should be conducted by a qualified engineer.

Periodic Inspection

As previously discussed, arrangements for inspection should be made immediately following completion of dams, embankments, and levees. In addition, all appurtenances and operating equipment should be inspected. Schedules should be made for future periodic inspection and examination of all such features and facilities (U.S. Bureau of Reclamation 1987). Maintenance supervisors and damtenders should conduct monthly inspections of major facilities.

Operation and Maintenance Instructions

Written instructions for operation and maintenance of more important structures and appurtenant equipment should be prepared as part of the design function and be furnished to the owner or operating agency. These instructions should establish frequency of and describe extent and nature of inspections. The instructions should also provide for routine servicing of mechanical equipment where gates and valves are provided and should include instructions furnished by the manufacturer.

Objective of Inspection

All structures should be periodically inspected with the following objectives in mind.

- Verify physical safety of structures and facilities.
- Disclose conditions that might cause disruption or failure of operation.
- Determine adequacy of structures and facilities in serving the purpose for which they are designed and being used.
- Note extent of deterioration as a basis for planning maintenance, repair, and rehabilitation.

Report of Inspection

A written report of inspection should be made to the proper authority of any and all structures. The conditions observed should be recorded and recommendations made for corrective measures where required.

4.8.2. Storage Dams

Storage dams are an integral part of the facilities of many irrigation developments. These dams represent many types or combinations of types. Among the more common designs are gravity dams, arch dams, buttress dams, earth dams, and rockfill dams (U.S. Bureau of Reclamation 1987). Regardless of type, all should be periodically inspected.

The general plans for the dam and appurtenant structures should be on file for ready review along with any documents furnished by designers and equipment manufacturers. Operation of these dams should be in strict accordance with operating criteria and SOPs.

Concrete Dams

Annual inspections of concrete dams should be made by operating personnel and, at intervals of not more than 6 years, major concrete dams should be inspected by qualified engineers.

Inspections by engineers should be more thorough and detailed than those made by operating forces and should include portions of the structures not ordinarily accessible such as penstocks, conduits, etc. These inspections should be scheduled during periods of low water to check condition of structures normally submerged.

The dams should also be inspected during periods of maximum water level to check structural behavior under full load as well as or during spillway discharges. The inspection should cover such items as (see Appendix H).

- Abnormal settlement, heaving, deflection, or lateral movement.
- Cracking or spalling of concrete and opening of contraction joints.
- Deterioration, erosion, or cavitation of concrete.
- Abnormal leakage through foundation or formed drains or through concrete surfaces, construction joints, or contraction joints.
- Possible undermining of downstream toe or other foundation damage.
- Outlet work(s) operation.
- Unusual or inadequate operational behavior.

Earth Dams

Earthfill dams present a somewhat different set of problems than those associated with concrete dams and should be examined annually by operating personnel and periodically by qualified engineers, as are concrete dams. The annual inspections should include all portions of the structures readily accessible and all other portions where there is reason to believe that damage may have occurred. For the first few years after completion and during rapid filling and drawdown cycles, more frequent examinations may be necessary as discussed later.

Routine maintenance of embankment slopes and crests of earth embankments can be expected. However, any unusual conditions that may adversely affect the safety of an earthfill dam should be reported promptly as should any abnormal requirements for maintenance. The embankment, abutments, and visible portions of the foundations adjacent to an earth embankment should be inspected at regular intervals for evidence that unfavorable conditions are developing.

When a reservoir is rapidly filling, the downstream slope of embankment and foundation downstream from the embankment should be carefully inspected at frequent intervals for indications of cracks, slides, sloughs, subsidences, springs, seeps, or boggy areas caused by seepage from the reservoir.

The upstream slope of the embankment should also be carefully inspected after periods of sustained high-velocity winds as reservoir water surface is being drawn down. The slope should be examined for evidence of cracks, slides, sloughs, subsidence, or damages to slope protection such as displacement of riprap or other signs of serious erosion.

During periods of low reservoir level, exposed portions of abutments and reservoir floor should be carefully examined for sinks or seepage holes, unusual beaching conditions, or cracking. During periods of sustained high reservoir level, monthly inspections should be made of the embankment with particular attention given to the crest of the dam, visible portions of upstream slope protection, downstream slopes, and areas downstream from the dam for evidence of abnormal development. The frequency of inspections may be decreased after several seasons of operation have disclosed no abnormal conditions.

The occurrence of unusual conditions should be reported immediately to the operating agency or owner of the dam by telephone, telegram, or letter, depending upon the nature of the development and apparent urgency for repair. The description of slides, sloughs, or sudden subsidences should include location, extent, rate of subsidence, effects of adjoining structures, reservoir and tailwater elevations, prevailing weather conditions, and other facts believed to be pertinent.

Information regarding development of springs, seeps, and boggy areas should include such data as location and size of affected areas, estimated discharge, nature of discharge (whether clear or cloudy water), and reservoir tailwater elevations. To facilitate analysis of conditions, a map should be prepared showing the extent of all seeped areas, springs, and data such as dates and reservoir levels at time of observation. This map should be revised periodically.

Rockfill Dams

Inspection of rockfill dams generally follows the procedures given previously for concrete and earthfill structures. One item, however, not covered is the requirement to carefully inspect the impervious membrane for signs of deterioration, displacement, and leakage.

4.8.3. Diversion Dams, Embankments, and Levees

As is the case with storage dams, there are several types of diversion dams. These dams are low-head structures designed to raise the hydraulic grade of a stream or waterway so that water will flow by gravity into canals that head at these dams.

There are two basic types of diversion dams, an overflow weir type and a structure composed of a series of gated discharge bays. There are, of course, many modifications of the two types embodying the principles of both. These structures are generally constructed of concrete with associated steel gates. Inspection and operating requirements similar to those outlined for storage dams, but modified as required by individual structure, are applicable.

Often, earth tieback levees are associated with diversion dams. These and other earthen embankments and levees require frequent maintenance and periodic inspection. If properly designed, there should be no overtopping or serious erosion. As a practical matter, however, most levees and embankments do require strengthening, raising, or other modification from time to time.

Erosion of embankments or levee banks from streamflow frequently occurs and may be corrected by placing adequately designed riprap, mechanical devices, or jetties and groins to reduce velocity. Minor erosion by wind and rainfall occurs on a continuing basis and is a continual maintenance item.

Vegetation, excepting grasses, should be routinely removed, as roots create paths of percolation through the bank. Burrowing animals working in the bank must be controlled for similar reasons.

Levees in some humid climates are constructed of stable material; nevertheless, they are subject to erosion by excessive wind-driven wave action. Preventive measures consist primarily of a grass cover made with a combination of bermuda and other type grasses. The levee slopes are designed so that grass-cutting equipment as well as choppers can be used. Rye is often included in the initial planting to provide a quick growth to reduce sloughing of newly placed material.

Another practice to reduce wave erosion from high winds is construction of submerged mounds some few hundred feet (meters) from the shore.

During periods of high flow, levees and embankments should be carefully inspected on a continuing basis. During these periods, equipment should be on a standby basis for immediate repairs as needed.

4.8.4. Appurtenant Structures and Facilities

Inspection of channels and surrounding areas including backfill adjacent to concrete structures and embankments not included in the limits of an earthfill dam should be made in conjunction with concrete structures. These inspections should cover such items as: channel bank or bed erosion and silting; condition of riprap areas; presence and condition of undergrowth in bottoms and on sides of channels, and estimated effect on tailwater levels; river aggradation or degradation and possible affect on hydraulic operation of structures involved; abnormal subsidence of backfill or embankment areas; and unusual or inadequate operational behavior.

4.9. CANAL SYSTEM MAINTENANCE

This section deals with maintenance of open irrigation canals and drainage channels, the latter frequently being referred to as drains. There are two types: unlined and lined. A lining may consist of impervious earth or soil-cement, asphaltic or plastic membranes, shotcrete, asphaltic or Portland cement concrete, brick, or stone, which has been used in many places throughout the world including some of the older systems in the United States.

To maintain any irrigation or drainage canal, it is necessary to review its design. Those responsible for maintenance should be familiar with the cross section, slope, and capacity of each section of canal and should have drawings available for all structures. Maintenance and repair of canals usually can be performed in a routine manner; however, maintenance and repair of canal structures quite often require reference to the design drawings.

Design velocities should always be below that necessary to produce channel erosion. An excellent reference on canal design is a publication of the Bureau of Reclamation (Rippon 1962).

4.9.1. Operating Roads

In order to operate and maintain any system of canals or drains, there must be a road for vehicular access. The roads should be located so that operating personnel can observe the canal, and maintenance personnel and equipment can have ready access.

Location and Width

Whenever possible, canal access roads are located on berms. In low, wet terrain, road berms are usually built up from channel spoil as the channel is excavated. In reaches where an adjacent levee is also required, levee crown is sometimes maintained as a road for use during wet periods.

Road widths should be sufficient to handle the largest equipment used by the entity maintaining the canal. The widths should also be sufficient to allow vehicles and equipment to pass and to carry out needed maintenance.

Unlined canals are usually constructed with a minimum 12-ft (3.7-m) width on top of both banks. At least one side should be an all-weather road (gravel surfaced road); the other bank should be maintained so that the road can at least be traveled by tracklaying or four-wheel-drive vehicles. If gravel or similar material is too expensive, both banks should be maintained so that travel by track-laying or four-wheel-drive vehicles is possible.

Where there is a levee adjacent to the canal, berms are often designed to slope landward to the base of the levee. This practice reduces bank erosion in areas of appreciable rainfall. Wherever possible, drainage water should flow under the canal and be returned to the drainage channel. Small culverts at intervals on the bank slopes direct water into the canal. Primary maintenance consists of keeping these culverts open.

Lined canals do not require wide banks to minimize saturation and often are built on relatively high fills. Construction of banks sufficiently wide to carry traffic on top could be excessively expensive for small canals and laterals. These may have a berm road on the outside slope which should be of sufficient height to allow observation of the canal from a vehicle and, by all means, high enough for the operator of cleaning equipment to observe the canal. From experience, this height has been found to be approximately 2 ft (0.6 m) below the operating water level, which is usually about 2 ft (0.6 m) below top of the bank.

Road Maintenance

Roads must be maintained, and unless barricaded, may receive more use by others than by the maintaining agency. Dirt roads can be maintained by road graders, and if desirable, can be plated with gravel or crushed stone. The common method of maintaining roads with gravel or crushed rock surfaces is by wetting, followed by blading. Another method of maintaining dirt roads is to encourage grass growth, mowing to control growth, and blading only when absolutely necessary.

Cattle Guards

When canals are fenced in stock raising country, cattle guards are needed on canal bank roads and other maintenance roads. There are many designs, all of which require regular maintenance.

Crossing Pads

Where maintenance roads cross asphalt-surfaced highways, crossing pads will be necessary to provide for heavy tracklaying maintenance equipment. One method of providing a crossing pad is to allow the heavy tracklaying equipment to cross concrete or asphalt-surfaced highways atop used rubber tires laid tread to tread. A permanent solution is a 6-in. (150-mm) thick reinforced concrete slab specifically constructed to carry such transverse loads.

Road Signs

Maintenance roads may not need a great number of signs; however, dead ends, right-angle turns, road crossings, and other existing danger spots should be properly marked. This is for employees, fishermen, and others of the general public who might use the roads. Stop signs should be placed at *all* road crossings on canal roadway approaches. It has also been useful to post on the other side of the stop sign "Authorized Use Only" or something indicating restricted public use. These and any other signs require inspection, maintenance, and replacement.

4.9.2. Unlined canals

An unlined canal is a ditch without compacted soils to reduce seepage losses.

Priming

Much care is needed when running water for the first time in new unlined canals, as canal banks and backfill around structures may not be sufficiently compacted and settled. No amount of care in construction is certain to safely bring canals quickly under strain of full-flow depth. If a small depth can be carried for a relatively long time, banks will absorb moisture and settle; weaknesses can be detected and repaired before the structure is damaged.

Several weeks of use may be required before new canal banks will become sufficiently saturated to develop weakness. If conditions permit priming of a new canal during the season before actual delivery of water, many problems can usually be avoided.

Where checking flow in the canal is not necessary, a new canal may not be required to carry full depth of flow for 1 or more years, depending on the rate of development. If checking to full depth is required for delivery, the canal will be under its full strain in the first year of use. Where checks are available, however, the canal can be primed by sections, holding water above each check in turn. This reduces rate of flow and volume of water that may cause damage in case breaks occur.

For old canals, water should be turned in from 1 to 2 weeks before delivery will be required. If 1 week is desired in which to bring a canal to full depth, priming should be started 2 to 3 weeks before water is needed in sufficient amounts so that an interruption in service will not be serious. This allows time in case the need to repair the canal develops during the priming.

Where there may still be frost in the banks, running water early helps to thaw the banks and provides a longer period for any frost having to settle. Running a small flow in priming also enables weeds and other debris that have accumulated to be carried through or collected at checks with less damage from clogging, which would be the case if the water was held high for delivery.

Burning weeds ahead of priming, being careful not to damage wooden structures, will remove a large portion of weed/trash accumulation and debris on the trashrack and/or reduce clogging.

Draining Canals

Draining water out of a canal too suddenly may be more harmful than filling too quickly. In some soils, sudden dewatering of a canal may cause more damage than a break because of sudden relief of pore pressure in the soils near surface of the banks, causing sloughing. A good rule of thumb is no more than 6 in. per day (15.2 cm per day) in unlined sections and 12 in. per day (30.5 cm per day) in lined sections.

Unstable Formations

Where canals are located on side hills or other unstable ground, difficulty from settling or sloughing of the banks is expected. Bank settlement, especially in humid areas, is usually a design deficiency created by too steep a bank slope for the type material. Maintenance consists of replacement with a more resistant soil or by stabilizing the existing soil with sand, cement, clay, etc., and compacting. It is often more economical for long reaches to flatten the bank slope where berm is available. Stabilization of the slope with a suitable grass is a requisite.

In arid areas, stability difficulties are usually of two general kinds—where a canal is excavated on talus slopes below higher ground, destroying the natural slope balance that has existed, and where seepage from a canal reaches uncompacted material that settles under influence of the seepage water.

The first condition occurs where a diversion canal follows contours from the stream to bench land and passes for part of its length through the sloping side hill. Cutting into the slope to form a canal section destroys the footing of the higher slope and upper material may then slip. Such movements are hard to restrain and usually continue until the natural slope balance is restored.

In very steep slopes, it may be preferable to construct the canal as a bench flume to reduce amount of disturbance to the natural slope. To maintain canals in areas where the natural slope balance has been disturbed, the usual practice is to correct conditions when they occur rather than to attempt preventive measures. Where the formations occur in strata and movements consist of one stratum slipping over another, rather than as a general bulging, piling may be effective. The piling acts to bind the strata together and has been used in some cases with good results. Where seepage from the canal softens material on the lower slopes so that sloughing may occur, treatment of the canal to reduce seepage losses is a workable solution.

In banks of permeable material, visible seepage may occur without immediate danger. If seepage water is clear, indicating that underlying material is not being moved, it may be safe to leave repairs until after the operating season ends. This may be done with less danger on old canals, as settlement is less liable to occur.

Canals through soluble formations require great care in operation, as such material softens when wet and has little strength. Canal lining may be used to prevent seepage and saturation of banks; however, even a concrete-lined canal can be trouble because of possible backfill softening by seepage through joints or cracks in the lining.

When repairing breaks in side-hill canals, it is not usually desirable to rebuild on the same alignment. If the hill is too steep for relocation, a flume should be built over the eroded section.

Overtopping Banks

Breaks directly due to overtopping of canal banks occur occasionally. Some canals pick up cross-drainage, which may overload the canal particularly where summer rains occur. However, with an adequate amount of freeboard used, a break will generally occur at some point of weakness in the bank before actual overtopping takes place.

Where canals are operated under checks, rejection of water by users may overload the canal unless ample wasteways are available. Where such conditions occur, much closer control of water delivery is required.

Protection Against Erosion

Bank erosion can be the result of surface inflow from the berms. Good corrective measures after soil replacement consist of constructing culvert inlet channels at intervals and redirecting the runoff.

Erosion within the canal prism can be controlled by the use of linings or changes in operational patterns. Where erosion is due to wave action or to high velocities below structures, rock riprap is preferable; where velocity does not materially exceed that which causes soil erosion, a blanket of crushed rock may be sufficiently heavy to protect the canal. Placing a filter fabric beneath rock riprap has been used to control erosion downstream of checks.

In sandy soil, brush or even straw may be plowed or disked into both canal bank and prism to prevent erosion. Such material can work loose and be carried down to the checks or turnouts, so that much care may be needed to prevent checking the flow at such structures. In sandy soils, greater difficulty in holding the brush or straw is usually encountered unless it is well weighted with rock or fastened with wire.

In protecting canals that have eroded, it is generally considered preferable to trim the eroded section to smooth lines rather than attempt to restore the original section except in cases where *lining* is to be placed. The eroded section will more nearly conform to the natural section for actual conditions of flow and will be more easily maintained. On curves, material deposited on the inside may be moved to the outside of the curve before protection is placed if the erosion has reduced the outer banks to less than desired size.

Sediment Control

The deposition of sediment in canals may be desirable or objectionable, depending on the extent to which it occurs. In porous soils, a deposit of silt over the canal bed and sides will be of benefit in reducing seepage losses. On a few systems, silt has been artificially applied to seal the canal. Artificial silting could save water and prevent losses associated with lands waterlogged by such seepage.

In canals operating under checks, the deposit of silt will be greater than where the water is carried at a fairly uniform velocity from headgate to the fields. In systems diverting from streams carrying an excess amount of silt, deposits may be so extensive as to seriously affect canal capacity. The majority of streams used for irrigation in the United States do not carry sufficient silt to give serious trouble in operation; however, for a number of systems in the southwestern United States, removal of silt is the largest item in maintenance cost.

Silt deposited in place during the nonoperating season is known in some areas as "puddle lining." After the silt is spread, a drag consisting of planks spiked together with overlapping edges is run over the surface to break the clods. The canal is then filled and water held over the section by checks for 24 hr. It is then lowered to a depth of 12 in. (300 mm), and a harrow is dragged through the canal to puddle the material.

Puddling may also be accomplished by dragging a heavy chain along the canal when the silt is wet. In some instances, puddle linings have been found to give the best results if placed so that the linings have an opportunity to dry before being subjected to erosion by flowing water. On some of the most porous subgrade materials, burlap is spread over the canal before the puddle lining is applied.

When using silt or clay from local deposits for silting, material and water should be chemically analyzed. It is possible that the two will not combine to perform in the manner desired. There are numerous soil sealants on the market that should also be investigated before embarking on an extensive earth canal sealing program.

Sediment Removal

Sediment removal is a continuing problem in any system. Maintenance is similar in arid and humid areas, except in humid areas, the sediment generally can be removed more efficiently by dredging. The methods of handling silt deposited in canals by water diverted from the streams depend largely on the rate at which such deposits occur.

Where the rate of deposit is low and there is some margin of capacity available in the canal, silt may be allowed to collect until the amount is sufficient to make its removal by machines economical. The cost of cutting runways in canal banks for access and other fixed charges are then distributed over a larger yardage.

In systems operating under checks, silt deposits above the checks may be sluiced during seasons when checking for delivery is not required. Stirring or loosening the silt with harrows, disks, or drags during such sluicing may increase the amount removed. To succeed, such sluicing requires that water be relatively free from silt when entering the canal and that excess water is available to be wasted.

Silt can be more economically removed by tractors from small canals; consequently, using higher velocities in larger canals may be preferable if sufficient fall is not available to carry silt through to the fields. Enlarged cross sections may be used at selected locations from which silt can be more easily removed. This may be accomplished by leaving the canal bottom below grade in fills.

For systems handling water carrying much silt, the design of headworks and canals must be such that the minimum amount of silt will be taken into the canal system. Of that silt brought into the system, as much as possible will be carried through to the fields or deposited in selected locations along the canal where the silt can be more easily handled.

A settling basin (section of canal widened to allow a slower velocity for a suspended load to drop) may be constructed immediately below the canal intake. In larger canals, floating dredges may be required for cleaning. These dredges require an area in which the pumped effluent may be deposited.

On small canals or laterals, silt may be best removed by hydraulic excavators. On still smaller canals, a V-shaped drag may be used. This requires a tractor, probably tracklaying, on each bank. The drag is actually a middle-busting plow that forces the deposited silt to the top of the bank where it can be bladed flat or pushed to the outer edge with a road grader. The more elaborate ones are constructed of two or three scraper blades, similar to those on a road grader, one for the bottom of the canal and one or two for the side slopes. Such an arrangement can be pushed by a tracklaying tractor in the bottom of a dry canal.

Seepage Losses

Water loss through canal seepage can be a major problem. Not only is the water lost from the system thus not available for delivery as intended, but it also can create waterlogged conditions and add to drainage problems.

The location of seepage sometimes may be apparent from visual indicators such as tules or other water-loving plants growing along the canal. The location and intensity of seepage can also be determined by a sophisticated electric logging process.

Amounts of seepage can be determined by flow measurements using current meters, weirs, or flumes above and below the reach in question, or by the more accurate method of ponding.

4.9.3. Lined Canals

Lining of waterways may be done for any one of a number of reasons. Lining is costly and justification must be provided.

Earth Lining

Earth canals that have been lined with clay, bentonite, soil cement, or other relatively impervious materials require great care in maintenance, particularly in sediment removal, so that the lining will not be destroyed or penetrated. This requires knowledge of the canal cross-sectional dimensions, thickness of lining, and skilled machine operators who respect that knowledge.

Membrane Lining

Asphaltic or plastic membrane-lined canals are usually covered with 1 ft (0.3 m) or more of earth for the purpose of protecting the lining against erosion and maintenance machinery. Here again, great care must be exercised in maintenance.

Shotcrete Lining

Canals lined with Portland cement mortar applied by air pressure (shotcrete) are very difficult to maintain. The lining is seldom more than 2 in. (51 mm) thick, surface is usually rough and irregular, and side slopes are usually quite steep. There is not a metallic bucket light enough nor a machine operator skillful enough to prevent damage to the lining; therefore, cleaning is not practical. The only safe method to repair this lining is to dewater the canal. Dewatering must be done with care to avoid breakage by hydrostatic water pressure behind or under the lining.

Some canals have been lined with shotcrete on side slopes only. Such canals are more easily maintained by careful dragging with light chains or by dewatering and cleaning with a dragline or other excavating machine without touching the shotcrete. However, such a lining is usually less effective in controlling seepage.

Asphaltic or Portland Cement Concrete Lining

Sediment and moss removal from concrete linings can be performed in much the same manner as described for earth canals.

Small canals can be cleaned effectively with a small hydraulic excavator. An advantage here is that a toothless bucket can be turned to fit the sideslope and with the vehicle put in motion, it provides a scraping action. Small canals usually can be dewatered, at least seasonally, thus giving the moss a chance to die and the excavator operator an opportunity to see and remove larger amounts of accumulated sediment.

The surfaces of asphaltic or Portland cement concrete linings that have deteriorated can be resurfaced with asphaltic concrete or with shotcrete. Either of these is a major operation that can be classed as reconstruction and should be studied and performed with the same degree of care as a new construction project.

Portable steel cofferdams, usually homemade to fit local conditions, can be used to dewater a relatively small area so that repair of any hard surface lining can be made in a flowing canal. These cofferdams are made to fit the slope of the existing canal with a rubber seal or flap on the edges, are put in place, and area dewatered with a small pump. As the water is drawn out, soil is shoveled in on the outside where leakages occur.

Broken concrete should be replaced in a dewatered canal. Earth voids should first be filled with gravel, then asphaltic concrete or Portland cement concrete placed.

Cracks are repaired by sandblasting, cleaning with compressed air, tamping in dry mortar (sand and Portland cement) for half the thickness, then filling the remainder with a special quality asphaltic mastic pumped in under pressure. The purpose of the dry mortar is twofold, prevents moisture from hydrostatic pressure from entering and prevents asphaltic material from being forced out.

The application of asphaltic mastic for crack repair should be limited to temperatures above freezing. Temperatures above 50° Fahrenheit provide the best results.

If time is limited, it may not be possible to remove sections of lining that have been broken. In such cases, filling broken areas with sacked dry Portland cement concrete has been found to be expedient.

Even sideslopes can be treated in this manner up to a height where the earth is sufficiently dry to hold a 6-in. (150-mm) blanket of gravel, then the concrete of desired thickness can be placed from the top row of sacks upward. In this process, a weep should be provided to receive hydrostatic pressure by placing a 2-ft (0.6-m) section of plastic hose between the sacks near the bottom of the slope, with the back end of the hose in a gravel pocket. Such weeps should be not more than 10 ft (3 m) apart.

Occasionally, canal lining needs to be raised to increase canal capacity. This has been tried with concrete block and has served the purpose of increasing the capacity; however, concrete block presents an irregular cross section that is most difficult to maintain. It is better to compact additional soil to the height needed, then shape the concrete for the remainder of the slope by hand.

Escape Devices for Humans

Lined canals should be equipped with devices by which humans can escape, since sideslopes are usually too steep or too slippery to gain a foothold or handhold. The most common escape device is steel ladders set in concrete not more than 750 ft (230 m) apart with the top rung above the high water line so that the ladders can be seen. Painting the lining behind the top of the ladder improves its visibility. These ladders (especially the top rung) are often damaged or destroyed by cleaning equipment and must be repaired or replaced.

Other escape devices for humans such as floating ropes on buoys, suspended nets, or knotted ropes should be installed immediately upstream from each dangerous structure. These safety devices should be inspected and replaced as necessary. Appendix F provides an example of a public safety policy.

4.9.4. Control of Burrowing Animals

In practically all irrigated areas, some various forms of burrowing animals make canal maintenance difficult. The holes these animals burrow are points of weakness at which canal breaks may start. Such breaks are particularly likely to occur when water surface in the canal is raised above new holes. Such holes are also more troublesome and dangerous in fills.

In some localities, prevention or repair of breaks caused by burrowing animals may be the largest single item in the cost of canal maintenance, particularly on laterals. Where water is rotated between laterals, burrows may be built in the banks during the time water is out. In some cases, canals are operated under checks so as to maintain a uniform depth of water in the canal throughout the season. In such cases, burrows will be above line of saturation in the banks.

The type of animals causing damage vary in different localities. The most successful methods of control are based on a knowledge of the different animal habits. The most generally employed methods of control are poisoning and trapping. In fairly tight soils, gopher damage may be greatly reduced by compacting the inside bank of the canal above and below the water line.

4.9.5. Fences

The question as to whether or not canals should be fenced has caused much controversy between landowners and canal agencies. The controversy is who builds these fences and then who is responsible for maintenance. This is particularly true when permitting fences with gates or cattleguards to be built across canals at road lines in order to avoid fencing the canal through the lands. These issues should be clarified in right-of-way agreements whenever possible.

In any event, if the irrigation agency owns the fences, then the agency is responsible for the maintenance. This means keeping the fence line free of weeds to prevent unsightliness and to protect the fence from damage by fire if the weeds burn.

Fence wire should be kept free of direct dirt contact to prevent rust and ultimate failure of the wire. For this reason, a fence parallel to and at the toe of canal slope is difficult to maintain properly, because dirt spilled over the bank in the canal cleaning process will collect on the fence. Alkaline soils are particularly damaging to metal fenceposts.

In some states, fencing of livestock is the responsibility of the livestock owner. Thus, the agency maintains only fences that enclose storage yards, pumping plants, substations, and water structures that present dangerous conditions to the public. Fences around such features should be chain link with steel pipe posts set in concrete with overhanging barbed wire at the top and wing extensions over concrete walls. Maintenance consists of keeping wire tight and dirt away from the posts and wire.

4.9.6. Canal Structures

In maintenance of irrigation and drainage system structures, much emphasis should be placed on requiring maintenance personnel to review the design. The superintendent of maintenance should have drawings on hand for all structures in order to standardize and maintain a permanent record.

Bridges

Bridges over canals and other waterways are sometimes maintained by a government agency such as county or state. Regardless of who maintains the bridges, there are certain bridge features that must be inspected regularly, maintained, and replaced as needed.

Bridge timber should be well drained and treated if above water, and creosoted if below. Creosoted timber below water can deteriorate rapidly depending on timber quality, creosoting, and water. When possible, timber bridges should be raised above the water or replaced with precast concrete.

Most steel segments of bridges on an irrigation and drainage development will be above water. These steel segments should be inspected regularly, and cleaned and painted as required.

Live load sizes tend to increase with time and increased vehicular traffic. Bridge loading should therefore be monitored, and as loads reach bridge capacity, load limits must be imposed or the bridges must be modified.

Checks and Wasteways

Timber structures should be inspected and timber treated or replaced much the same as that for bridges. A cost effective activity during the nonirrigation season could be the replacement of timber planks with concrete planks.

Concrete checks and wasteways usually have vertical or radial steel gates, or both. The smaller gates generally consist of a single-thickness steel plate equipped with a vertical threaded stem that allows the threaded wheel, mounted on a rigid frame of steel or concrete, to raise and lower the gate.

The gate rides in a slotted frame, sometimes fitted with a rubber seal, usually with a rubber seal on the bottom sill into which the gate fits at the bottom. The threaded stems should be equipped with a fixed nut to prevent the stem from being bent when the gate is closed. Also, this tells the operator that there is an obstruction if the stem begins to bend before the fixed nut reaches the frame.

Larger gates may be reinforced steel plates or steel-encased wood with a thickness of several inches that require vertical steel channels in concrete as guides. These are equipped with rubber seals, side and bottom, that almost invariably leak when installed more than 4 ft (1.2 m) below the water surface.

Radial gates, as the name indicates, are fabricated in circular arcs, usually made up of reinforced steel plates totaling several inches thick. The spokes of the arc are steel arms attached to a hub or trunnion embedded in concrete with one set of arms at each end of the gate. Wire ropes, attached to the gate, lead to a hoist mechanism located on a concrete deck above the gate. The gates may be operated manually or electrically.

Maintenance is virtually the same for all types of gates. Threads, gears, and wire rope must be kept clean and lubricated. Exposed steel should be kept cleaned and painted. Submerged or alternately submerged steel must be cleaned, perhaps sandblasted, and painted periodically. This presents problems in systems that require waterflow 12 months of the year. Epoxy or vinyl-resin paints are usually recommended.

Submerged metal can possibly be protected against corrosion or electrolytic deterioration by an electrical process known as cathodic protection. As cathodic protection is a highly specialized field, installation should be fully investigated by experts whose advice should be followed. This and other maintenance pointers are discussed under repair and maintenance materials and procedures (section 4.13).

Automatically controlled gates are sometimes complex devices used to obtain a desired flow past the check by maintaining a fixed water level above or below the gate. Specially trained personnel may be needed to maintain these devices.

Overchutes and Culverts (Cross-Drainage Structures)

These structures carry surface drainage runoff across a canal and vary from small diameter pipes to large open concrete chutes, each designed for drainage areas that it serves. Maintenance is principally a matter of inspection after rainstorms and keeping the entrance open and free of debris. Other maintenance is the same as for other structures of the same material.

Drain Inlets

These structures carry surface drainage runoff into a canal and are for drainage areas too small to require a cross-drainage structure. These structures usually consist of a reinforced concrete gutter with a wide entrance leading to a small-width chute that allows surface runoff to enter the canal without damage.

For still smaller areas, short lengths of pipe may be used. If a canal is not lined, concrete should extend at least to a point 3 or 4 ft (0.9 or 1.2 m) below the normal water line. Riprap and crushed rock should be placed so that flow from the pipe does not cause erosion of earth canal banks.

Undercutting at the downstream ends of the pipe or chute results from poor design and should be corrected as it occurs. Erosion under the downstream apron of larger installations may create a need for major repairs. Inspection should be routine. Downstream erosion maintenance problems can be materially reduced if the crown of the inlets approximate the elevation of the water into which the inlet is discharging.

Drops and Stilling Structures

A stilling basin or energy dissipator of some kind is required whenever the water velocity generated at drops and stilling structures is sufficient to cause scour of banks or overtopping of lining.

Maintenance is similar to that for any other concrete structure. However, drop inlets often have a tendency to collect material in downstream basins if stilling of the water is necessary. Such debris should be removed periodically.

The water in the stilling basin should be drained or pumped out periodically and the basin inspected to determine if there are cracks or breaks that can cause cavities under the floor; and if there are, these must be repaired. Inspection during maximum flow can also determine if water is flowing or splashing over side walls of the stilling basin, and if so, extension of the walls or perhaps riprap is required.

Measuring Devices

Water measurement devices are enumerated and described in the Water Measurement section. In an open canal system, measuring devices generally are gate openings with staff gauges, pumps with rated flow at varying heads, weirs, Parshall flumes, or propeller meters.

Maintenance of gates that are used for measuring consists of keeping the edges of the rectangular opening clean. These edges are the bottom of the gate (radial or vertical), two side walls or gate guides, and the sill upon which the gate rests when closed. This is rather difficult at a structure that is seldom dry. In such cases, a great deal of dependence is placed upon the velocity of the water to keep surfaces clean. Staff gauges on upstream and downstream sides of the structure must be kept in readable condition, which requires frequent cleaning and/or replacement.

In a closed or pipe system, measuring devices are Venturi, ultrasonic, and propeller meters. Maintenance of Venturi meters, since there are no moving parts, is a matter of keeping the flow surface and standpipe interior surfaces clean of algae. To clean the tube, a chemical cleaning compound should be used. There are many types. The interior of standpipes can be cleaned in place with brushes of the proper size in much the same manner as one would clean a test tube.

Where stationary pumps are used as measuring devices, they must be frequently tested and rated since measurement accuracy diminishes with use. Frequent inspections and adherence to good preventive maintenance practices in care of pumps and motors are the best assurance of long life and reasonable accuracy in measurement.

Maintenance of Parshall flumes consists principally of keeping them free of debris and algae. In some cases, it is necessary to erect a shade over the flume throat to discourage algae growth. Copper-based paints are available to assist in keeping algae from adhering to the throat area. Periodically, flumes should be checked to verify that the flume structure is level to ensure accurate flow reading.

Maintenance of propeller meters is a ceaseless task. Propeller meters that are left in place should be checked daily, and any moss or other debris should be removed. If one is located in a pipe, the pipe must be drained and the meter removed; if it is located in a manhole or junction box, it can be removed, cleaned, and replaced during flow. All propeller meters should be overhauled annually by cleaning, oiling, replacement of worn parts, and recalibrating. This can usually be done by mechanically inclined ditchtenders during the off season that have been properly instructed and trained.

Sand Traps and Excluders

A sand or sediment trap is a structure built for the express purpose of collecting sand or silt, or both, which is carried suspended in the water, and of removing that load from the canal system. These can vary from a highly mechanized arrangement to a widened section of earth canal such as previously mentioned in the paragraph on sediment removal.

There must be a means of disposing of the collected material. Some systems have floating dredges that operate during the irrigation season to keep sediment out of the canals. Any sand trap that operates for an entire system is expensive to maintain, and all will require a waste of water.

Excluders are usually concrete or steel devices constructed at turnouts or junctions that allow water that is leaving the canal to be taken from the top, thus sending the heavy suspended matter such as sand down the canal. Thus, maintenance is the same as for any other underwater concrete or metal features.

Siphons and Tunnels

Maintenance of concrete pipe siphons and concrete-lined tunnels consists principally of keeping the interior clean. These siphons and tunnels should be dewatered occasionally for inspection and for removal of undesirable objects such as rocks, oil drums, and car bodies. The interval at which these structures should be dewatered will vary with the structure. Structures that drain freely, such as most tunnels, should be inspected annually.

Structures that require pumping to dewater such as siphons should be dewatered periodically, dependent on the amount of debris that each structure accumulates. Drain valves should be operated annually and cleared and painted as needed to keep the valves fully functional. Algae can usually be removed by chemicals while the canal is in use. Mineral deposits such as iron and manganese oxide can be removed with metal scratchers or reamers but requires flow stoppage in the canal. In like manner, brush reamers can be used to remove algae but also require flow stoppage or near stoppage.

Cracks and ruptures of concrete pipe siphons or tunnels must be repaired. Cracks can sometimes be sealed with tar or epoxy or by treating with ammonium sulfate under controlled flow. Ruptures are major reconstruction jobs and should be treated as such. Before repairs are initiated, a qualified concrete design engineer should be consulted.

Metal pipe siphons are kept clean in much the same manner as described for concrete siphons. Steel does not have the life expectancy of concrete; thus, metal siphons should be dewatered and inspected more often. If the diameter is too small for human entry, determination of internal conditions must be made from what can be seen at the ends or by the use of cameras.

4.10. VEGETATION MANAGEMENT

The term vegetation management includes all planning, preparations, and actual practices used to both maximize beneficial vegetative growth, and at the same time, minimize potential adverse effects of vegetation on and in open draws, canals, and other facilities. The first step is to determine optimum vegetation for the specific work or facilities. It is also appropriate to define vegetation management as including those elements that maximize efficiency, economy of operation, and aesthetic qualities of these works.

The many aspects of vegetation management and pest control on irrigation and multiple-use water systems represent one of the most expensive items in the operation and maintenance budgets for these facilities, averaging 20 to 25% of total costs.

To conduct successful vegetation management programs, managers must know the plants that grow in their area. Following identification of weed species and desirable plant species, maintenance management personnel should learn growth habit (annual, biennial, perennial), season of growth, and methods of reproduction and dissemination. These plant growth characteristics will largely determine methods required to control or eradicate weed species and prevent their spread.

A well-planned vegetation management program includes weed prevention, control, and remedial recovery. Weeds are defined as plants that produce a negative impact on man, his environment, or his activities. They are aggressive, invasive, and obstructive. Even the hardiest stands of desirable vegetation will suffer some invasion by aggressive weeds.

Prevention

Weed prevention should be based on knowledge that practically all parts of a system, excluding rocky and other inhospitable areas, such as lined reaches and paved roads, will be subject to habitation by plants. The logical action is to manage and encourage permanent plant populations having the least adverse effect on the facility. This can be accomplished by planting and encouraging species that are adapted to the local environment and have qualities compatible with operation of the system.

Control

A vegetative management program could be integrated with other pest management programs to seek to maximize use of nonchemical controls on vertebrate, nonvertebrate, and vegetative pests while minimizing the use of chemical treatment. This approach emphasizes monitoring the population of pests and establishing a threshold where control of pests is necessary. Both nonchemical and chemical control methods should be examined before selecting the control method to be used against pests. Use of herbicides, mowing at a particularly effective stage, or even fertilization to tip the balance in favor of the desirable species are examples of vegetative control.

Remedial Recovery

This phase is required when a combination of prevention and control fails to the extent that pests continue to cause a detrimental effect on operation of the facility. Examples of weed recovery costs are personnel, equipment time spent removing and disposing of debris, repair of ditches and structures washed out due to plugging, and loss of delivery capacity from flow impedance by aquatic weeds. Costs required to recover from the effects of weed growth are often overlooked and hidden in other operation and maintenance costs. This makes assessment of weed-related damages and maintenance very difficult. Prevention of weed costs is the most economical of three phases—remedial recovery from effects of runaway infestations is the most expensive.

4.10.1. Aquatic and Terrestrial

The efficient movement of water, whether for a water supply or drainage, requires an effective program for control of aquatic and ditchbank weeds. Aquatic weeds interfere with irrigation by restricting water movement through canals, by clogging siphons, trashracks, turnouts, pump filters, and sprinkler and drip irrigation systems.

Although weedy vegetation on ditchbanks is disadvantageous, some vegetation is useful or even necessary. Where the erosion of ditchbanks is a problem, some vegetation, preferably a low-growing, soil-binding/stabilizing perennial grass, is desirable. In the absence of a desirable species, controlled weed species may be a short-term alternative.

There are hundreds of species of aquatic and ditchbank weeds, but only relatively few are troublesome. The classification of aquatic weeds is usually separated into five general classes: submersed, floating attached, floating unattached, emergent, and algae. Ditchbanks exhibit a definite soil moisture gradient running from a saturated zone at the waterline to a dryer zone on bank tops and outside slopes. This gradient is a major factor in determining distribution and composition of plant species on ditchbanks.

Submersed aquatics are plants that are rooted in the bottom of water channels and spend their life cycles completely underwater, growing mostly during warm seasons. Common examples are sago pondweed, horned pondweed, watermilfoil, elodea, and coontail. These weeds are often inaccurately referred to as "moss" and are commonly the cause of vegetation problems in irrigation systems.

Floating weeds occur as two types, either rooted to the bottom or free-floating. Although young plants may be completely submerged, the plants are generally adapted for buoyancy producing most of their leaves at the water surface. Alligator weed and water smartweed are anchored to the substrate; examples of free-floating types are duckweeds, water lettuce, and water hyacinth.

Emergent or marginal aquatic weeds include plants that are rooted in or near water channels and grow above the water surface. Examples of emersed types are cattail, sedges, and bulrush.

Algae are also submersed and free floating, and may be anchored by "hold fasts" to rocks and ditch linings. The most serious algae problem plants are the filamentous green algae and stoneworts (chara). Algae are primitive plants that do not have true leaves or roots. These plants reproduce by spores (or by fragments) and are frequently called "slime," "floating mats," or "pond scum."

In the Pacific Northwest, reed canary grass is a major problem. It is a hardy perennial that flourishes in wet, poorly drained soils. In ditches that carry water on an intermittent basis, rhizomes of this perennial will spread through the ditch bottom. Other major northern ditchbank weeds are quack grass, bull grass (carex), Canada thistle, brush species such as willows and wild rose, and annual weeds such as Russian thistle and sunflower.

In the southwest, Johnson grass is a serious grass weed, while brush types include salt cedar and willows. Johnson grass dominates the inside shoulder of ditches and shades out low-growing desirable plants. Like reed canary grass, Bermuda grass will spread into the bottom of ditches that carry water on an intermittent basis. Other perennial ditchbank weeds include field bindweed, spring aster, docks, nut grass, knotgrass, salt grass, and silverleaf nightshade. Major annuals include pigweeds, London rocket, sunflower, and Russian thistle.

Recently, introduced weeds have appeared that have potential to cause serious impact to western water system maintenance activities. Examples include submersed aquatic weeds such as hydrilla and Eurasian watermilfoil. These weeds are noted for rapid growth rates, capable of filling small reservoirs and delivery systems in one growing season.

Water hyacinth, a floating aquatic weed that has become notorious for blocking waterways in the southeastern United States, has spread into California. Purple loosestrife, a riparian weed, is spreading across the northern tier of states, displacing desirable wetland plants and destroying valuable wildlife habitat.

Flowering rush, which is well adapted for growth as either submersed or emergent forms, has recently been causing problems such as blockage of waterflow in irrigation systems in Idaho and limiting access to recreation (boating and fishing) areas in Minnesota. While these weeds may often be found in isolated areas at the present, their potential for spread throughout the Western United States should not be overlooked.

4.10.2. Prevention

Weed prevention methods include procedures aimed at limiting the spread and establishment of weeds. It would be poor economics to base a program entirely on continual control and eradication without including plans for weed prevention. Knowledge of how weeds find their way to ditchbanks and using reasonable care wherever possible to prevent infestations from these sources will save much labor and expense.

Terrestrial weeds employ many natural methods for dispersal by wind, water, and animals. Many weed seeds (Canada thistle) are equipped with cottony appendages similar to parachutes that allow the seeds to travel great distances by wind and eventually lodge on ditchbanks or nearby farmland. Some weed seeds are transported by water.

Many ditchbank infestations have started from seed originating in watersheds, around margins of lakes and reservoirs, or along rivers and streams. Both wild and domestic animals carry weed seeds on muddy feet and in wool and hair. People also spread weeds to ditchbanks through planting grass or crop seeds contaminated with weed seeds and by obtaining repair or fill dirt from areas adjacent to ditchbanks infested with weeds.

Aquatic weeds are spread to irrigation ditches mainly by water from sources upstream. Birds also move seeds of aquatic plants which pass undigested through their digestive tracts. In addition, some water weeds may start new infestations from vegetative parts such as fragments of stems and roots and winter buds and tubers which break loose and wash to a suitable growing site. Both wind and water play an important part in the spread of algae spores.

The most effective means of preventing both land and water weed infestations on ditches is to eliminate the source. There are many instances where weeds at the source can be controlled or eliminated, and even though the initial cost is comparatively high, controlling or eliminating weeds in this manner can be less costly over time.

The planting of desirable sod-forming perennial grasses at the waterline and adapted species on dry zone is often the most successful means of preventing land weeds on ditchbanks and costly wind and water erosion. The full realization of the magnitude of ditch weed problem, and operation and maintenance costs necessary for controlling weeds once the weeds become established, should create an interest in devising every possible method of preventing future infestations. The mechanisms by which weeds become established in ditches offer clues to weed prevention; therefore, every operator of an irrigation system should determine these means for his own area.

4.10.3. Identification of Plants

Identification is an important step in a management program. Assistance in identifying weed species can be obtained from state extension or university personnel or both. Several publications covering regional and national weeds are available for identification purposes.

Major aquatic weeds in western irrigation systems have been described and illustrated by a Bureau of Reclamation publication (Otto, et. al. 1980). Common aquatic weeds also have been described and illustrated with photographs in other Federal publications (Weldon et al. 1969; Westerdahl 1988).

It is important to be able to distinguish between grass and broadleaf plants because these differ in reaction to herbicides and other control methods. For weed control purposes, plants are divided into the following two main categories.

Grass plants have one seed leaf (monocotyledon) and generally have narrow, upright, parallel-veined leaves and fibrous root systems.

Broadleaf plants have two seed leaves (dicotyledon) and generally have broad, net-veined leaves and a taproot or coarse, branched root system.

Plants are also classified into three groups according to life cycle. Knowing growth habit of weeds is important to choice and effectiveness of control methods.

Annuals complete their life cycle from seed in less than 1 year. As a general rule, annuals are easier to control with herbicides and mechanical methods than biennials and perennials. *Winter* annuals germinate in the fall, lie dormant over the winter, and complete their life cycle early the next summer. *Summer* annuals germinate in the spring and complete their life cycle by fall. Among the troublesome annuals on ditches are Russian thistle, mustards, lambsquarters, kochia, and sandbur grass.

Biennials complete their life cycle in more than 1 year but in less than 2 years, and produce taproots and basal leaves the first year, storing an abundance of reserve food. The second year, growth is rapid, producing flowers and seed. Some of the most troublesome are mullein, bull thistle, and burdock. There are no grasses in this group.

Perennials live for more than 2 years; only the above ground parts die each fall. The perennials are more difficult to control with herbicides or mechanical methods and spread by seeds, roots, and above ground stems. *Simple* perennials, such as dandelion, spread mainly by seed and by their large, fleshy root. *Creeping* perennials spread by seed and extension of underground root systems amply supplied with buds from which new plants can be initiated. Some of the most troublesome perennials on irrigation systems are Canada thistle, Russian knapweed, reed canary grass, Johnson grass, and Bermuda grass.

4.10.4. Applying Weed Classification to Control

Grass plants are generally more difficult to control and eradicate than broadleaf plants due to their structure and growth habit. The growing points (sites at which plant elongates) in grass plants are in the crown;

whereas in broadleafs, growing points are in terminals of branches and the points where leaves are attached to the stem.

Grasses recover from mowing and grazing while simple-rooted broadleafs are killed. Herbicide applications to grasses often fail when material merely burns off foliage and is not translocated to crown and roots. Spraying of perennial weeds with creeping roots must be done so as to use the above ground parts of plants to move translocating herbicide to the roots and their rhizomes and dormant buds.

Weeds are most vulnerable when in the seedling stage of growth and are actively growing. Of the three groups of plants, annuals are most nearly like seedlings and are very susceptible to control with herbicides and mechanical methods. Biennials and perennials are most easily controlled if attacked when development is similar to that of an annual or during first year of growth. Food reserves are low then, because plants have not had time to fully develop taproots and food stores.

Perennials have not yet developed extensive root systems in which food is stored and from which stand can be regenerated by release of dormant buds. After the perennials are well established, perennials are more vulnerable at certain times, such as when nutrients are at low levels following rapid growth, parts above ground are new and tender, and physical processes (cell division and movement of food and water in the plant) are in full swing.

Once plant species have been identified, knowledge of growth characteristics (mentioned previously) will follow. It is especially important to understand growth of plants as individuals and as members of plant communities. Here again, this information is available from state extension and university personnel, and publications on plant identification and plant ecology.

With these facts at hand, a plan can be formulated to effect prevention, control, and eradication of weeds. An ideal vegetation management plan should go beyond a program of general suppression to one designed to replace undesirable weed species with desirable low-growing, weed-competing plants. This can be done through seeding or vegetative sowing of desirable species, encouraging growth of established desirable species, and controlling, eradicating, and preventing spread of undesirable species.

In general, there are six principal methods of weed control: mechanical, draining and flooding, fire, biological, competition and mulching, and chemical. These methods will be discussed subsequently in some detail; but first, there are three points that must be considered when control methods are being evaluated for implementation in a weed control program. Seldom will any one method of control meet needs or accomplish goals of a weed control program. Instead, a weed control program should employ multiple control methods, all of which complement each other.

Secondly, nature has the habit of filling a void created by control or eradication of specific species. In such situations, a weed control program must have enough flexibility to allow for employment of alternate measures, if required, to control weeds that have filled a void.

Thirdly, cost will play a major role in selection of control methods. Naturally, the most economical and effective control measures should be selected. However, the cost of a control program should be evaluated in terms of program goals and number of years required to achieve such goals.

The long-term goals of a program should not be short changed through limited year-to-year funding. In the long run, such a lack of foresight may make weed control more costly.

4.10.5. Mechanical Control of Terrestrial Weeds

Mechanical methods for control of terrestrial weeds can be classified into categories of tillage and mowing.

Tillage by itself or in combination with other methods, especially chemicals, can be a good method of weed control. However, use of harrows, disks, cultivators, and blades is not conducive to ditchbank applications since it will loosen the soil and leave the surface in a rough condition. Some tillage might be applicable on ditchbank tops (right-of-way) and in bottoms of dewatered ditches for control of some aquatic weeds. When used to reshape ditchbank slopes and tops, scraping machinery will remove many weeds. However, this process may also spread perennial weeds along a ditchbank.

Generally, tillage controls weeds in two ways—burial and severing plants from root systems. Burial and root severing are effective methods for control of many annual weeds. As seedlings, perennial weeds can easily be destroyed by tillage, but well established perennials are not easily killed by tillage methods. In essence, tillage has to kill established perennials through starvation of regenerative parts.

The severing or burial of above-ground plant parts prevents the manufacture of additional food by the plant and forces the plant to use its stored food reserves in producing new growth. In order to accomplish this, tillage must be repeated on a frequent basis throughout one or more growing seasons.

Unlike tillage, mowing is an effective method of control that is adaptable to most ditchbanks. It is an effective control for tall-growing species but not for low-growing or prostrate weeds such as Bermuda grass. As a matter of fact, mowing reduces competition by tall-growing weeds which then presents a more favorable growth environment for the low-growing species.

If done often enough through the growing season, mowing can prevent or reduce the amount of flowering and seed production. In addition to the control or suppression of vegetation, reduction of weed seed production is an important aspect of a weed control program.

Like tillage, mowing can be effective in controlling annual weeds, but control of established perennials is another matter. Here again, frequent repeat mowing is required to upset favorable carbohydrate or food balance of perennials. The plants have to starve to death by destroying new growth before it yields a net gain in food and by forcing regrowth that decreases food reserves of underground or reproductive parts. For example, Johnson grass stands can be greatly reduced, if not eliminated, by frequent repeat mowing over a period of 1 to 3 years.

4.10.6. Mechanical Control of Aquatic Weeds

Draglines, chains, hydraulic excavators, backhoes, and underwater mowing machines can be used to temporarily reduce aquatic weed infestations. Although these methods do not have the environmental hazards associated with chemicals, they are usually the most expensive of control methods. Another major disadvantage is downstream infestation of dislodged aquatic vegetation which requires removal at one time or another.

With chaining, a heavy link chain is pulled over the bottom of canals or ditches, pulling out or breaking off the weeds. Several types of cutting or "demossing drags" have been designed for cutting such aquatic weeds or pondweed. In the southeast, special dragline buckets such as the hyacinth bucket have been effective in removing aquatic weeds. Like chains, drags are pulled along the bottom of a canal and may have to be employed more than once during the growing season. Underwater mowing must be repeated to obtain control. Chaining has not been effective in controlling many aquatic species.

Once aquatic weeds are dislodged, their removal and disposal becomes the next concern. In areas where dislodged aquatic weeds may clog pumps, siphons, and irrigation sprinklers, special diversion structures can be constructed to keep the water relatively free of weed debris. Other structures such as "moss traps" and trashracks can be used to catch dislodged weeds for removal and disposal. In the southeast, mechanical harvesters have been used for removal of plants from water for eventual shore disposal. Small areas can be cleaned with mobile equipment equipped with special forks, rakes, or buckets.

4.10.7. Draining and Flooding

Where conditions permit, draining and drying canals is an effective method for controlling submersed aquatic weeds. The drying of dewatered canals is the most important factor involved in killing vegetation by this method. In order to speed drying, canal bottoms may require grooving to accelerate drainage of low spots (Muzik 1970); however, this method is not very effective against emersed weeds that are rooted in ditch bottoms.

On most water management systems, flooding may not be a practical method for controlling terrestrial weeds. However, the method might be applicable to small, special areas. In order to be effective, plants must be completely submersed (denying oxygen to both roots and leaves) for an adequate period. Bindweed, Russian knapweed, and horse nettle are some noxious perennial plants that can be controlled by flooding. On the other hand, many weed seeds (bindweed) can withstand flooding for many years.

4.10.8. Fire

Fire can be used to control vegetation and dispose of dry debris that has collected on a ditch system. Both practices involve the use of special equipment and either diesel or liquid petroleum gases (propane or butane). With vegetation, the practice of flaming apparently kills by coagulating cell protein which probably occurs between 113° F (45° C) and 131° F (55° C). In western areas, fire has been very helpful in disposing of windblown tumbleweeds that have collected in irrigation ditch systems.

Since flaming or burning usually only kills the tops of plants, its greatest effectiveness is usually with annual weeds rather than with established perennials. Flaming can give good results when used on small or seedling weeds. In order to effect the control of some perennials, burning must be repeated at frequent intervals; however, this is an uneconomical means of control.

Like all control measures, fire has its advantages and disadvantages. Unlike the use of chemicals, burning does not leave a chemical residue that can contaminate soil or water. The purchase and maintenance costs of burner equipment can be lower than that for sprayers and mowers. However, with the increased concern for quality of the environment, use of burning is being restricted by implementation of stringent air pollution control regulations, both state and federal.

The improper use of burning can easily result in a fire hazard to adjacent nontarget areas. An increase in weeds and erosion could result from the burning of dry vegetation that is functioning as a mulch for the surface of soils. Under the circumstances, such debris could pose a serious hazard.

4.10.9. Biological Control

Biological control involves the use of natural enemies such as predators, parasites, and pathogens in reducing the population of an organism below levels that occur without presence of a natural enemy. In recent years, introduction of fish and insects to control aquatic and terrestrial plants has been very successful in the control of certain vegetation in irrigation canals and drains.

Continuing efforts are made to find and evaluate new organisms that are specific for problem weeds. However, such organisms have to be thoroughly investigated under safeguards and quarantine conditions since their introduction might result in the destruction of desirable native species, both plant and animal.

The grass carp or white amur (*Ctenopharyndon idella*) is being used either in research studies or operationally in approximately two-thirds of the states for controlling submerged aquatic plants (Allen and Wattendorf 1987). These fish have proven successful in controlling numerous species of aquatic plants in warm-to-cool water temperatures and in large reservoirs to small irrigation canals.

Like all species introduced into a new environment, the grass carp has potential for adversely impacting indigenous plant and animal populations; therefore, their ecology has undergone extensive study. To reduce the possibility of the grass carp proliferating, a "triploid" grass carp has been developed which so far is proven to be functionally sterile (Allen and Wattendorf 1987).

In addition to preventing reproduction of the species, stocking densities are important in managing fish to provide the amount of aquatic plant control that is desired in a certain area (Sutton and Vandiver 1986). Understocking will not control vegetation, and overstocking will either clean out all vegetation when some vegetative cover is necessary for game fish or clean out all available food to the grass carp. The grass carp will then move out of the area in search for food or will go hungry.

If ditchbank grasses hang over the water body, grass carp will jump out of the water to feed on the grass when there is no food available. This is how this fish obtained the name "grass carp" (Sutton et al. 1987). Numerous studies have shown, with the exception of overstocking and cleaning out all vegetative cover of other desirable fish, grass carp do not adversely impact the ecology of a water system (Leslie and Kobylinski 1985; Chapman et al. 1987; Small et al. 1985; Mitchell et al. 1984; and Canfield et al. 1983).

Grass carp can survive in a large range of water temperatures from 0 to 52° F (36° C), and are effective in controlling vegetation in temperatures between about 39 to 51° F (12 to 34° C) (Van Zon 1973; Opuszynski 1972; Edwards 1974; Stevenson 1965). Grass carp can overwinter under ice provided there is adequate water and water contains sufficient oxygen (Thullen and Nibling 1988). Grass carp are very hardy and can be moved with seines and dip nets up to 36 times without significant injury (Thullen 1989). Therefore, the fish can be used for a number of years to control aquatic vegetation.

After the fish reaches a weight over 14 kilograms, its feeding capacity declines just like any older animal (Osborne and Sassic 1981). The number of years the fish can be used depends on the area. In warmer climates with abundant vegetation, grass carp eat rapidly and thus grow rapidly, and usually will reach maturity before a fish who is raised in a cooler climate with less vegetation.

In order to keep the fish in a particular area, fish barriers must be used. Fish screens of various types may be used in addition to stationary, drum, and rotating screens and fish ladders. Research on other more economical barriers is continuing. Electrical barriers for preventing passage, as well as herding the fish, looks very promising for the future (Hiebert, S. D., 1989, Bureau of Reclamation, personal communication).

Shireman et al. (1978) concludes that grass carp greater than 18 in. (450 mm) in length are necessary to totally eliminate the possibility of being consumed by largemouth bass in Florida. Due to lower metabolisms of fish in cold water, Swanson and Bergersen (1988) recommend in their stocking model to stock grass carp larger than 8 in. (203 mm) in cold water lakes to prevent predation by other species.

Hill (1986), on the other hand, found that when fingerling grass carp were stocked in colder climates into a water body that contained largemouth bass, there was low mortality (less than 8% during a 3-year period). Therefore, size of grass carp determines whether grass carp will be consumed by predator fish, but size that will prevent predation depends on environment and type of predator.

Not all states allow the use of grass carp, while others allow only the sterile triploids. Individual State Fish and Game officials will be able to provide all the regulations that apply in each state.

Various species of tilapia have also been used for aquatic plant control with various success. The tilapia do not withstand cold water temperatures below 38 to 41 ° F (10 to 16°C), and in colder temperatures become lethargic; therefore, a high degree of predation by largemouth bass occurs resulting in having to restock the tilapia each year. Additionally, tilapia spawn almost continuously when the average water temperature is approximately 44° F (21°C) (Legner et al. 1975).

Insects have also been investigated for control of aquatic weed species with varying success. In 1963, the alligatorweed flea beetle (*Agasicles hygrophila*), a South American native, was first introduced for alligatorweed control in several areas of the southeast. However, the beetle cannot withstand cooler temperatures than those that occur in Florida and other warm areas of the southeast.

The same species collected in 1979 in the cooler region of Argentina was then released in the Southern United States to determine its ability to withstand the climate. Much of the alligatorweed was destroyed in some ponds in South Carolina but had to be redistributed each spring or summer in cooler climates (Buckingham et al. 1983). Two additional species of Argentine insects were also tested on alligatorweed, but neither has been successful in Florida (Buckingham 1987).

Two species of weevils (*Neochetina eichhorniae* and *N. bruchi*) from Argentina were imported in 1972 and 1978 and proved to be fairly successful for controlling waterhyacinth. The addition of a moth (*Sameodes albiguttalis*) adds additional stress on the waterhyacinth population to keep it in control, but is not as abundant as the weevils (Buckingham 1987).

In general, however, it has been found that none of the insects cause a dramatic decline in waterhyacinths except to young waterhyacinths in the early spring. Currently, management programs combining herbicides, growth regulators, and insects are being evaluated (Hoag 1986; Van 1988).

An Indian weevil (*Bagous affinis*), which attacks the subterranean turion (an overwintering organ much like a small potato) of hydrilla when the soil is exposed and water drained, is being investigated. The usefulness of the weevil is limited because its young cannot survive submergence. Most of the areas containing hydrilla are in warmer climates where waterways are not drawn down for a required length of time necessary for the weevil to mature (Buckingham 1987).

A leaf mining fly (*Hydrellia pakistanae*), also from India, looks very promising for the control of hydrilla. All of its immature stages are found on submerged hydrilla, so it is more useful in the Southern United States than the weevil (Buckingham 1987). Both hydrilla insects have recently been approved for field release in the United States, and studies are continuing (Buckingham 1988).

Two insect species are currently being investigated for use against Eurasian watermilfoil. The *Parapoynx stratiotata* and a European aquatic moth, *Acentria nivea* (Habeck 1983; Buckingham and Ross 1981, respectively). Neither species is considered to be host specific on Eurasian watermilfoil, so neither has been distributed for weed control. Painter and McCabe (1988) present evidence that a native population of *A. nivea* largely caused the decline of Eurasian watermilfoil in Ontario, Canada, during 1987, so further research is in order. In the meantime, search for biocontrol species continues for the control against Eurasian watermilfoil.

The waterlettuce weevil (*Neohydronomus affinis*), a native of Brazil, was released for testing in Florida in 1987. Two years later, virtually all waterlettuce in the test lake was gone. Monitoring is continuing, but results are so promising that arrangements are being made for other waterlettuce infested water bodies to receive the weevils for controlling the plant (Thompson and Habeck 1988).

Insects generally take longer to control an obnoxious aquatic plant population than fish. However, fish are not very selective and must be distributed wherever needed. Insects, on the other hand, are used only for specific plant species and most are able to fly to new waterways (Buckingham 1987).

The use of plant pathogens for biological control of aquatic plant species has so far not been important enough to produce commercially. *Cercospora rodmanii* was shown (Charudattan et al. 1985) to be successful in controlling waterhyacinths when plant growth was reduced by lack of nutrients, insect damage, or application of sublethal doses of herbicides.

More specifically, Charudattan (1986) found that control could be attained by combining *C. rodmanii*, *Neochetina* weevils, and 2,4-D amine or diquat. Martyn (1985) reported using the pathogen *C. piaropi*, alone for destroying large populations of waterhyacinths in Lake Conroe in Texas. Additional study is needed to determine what environment is necessary for optimal effectiveness of pathogens and to find other effective species of specific pathogens.

Two other pathogens that have shown some success are *Fusarium roseum* on hydrilla and *Mycloleptodiscus terrestris* on Eurasian watermilfoil (Charudattan et al. 1980; Gunner et al. 1988, respectively). Studies are continuing on both species.

Grazing by animals can be a very effective method of biological control. Grazing can be used to control many herbaceous weeds and reduce growth of woody species through the grazing of tender shoot tips. Animals such as cattle, sheep, and geese can be used to graze ditchbank areas.

The effective use of grazing requires herding or fencing and rotation of animals through grazing areas. Livestock guards or gates are necessary to provide easy access to ditchbank roads by vehicles, and at the same time, prevent livestock from escaping from fenced areas.

Although grazing is an excellent method of controlling vegetation, there are some disadvantages. Where ditchbank communities are composed of a mixture of weed species, livestock will usually engage in preferential grazing of the most palatable species. This will favor survival of less palatable weeds and could lead to their dominance of the community. Such weeds might be completely undesirable as ditchbank vegetation.

Since many seeds can pass through the digestive tract of animals and still remain viable, livestock are efficient disseminators of weed seed. In order to prevent the dissemination of noxious or undesirable weeds, animals should be grazed on areas free of undesirable weed species or held off such areas prior to their introduction to ditchbanks. Large animals such as cattle or horses tend to damage bank slopes and increase potential for erosion, while smaller animals such as sheep tend to damage slopes less.

Use of two or more forms of control of aquatic plant pests together can be more economical or more effective than one technique alone. The combination of two or more control techniques is known as integrated pest management (IPM). Fewer numbers of fish or insects may be necessary when an area is first treated with chemicals or is mechanically harvested to reduce vegetative biomass prior to stocking. To use this kind of control, however, herbicide residue levels must be within safe limits before fish or insects are stocked, and dissolved oxygen levels must be adequate for the species to be stocked.

4.10.10. Competition and Mulching

Another type of biological control that does not involve actual destruction of a plant is competition by living and dead plant materials. Plant competition, depending on species and environmental condition, can be an effective method of weed control. Plants compete with each other for light, nutrients, water, space, and carbon dioxide (required for photosynthesis).

Those species that can use these factors to the disadvantage of others could shade or crowd out other less competitive species. If a desirable species were highly competitive, its propagation and spread could result in lower maintenance requirements and consequently lower costs. In a weed control program, control of other species through the establishment of desirable species should be a long-term management goal.

A desirable species that competes well with one community of weed species may not be competitive with other species. For example, under favorable environmental conditions and appropriate plant community, Bermuda grass can form a dense turf or stand and crowd or shade out many weed species. But because of its intolerance to shading, spread of Bermuda grass can be limited by such tall-growing species as Johnson grass.

Currently, selected plants are being evaluated for competitiveness with weeds. For example, slender spikerush, a low-growing aquatic plant, competes well with aquatic weeds. Due to its low-growing characteristics, it does not impede the flow of water as do other aquatic plants.

Dead vegetation used as mulch, either cut or uncut, can protect soil against erosion and at the same time shade out some weed seedlings. Mulching helps control weeds by preventing light from reaching young weed seedlings. This, in turn, prevents the light-dependent process of photosynthesis, and weak seedlings or plants die. Mulching is not a practical method for controlling established perennials, but where it is thick enough to prevent penetration of light, it can inhibit growth of seedlings and some low-growing annuals.

Mulches may be composed of dried weed vegetation, straw, hay, paper, plastic, or other materials. Dried weed vegetation may include cuttings or intact vegetative parts that have been desiccated via flaming, frost, or herbicides. Nonvegetative mulches such as plastic and geotextiles are often impractical for large-scale situations but may prove functional for small critical areas. Dried weed vegetation, either cut or uncut, may appear unsightly in areas where esthetics are a prime importance. The removal or burning of dried mulching materials destroys their value for erosion and weed control.

4.10.11. Chemical

When used properly, chemicals (herbicides) are very effective tools to use in achieving the goals of a weed control program. However, improper use could result in poor control of target weeds, damage to crops or desirable plants, and contamination of the environment, especially water, soils, and crops.

The effective use of chemicals to control pests requires personnel who are well trained in the application of a chemical, modern equipment to apply a chemical according to labeling requirements and good records of when, where, and how a chemical was applied and the result of that application.

When herbicides are being considered for weed control purposes in aquatic and ditchbank environments, there are several biological, water, physical, and chemical aspects that should be considered before a final decision is made. Major aspects are outlined as follows.

Problem Analysis

Biological Aspects

Identify problem weed species, know growth habits.

Determine density, stand, extent or scope of problem and stage of weed growth.

Determine species of fish or wildlife, or both, that use area to be treated or that might be affected by movement of herbicides through either the soil or water.

Water Use Aspects

Identify water use(s) (irrigation, potable, recreational, fish production, livestock, wildlife). The use of many herbicides is specifically prohibited under certain water use conditions.

Determine length of time water can be quarantined from each use. Some herbicides (diquat and endothall) can only be used if treated waters are held for specific periods.

Hydrology of Water to be Treated

Size of channel and depth are required to determine amount of herbicide required.

Water flow or velocity information is needed to determine contact time of herbicide on aquatic weeds. This is a prime factor in success of herbicides in flowing water. (Many herbicides are prohibited from use in flowing water.)

Water Quality Characteristics of Treatment Area

Turbidity and suspended solids in flowing water can deactivate herbicides such as diquat by adsorption on clay colloids.

Water temperature affects rate of activity of herbicides with weeds.

The pH of water will affect chemical structure of some herbicides and consequently their efficacy.

Dissolved oxygen is critical to life support of many nontarget aquatic organisms. Herbicide treatments should be made in a manner that minimizes impacts on dissolved oxygen. Water hardness as calcium carbonate affects chemical characteristics and buffering capacity of water. High values may inactivate herbicides such as copper sulfate. Low values may cause toxic conditions for fish and other wildlife when herbicides are applied.

Physical Terrestrial Aspects

Ascertain soil texture and organic content. The soil may be subject to unacceptable sloughing or erosion if vegetation is not managed properly or is eradicated. If soil residual herbicides are being considered, heavy soils (clays) or soils with high levels of organic matter will often require a higher rate of application than light soils.

Slope of ditchbank should have a suitable gradient such that control or eradication of vegetation does not increase the potential for soil erosion. Erosion potential of herbicides in soils should be considered.

Herbicide Selection Criteria

Safety

The herbicide should be safe for applicators and for fish and wildlife. Read label and use the herbicide strictly in accordance with cautions, warnings, and directions. Know the antidotes. Antidotes and toxicity properties for important herbicides also are listed in the *Herbicide Handbook* of the Weed Science Society of America (1983).

Effectiveness and Selectivity

Most herbicides are designed to control target weeds. The conditions for which herbicide is most effective in controlling the target weeds should be determined. There are several plant factors (leaf shape and angle, leaf waxes or leaf hairs or both, vegetative density, growth vigor, stage of growth), environmental factors (temperature, humidity, light, available moisture), and application factors (formulation, pH, surfactant, droplet size) that determine effectiveness of a herbicide.

In order to use any herbicide successfully, these interacting factors should be well understood by weed control personnel. These factors are generally covered, though briefly, in weed control training courses and are explained in introductory weed control texts (Klingman and Ashton 1982; Muzik 1970). Herbicide selectivity is an important tool when the objective is to eliminate undesirable species while retaining desirable species. The reasons for selectivity should be understood by weed control personnel, since improper usage might eliminate the selective qualities of a useful chemical.

Publications on chemical weed control suggestions can be obtained from the state extension service or from federal sources. A federal publication is *Guidelines for Weed Control.* For best results with a herbicide, follow label directions, which in many cases are legal requirements.

Residues

The intended use of a herbicide should not exceed the legally established tolerance for the herbicide in water or in or on a food crop. The consequence of residual soil activity of soil applied or even foliar applied herbicides should be considered.

Cost

In some cases, cost may be a limiting factor in selection of herbicides. In formulating a weed control program, whether with herbicides or other methods, costs should be considered on a long-term basis.

Availability

The immediate and future availability of herbicides also should be considered.

Personnel

Field crews should be trained for the application of a particular herbicide. Field applicators and supervisors are often required to be licensed and should be knowledgeable in operation and calibration of spray equipment.

Additives

Various additives are included in a pesticide to facilitate or enhance the effectiveness of the active ingredient. Any given pesticide contains one or more active ingredients and an inert diluent or carrier. Several additives may be mixed in at the time of manufacture; others may be added or increased at the time of use. Surfactants are added to overcome surface tension and to make sprays more effective in other ways. "Surfactant" is a coined word which combines the words "surface active agent."

Environmental Protection Agency (EPA) and State Registration

Herbicides should be registered with the EPA for their intended use along irrigation ditchbanks or in the site to be treated. Note that although several chemical companies may manufacture the same formulation of a herbicide, all such formulations may not be registered for the same intended uses. The mixing of a herbicide with one or more herbicides is only permitted if the label registration permits such mixtures. The registration status of federally registered herbicidal uses is summarized in the EPA's *Compendium of Registered Pesticides*, volume No. 1, "Herbicides and Plant Regulators."

Laws and Regulations

Pesticides are defined in brief as any substance or mixture of substance intended to eliminate a pest. Herbicides are a class of substances intended for specific use similar to insecticides, rodenticides, and disinfectants.

The amended Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1972, its regulations, and subsequent amendments are administered and enforced by the EPA. The EPA has agreements with nearly all states to administer and enforce provisions of FIFRA. FIFRA regulates registration, labeling, formulation, distribution, use of pesticides, and training and certification of pesticide applicators in the United States. This all applies to the pesticide use by water system managers and water users.

All who apply pesticides or supervise their use should be familiar with the basic requirements of federal, state, and sometimes county and local pesticide laws, regulations, and policies. In addition, all who apply must know how to comply with these established guidelines and should keep abreast of changes that impact their pest control operations. This is accomplished by maintaining regular communication with respective regulatory agencies and primarily the local agency.

The local agency usually issues permits, checks equipment and licenses, and conducts the initial investigation and enforcement if there is a problem, injury, or complaint. A well-planned program includes the above which usually prevents any errors or problems followed by legal regulatory action. READ THE LABEL AND LABELING!!

Herbicide Classification

Herbicides may be classified in several ways. One common method is to group herbicides into three general classes—contact, systemic, and soil applied.

Contact herbicides kill by direct contact with plant tissue. Due to their inability to kill via translocation within the plant, contact herbicides must thoroughly cover the surface of target plants (Klingman 1961; Muzik 1970). Proper coverage with a contact will control most annual weeds but will only chemically mow (burn off) tops of perennial weeds. Depending on degree of wetting by foliar sprays and based on plant characteristics, such as cuticle uniformity and thickness, leaf arrangement (angle), and bud locations, contact herbicides may be *selective* or *nonselective*. A selective herbicide will kill or injure specific plants while not injuring others. For example, Stoddard's solvent, an aromatic oil, will kill weeds in a carrot plant without harming the carrot. Nonselective herbicides kill any plant tissue contacted.

Systemic herbicides are absorbed either by roots or above-ground foliage growth and translocated via the vascular system (with water in xylem or with food in phloem, or both) to different parts of the plant. The selectivity of these herbicides is usually biochemical in nature, involving differences in enzyme systems. To kill established perennial weeds, herbicides in the systemic group must be translocated to underground parts such as roots, rhizomes, and tubers.

The growth stage and rate of application is important in achieving control of perennials. *Foliar-applied* systemic herbicides move to underground tissue with food products of photosynthesis. To accomplish this, the systemic herbicide must be applied at an appropriate growth stage to allow for the source-to-sink translocation of plant food plus herbicide to underground parts.

For herbicides to be available for translocation, they must be absorbed and conducted by living cells. This, in turn, requires the right rate or dose of application since high unrecommended rates of application could kill the absorbing and conducting cells required for the translocation of the herbicide.

In addition to rate of application, rate of absorption and translocation must be such that enough of the herbicide is conducted to underground tissue to kill buds capable of producing shoots. To accomplish this type of kill, repeated applications of the systemic are usually warranted. Examples of systemic foliar-applied herbicides include glyphosate and the phenoxy herbicides, such as 2,4-D. Glyphosate is a herbicide that is excellent in controlling perennial weeds and also annual weeds at very low rates.

Soil-applied herbicides prevent emergence and growth of plants. In most cases, rate and frequency of application and rate of inactivation will determine if residual is temporary (less than 1 year) or relatively permanent (more than 1 year). Examples of soil-applied herbicides include such compounds as diuron and sulfonylurea.

Herbicide Mode of Action

Another classification of herbicides is primary mode of action. This is another factor to consider when selecting an herbicide by its activity in the plant and safety to the applicator. Mode of action is the mechanism by which the herbicide kills the plant. For example, growth regulators kill plants by interfering with the normal plant hormone system, thus causing abnormal growth and finally death of the plant. The photosynthesis inhibitors stop photosynthesis and the mitotic poisons disrupt normal cell division. A detailed description can be reviewed in *Mode of Action of Herbicides* (Ashton and Crafts 1981).

Herbicide Formulation

Formulation of herbicides is another important selection consideration. Herbicides may take a given physical form as a consequence of chemical makeup or may be prepared in a specific form to facilitate application.

Soluble Forms

The chemical can be dissolved in water or oil. The resulting solution does not separate into solute and chemical if allowed to stand, and after initial mixing, agitation is not required. Most herbicides fall into this category.

Emulsion

This type of preparation permits mixing oil-like chemicals with water. The emulsifier may be added to the herbicide at manufacture or just before use as with xylene. The better the grade of emulsion, the less agitation is required to mix it with water. A good emulsion is cream colored and does not separate into its components for a considerable time.

Wettable Powder

This type contains a pesticide that has been mixed with or sprayed on a carrier powder. The entire mixture has been treated with a wetting agent to go into suspension in water readily. Spraying of wettable powders requires constant agitation of water carrier. The solubility of the herbicide determines how quickly it is freed from the carrier and depth to which it is leached into the soil with a given amount of precipitation, thereby determining depth of soil treated. Many soil-applied herbicides are prepared as wettable powders.

Granules and Pellets

The herbicide is incorporated with clay or another dry diluent to facilitate spreading a small quantity of active ingredient over a large area by hand or machine application. The release and action of the herbicide are the same as with wettable powders. Granules and pellet forms are widely used for soil-applied materials.

Major Herbicides in Irrigation and Drainage Ditches

The use characteristics and environmental aspects of major aquatic herbicides used in western states irrigation conveyances have been discussed in the *Herbicide Manual* (US Bureau of Reclamation 1983). Most of the herbicides discussed have only been used in the southwestern United States. These herbicides and their uses are also discussed in *Weed Science: Principles and Practices* (Klingman and Ashton 1982).

4.10.12. Summary

In the administration of a successful weed control program, problem weeds and desirable plant species must be identified and their biology understood. The long-term goals or objectives of a weed control program must be determined. The knowledge of weeds and program goals should be applied to appropriate and economical weed control measures on an extended basis. In successful programs, several control measures previously described are employed in an integrated approach, where program goals are obtained in a cost effective and environmentally safe manner.

Weed control personnel, both field and supervisory, should be trained in efficient weed control methods and obtain necessary professional certification. Personnel should be supplied with appropriate modern application equipment and be responsible for properly maintaining the equipment. To receive adequate training and maintain proficiency, personnel must attend appropriate pesticide meetings and workshops.

In addition to meetings, supervisory personnel should remain current with publications dealing with their weed control problems and maintain contacts with state extension and university weed control personnel. The attendance at meetings and contacts with regulatory officials is essential to ensure compliance with all federal, state, and local rules and regulations.

Finally, records of all weed control efforts, especially for herbicides, should be maintained, summarized, and exchanged with colleagues.

4.11. MAINTENANCE OF CLOSED CONDUIT (PIPE) SYSTEMS

This section deals with the maintenance and repair of closed conduits. System operations are covered in section 3, and no discussion of this subject will be included here, although the operation of the system will have considerable influence on the overall system maintenance and repair program.

4.11.1. Type of Systems

There are three main types of pipe systems (discussed in section 3), low-head open, low-head closed, and high-head or pressure systems. The type of system is determined by head class and type of conduit found within.

Low-head open systems are generally those with unreinforced cast-in-place concrete pipe for heads to 10 ft (3 m) and unreinforced concrete pipe with mortar joints or rubber gasket joints designed for heads up to 20 ft (6.1 m).

Low-head closed systems within the head range of 20 ft to 150 ft (6.1 m to 38.1 m) may have reinforced concrete pipe with rubber gasket joints, asbestos-cement (A/C) pipe, reinforced plastic mortar pipe, and polyvinyl chloride (PVC) pipe, or a combination of these various types of pipe.

High-head systems may have either prestressed noncylinder or cylinder pipe, pretensioned concrete cylinder pipe, asbestos-cement pipe, steel pipe, PVC pipe, reinforced plastic mortar, ductile-iron, or a combination of these various types of pipe.

In pipelines, maintenance of both conduits and appurtenances must be considered. These appurtenances include sectionalizing valves; metering devices; moss screening mechanisms; pumps and motors of various types; electrical controls; regulating devices such as control valves, tanks, and reservoirs;

slide gates; and some type of automated equipment and controls. The appurtenances on the pipe system will generally require more extensive maintenance than the conduit itself regardless of system type.

The complexity of the system will determine which crafts and types of technicians must be included and integrated into the maintenance organization. Once the maintenance superintendent is equipped with a staff, he or she must next obtain or develop written maintenance procedures. These procedures should be in sufficient detail for the maintenance foreman and crew members to clearly understand the contents of all documents. Much of the necessary information is included in important documents such as designers operating criteria, carefully prepared "as-built" drawings of the completed system, and manufacturer operation and maintenance instructions.

If these documents are not available, the superintendent should develop a field manual with definitive maintenance procedures for upkeep and preventive maintenance work on the system. Appendix G has examples of forms that may be used to assist the maintenance superintendent in reporting and scheduling work on a closed conduit system. Pertinent data can be entered on the forms for reproduction and inclusion in field manuals as examples to aid and direct maintenance personnel in their duties.

4.11.2. Maintenance of Buried Conduits

Conduit is the greatest share of initial cost of any pipe system. Adequate quality control during the manufacturing process, coupled with good project construction management and skilled workers to install the conduits in the system, determine for the most part how extensive the agency field superintendent must plan his maintenance program.

Under today's system of design and construction, the agency will normally find that approximately 90% of the conduit's potential failures will occur and be corrected during initial field tests made at the completion of system construction. Approximately 95% of the remaining 10% of potential failures will occur during the maintenance warranty period of the pipeline system, assuming a 3-year warranty period.

More time will usually be spent on pipeline repairs than on maintenance. Conduits of large diameter, large enough to allow personnel to enter the system, should be scheduled for periodic interior surveys for damage to linings, corrosion, separation of pipe joints, and for any buildup on the pipe walls (bryozoa [aquatic organisms], and calcium carbonate). Fresh water clams may create problems in some areas.

Copper sulfate, chlorine, and acrolein are very effective cleaning and control agents for pipe interiors. Chemicals must be used with extreme caution if water service is provided for human and animal consumption or when there is potential damage to agricultural lands and crops (see section 4.10.).

Pipeline systems constructed in areas where land subsidence may be experienced should be provided with suitable reference points to monitor possible movement of the conduit. In areas of known subsidence, prewetting or preconsolidation of pipeline locations should precede installation of pipelines to restrict or possibly eliminate unequal land subsidence. Pipe alignments in known land subsidence areas should be regularly inspected for any areas of unusual settlement that may cause pipe leaks.

Leakage at pipe joints is the most troublesome problem associated with pipe systems. The method of repair requires investigation to determine original construction of the pipe joint and materials used in the manufacture of the conduit. In general, repair work should be approached with the intent to use the same type of material as originally used by the manufacturer and constructor. There may be, however, other compatible substitute materials on the market for use in joint repairs.

Concrete Pipe

The pipe joint is probably the most important single feature in any pipe system, especically in a concrete pipe system. A good pipe joint must be flexible enough to permit longitudinal movement due to temperature changes in the water, wetting, and drying of the pipe. Vertical displacement due to settlement that sometimes results from the application of irrigation water to adjacent lands must also be accommodated.

Low-head pipe initially used tongue and groove precast concrete pipe with a mortar-banded, rigid-type joint (type B, Fig. 22). Pipelines laid with this joint have a low first cost, but generally a higher maintenance cost. This type of pipe joint gives satisfactory service in low-head, open-standing type systems; however, heads on this pipe should not exceed 20 ft (6.1 m) measured from the center of the pipe.

The rubber-gasketed pipe joints (R-1, R-2, R-3, and R-4) are very dependable and are now used exclusively for most pipe systems with all ranges of head. Similar types of rubber-gasketed joints are also used with steel, plastic, ductile-iron, fiberglass, asbestos-cement (A/C) and other types of pipe.

Principal causes of leakage in precast reinforced or unreinforced concrete pipes, in addition to joint failures, are broken backs or bellies, broken collars, splits, temperature cracks, and settlement at structures. During construction, the pipe should be carefully bedded to provide uniform support for its full length. If this procedure is not followed, the result may be circumferential cracks that may develop into broken backs or broken bellies and can also result in broken collars.

Splits, which are longitudinal cracks, are sometimes caused by the pipe having experienced water hammer (surges) caused by filling the pipeline too quickly or closing an inline valve too quickly, or expanding in length from warming or absorption of moisture. Large-diameter siphon pipes have been found with crushed joints and breaks in collars allowing water to bypass gaskets. This was attributed to installing pipe on a steep grade and on granular backfill allowing pipe to slowly migrate downslope.

Temperature cracks are most prevalent in unreinforced concrete pipe but can cause trouble in reinforced pipes as well. These cracks occur when colder than normal water is introduced into the pipes which contract and literally pull themselves apart. The cracks are usually circumferential, will vary in width from hairline to 1/4 in. (6 mm), and may occur at locations other than mortar joints. Temperature cracks may be aggravated by laying the pipe in extremely hot weather without sufficient protection. Temperature cracks are sometimes mistaken for broken backs or vice versa.

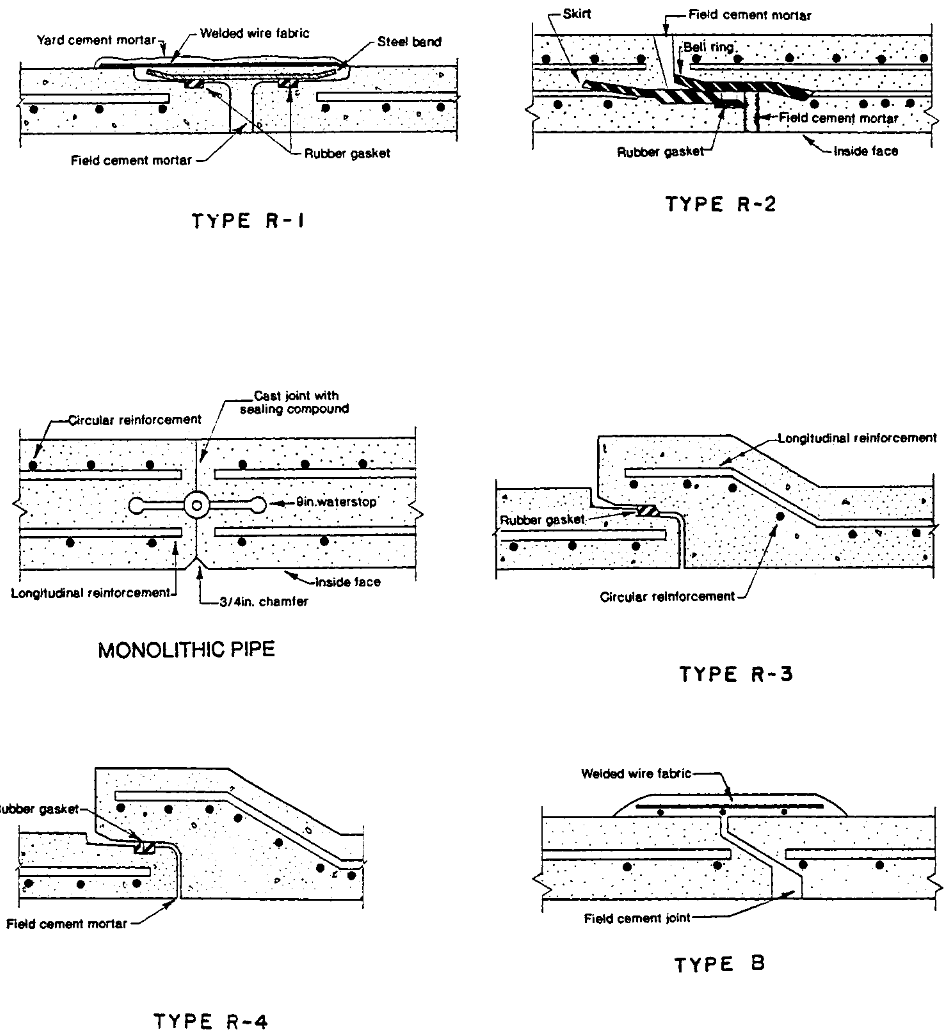


Fig. 22. Concrete Pipe Joints

One of the most expensive pipeline failures is caused by settlement of structures. Structures are likely to settle due to differences in weight or unequal compaction of foundations. When structures do settle, pipes may be sheared at entrances to the structure. Repairs of shearing cracks due to settlement of structures tend to be expensive. It is frequently necessary to chip away part of the structure to make a flexible connection. At other times, the entire structure must be replaced. Most specifications require a flexible joint within 18 in. (450 mm) or one-half the pipe diameter from the structure.

Among the quickest and easiest ways to stop low head pipeline leaks is the introduction of material into an operating pipeline to act as a sealant for small cracks. Sealants may be horse manure, peat moss, or sawdust.

Sawdust flour and coarser ground sawdust can be mixed with water and pumped into a pipeline. However, these materials may tend to plug or damage appurtenant structures such as valves and meters. These sealants may be undesirable if the pipe is supplying water to a sprinkler system or for municipal and industrial uses.

The introduction of anhydrous ammonia (NH_3) to water flowing in low head concrete pipelines has been beneficial. The success of the method depends on precipitation of calcium carbonate when ammonia is introduced. Unfortunately, the action does not occur with all waters (Morrison and Walker 1969).

A method commonly used to repair transverse broken backs or bellies in irrigation pipe consists of chipping or chiseling the crack to form a V-notch 1½ to ¾ in. (13 to 19 mm) wide and deep. Leakage can then be stopped by caulking with lead wool. After the caulked notch is thoroughly cleaned by wire brushing or sandblasting, an epoxy-base compound or mortar can then be troweled into the notch.

The exterior of the notch should also be troweled to form a relatively uniform surface. A piece of sheet rubber can then be wrapped around the crack, then covered with a thin metal band cinched up with narrow steel bands. After cleanup and drying of the area, foundation for the pipe should be compacted and a concrete encasement placed around the pipe.

Rubber-gasketed joint leaks caused by pinched gaskets also can be stopped under pressure by caulking with lead wool. As the joint commences to work, there is a good possibility that eventually the joint will again leak. Filling the joint with concrete after caulking often may cause shearing next to the filled joint; however, some repairs have been successful with this method.

Some agencies have arrived at the conclusion that one cannot effect a permanent cure for leaks in a mortar-jointed concrete pipeline that must operate under low water temperatures. Where such conditions exist, the pipe is replaced with rubber-gasketed pipe of concrete, asbestos-cement, or PVC, whichever is the most competitive on a year-to-year basis. Asbestos-cement pipe should be the pipe choice of last resort due to the presence of asbestos particles.

In a warm nonfreezing climate, preventive maintenance on concrete pipelines consists of keeping pipes full of water at all times, even during nonoperating season. In a cold freezing climate, all pipelines must be drained and kept empty during the cold months. Periodic inspection of large diameter pipe interiors and necessary repairs to interior coatings, joints, etc., must be made.

Asbestos-Cement (A/C) Pipe

Asbestos-cement pipe has been used in irrigation and drainage systems for low and high heads particularly in sizes through 24 in. (610 mm) in diameter. This pipe is immune to rust and chemical, galvanic, and electrolytic types of corrosion and is considered one of the most corrosion-resistant pipes in general use.

Although asbestos-cement pipe exhibits many desirable characteristics, its use in irrigation systems has been less extensive in recent years because of asbestos-related exposure restrictions. When required to tap into asbestos-cement pipe, the maintenance manager should refer to Recommended Work Practices for A/C Pipe published by A/C Pipe Producers Association.

Asbestos-cement pipe is not as susceptible to temperature cracks as unreinforced concrete pipe. One report states that cement is the only constituent of asbestos-cement pipe liable to corrosion attack, thus, oxygen plays no part in its corrosion.

The pipe is attacked only by aerobic acid soils and soils that are alternately aerobic and anaerobic because acidity is the only decisive factor.

Breaks in (A/C) pipe may occur as broken joint collars, broken backs, broken bellies, and occasionally, as pressure breaks. However, past experience seems to indicate very little trouble with properly installed asbestos-cement pipe. Repair of asbestos-cement pipe can readily be made by use of a standard stock repair kit consisting of three couplings with gaskets and two one-half joints of pipe. Since some sizes of repair kits for this pipe are not available, other types of repairs have to be used. The maintenance manager should refer to A/C Pipe Producers Association publication on proper repairs to asbestos-cement pipe to avoid exposure of maintenance workers to asbestos.

Steel Pipe

Corrosion is probably the greatest concern associated with steel pipe, and any pipe that has steel components including reinforced concrete pipe and prestressed concrete pipe. In an area in which the soil is highly corrosive, most pipe with steel components can be protected effectively by cathodic protection.

The joints should be electrically bonded at the time of installation. Corrosion test stations should also be installed throughout the system for the purpose of providing electronic access for testing. Regular monitoring of the system will help determine if additional protection is needed.

Test stations should be clearly identified. The maintenance superintendent should schedule periodic field inspections to repair or replace damaged identifying markers and to check for possible damage, particularly of conductors leading to the test stations. Maintenance crews should be fully briefed on locations of buried cables to avoid underground damage and loss of any of the cathodic protection system.

A complete cathodic protection survey should be made annually using test stations to assure that cathodic protection is functioning properly. Larger pipe systems may justify having corrosion engineers or technicians on the maintenance staff; otherwise, consultants can be called in to assist in this important program. System standing operating procedures should provide clear and complete instructions for maintenance of cathodic protection systems.

Reinforced Plastic Mortar (RPM) Pipe

Commonly called RPM pipe, this pipe has been designed in sizes from 8 in. (100 mm) to 54 in. (1370 mm) in diameter. Experimental pipe up to 96 in. (2,400 mm) in diameter has been fabricated and tested. The

RPM pipe is composed of several layers of glass reinforcement, sand and aluminum silicate filler, and polyester resin. The nomenclature RPM has now been changed to fiberglass. Fiberglass pipe now includes glass-fiber-reinforced, thermosetting-resin pipe, and glass-fiber-reinforced plastic mortar pipe.

Plastic Pipe

Plastic pipe of the PVC type in diameters up to 27 in. (686 mm) is now being used with no apparent problems.

4.11.3. Appurtenant Facilities

The number and type of appurtenant facilities in a pipe system will require the majority of maintenance and preventive maintenance work on the entire system. This is especially true in systems with many pumping plants and moss screen structures.

Supervisory maintenance personnel should be selected well in advance of completion of the system. In large pipe systems with complicated structures and machinery, it would be well to have the maintenance supervisor on the job during construction. This observation period can be well spent in compiling data, studying installation drawings, and determining spare parts inventory requirements. Also during this period, preliminary plans should be formalized for proposed maintenance staff, shop facilities, and mobile equipment needs.

At the time the system is placed into operation, a system of record keeping should be established. In large pipe systems, it may be desirable to arrange maintenance of mechanical and electrical equipment under separate departments. In very large systems with many pumping plants, separate departments generally are a necessity.

Water Metering Devices

One of the most important devices on the pipeline distribution system is probably the water meter. Flowmeters are used at the canal and lateral turnouts for system water management and near the user delivery point for on-farm water management. The most common type of delivery meter in agricultural closed pipe systems is the propeller-type meter.

More recently, flow-control type meters have been introduced for use on closed systems that are subject to considerable fluctuation in the pressure gradient. This type meter is designed to reduce delivery head to maintain a constant flow rate for deliveries made into farm ditches, especially ditches where the water user employs siphons to apply water to the field.

On low-head pipe systems, the calibrated meter gate is probably the most commonly used metering device. Open flow-type propeller meters are also often used and are very adaptable to low-head open systems. The open flowmeter propeller is located at the base of the register shaft that projects into the open end of the conduit. This type of meter should be fixed to the structure headwall with interlocking brackets. The bracket arrangement allows ready removal of the meter for servicing and maintenance work.

Ultrasonic and orifice-type flowmeters are also being used for agricultural applications. If good water management is to be attained, a strong meter maintenance and preventive maintenance program should be established. After the meter has been installed, an installation and maintenance form such as those shown in Figs. 23 and 24 can be useful. Minor meter maintenance work should be entered on the meter log in chronological order. Major meter work such as complete breakdown and parts replacement can be recorded on a form such as Fig. 25. If the water agency is of sufficient size to warrant a microfilm copier or computer, these data should be transferred to the appropriate data storage section.

A good meter maintenance program also means reliable meter accuracy. A meter testing facility should be constructed as soon as possible, particularly if many propeller-type meters are used. The permanent testing facility can be equipped with mechanical or electronic type test meters. Fittings for pitot tube testing should also be integrated into the testing facility. Fig. 26 is a sample form for recording meter test results.

Preventive maintenance work will greatly strengthen meter dependability. Generally, propeller meters should be inspected periodically depending on the flow through the meter. Propeller watermeters should be inspected at least every 2 years regardless of flow through the meter. Metal ball bearings will wear very rapidly in water with high salt concentrations. Ceramic bearings are a good alternative. A sizeable inventory of spare meter parts is essential in this type of preventive maintenance program. Annual meter maintenance costs should not exceed 5% of initial cost of the meter. Annual maintenance costs of 2 to 3% are typical.

Pumping Plants and Moss Screen Structures

Pipeline systems originating at diversion dams, reservoirs, well fields, and canals may have pumps to furnish the system with sufficient operating heads. The plant structures may be of the open or completely closed-in type. In all cases, as discussed in subsequent sections on the maintenance of mechanical, electrical, and hydraulic equipment, trashracks must be provided for such plants serving pipeline systems. In addition, on most pipeline systems, moss screens also should be an integral part of each plant.

Although complex plants are not found on many pipe distribution systems, the motor control center should contain a plant log book for recording plant operation and for use in scheduling and tabulating maintenance work. Appendix G has examples of history and maintenance records for items of machinery.

Valves

A pipeline distribution system will have both buried and exposed valves of various types and descriptions. All valves will require maintenance to some degree, but a periodic inspection and an opening and

LUNF 112

METER INSTALLATION AND MAINTENANCE PROGRAM

WATER USER	LOCATION	SIZE	MANUFACTURER	METER NO.	DIRECTION	TIME	APPLICATION

REMARKS:

CERTIFIED LAND ELIGIBLE BY: ____________________ APPROVED BY: ____________________ C.E.

DATE: ____________________ DATE: ____________________

DATE INSTALLED: ____________________

BY: ____________________

Fig. 23. Meter Installation and Program Form

closing operation should be scheduled for buried valves. This will ensure that the gates are free and not binding or frozen due to corrosion or debris. If problems are discovered, repairs should be scheduled as soon as possible.

LUNF 113

MAINTENANCE
METER LOG

Date Installed ____________________ Delivery No. ____________________

Type ____________________ Initial Reading ____________________

Manufacturer ____________________ Serial No. ____________________

DATE	REMARKS	MAINTENANCE TIME	
		EQUIPMENT	LABOR

Fig. 24. Meter Maintenance Form

Closing a system down because of a buried valve malfunction could be very troublesome and costly, especially on those systems that are in use throughout the year. Buried butterfly-type valves are becoming more popular; these valves may prove to allow some adjustment in periodic inspec-

LUNF 114

IRRIGATION AND DRAINAGE SYSTEMS

METER MAINTENANCE REPORT

DEL. NO.__________ SIZE __________ DATE__________ 19 __________

METER S.N.__________ MANUFACTURER __________

Foreman__________ Crew__________

WORK PERFORMED __________

EQUIPMENT USED __________ HOURS__________

LABOR __________

REPORT BY __________

Fig. 25. Meter Maintenance Report

tion intervals and, hopefully, less maintenance. The O-ring seals for various sizes and types of valves should be carried in stock at all times.

Manufacturer drawings and operating instructions should be a part of the maintenance superintendent's file, especially for valves equipped with hydraulic control devices.

LCNF 115

METER TEST DATA

MANUFACTURER ______________________ DATE ______________________

METER NO. ______________________ MEAS. BY ______________________

LOCATION ______________________ CHKD. BY ______________________

MAXIMUM CAPACITY ______________________

PITOT TUBE TYPE __________ SERIAL NO. ______________________ TIME START __________

	DISTANCE	DIFFERENCE	VELOCITY	DISTANCE	DIFFERENCE	VELOCITY
1.						
2.						
3.						
4.						
5.						
6						
7.						
8.						
9.						
10.						
11.						
12.						
13.						
14.						
15.						
16.						
		Total			Total	
		Mean Velocity			Mean Velocity	

Mean Diameter __________ Area Sq. Ft. __________ Mean Velocity __________

C. __________ Q. __________ Total Q. __________ Time End __________

Totalizer End __________ Elapsed Time __________

Totalizer Begin __________ Min. __________ Sec. __________

Difference __________ Total Sec. Run __________

REMARKS: ____

Fig. 26. Meter Test Data Form

Air release and vacuum valves should be placed in the same category as line valves in the maintenance program. These valves perform a very important and necessary function in a pipeline distribution system and should be kept operable at all times. Trapped air in conduits could cause serious damage. An adequate supply of spare parts should be kept in stock to avoid delays for emergency repairs. "As-built" records should be on hand to show the location of all corporation cocks at the beginning of air release lines off the main conduit.

Automation

The automation of water distribution systems to various degrees is rapidly becoming more feasible and less expensive. The operation of an automated system should prove to be more efficient; however, additional maintenance will be required. The need for more technically oriented maintenance personnel must be considered. Again, the size of the system and degree of automation will determine whether the agency should staff-up with its own personnel or rely on commercial maintenance contracts.

From the standpoint of efficiency, serious consideration should be given to employing staff technicians. Maintenance and preventive maintenance schedules and inspections should be developed to satisfy the needs of the equipment furnished with the system.

4.12. DRAINAGE SYSTEM MAINTENANCE

4.12.1. General

Basically, the three types of drainage systems are open or ditch type, closed or buried-pipe type, and drainage-well type with each system having its unique maintenance problems. However, an adequately designed and constructed drainage system should provide many years of trouble-free performance with normal routine maintenance.

Generally, no attempt is made in this manual to distinguish between maintenance problems for drainage systems constructed to drain mineral soils in arid and humid regions, since general maintenance procedures are usually the same for both areas. Open or surface drainage systems require significantly more maintenance than buried or subsurface systems and have many problems similar to those previously discussed under canal systems such as weed control, bank sloughing, and wind erosion.

When a malfunction occurs in a drainage system, whether an open or closed system, it is imperative that the problem be corrected as soon as possible. This is particularly important if the problem is in a system handling subsurface drainage effluent from an area supporting actively growing agricultural crops. A stoppage in a drainage system usually will prevent the removal of free water from the soil surface or from the crop root zone in an efficient manner. Persistent free water either on the soil surface or in the root zone could either significantly affect crop yields or completely drown the crop.

Every agency or district that has the responsibility to maintain a drainage system must keep the system in good operating condition. Negligence on the part of operating personnel could be disastrous for landowners relying on a continuously functioning drainage system. When a maintenance problem develops or is suspected, a complete investigation should be undertaken. The investigation procedure, cause of the problem, and recommended corrective measures should be listed on each report. Once the problem is determined, steps should be taken to correct the malfunction immediately.

All maintenance programs should include a plan to maintain sound structures throughout the drainage system. Particular attention should be paid to inlets to the system, drop structures, and controls where a malfunction could cause severe flooding or improper drainage of the area served.

4.12.2. Open Ditch-Type Drains

Open or ditch-type drainage systems can become clogged with vegetation and sediment, and most drains soon lose their effectiveness unless properly maintained. Therefore, every effort should be made to establish a continuous maintenance program.

A grass cover should be established on ditchbanks as soon as possible for erosion control since open drains are particularly susceptible to erosion and growth of undesirable vegetation during the first several years of use. Continuous maintenance of vegetation by either mowing, pasturing, or chemical control will ensure good operation of open drains.

The most economically effective maintenance program should be established by comparing the cost of various maintenance alternatives. Open drains that are permitted to become clogged with weeds, brush, or small trees will have limited capacity and create poor drainage conditions in the area needing drainage.

Open drains are quite susceptible to the accumulation of sediment due to either erosion of drain banks or sediment load from surface drainage water entering the channel. In this regard, flood and furrow irrigation methods contribute significantly more sediment to a drainage system than do sprinkler or drip irrigation methods. When sediment accumulation is a problem, a routine program of sediment removal should be established.

Usually small clamshell diggers, draglines, or Gradall excavators used in construction of the drainage system can be utilized for removing silt and reshaping the drain banks. Unstable sandy or silty soils usually slough-in readily, particularly under high water table conditions. The spoil banks can generally be stabilized by widening, reducing side slopes, and tamping with clamshell or dragline bucket during the cleaning operation. Additional detailed information on equipment and the use of equipment in maintaining open drains is presented herein.

4.12.3. Closed Buried Pipe-Type Drains

A well-designed and constructed subsurface drainage system usually requires minimum maintenance to keep the system operating properly. The principal point of concern for a subsurface drainage system is the outlet. Even an adequate subsurface drainage system will not function properly if the outlet is not maintained to permit free flow from the drain. All subsurface drainage outlets should be protected to prevent submergence by either silt or vegetation growth. Small animals are generally excluded by installing a flap gate or open grating on the outlet of subsurface drainage systems.

In areas where drained soils shrink and swell sufficiently to cause applied irrigation water to drain away before the crop root is rewet, valves are placed on drain outlets to control flow from the drain. Generally, valves are closed until irrigation application is completed, then valves are opened to the desired position to permit the water table to be lowered at a controlled rate.

In general, surface water inlets should not be permitted into subsurface pipe drainage systems principally because of the possible sediment load in surface drainage water. Surface drainage water with a heavy sediment load can plug a subsurface drainage system in a short period of time. If surface wastewater is permitted to enter subsurface drainage systems, inlets to the system should be inspected frequently since the inlets are subject to considerable damage due to erosion or trash accumulation. Catch basins and silt traps should be installed and kept clean to prevent considerable trash and sediment accumulation in subsurface drainage lines.

When a subsurface drainage system stops functioning, the reason for the malfunction should be determined as soon as possible. Frequently, a subsurface drain placed near trees will become blocked by tree roots. It will be necessary to either remove the tree roots by hydraulic drain cleaners, mechanical means, or repair the drain line by removing, cleaning, or replacing. Water-seeking trees, such as cottonwoods, tamarisk, and willows generally cause major problems in subsurface drainage systems unless the trees are removed or killed when the drain system is constructed. The safe distance between a drain and a tree depends on climatic conditions and species of tree, but usually is not less than 100 ft (33.3 m).

In general, roots of agricultural tree crops do not cause plugging problems in subsurface drainage systems. Note that it may be difficult to mechanically remove roots that plug subsurface plastic drain lines. The use of mechanical equipment in plastic drain lines is difficult because of the nature of the plastic material. High-pressure jetting equipment can be used in plastic pipe to cut small roots (up to 3/8 in. (9.5 mm) in diameter) and help flush sediment and other foreign material from the pipe.

Improper construction of a drain line or poorly constructed connections between two drains can cause a rupture to develop. Repairs to ruptures must be made immediately to minimize sediment accumulation in the drainage system. Generally, repairs are made by replacing the drain or by covering the hole in the drain with additional pieces of drain tile.

If a subsurface drainage system becomes plugged with a considerable amount of sediment, it is usually necessary to bypass the problem area by temporarily pumping drain flow around the plugged portion of the system. It is then less difficult to remove and replace the inoperative portion of the drain line. It is important that a stable foundation be prepared prior to relaying or repairing a subsurface drain line. Repairs made on unstable material will generally fail in a short time. Successful subsurface drain lines need a properly graded blanket around the pipe to prevent piping and sediment from entering the pipe. Sometimes, installation of inlets at the upper end of subsurface drains are provided to permit flushing of the lines.

When flushing of a drainage system is possible, a large supply of water will be required to adequately do the job. It is important that a routine flushing program be developed, particularly in systems where surface water is permitted into a subsurface system.

In general, where subsurface drainage systems do not have manholes or inspection wells, the malfunctioning drain must be excavated at various intervals until the trouble causing the malfunction is located. Jetting equipment can sometimes be used to locate the problem area in a buried pipe drain.

In certain subsurface drainage systems in arid areas, the accumulation of insoluble iron or manganese oxide in tile joints may cause poor performance of the drainage system. Sulphur dioxide gas has been used fairly successfully to unclog the sealed joints of such drainage systems (MacKenzie 1962). Sulfuric acid has also been used to sucessfully clean iron ochre-clogged pipes.

High-pressure jetting equipment can be successfully used to remove the accumulations. Where the problem is severe, use of jetting equipment should be scheduled annually. Maintenance must be scheduled in problem areas prior to pipe joints becoming completely sealed or full of tree roots.

The use of insufficient or poor quality envelope material during installation of subsurface drainage systems will also cause poor operation of the drains. This type of problem is usually rectified by improving envelope condition and replacing poorly constructed drains.

Subsurface drainage systems may also fail to operate properly because drains have been installed with insufficient capacity or because drains are placed too shallow. Drain lines that are installed with too little cover are quite susceptible to collapse from surface loads crossing the drains.

4.12.4. Drainage Sumps, Pumps, and Wells

Excess subsurface ground water can be controlled in some areas through the use of drainage wells. Also, many subsurface drainage systems discharge into sumps with small pumping plants to lift drainage effluent into either open drains or adjacent subsurface drains. Drainage pumping equipment should be constructed to require the minimum amount of economically possible maintenance.

Complete inspection of all pumping facilities should be made on a definite schedule which should be adjusted to system discharge. Routine inspection and cleaning of all pumping equipment should be carried out on a continuous basis. In addition, testing of all pumping equipment should be made periodically to determine the operating efficiency of each unit, and repairs and replacement of pump and motor parts should be made when necessary.

The majority of drainage pumping facilities operate automatically. Since automatic controls are susceptible to unexpected malfunctions, the controls should be checked periodically to ensure continuous operation. A more detailed discussion of maintenance procedures for pumping plants and related facilities can be found in section 4.15.

Maintenance procedures for drainage well pumping facilities are similar to those already mentioned whether the well provides a water supply through relief of a subsurface drainage problem or pumped water is disposed of as agricultural wastewater. Care of the well itself will be covered in more detail in section 4.14.

4.12.5. Ground-Water Quality

Ground-water quality must be protected when drainage wells are used to pump poor quality subsurface water from the underground. The perforations in draining wells must be located so that poor quality ground water will not be able to flow into usable ground-water strata. Surface seals should also be provided on wells where necessary to prevent pollutants from entering the well. In addition, when drainage wells are abandoned, these wells should be filled and sealed to protect the quality of usable ground-water aquifers.

4.13. REPAIR AND MAINTENANCE MATERIALS AND PROCEDURES

All structures are designed for some permanence and for a purpose. Each should be maintained to last its expected life and perform its designed purpose. Structures may include buildings and devices for the control of water. Structural problems requiring attention include corrosion, erosion, rot, termites, freezing, and unsightliness.

Another element of structural maintenance includes timely replacement of facilities appurtenant to and within the structures. For example, mechanical equipment or electrical equipment attached to the structure may need to be replaced several times during the lifetime of the structure itself. Accordingly, operation and maintenance of equipment is an element in the maintenance of the structure.

One element in proper structure maintenance is operator alertness to the need for basic design adjustment to avoid problems not previously foreseen. For example, a loading dock may need to have rubber bumper strips added where damage from vehicles consistently occurs. Other examples would be addition of protective covers to prevent padlocks from freezing in cold climates, use of silicone lubricants to prevent rattling doors and extend hinge life, and development of an aid to underwater inspection using an illuminated optical device to give a visual check of underwater structures without the need for a diver.

4.13.1. Wood Structures

Certain bridges, buildings, decking, shelves, and other structures and portions thereof are constructed of wood in many parts of the world. The principal method of maintaining wood structures is with protective coatings. Regular inspection is essential and could lead to continuing maintenance through partial replacement of wood members and treatment for termites and dry rot.

With the decrease in lumber quality, the increasing practice is to use more pressure-treated material. Painting also increases life. More will be said about woodwork protection under the heading "protective coatings."

4.13.2. Metal Structures

Metal structures include buildings, bridges, and substructures such as shelves, headgates, pipes, valves, siphon tubes, drainage pipes, and corrugated culverts. Other examples of metal devices that are component parts of irrigation and drainage structures are moss screens, radial gates, trashracks, expanded metal walkways, and steps.

Metal structures also include elements salvaged from other structures and devices. For example, beams from railroad cars have been used in some cases for the construction of foot bridges across canals. Expanded metal from other uses may be nailed to slippery walkways in both indoor and outdoor applications. Maintenance of metal structures depends especially on how well problems were anticipated in design and installation.

Corrosion, the principal problem, is usually managed with protective coatings and cathodic protection. The metal used on irrigation and drainage structures and mechanical operating facilities is primarily limited to steel, generally with a protective coating. It is prepared for coating by sandblasting, applying a primer coat, then painting with any one of several types of paint.

Other innovative maintenance procedures to protect metal from wear, erosion, and corrosion have been devised. For instance, hardwood blocks may be installed to prevent the wear of cables against radial gate surfaces. Automatic greasing equipment to provide underwater lubrication for fish screens is another example.

4.13.3. Earthwork Practices

Planning Repairs

Earthwork practices are extremely important in the maintenance of irrigation and drainage structures. Subgrade preparation and earth construction begins with design and installation which, if done properly, will require little maintenance. When problems do occur, however, techniques mentioned are essential to successful operation and maintenance.

Planning repairs first involves diagnosis of the cause of failure. Sources of information might include geology reports, specifications, construction control reports, laboratory reports, weather conditions, seismic disturbances, and operator observations.

Repairs might include placement of dumped fill or equipment-compacted earthfill requiring select material, moisture control, and density monitoring. In extreme cases, removal of unsuitable material may be necessary. Plans must be made for inspection, placement methods, field and laboratory tests, drainage control, erosion prevention, and other procedures.

Soil classification is necessary to properly assess the need and prescribe the remedy for any problem. From the soil classification, there should follow a determination of bearing capacity, stability of cuts and slopes, and some measure of predicted settlement or uplift. It is also important to anticipate possible future deterioration of soil such as might result from wetting of shales or drying out of clays.

Foundations

Foundations may be maintained and repaired through grouting. A structure may be suspended with jacks and foundation replaced with more secure footing. Pilings may be used to replace an existing foundation or strengthen one that is failing.

Embankments

Embankments need proper material and moisture conditioning. Occasionally, blending of plastic and nonplastic soils may be required. It is important that preconditioning of earthwork be carefully done prior to compaction of embankment repair material.

Following earthwork repair, grasses should be planted to prevent future erosion of the slope. Embankments often have roadways on top that can be maintained with scrapers. Sloper attachments are also available for maintaining the roadway embankment below.

Backfill

Backfill in confined spaces or within certain boundaries is usually critical because of the small amount of soil required within a limited working space often requiring a bond between soil and concrete, rock, or asphalt. A localized failure may cause failure of the structure. Accordingly, preconditioning of soil, proper preparation of foundation and abutments, and attainment of adequate compaction are extremely important.

Hand-operated power tampers and vibrators are usually used to compact 6-in. (150-mm) layers to obtain specified density of soil preconditioned to optimum moisture. In the case of inner canal sideslopes, compaction is often done with a sheepsfoot roller winched up and down the slope.

Earth Canal Linings

Earth linings for canals may successfully employ a variety of soils, provided a suitable combination of graded gravel, sand, and plastic cohesive clay is produced and compacted properly. This material will then have good shearing strength and erosion resistance and may be more than competitive in price with other types of canal linings. Economical control of seepage and sideslope stabilization may be achieved with 2 ft (0.6 m) thick linings on canal bottoms and a normal thickness of 3 ft (0.9 m) to sideslopes.

A typical installation involving earth lining would blend carefully selected fine-grained soils from borrow pits with gravel in approximately a 30 to 70% mixture. In large canals with suitable materials, compacted earth lining will usually offer the lowest first cost and maintenance cost. This would not be true for small canals. The thick compacted earth linings are characterized by greater weight and flexibility than rigid concrete and other thin linings. This has advantages against disruption by expansive subgrade soils or by hydrostatic pressures from high ground-water tables.

Thin compacted earth linings composed of cohesive soil protected by a layer of coarser soil or gravel are still in use. Where the water conveyed carries sediment, earth-lined canals also receive thin layers of clay or silt. This assists significantly in the reduction of seepage. Bentonite clay is also sometimes used as a membrane layer or mixed with the lining soil in order to reduce seepage.

These earth linings are highly susceptible to erosion, puncture, deterioration by weathering, and destruction during cleaning operations. However, maintenance costs have been found to be about the same as for other types of canal linings.

Filters

Filters are often included underneath irrigation and drainage structures. When properly designed, filters should require very little maintenance. However, if a sand filter is penetrated by a perforated drain, the growth of clogging roots should be prevented. If this should occur, the roots can be removed with special tools.

Riprap

Placement of riprap at diversion structures and on certain canal sideslopes is sometimes an element of earthwork practice. Many techniques are available including precast reinforcement concrete jacks, small rocks placed in wire mesh gabions, and large rocks placed individually with special equipment.

Earth Blankets

Blankets of earth are sometimes placed around structures to provide ballast and/or drainage protection and may be maintained through landscaping and/or paving.

4.13.4. Concrete Structures

Concrete structures (buildings, bridges, headworks, canals) make up the largest portion of irrigation and drainage facilities. Properly designed and placed, concrete is simple to maintain. Spalling, erosion, structural failure, and esthetic problems may be solved by replacement, coating, and other techniques subsequently described.

Structures may be cast in place or prefabricated and assembled on-site, and formed with plain concrete. However, reinforcing with occasional tensioning will generally be included. Where this is the case, maintenance of the concrete will involve special care to prevent corrosion to reinforcing steel.

Precast concrete structures are feasible for cost saving in many applications where adequate equipment is available for handling, transporting, and setting the structures. In the case of smaller structures, an appreciable saving may be realized in comparison with casting in place. Also, in cases where the climate is not severe, it is economical to use shotcrete for canal linings and special repair work.

Good concrete practice reduces problems and does not add to construction costs. Good concrete is as important in a small structure as in a large one. A color film is available from Portland Cement Association and American Concrete Institute that tells in a very effective way, "How to Make Quality Concrete." The film illustrates the importance of water-cement ratio, quality and grading of aggregates, effect of entrained air, and other factors that contribute to strength, durability, and water tightness of concrete. In addition, several excellent manuals are available (*Concrete manual* 1981; *Materials and properties of concrete* 1970).

Concrete Elements

Concrete elements begin with the choice of cement and aggregate. Special care should be exercised in selecting cement to be used where white alkali sulphate is prominent in the structure area or where sulphate-laden waters might produce a corrosive attack. The use of proper cement and aggregate can delay disintegration of concrete under such conditions.

Many sands and gravels contain reactive elements that may cause concrete to swell and crack. Testing is essential to ensure that sand and gravel are clean, reasonably free of weak particles, well graded, and low in alkali. Special low-alkali cement may be required at a premium cost in order to produce satisfactory results.

Admixtures include air-entraining agents (especially in areas of cold weather) and calcium chloride may be used to speed curing, except where exposed to alkali-sulphate conditions and concrete containing reinforcing or prestressing steel. The entrained air makes for better mixing, density, and strength, which is desirable in maintenance repair jobs. The calcium chloride causes concrete to mature and cure earlier. This is an advantage in cold weather areas and for most maintenance repair jobs. Any water that is drinkable is suitable for mixing concrete.

Batching

Batching, by weight, is preferred to batching by volume to give predictable results and uniformity of concrete. On maintenance jobs, a standard platform scale can be arranged to weigh a wheelbarrow. Following the determination as to amount of water needed to mix with the moisture in the sand and aggregate, the same amount of water should be measured by volume for each succeeding batch. The air-entraining agent is also most satisfactory when batched by volume.

In designing batch mix for a concrete maintenance repair job, it is important to remember that cement is the most significant element leading to quality concrete; no less than six sacks should be used for each cubic yard. Water is the second most important element in concrete quality. As long as the mix is workable, less water used will produce better quality concrete. Where a concrete vibrator is available, a stiffer plastic consistency will be amply workable and responsive to good placement without the use of as much water.

Mixing

Consistency and workability will be visually indicated by how concrete moves around blades in the drum mixer, how uniformly the coarse aggregate is distributed, how concrete hangs together during mixing, and how it discharges.

Where concrete is purchased from transit mix operations having adequate equipment, acceptable concrete from these sources may be available. Care is needed to avoid careless entry of excess water, overmixing, and inadequate mixing.

Placement

Placement preparation is especially important in maintenance repair work. This includes form construction and conveyance of concrete into the forms. In preparation for placing, excavation and forms should be carefully checked for line, grade, and stability. Poor workmanship and form material may result in unnecessary expense for dressing up the structure after form stripping.

The placement of properly prepared concrete is also crucial. Adequate equipment and sufficient, capable personnel should be on hand to do the work. The arrangement of chutes and hoppers should be such that segregation does not occur.

There are many techniques that need to be understood to prevent aggregate gravel separation which leads to rock pockets. Concrete should be placed in horizontal layers of not more than 1 ft (0.3 m) deep, or 2 ft (0.6 m) if vibrators are used. Rodding and vibration should follow just far enough behind placement to avoid forcing concrete to flow. Concrete can be vibrated to advantage until setting has progressed to the point that vibration will no longer make the concrete plastic. Late vibration increases strength and reduces settlement cracking. For this reason, concrete delayed in placing can still be used as long as it is plastic and can be consolidated satisfactorily into the structure.

Where concrete is placed on a slope, a slipform strike-off screed should be used for best results. As the slipform slowly moves up the slope, rodding and vibration should take place above the headboard to obtain good consolidation.

Curing

Curing is the final important step in concrete placement. A constantly moist condition for 7 days is ideal. Forms should be removed at the earliest practical time to permit proper curing and effective repair of concrete, if necessary.

Where constant wetting is not possible, a thin plastic membrane may be placed over the concrete, or curing membranes may be sprayed on as soon as the surface moisture has disappeared. The spray must be applied evenly on the moist but water-free surface, and care must be taken to see that no pinholes develop. For a small repair job, a brush or orchard sprayer might be adequate. The use of a pigmented curing compound makes it easier to get uniform coverage.

4.13.5. Concrete Repairs

Concrete repairs are required where the original design and construction was inadequate, where unforeseen conditions may have developed to cause damage, or where a structure has either worn out or become outdated. Sometimes repairs are considered temporary; however, most maintenance repairs attempt to extend the life of the entire structure.

Painting

Painting is probably the most common preventive maintenance for concrete structures to increase its water tightness or to prevent attack from chemicals. Linseed oil coatings with and without pigments are sometimes used. Coal-tar and asphalt coatings are also used, but not noted for presenting a pleasing appearance. Epoxy coatings, where successfully applied, seem to present a better appearance than linseed oil, coal-tar, and asphalt coatings.

Portland Cement Mortar

Portland Cement mortar is often used to repair eroded concrete. All repair operations should begin with complete removal of all defective or damaged concrete; no repair is better than the material to which it is bonded. It is good practice to continue removal until aggregate is being broken rather than loosened. After washing, the mortar applied to a wet surface may be troweled or placed into a form and vibrated. In the case of substructure damage, the mortar would be placed as grout through holes drilled into "hollow sounding" concrete slabs.

Dry-Pack Portland Cement Concrete

Dry-pack Portland Cement concrete is a conventional method for small and relatively deep repair areas. The dry-pack material must be tamped in place; if done properly, results will have a good appearance and excellent durability. This is because dry-pack concrete has low shrinkage and accordingly does not tend to break its bond with the parent concrete. Careful preparation, good workmanship, and proper curing are essential. Twenty-eight days of moist curing is recommended.

Conventional Portland Cement Concrete

Conventional Portland Cement concrete is often used to repair elements of concrete structures needing replacement. In this procedure, the entire section needing repair is normally removed by breaking or jackhammering. The mixing and placing of concrete follows general concrete practices.

Pneumatically Applied Portland Cement Mortar

Shotcrete, as pneumatically applied mortar is commonly called, is often used in maintenance and repair of eroded concrete structures. This is particularly true where erosion and other damage is extensive but where much of the remaining concrete is suitable for continued service. The Portland Cement mortar mix is normally about one part cement to four parts evenly graded clean sand. The shotcrete can be used for repairs with or without steel reinforcing.

Epoxies

Epoxies are sometimes used with Portland Cement mortar and concrete in maintenance repairs. This is especially true where tight repair schedules can be served by rapid-curing epoxy materials and where proven repair techniques and materials can be used by skilled workmen in the presence of experienced supervisors (Graham 1971).

When epoxy resins are properly applied, these resins will bond fresh Portland Cement mortar or concrete to hardened concrete, hardened concrete to hardened concrete, and dissimilar materials to concrete. Although epoxies are expensive and require care in handling, epoxies can be very worthwhile, especially in special repair jobs. Preparations for placement of epoxy repairs include cleaning of damaged concrete in the area to be repaired by sandblasting and thorough washing, followed by thorough drying prior to applying activated liquid epoxy bond coat. Portland Cement mortar or concrete of dry consistency not more than about 1 in. (25 mm) slump must be compacted immediately into the fluid bond coat.

The resin and reactive hardeners of this thermosetting plastic must be thoroughly mixed in proper proportions and applied within material "potlife." Workmen must take necessary safety precautions and wear proper gloves, clothing, and face protection to avoid injury when using the materials. One part of the blended resin may be mixed with three or more parts, by weight, of properly graded dry sand to produce a patching mortar for small repairs of concrete.

4.13.6. Asphaltic Materials

Asphalt structures needing repair are logically repaired with the same type of asphalt as the original, either hot applied or catalytically blown. Asphaltic prefabricated canal liners have been used in certain instances for repairs with a very carefully prepared, smooth, uniform subgrade. In each case, an earth cover or protective gravel blanket is normally placed over the asphalt structure for protection.

Asphalt concrete is also used for rehabilitating damaged or eroded Portland Cement concrete structures. Asphalt concrete is used when the expense of paving equipment needed to place hot mix is justified. Cold mix asphalt concrete is not suitable for canal lining service. For example, repair of an eroded canal bottom has been accomplished by placing a 11.5 in. (38-mm) thick asphaltic concrete mat. Prior to placement, the surface of the old lining was cleaned with a rotary brush, primed with kerosene, and given a tack coat of hot 50-to-60 penetration asphalt. The asphalt concrete was transported from a hot mix plant and placed with a paver. A good bond was generally obtained between the two layers and successful operation has been experienced for many years.

Repairs have also been made with asphaltic-emulsion concrete placed hot and then rolled. After years of service, this material remains in good condition with very little spalling and few cracks.

4.13.7. Synthetic Materials

Synthetic elastomeric sealers have become important in the repair of irrigation and drainage structures. It is important to prepare concrete joints properly before applying synthetic sealer. The joints should be sand blasted and routed, then the sealer should be applied in accordance with the manufacturer's instructions. A small mastic pumpcan be used to obtain good penetration in the grooves. This sealing compound is an important tool for the maintenance of such structures.

Plastic canal linings and pipe are also important in maintenance of water transportation facilities. These materials are sometimes used to replace or cover eroded canal sections, install plastic pipes inside leaking and eroded concrete pipelines without loss of carrying capacity, and repair damaged plastic pipe while in service.

4.13.8. Protective Coatings

Protective coatings are usually provided to prevent corrosion. However, these coatings may also be needed for protection against rot, mildew, and pests as well as for providing a more attractive structure, improving flow characteristics, and waterproofing.

Protective coatings are relatively thin films generally containing organic matter and are vulnerable to many of nature's destructive forces. These coatings deteriorate with time and need to be restored or replaced before the provided protection is lost. This requires that coatings be inspected at regular intervals. If not, maintenance costs will eventually prove quite costly.

At the outset, the maintenance superintendent should establish some history of the original paint. Copies of the construction specifications describing painting procedures and materials may be the best source and may serve as a basic guide in preparing a sound maintenance program.

Proper management also requires that records of inspections and coating applications be kept. This is because coating deterioration is usually gradual, and information needs to be maintained for future reference. Cost data on completed work should also constitute a part of the record.

Maintenance personnel need to keep abreast of new developments in coating and application techniques to effectively maintain structures for uninterrupted performance throughout the full expected life of the structure.

Selection of Coatings

Selection of coatings requires a specialty study to select the material best suited to the need. A paint manual has been prepared by the Bureau of Reclamation that might well be used by any maintenance personnel (*Paint Manual* 1976). Paint vendors can also supply good information. Finally, there is no substitute for experience of a maintenance superintendent in determining the type of coating to be used for a specific application.

There are many types of coatings, rust-preventive compounds, and accessory materials. Each has a variety of composition and properties available. The person responsible needs to be knowledgeable about thinners, colors, stains, dryers, putties, glazing compounds, waxes, pigments, vehicles, dampproofing, and materials.

Some basic types of materials available include coal-tar pitch, coal-tar paint, vinyl resins, latex paint, boiled linseed oil pigmented paint, epoxy paint, hot-dip galvanized coatings, and red-lead primers. Obviously, a careful study of these materials is needed prior to any application. Regulations governing hazardous materials or environmental compliance may limit or restrict the use of certain protective coatings.

Where rapid deterioration of painted surfaces takes place, either exposed or submerged in water, it behooves supervisory personnel to make thorough on-the-spot investigations to determine cause of failure. In many cases, changing from one type of coating to another may be necessary and beneficial.

Interior Surfaces

Interior surfaces most often employ a semigloss enamel, latex-based paint. No primer is necessary where a dull finish is acceptable.

Boiled linseed oil thinned with mineral spirits or lacquer may be used to retain and enhance the natural beauty of wood grain. Special plastic paint is sometimes used where a speckled or flaked characteristic is desired on interior wallboard and where extra cost is not a problem.

Interior woodwork, properly coated with paint and varnish, should remain in good condition for many years. Deterioration from repeated washings, scratching, and impact chipping will ultimately mean that old coatings must be removed before repainting. Accordingly, added coats of paint should be applied with reluctance to interior surfaces in the interest of overall economy.

Exterior Woodwork

Exterior woodwork will experience much more rapid deterioration of coatings because of the greater effect of sunlight, moisture, and temperature changes. Accordingly, inspections of such surfaces should be scheduled at more frequent intervals, such as annually in the case of extreme exposure.

Again, the pitfall of too frequent repainting with resultant cracking and peeling should be avoided. Generally, surfaces in the northern hemisphere facing north will require less painting than those facing south.

Pigments containing lead are no longer used in exterior coatings, except possibly as tinting colors in minor amounts. Acrylic, polyethylene emulsions, or different types of emulsified resins are the coatings in common use today.

Exterior oil paints are formulated as "self-cleaning" through chalking as the surface of the coating gradually becomes powdery and is washed away by rain. The gradual reduction of film thickness reduces the tendency for cracking and peeling, so that when additional paint is applied, a flexible well-bonded film is usually restored.

In the case of structural timbers that may or may not have been pressure-treated prior to construction, a successfully used technique for coating is the application of shotcrete. This application increases the service life by protecting against rot and mildew.

Concrete

Concrete painting for decoration and dampproofing may be accomplished with a variety of paint choices, including Portland Cement paint, oil vehicle paint, latex paint, and epoxy and silicone materials. The control of algae growth in concrete structures can also be provided with special protective coverings including coal-tar enamel and catalytically blown asphalt. Two coats of copper-base, antifouling paint also have been successfully used to retard algae growth.

Generally, good high-strength concrete is sufficiently waterproof to provide its own protection during its intended service. However, where deterioration due to excessive freezing and thawing occurs, a four-coat linseed oil and paint treatment has generally served satisfactorily. Polyvinyl acetate paint, styrene butadiene paint, and epoxy resin materials have also shown promise for such applications.

Neoprene compounds have been found effective for waterproofing concrete in the upstream faces of older dams. Chlorinated rubber-base paints are less costly, and although not as effective as neoprene, are still considered excellent paints for water tank and reservoir application. Neoprene has also proved very satisfactory in freezing and thawing and waterproofing tests, and has excellent erosion resistance qualities. Another method of waterproofing concrete is to place a protective plastic membrane over the concrete with a bonding agent.

Sometimes painting interior concrete walls is needed to improve appearance. A varnish-base paint may be applied if the surface is thoroughly dry. Latex-base paints have been successfully used for this purpose.

Metalwork

Metalwork painting may be the most important maintenance program for irrigation and drainage structures. This is especially true for underwater and varied exposures of metal surfaces.

Coal-tar enamel and cement mortar coatings provide the best protection for such items as power penstocks, but these coatings are difficult and costly to apply. Two-component materials such as epoxy and coal-tar epoxy offer advantages but require very special care and application.

Two package epoxies, polyurethanes and polyesters, are the most common replacements for multicoat vinyl paints. Metalizing with organic seal is one option, and topcoats is another.

Large underwater metal structures may also be protected by hot-applied, heavy epoxy coating. This material requires special equipment and care in application.

Metal structures exposed to outside atmospheric conditions are no longer protected with red-lead priming paint covered with an aluminum-pigmented varnish or alkyd enamel. Red-lead priming paints have been replaced with lead and chromate-free, anticorrosive primers, many of which are based on phenolated alkyds or cold-cut phenolic varnishes.

Where metal conduits are subject to erosion from silt, sand, or gravel-laden waters, neoprene paint, though more expensive than coal-tar enamel or cement mortar, seems to offer excellent resistance. Elastomeric and other two-package polyurethane coatings are also used for erosion and abrasion-resistant coatings. Neoprene paint is more expensive and is used less often than the urethane coatings.

Quality Control

Quality control in applying a protective coating results from many factors. These include a careful diagnosis of the problem, informed prescription of a remedy, logical but simple specification of materials and methods, rigid inspection requiring conformance, frequent inspection, continual maintenance, and proper records.

Preparations for Painting

Surface preparation is the key to successful protective coating. No coating is better than the foundation on which it rests. Surfaces that are coated with enamel or other nonchalking materials and are in fairly good condition at the time of repainting will require only scraping or sandpapering as surface preparation. Severe cracking and peeling indicates a condition that causes poor adhesion to the old paint, leading to cracking in the new paint. Where this condition is general and numerous repaintings have built up excessive film thickness, satisfactory results can be obtained only through complete removal of the old paint, followed by repainting.

The one method of complete paint removal for large areas is with a paint burner, followed by scraping while the paint is soft and hot. This method requires that safety precautions be taken to avoid fire damage to the structure. Remnants can be removed by scraping or wirebrushing woodwork after the paint has cooled. Corners and edges especially should be scraped clean. Sandblasting is another method and used most often to clean coatings from metal surfaces. High-pressure (2,000 psi) washers can also be used to remove old coatings.

It is extremely important that bare metal surfaces are protected immediately. When bare metal surfaces are left exposed overnight, minor rusting of the surface can occur. ***Always sandblast, clean, and prime metal surfaces on the same day.*** Any surface on which a coating is to be applied should be free of all dirt, effluorescence, oil, pits, alkali, moisture, or other conditions that would prevent bonding. This is true of wood, metal, or concrete surfaces.

Special rotating power tools are available for removal of all kinds of hard paints, rust, and scale from steel and concrete surfaces. These tools include power wire brushes, grinders, and chipping tools and are especially effective for touch-up recoating needs. The surface produced is not equal, for painting purposes, to that obtained from sandblasting, but it is free of loose and poorly bonded material and is roughened somewhat. These tools are normally limited to use of flat or large-radius curved surfaces.

Following removal of foreign materials, further cleaning by light wire brushing or wiping with solvent, or with other treatment solution may be necessary to ensure removal of all loose dust and rust from a metal surface before recoating commences. Physical adhesion is enhanced if the surface is roughened while chemical adhesion is sometimes improved for metal surfaces by pretreatment with conditioners.

Mixing

Mixing of coating materials must be done according to manufacturer specification. Obviously, a linseed oil-based paint cannot be thinned with water, nor can a latex base paint be thinned with mineral spirits. Epoxy-resin compounds must be precisely blended with curing agents in a clean working area with good ventilation by trained personnel wearing rubber or vinyl gloves.

Manufactured paint should be vibration mixed if possible and thoroughly stirred to provide satisfactory results. The intent should be to preserve a balance of pigment and thinners by stirring until smooth consistency is achieved. Mechanical mixers are preferred. A stirrer on an electric drill also works well. Some paints require frequent reagitation. Coating materials should be thinned to proper proportions and sometimes heated to yield the specified applied mil-thickness.

Application

Application of protective coating by brush, dauber, trowel, or spray is obviously important. Painting and coating should not begin unless the surface to be painted or coated is at least 50°F above dewpoint. Inspection should include mil-thickness testing so that adjustments can be made where deficiencies are noted.

Brushing is recommended for the first application of most protective coatings to ensure intimate contact of paint with the surface. Painting skill will produce a reasonable degree of uniformity without brushing the first coat on too thinly. Roller coating and spray painting may be effectively used for application of coatings with uniformity and speed. Spraying requires specialized skill and correct equipment in good condition. The spray nozzle should be held perpendicular to the surface and about 8 to 10 in. (200 to 250 mm) away. Uniform application with systematic patterns should be used when coating an area.

With wet techniques, coating will be applied wet, never partially dried, when it reaches the surface. Application should proceed only under suitable atmospheric conditions. To the extent possible, each work area should be started and completed within one continuous timeframe.

4.13.9. Cathodic Protection

Buried and submerged metalwork is subject to electrochemical deterioration (corrosion). This is a major maintenance and economic problem for many irrigation and drainage structures. Corrosion or oxidation on a metal surface submerged in water is an electrochemical reaction in which the electrical current flow from metal surface to water results in metal loss. This phenomena can be eliminated by stopping the flow of current.

Generally, this is accomplished by coating the metal surface to insulate it from the wet environment and by imposing an electric voltage in opposition to the current flow that causes corrosion. Some examples of other structures that can be protected by cathodic protection include underground metallic conduits and underground fuel storage tanks.

Principles Involved

Corrosion and cathodic protection involve the same electrochemical principles at work in a primary battery, of which the common dry cell is an example. In the cell, a direct current flows from the anode (which corrodes), through the electrolyte to the cathode (which does not corrode). By protecting the anode of an electrolytic or galvanic cell with an external anode, natural corrosion currents are neutralized and corrosion does not take place. This can be accomplished by impressing a direct current between the external anode and metal to be protected with a rectifier or other direct-current source.

Cathodic protection can also be accomplished by protecting the anode of a primary battery by proper selection of material for the external anode. Such anodes are called galvanic or sacrificial anodes. When a submerged steel surface is receiving cathodic protection, a protective film of hydrogen, calcium carbonate, and other chemicals forms on the surface of the metal and is constantly renewed by keeping the metal surface charged cathodically.

A common practice in arid areas or where relatively large quantities of current are required is the use of anodes with an impressed current. These anodes are constructed of material that is depleted slowly with current discharge. Examples of impressed current anodes are graphic, cast iron, plutonium, and mixed metal oxides.

In tidal areas, a common practice is to use one or more plates, usually zinc or magnesium, placed on the gate face. The resulting galvanic action on the anode necessitates replacement every 4 to 5 years. An anode made of zinc is consumed at the rate of 26 lb (57.2 kg) per amp-year and magnesium at 17 lb (37.4 kg) per amp-year. This method has been used successfully on the downstream side of salinity control structures. A zinc oxide paint, which has excellent steel-adherent qualities followed by a coating of epoxy, is effective in further protecting the gate face as well as extending the life of the anode.

Direct-current power for cathodic protection is supplied by a rectifier where alternating current is readily available. Where electric power is not economically available, galvanic or sacrificial anodes can be used. Magnesium or zinc are two types of anodes commonly used without an external source of power. The magnesium or zinc anode and submerged steel surface to be protected constitute a galvanic cell.

Since magnesium or zinc has a higher solution potential than the submerged steel surface, a driving force of approximately 1 volt and 0.5 volts is obtained from these combinations, respectively, and necessary cathodic protection current flows through the circuit. As this current flows, the anode gradually dissolves at a rate proportional to the amount of current.

In most cases, the use of cathodic protection to supplement regular surface coatings as a means to increase the time between recoatings is desirable. As a coating begins to fail, the area requiring protection increases. Experience has shown, however, that a current of appoximately 1 milliampere per sq ft (11 milliamperes per sq meter) of submerged area to be protected is adequate.

Limitations and Problems

Where water levels vary in a submerged structure, voltage adjustments are necessary to provide adequate protection. The voltage can be adjusted by operating personnel or automatic equipment.

The flowing electric current must be carefully confined to wires and anodes by excellent insulation; otherwise, the wire itself will become an anode and corrode, interrupting the flow of current to the anode.

There are instances in which cathodic protection of one system of underground and underwater metallic structures must necessarily involve the protection of other neighboring structures. This phenomenon is the result of stray current corrosion (electrolysis). These facilities must be accounted for in design and maintenance as one complete system. The corrosive nature of soil will vary from place to place, according to soil propensity to carry electric current. Soil electric resistivity should be measured at the point of installation.

Field Techniques

Most cathodic protection installations are accomplished by contract with suppliers and equipment manufacturers. The maintenance of these facilities is principally one of inspecting, testing, and analysis of the results. Obviously, good records are essential to successful use of cathodic protection. Changes in electrical potential are sometimes very gradual. The anodes are dissipated on a generally straight-line basis, and records are needed to predict when replacements will be required.

4.14. WELLS AND GROUND-WATER RECHARGE

4.14.1. Wells

The maintenance of wells is important to maintain well efficiency and prolong the life of the well. Well maintenance may also require proper closure and sealing when the well is beyond its useful life in order to prevent accidents.

Removal of encrustations resulting from mineral deposits and/or biological activities is a primary maintenance problem associated with wells. Introduction of properly designed plastic well screens and new metal alloys have greatly reduced the problems associated with corrosion. Periodic treatments with chemicals and/or jetting may be required to properly maintain certain wells.

Regular inspections with well-kept records are essential to good maintenance. Inspections can be completed by means of lighted television cameras. However, the simplest method of determining the well condition is with a hydraulic test for specific well capacity. Efficiency testing should be a routine procedure in the maintenance of wells. Testing is a method to evaluate economics of well performance.

It is occasionally necessary to add gravel to a gravel-enveloped well. A chemical analysis of water pumped from the well is also important in diagnosing well problems.

4.14.2. Ground-Water Recharge Facilities

Other features of irrigation and drainage systems may include ground-water recharge basins or spreading grounds. Maintenance of these facilities includes removal of silt, trapping and removal of gophers, dike sloping, and weed control. Frequent inspection should be made of any corrosion that might occur to flocculation agent dispensers if these are used to facilitate removal of sediment in the water.

Injection wells can also be used in some instances for the purpose of ground-water recharge. Maintenance of injection wells generally is similar to that of production wells. Regular performance records are also important to assess maintenance needs for these wells.

4.15. MAINTENANCE OF MECHANICAL, ELECTRICAL, HYDRAULIC, AND ELECTRONIC EQUIPMENT

The equipment associated with the operation of an irrigation or drainage development generally consists of mechanical, electrical, hydraulic, and electronic equipment. Most of this equipment is highly specialized and vital to operations. Because of its specialized nature, instructions regarding its care and maintenance are difficult to give in a manual such as this. Specific care and maintenance are usually described in bulletins and manuals furnished by manufacturers.

There are five reasons why equipment fails. Failure can be attributed to design faults, manufacturing faults, installation faults, poor maintenance, and lack of operating know-how.

From time to time, equipment will not meet the specific agency needs. This frequently occurs when designers are not informed sufficiently to understand the function required of the equipment. Manufacturing faults generally occur the least among the five problems encountered. However, it is necessary to be diligent in watching for dangerous defects at the time of installation and during testing of the equipment, which should be done as soon as possible after installation.

Good installation is of utmost importance. The final result is no better than the quality of installation work—excellent design and manufacturing can be nullified by poor installation. On the other hand, a good installation staff can often correct manufacturing errors and often can redeem a poor design situation. Wherever possible, the responsibility of the installers should extend through testing. Equipment should not be officially turned over to operation and maintenance personnel until equipment has been satisfactorily tested and performs as desired.

In this connection, the construction staff should include personnel who are responsible for final correct operation of the equipment, and installation staff should maintain close liaison with both designers and operation and maintenance people.

4.15.1. Recommended Maintenance Procedures

After equipment is installed and operational, manufacturer-recommended maintenance procedures should be strictly followed. Good preventive maintenance is essential for efficient operation of any type of equipment. After equipment has been in service for an extended period of time or usage, teardown and inspection with replacement of necessary components is good practice.

4.15.2. Maintenance Shops, Equipment, and Supplies

Many factors influence the need and extent of the agency maintenance center. The important factors are the geographic location of the operating system, size and machinery, and availability and dependability of commercial concerns. Pipeline distribution systems having a large number of pumping plants may find it advantageous to be equipped with a complete machine shop for both electrical and mechanical work.

Machinery for this type of shop includes hydraulic presses, radial drill presses, shaft alignment bench, impeller balancing machine, milling machine, lathes, a steam cleaner, and bake oven for electric parts. Journeymen machinists and electricians must be a part of this type of organization. Adequate warehousing must also be available for materials and spare parts.

The availability of materials or supplies is always an important aspect of an effective maintenance program. In keeping with the type of maintenance program previously discussed, a dependable warehousing program must be established and maintained. Appendix G has examples of inventory and material control forms for use as aids to the maintenance superintendent in supplying his field crews with materials.

Useful life of equipment should be estimated and replacement should be programmed. It may be prudent, depending upon availability from the manufacturer, to warehouse some parts and components of equipment that are especially vital to operations.

4.15.3. Gate Control Structures

Manual and automatic control facilities include mechanical, electrical, and electronic equipment. Moving components of the gate should be lubricated periodically, and gate hoists operated throughout their entire operating ranges frequently to assure continued operational reliability. This is particularly necessary for splash systems in order to prevent rust, which can readily occur in humid areas, and to free debris that can accumulate when equipment is not in use. Emulsion-type lubrication oil is standard in these applications because of its ability to absorb condensation.

Gate vibration can be a problem with guide wheels on automatic gates. This can be largely eliminated with sealed bearings that require infrequent lubrication and by case-hardened wearing surfaces.

Periodic inspection of spillway gates and tests of operating equipment should be made by an engineer or a mechanic familiar with the purposes of the equipment. Trashracks should be cleaned of debris and accumulated sediment, and metalwork should be painted to prevent rusting.

Inlet and outlet gates and valves should be tested regularly to make sure gates and valves work freely. Like gates, valves should be exercised periodically to determine that the valves are in good operating condition. All mechanical equipment should be lubricated and serviced in accordance with manufacturer or designer instructions.

4.15.4. Combustion Engines

Detailed instructions for maintaining combustion engines will generally be adequately furnished by the manufacturer supplying the engine. These instructions should be followed and the manufacturer contacted when unforeseen problems arise.

Many agencies make it a practice to periodically operate the engine even though the function for which the engine was installed is under a "no-operation" condition. Such a procedure is recommended to assure operation in an emergency.

4.15.5. General Electrical Maintenance

This is a broad subject and maintenance procedures will depend upon the type of system installed. Manufacturer bulletins and instructions should be included in agency files for reference and guidance. However, maintenance frequently consists of replacement of wiring due to insulation breakdown. In the case of motors, it is advisable to have space heaters inside the housing to reduce such insulation problems. Heaters of 25 to 30 watts also can reduce the insulation and moisture problems that cause faults in automatic control housings.

Frequent inspection of electrical equipment and powerlines should be routine on any system, and the agency should be staffed with qualified repair and servicing personnel, or such personnel should be available nearby.

An electrical maintenance program can be divided into three types:

- Corrective or breakdown maintenance—Repairing equipment after an in-service failure.
- Preventive or planned maintenance—Scheduled inspection, lubrication, adjustment, testing, and repair of equipment components to prevent in-service failure.
- Predictive maintenance—Inspections and tests that can predict which components must be repaired or replaced to ensure trouble-free operation of the equipment.

Preventive maintenance has several advantages over breakdown maintenance. One of these advantages is the elimination of many breakdowns when the equipment is urgently needed for service. In addition, it can also be more economical; substituting minor repairs for major ones. This helps keep electrical systems in good operating condition and promotes higher operating efficiency. Performing maintenance on a preventive basis permits orderly budgeting and manpower planning and provides information for a realistic stock of spare parts.

Agencies that propose to establish their own electrical department will find that test instruments such as a digital V-O-M instrument (for extreme accuracy), power driven megger, D-C dielectric test set, portable alternator, A-C volt ammeter, variable frequency generator, portable A-C ammeter, portable A-C voltmeter, portable oil tester, vibrometer, and small portable vacuum cleaner and air compressor should be part of electrician maintenance equipment. Some manufacturers offer special training courses in the use of their instruments. Sending technicians to these schools is certainly a worthwhile investment and a necessity.

A word of caution, however—preventive maintenance can be carried to the point where its cost exceeds periodic replacement of the component. For example, annual cleaning and regreasing of ball bearings in a small electric motor may exceed the cost of replacing the bearings every 2 or 3 years. In fact, small motors on ventilating fans often can be replaced after breakdown for less cost than periodic service.

4.15.6. Servicing, Performance, and Replacement Records

Several forms used by various agencies are included in Appendix G and are self-explanatory. The fact that such forms can be found in most maintenance offices attests to the importance of adapting similar forms for use.

4.16. PUMPING PLANTS

Pumping plants generally can include a combination of mechanical, electrical, hydraulic, and electronic equipment. The size of the pumping plant and overall plan of operation and maintenance of the system will determine the proper care and maintenance that must be given pumping plant facilities.

Operators and others who visit a pumping plant in their normal tour of duty should be responsible for a complete check of all plant facilities and the preparation of necessary reports. Certain light maintenance work may also be accomplished by these personnel rather than scheduling a maintenance man to cover the same plants. Checklists should be prepared to assist the operator and should include the following inspection guidelines.

- Listen for buzzing sounds from unit control panel.
- Listen for excessive noise in pumps or motor.
- Check all packing glands.
- Note excessive vibration of pumping units.
- See if motors are overheating.
- Check conditions of oil in motors (is it clear, cloudy, dirty, bubbly).
- Check operation of oilers for pumping bearings.
- Check to see if unit heaters are operating properly.
- Check float tapes for proper position.
- Check traveling moss screens for clearance and performance and remove excess moss.

Electric motors and control panels must be kept clean and free from accumulations such as spider webs, dirt, and birds nests. Overheating of a particular motor should be checked, keeping in mind that some motors are designed to run hotter than others. Loose connections can cause excessive heating or complete failure; normal vibration will cause connections to loosen.

Various motor and pump controls and relays are specialized devices. All have important functions and usually should be checked by the plant mechanic or electrician with any malfunction reported immediately to the specialists.

Float switches activated by the water can shut a pump off if water level drops below a safe depth. These switches should be checked for freedom of operation to ensure that they will move up and down with changes in water level.

All foregoing pertinent data should be transferred to a machinery card file in the maintenance records for future reference.

Electric motors should be lubricated at regular intervals. Fig. 27 is an example of a procedural outline for maintenance of small to medium-sized motors on a vertical turbine-type pump.

Periodic inspections also should be made of pumping units by supervisory personnel. Vertical shaft pumps normally are not removed unless vibration and efficiency tests indicate that a problem exists. If there is evidence of galvanic or electrotype corrosion of pumping units, a periodic

PUMP MOTOR RELUBRICATION PROCEDURE

Motors Equipped with Grease Fittings

UPPER THRUST BEARINGS -- Every 1,000 hours or 3 months

LOWER GUIDE BEARINGS -- Every 12 months

Relubrication procedure is as follows:

1. Remove the grease relief plus

2. Free the relief passage of hardened grease.

3. Wipe the grease fitting (zerk) clean.

4. With the motor at standstill, add grease, using a hand-operated gun until the grease begins to move in the relief passage.

5. Allow the motor to run about 10 minutes before replacing the relief plug.

W A R N I N G

NEVER ADD GREASE TO ANY MOTOR WITHOUT FIRST REMOVING THE GREASE RELIEF PLUG. TO DO SO WILL PUT A PRESSURE INSIDE THE GREASE HOUSING, CAUSING GREASE TO LEAK THROUGH THE GREASE SEALS AND INTO THE MOTOR, DAMAGING THE MOTOR WINDINGS. TAKE CARE TO EXCLUDE DIRT FROM THE BEARING HOUSING AND LUBRICANT.

Fig. 27. Pump Motor Relubrication Procedure

inspection schedule must be established for inspection and correction before serious damage results. Where this type of corrosion is a problem, pumping units should not be allowed to operate more than 2 or 3 years without a complete visual inspection of submerged parts.

Removal of trash, particularly vegetation, is an integral part of a pumping facility maintenance, especially in humid areas. Lack of attention to this can result in high operating costs and create critical upstream flooding conditions during high runoff. The mechanical features of the various types of racks now being used require constant inspection because these racks are subjected to such rugged operation.

Weed racks and moss screens should be inspected frequently to uncover the need for protective coatings, cathodic protection, parts replacement, and occasionally, vandalism repair.

Receiving basins of trash barriers upstream of structures should also be maintained reasonably clean at all times. The barriers should be checked periodically for large items (timber) to prevent stress on cables. Damaged floats should be repaired or replaced.

4.17. MANAGEMENT OF GENERATED WASTE

The management of irrigation and drainage systems can produce solid and hazardous waste in a variety of ways. Excess pesticides, cleaning fluids, and even drainage return flows can all qualify as hazardous waste under federal or state regulations. As a general rule, it is always an advantage to minimize the amounts of solid, and especially, hazardous wastes generated.

Solid and hazardous waste are regulated under the Federal Resource Conservation and Recovery Act (RCRA). The basic provisions of the act include minimizing the amounts of waste generated and tracking any waste generated from cradle to grave. As specific requirements vary by state, the system manager should be aware of the requirements applicable to his particular state.

Pesticides often qualify as hazardous wastes and will require special handling for storage and disposal. If properly used, minimal amounts of pesticides as a waste will be generated if applied in compliance with the label.

Cleaning fluids and solvents used around machinery as a routine matter or excess amounts or amounts that have been dirtied and can no longer be used may be classified as hazardous waste.

Proper storage and disposal are required. Monthly records of amounts generated should be kept to confirm the level of regulation applicable to an individual operation.

It is hoped that these three examples will serve to illustrate the range of possible wastes generated and some possible issues in dealing with them. Waste is generated by almost every activity to a greater or lesser extent. The first step in dealing with generated waste is to generate as little as possible. Operations should be examined to reduce the amounts of wastes generated and to handle the generated wastes in a manner that is safe, legal, and environmentally responsible.

4.17.1. Fertilizers

Applications of nitrogen fertilizers in excess of plant requirements for optimum yields tend to increase chances of water pollution through accumulations of nitrates in ground water. A soil analysis should be performed to determine proper application for soil, plants, and water conditions. All manufacturer recommendations as well as local, state, and federal ordinances should be obeyed.

There has been an increased awareness of potential hazards of irrigation return flows. This is especially prevalent in situations where the flows drain to an area with no outlet and evaporate, concentrating any contaminants that may be present. While not strictly regulated under RCRA, concentration of salts or other constituents in these flows can meet the definition of a hazardous waste. It is important that the destination of any drainage return flows be determined, chemical composition of return flows monitored, and amounts of return flows minimized over the life of the project.

4.17.2. Chemical Spills and Weed Burning

Spills of any material should be cleaned up immediately to prevent the spill from entering any surface or ground water. This material includes fertilizers, herbicides, and pesticides; oil used in pumping plants; and oil and other lubricants in servicing vehicles and equipment. An oil spill containment and cleanup plan should be prepared by the operating entity. Where burning is desirable for weed control, local air quality control laws and burning ordinances should also be followed.

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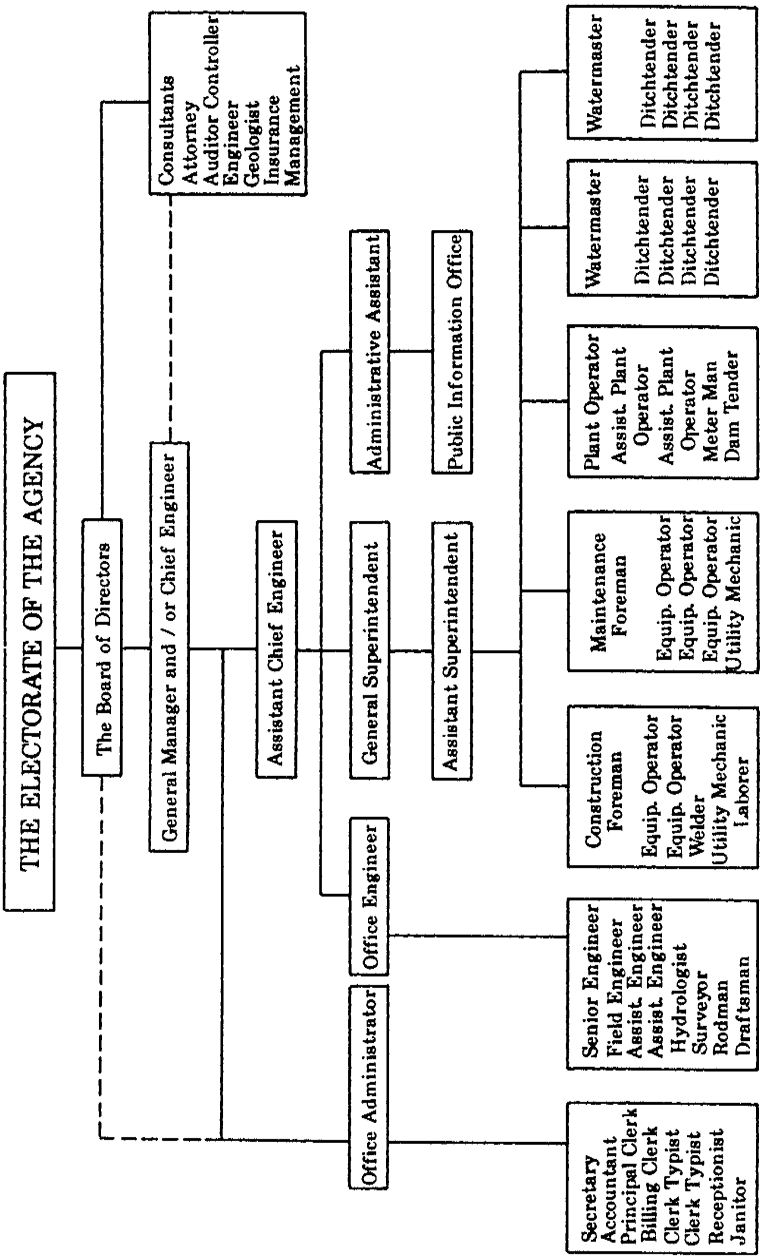
APPENDIX A. ORGANIZATIONAL CHARTS

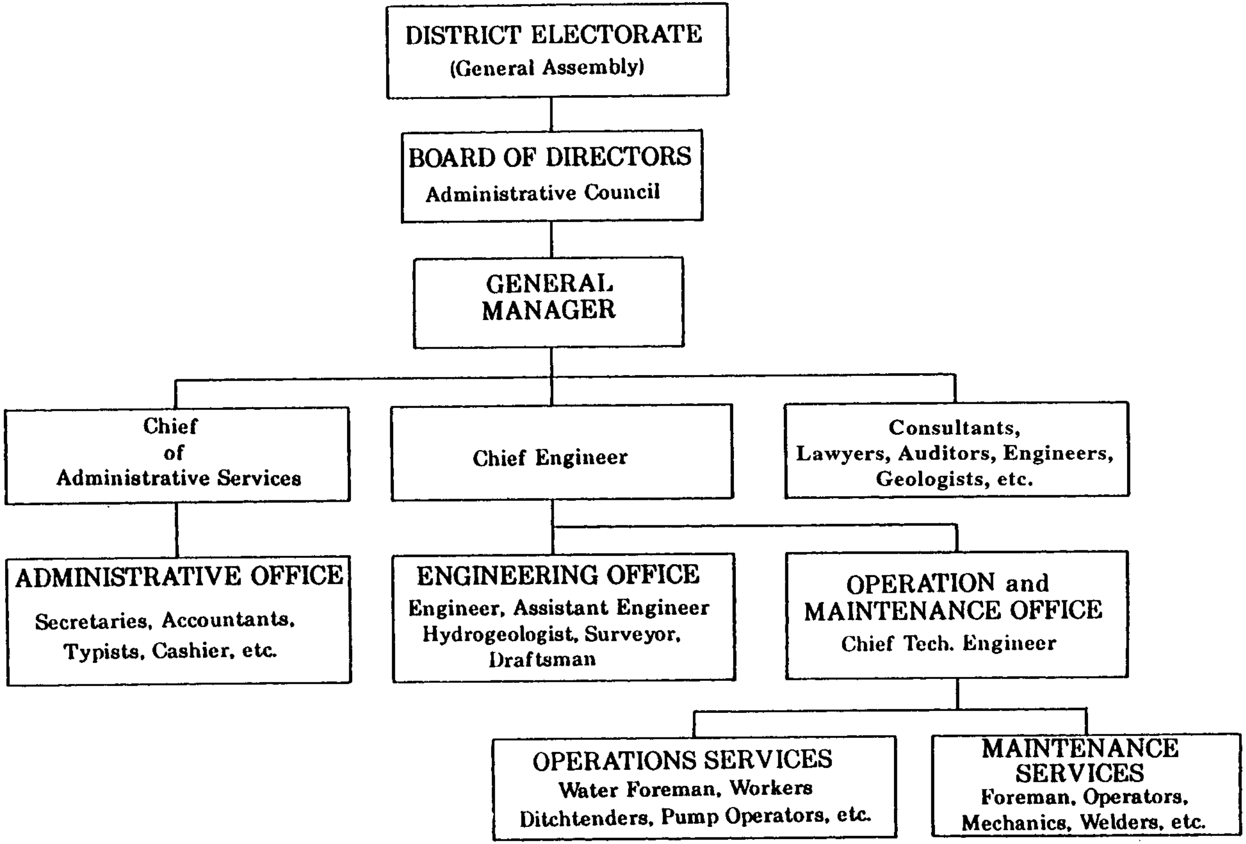
APPENDIX A
FIGURE A-1

ORGANIZATIONAL CHART OF AN IRRIGATION DISTRICT



APPENDIX A
FIGURE A-2

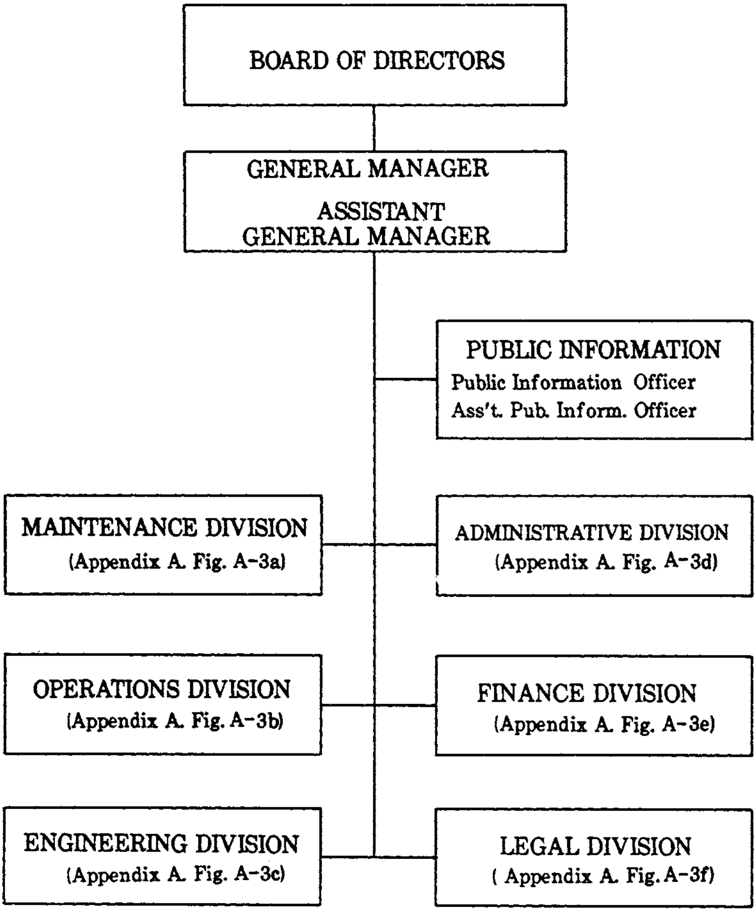
ORGANIZATIONAL CHART OF AN IRRIGATION DISTRICT IN USA*



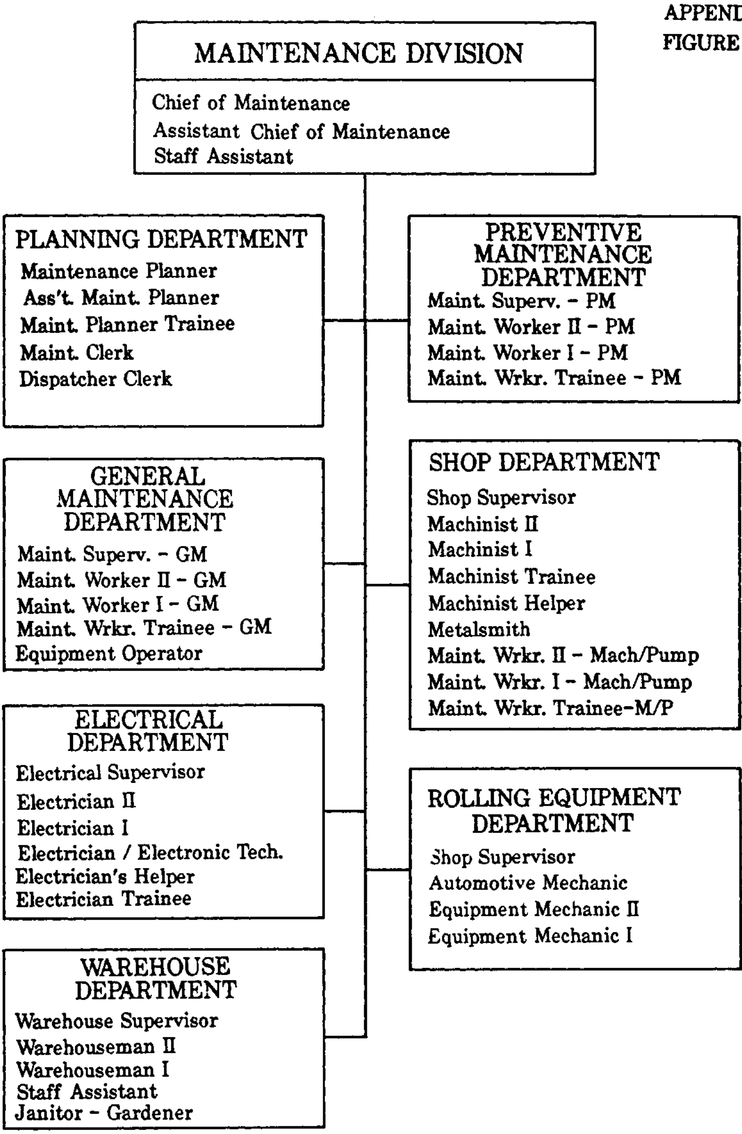
*From: (Organization, Operation and Maintenance of Irrigation Schemes.) FOA Irrigation and Drainage Paper 40, 1982.

APPENDIX A
FIGURE A-3

DETAILED WATER DISTRICT ORGANIZATION CHART



APPENDIX A
FIGURE A-3a



APPENDIX A
FIGURE A-3b

OPERATIONS DIVISION

Chief of Operations
Assistant Chief of Operations

FIELD OPERATIONS DEPARTMENT

Operations Supervisor
Operator II
Operator I
Operator Trainee

WATER MARKETING DEPARTMENT

Supervising Water Delivery Controller
Senior Water Delivery Controller
Water Delivery Controller II
Water Delivery Controller I
Staff Assistant

WATER MEASUREMENT DEPARTMENT

Water Measurement Supervisor
Water Measurement Specialist II
Water Measurement Specialist I
Staff Assistant

WATER MANAGEMENT DEPARTMENT

Senior Engineer
Water Conserv. and Managmt. Spec. II
Water Conserv. and Managmt. Spec. I
Staff Assistant
Water Conserv. Managmt. Spec. Trainee
Drainage Operator

APPENDIX A
FIGURE A-3c

ENGINEERING DIVISION

Chief Engineer

MAINTENANCE ENGINEERING DEPARTMENT

Ass't Chief Engr. (Maintenance)
Senior Engineer
Junior Engineer
Engineering Technician II
Engineering Technician I
Engineering Aide
Engineering Clerk

OFFICE ENGINEERING DEPARTMENT

Ass't Chief Engr. (Office) and Safety Officer
Senior Engineer
Junior Engineer
Engineering Technician II
Engineering Technician I
Engineering Clerk

CONSTRUCTION ENGINEERING DEPARTMENT

Ass't. Chief Engr. (Construction)
Senior Engineer
Assistant Engineer
Junior Engineer
Engineering Technician II
Engineering Technician I
Engineering Clerk

APPENDIX A
FIGURE A-3d

ADMINISTRATIVE DIVISION

Director of Administration
(Secretary to the Board of Directors)

PERSONNEL DEPARTMENT

- Personnel Assistant II
- Personnel Assistant I
- Staff Assistant

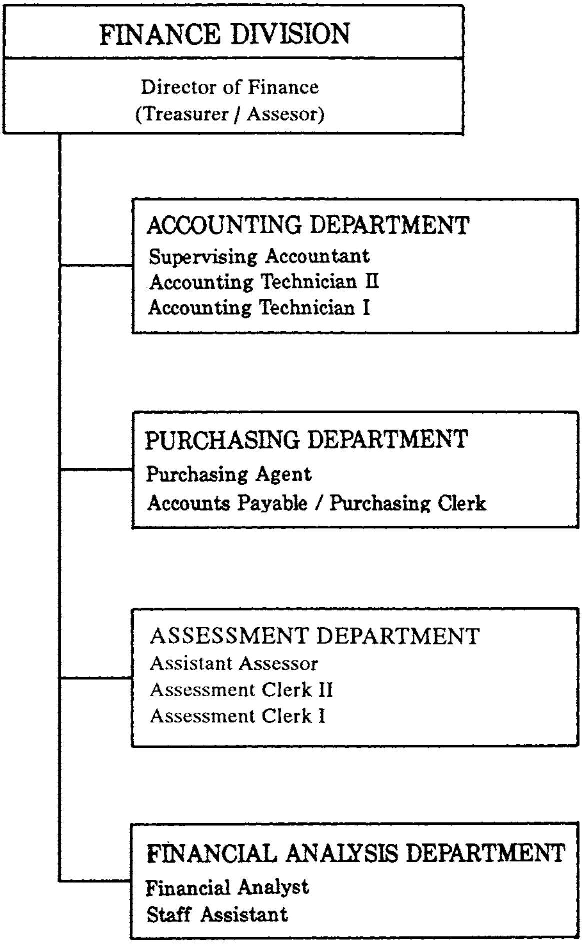
OFFICE SERVICES DEPARTMENT

- Supervisor of Office Services
- Office Assistant III
- Office Assistant II
- Office Assistant I
- Word Processor Operator II
- Word Processor Operator I
- Staff Assistant
- Receptionist

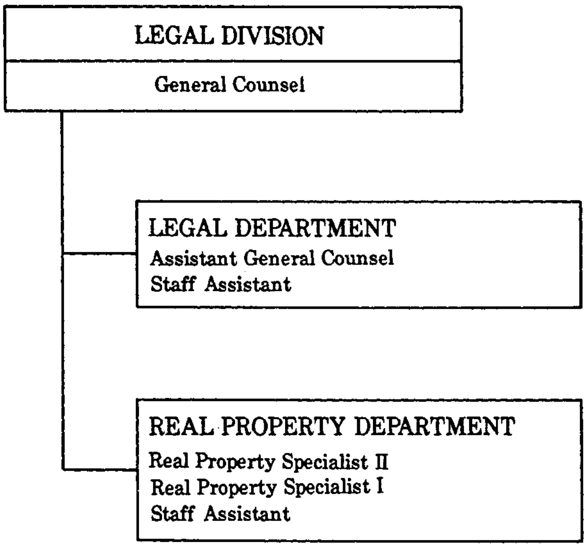
DATA PROCESSING DEPARTMENT

- Systems and Programming Supervisor
- Programmer II
- Programmer I
- Computer Operator III
- Computer Operator II
- Computer Operator I

APPENDIX A
FIGURE A-3e



APPENDIX A
FIGURE A-3f



APPENDIX B. PERSONNEL REGULATIONS

These regulations define policies and procedures, and serve as a guideline to assist managers and all employees in understanding the organization. The interaction of Personnel with management and employees is presented herein.

1. STAFFING

Purpose

To establish authority and responsibility to fill all positions with qualified personnel by defining procedures by which employees are recruited and selected.

Policy

Vacancies will be filled from within the organization whenever qualified full-time employees are available. If there are no qualified applicants within, Personnel will recruit from outside sources. The organization complies with all phases and aspects of equal employment opportunity (this program is described below). Note: Requirements to fill positions from within an organization frequently limits options to obtain the "best qualified person" to fill a position.

Procedure

Each division head is responsible to see that his or her division is properly staffed and that all employees are properly classified. Personnel is responsible for processing procedures that are required to fill vacant positions.

Supervisor Responsibilities

Communicate and coordinate needs and requirements to Personnel. The supervisor is responsible to initiate, prepare, justify, and submit a Personnel Request Form to Personnel upon approval by the division head. It is necessary to include a job description with the request form.

The supervisor will be responsible for interviewing and selecting an applicant from a list of qualified applicants that has been prepared by Personnel.

Personnel Responsibilities

Upon receipt of the Personnel Request Form, Personnel will begin the process to fill the position by preparing a Job Vacancy Notice. This notice will include position job description and any other pertinent information required. For example, if position requires irregular hours, if location is not within immediate area, or if a special drivers license is necessary.

Personnel will post the vacancy notice on all organization bulletin boards for 5 working days. If there are no qualified applicants from within the organization, steps will then be taken to advertise outside the organization.

Using outside sources is part of the Personnel Recruitment Program and is a very important function. Examples of some outside sources are schools, colleges, training institutions of predominantly minority or disadvantaged groups, employment agencies, and advertising in newspapers or other types of publications. Personnel should maintain an active file of unsolicited job applications. Such applications should be retained for 12 to 18 months.

When all avenues have been depleted, a list of qualified applicants will be compiled and sent to the supervisor for review and screening. After the supervisor has made a selection, management should review and approve the selection. Personnel will then notify the applicant selected as well as the non-selectees.

Personnel will then proceed with the necessary processing requirements to place the applicant in the position as soon as possible.

Employee Responsibilities

Employees may apply for a vacancy by notifying Personnel before the posted deadline (5 working days from date of initial posting). If an employee applies after the posted deadline, he or she does not receive priority over outside applicants.

If an employee is interested in applying, he or she must have a satisfactory rating in all categories on job performance, must meet attendance standards of the receiving supervisor or division head, and must meet the minimum requirements of the position.

2. JOB DESCRIPTION

Purpose

To aid in the development of work requirements, establish worker qualifications, and orient employees in the responsibilities, tasks, qualifications, and salary codes of the position.

Policy

Each division head has the responsibility to periodically review and analyze duties and responsibilities assigned to each position within the division.

Assigning an employee some similar additional duties is not justification for a higher classification. Problems of excessive workloads are properly solved by redistributing the work or adding employees—*not* by reclassifying existing positions. Reclassifications are made as a result of *changes in duties and/or responsibilities* assigned to a position.

3. EQUAL EMPLOYMENT OPPORTUNITY

Purpose

To describe the organization Equal Employment Opportunity (EEO) policy.

Policy

Positions are filled with the best qualified candidates in compliance with applicable EEO requirements when selection of an applicant is made. In addition, affirmative action program goals are also a consideration.

Definition

Equal Employment Opportunity

The organization provides equal employment opportunity to all people on the basis of qualifications without regard to race, religion, creed, color, national origin, physical handicap, medical or mental condition, marital status, sex or age (except where age, sex, physical handicap, or medical or mental condition becomes a bona fide occupational requirement for the job).

This policy commits the organization to provide equal employment opportunity in all phases or aspects of employment and employee relations including, but not limited to, recruitment, selection, placement, transfers, training, and development, promotion, demotion, compensation, benefits, layoff and terminations, and all conditions or privileges of employment. Whenever the organization recruits or advertises for qualified candidates for positions, it will state that the organization complies with EEO policy.

Principles of EEO

Advertising and Recruiting Activities. All employment advertising and recruiting activities—including, but not limited to, contacts with—will be directed to all qualified applicants in accordance with the EEO policy.

Inquiry. During the recruiting process, no inquiry relative to race, religion, national origin, age, or sex will be made. Information as to age of applicant may be requested only when there are reasons to believe the applicant does not meet the minimum age requirement. Information as to physical fitness, medical condition, or medical history may be requested if the inquiry relates to the determination as to whether the applicant would endanger his or her health or safety, or the health or safety of others. Following hire, this information may be recorded for personnel records only and will be used only for reporting purposes.

Employment of Women. No women will be denied opportunity for employment or any other consideration in employee relations because of her marital status or be denied the opportunity for employment because of the age of her children.

Women applicants or employees will be considered for any position regardless of hours of work, requirements for lifting and other conditions of work. Also, women can work the same number of hours as any other employee or perform any duties for which their qualifications reasonably exhibit proficiency. Specifications for any position will be based only on bona fide occupational qualifications.

Religion. The organization will not discriminate against employees or applicants for employment because of their religious preference. Further, the organization will attempt to make every reasonable effort to accommodate the special religious observances and practices of employees or applicants for employment, except where such accommodations create hardships on the conduct of organization business or are prohibited by law.

Age. The organization will not discriminate against any employee or applicant for employment because of age. This policy applies to all dealings with applicants and employees.

Physically and Mentally Handicapped. The organization will not discriminate against any applicants for employment or employees who meet the criteria as defined by the U.S. Department of Labor, that is, persons who have a physical or mental impairment that substantially limits one or more of his major life activities; have a record of such impairment; or are regarded as having such impairment, but who are otherwise qualified for the job.

Personnel Actions. All personnel actions, including those relating to compensation benefits, transfers, demotions, layoffs, terminations, and organization-sponsored training, will be administered in accordance with the EEO policy.

Working Conditions. All employees will be provided safe and healthful working conditions.

Organization Activities. All employees will be encouraged to participate in the programs sponsored by the organization.

4. PHYSICAL EXAMINATION

Purpose

To insure that an employee is physically fit to perform the job requirements for which he or she is being considered.

Policy

All qualified applicants, including former employees who are rehired, are required to undergo a preemployment physical examination by a qualified physician at organization expense. In some instances, a physical examination may be required for a promotion, reinstatement, demotion, or transfer.

Procedure

Personnel is responsible for notifying a prospective employee that a preemployment physical examination is required by an agreed upon physician. A Physical Examination and Medical Treatment Form, indicating the Physical Group number assigned to the job, will be issued to the prospective employee.

A physical group number is determined by referring to job titles and physical group schedule. This schedule should be developed by listing all jobs and the different levels of physical activities required for each job. The jobs can then be divided into four or five categories.

Upon receipt of the physical exam report, Personnel will notify the supervisor whether applicant is physically fit or not to perform the job. After discussion with the supervisor, applicant will be notified.

5. HIRING LIST

Purpose

To assist in recruitment and selection of new employees.

Policy

When competitive examinations are given, a hiring list is prepared and maintained for 6 months (starting when the hiring list is established). The list ranks qualified applicants in order of final testing scores.

When a position is to be filled, the top seven applicants on the list are eligible for employment. However, selection is based upon further evaluation, oral interview, work experience, references and other requirements.

Should a new examination for a position be given during the period of eligibility of an existing list, names of qualified applicants resulting from the new examination are integrated with names on existing list in order of final scores.

An applicant is removed from the hiring list when he or she cannot be located, does not respond to notification or other correspondence relating to availability, or when he or she declines consideration for a position.

6. STATUS OF EMPLOYMENT

Purpose

To define the classification of positions.

Policy

All positions are classified as full-time, part-time, or temporary. All new hires or rehires are required to complete a probationary period. The probationary period is also applicable for promotions, transfers, or reclassification (see Promotion and Transfer section below).

Definition

Full-Time

Employment that requires an employee to work a minimum of an 8-hour day and 40 hours per week on a regular and continuous basis.

Part-Time

Employment requires an employee to work at least half-time on a regular and continuous basis, i.e. average of 80 hours per month, or 4 hours per day on a daily schedule. This position is expected to extend for more than 1 year. Employee is not eligible for any benefits nor has any appeal rights.

Temporary

Employment does not exceed 12 consecutive months. Employee is not eligible for any benefits nor has any appeal rights.

Probationary Period

All new hires/rehires are placed on a 6-month probationary period beginning on an anniversary date (described below). This period provides a supervisor an opportunity to observe and appraise an employee to determine whether he or she is adequately qualified for a position described above.

The division head can request an extension of the probationary period if further evaluation of the employee is desired. On the other hand, the employee may be released from the position upon 5 days written notice prior to release during this period. Upon completion of this period, the supervisor is responsible to complete an Employee Evaluation Form.

During this period, the employee does not have recall eligibility if laid off as a result of a reduction in force, any right of appeal if released for any reason, any seniority rights, and is not eligible to apply for a job vacancy until the vacancy is announced to the public.

7. PROMOTION AND TRANSFER

Purpose

To provide full-time employees an opportunity to upgrade their position and/or gain job satisfaction.

Policy

Full-time employees must meet basic standards to qualify. These include satisfactory rating in all categories on present job, must meet attendance standards of receiving supervisor or division head, and must meet minimum requirements of required duties.

The employee must also serve a 6-month probationary period to determine if qualified. Should it be determined that the probationary employee is not qualified for the new position, he or she may return to previous position, if available, or another position, if one is available and he or she is qualified. However, the employee may be released if no position is available. Employees who are not full-time employees may apply for a position after it has been advertised to the public.

Reclassification of Present Position

An employee can be reclassified when his or her duties and responsibilities differ substantially from present classification. Reclassified employees who are on the 6-month probationary period keep the same rights as other employees insofar as their being subject to disciplinary action and rights to fringe benefits.

Reclassification to Newly Created Position

The rewriting of a job description to more accurately reflect current duties does not constitute a reclassification. Such redefining of duties, although it may create a new title and/or change of salary code, does not require job posting, change in anniversary date, or probationary period.

8. TERMINATION

Purpose

To define terms and conditions when an employee terminates his or her employment or when the organization terminates an employee for management reasons.

Policy

An approving official is required to approve any and all types of termination, for example, resignation, layoff, recall, and discharge. When the organization is responsible for notifying an employee of any such actions, the employee will be given a 2-week written notice for any termination action deemed necessary.

Resignation

An employee wishing to resign is required to notify his or her immediate supervisor, and complete an Exit Interview Form. Several other circumstances under which an employee indicates voluntary termination are the following.

- Absence of three or more consecutive working days without notice to the organization unless conditions prohibit an employee from doing so.
- Failure to return from a leave of absence (LWOP).
- Failure to return from layoff upon recall.
- When employee files for unemployment insurance or accepts other employment while on an authorized LWOP.

Layoff and Recall

Time in service is the determining factor for layoff. A senior employee is retained if he or she meets the job qualifications of the present position. In some circumstances, an employee may be placed in a new position and required to serve a 6-month probationary period.

A temporary layoff becomes necessary when work is no longer available but is expected to resume within 12 months. These employees are placed on a reemployment list which is maintained for 12 months by Personnel, and are considered first when a position becomes available. While in this status, employee is considered to be in a LWOP status.

A permanent layoff may be necessary for the same reason; however, in this circumstance, recall is not anticipated.

Employees scheduled for layoff are expected to continue working during this period and failure to do so will result in disciplinary action.

Discharge

Removal for disciplinary or for medical reasons. A forced resignation is considered a discharge; however, all discharges for full-time employees are subject to appeal.

Type of Discharge	*Notice Required*
Disciplinary	5 working days written notice
Medical	5 working days written notice

Under certain circumstances, immediate separation from duties may occasionally be desired to minimize an adverse effect on other employees, or to allow the separated employee to seek new employment. In such cases, an approving official may approve up to 2 weeks pay.

Retirement

Employee will notify his or her immediate supervisor, and will report to Personnel to complete all the necessary forms.

Deceased

If termination is due to death, personnel will be responsible to process all necessary forms. Payment of any amount due the employee will be made to the employee's estate.

General Information

To receive termination pay (computed to last day of employment) and any unused annual leave, employee is required to turn in all organization equipment, tools, keys, credit cards, and supplies, and obtain a final clearance from his or her supervisor.

Organization benefits remain in effect through the month of last employment day; however, employees are not eligible for severance pay.

9. DEMOTION

Purpose

To designate occasions when a demotion is deemed necessary.

Policy

An employee may be demoted from a position in one classification to a position in a lower classification. The employee is placed at the highest step in the lower range, does not receive an increase in salary, and must serve a probationary period in the position classification to which placed. No employee will be demoted to a class for which he or she does not possess the minimum qualifications.

Procedure

Reduction In Force Due to Lack of Work or Funds

Written notice is given to the employee at least 2 weeks prior to the effective date of such a demotion.

Employee Request

Employee must submit a written request for such a demotion to his or her supervisor. All forms approving or recording this request must indicate that the demotion is voluntary.

Unable to Perform Job Duties

When an employee is unable to perform his or her duties for medical reasons, he or she may be demoted.

10. TEMPORARY UPGRADE

Purpose

To detail an employee to a temporary (less than one year) position in a higher classification.

Policy

An employee is temporarily assigned duties and responsibilities of a higher classification for a period to exceed one month. Employee will be paid a minimum of two steps (5%) more than current salary, or first step of the classification to which assigned, whichever is greater.

The effective date is first day of pay period following assignment. An employee reverts to his or her former classification when assignment is terminated.

11. ANNIVERSARY DATE

Purpose

To establish date by which all personnel actions are defined.

Policy

If an employee is hired or reclassified between 1st and 15th of the month, anniversary date is 1st of that month. If an employee is hired or reclassified between 16th and last day of the month, anniversary date is 1st day of the next month.

12. SENIORITY

Purpose

To establish guidelines when selecting employees for promotion, transfer, demotion, or layoff. Seniority is defined as an employee's length of service with the organization.

Policy

Break in Service

An employee retains seniority when on approved LWOP, but does not accrue time in-service credit if LWOP exceeds 30 calendar days (does not apply to military leave).

If LWOP exceeds 30 calendar days, employee does not accrue service credits for the month that LWOP begins or the month that it ends or any intervening months. Such a LWOP is considered a break in service. However, the employee does not lose prior time in service when computing service credit for seniority or service award recognition.

Reclassification

Seniority is not affected by any reclassification, although the anniversary date changes. The employee begins earning seniority for his or her new position on the new anniversary date.

Promotion, Transfer, Demotion, or Layoff

Seniority prevails when selecting an employee for promotion, transfer, demotion, or layoff, providing the employee meets job qualifications.

Probationary Employees

There are no seniority rights during a probationary period.

13. REHIRE OF FORMER EMPLOYEE

Purpose

To provide guidelines for rehire of a former employee.

Policy

A former employee may be considered to fill any job vacancy for which he or she is qualified; however, the rules described herein will apply.

Salary Code

A former employee may be rehired at any step in the salary code (defined below) if returning to same position; but, under no circumstances at a higher salary step than that held when terminated. If hired in a new position, employee must begin at step 1 of that classification.

Seniority

A former employee does not lose prior time in service; however, he or she does not receive service credits for the month absence began, month absence ended, or any intervening months.

Service Award

Previous time-in-service is considered in determining years-in-service-for service award recognition. However, breaks in service are deducted from date of hire to determine length of service.

Benefits

A former employee must apply as a new employee.

Anniversary Date

Date of reemployment.

14. SALARY CODE

Purpose

To establish a pay scale for all employees. The basic salary code consists of 40 salary ranges with 9 steps each. There is approximately 5% between each salary range and approximately 2½% between each step.

Policy

All position classifications are assigned a salary range by level of the job. Salaries are determined from the range steps of a salary code. Step 1 is the minimum rate and is the hiring rate for all positions.

If the current salary of an employee is above Step 9 of a new salary code to which he or she is being placed, salary can either be frozen or reduced to Step 9 of the classification in which he or she is being placed. If salary is frozen, employee does not receive any further salary increases until such time as Step 9 of that code exceeds his or her present position.

Procedure

Merit Increases

Merit increases are not granted on an automatic basis but, rather, as a result of demonstrated performance. Those whose merit increases are considered in conjunction with a cost-of-living increase may receive a higher percentage increase.

Salary Revisions

After conducting surveys of pay rates and benefits, management is required to recommend annually to the Board of Directors any revisions to the salary code.

Payroll Deductions

Mandatory Federal and other withholding taxes are automatically withheld. Deductions are made in accordance with existing laws and regulations and based on information submitted by the employee. In addition, garnishments and wage attachments are honored to comply with the law.

15. HOURS OF WORK

Purpose

To define length of employee rest and meal periods, and occasions when an employee can establish his or her hours of work.

Policy

Rest and Meal Periods

Each employee is given and encouraged to take a rest period of 15 minutes during each 4 hours of work. If a rest period is not taken, employee is not entitled to an earlier quitting time. An employee is required to take at least a 30-minute lunch hour at approximately midday.

Flexible Hours

Employees are permitted to vary their specific report-to-work and depart-from-work times between the hours of 7 a.m. and 6 p.m. daily, so long as the minimum standard number of 8 hours per day and number of 5 days per week are worked. This is providing working conditions allow, work flow permits, and supervisor approves, unless particular jobs require working different hours.

Since organization needs have first priority, the amount of scheduling flexibility will differ between the various facilities, operations, departments, and jobs. Therefore, each supervisor is responsible for the degree and form of flexibility he or she wishes to establish within his area of jurisdiction.

Exchange of Work Days

Employees are permitted, if their supervisor approves, to exchange work days with each other as long as there is no additional cost to the organization and a full work force is maintained.

16. SEXUAL HARASSMENT

Purpose

To clarify and set forth policy regarding sexual harassment.

Policy

Sexual harassment in the workplace by any person in any form is prohibited in violation of Title VII of the Civil Rights Act of 1964.

Procedure

Each complaint will be investigated quickly and confidentially in order to determine if sexual harassment has occurred. All investigations will be conducted in a manner that will ensure the privacy of all parties concerned and strict confidentiality will be maintained.

If, as a result of investigation, a determination is made that an employee has sexually harassed another employee, appropriate disciplinary action will be implemented. The discipline will depend on the nature and severity of the offense. The range of disciplinary action is from verbal reprimand to discharge.

17. SUBSTANCE ABUSE

Purpose

To establish a policy for dealing with alcohol and drugs in the workplace, provide guidelines for handling alcohol and drug usage situations. and assist employees in arresting the further advance of alcoholism and drug use before the condition renders them unemployable.

Policy

The sale, purchase, transfer, use, or possession of alcohol or illegal drugs in the workplace during work hours is prohibited and may lead to disciplinary action. Deliberate misconduct involving substance abuse could result in the employee being suspended or discharged.

Procedure

Alcoholism

When there is evidence that intoxication or use of alcohol is part of a pattern suggesting alcoholism, every effort will be made by management to determine the cause of the behavior. All actions taken must show concern for the individual regardless of how an employee may rationalize his or her actions.

Drug Abuse

A supervisor who suspects an employee (while on the job) of selling, buying, or using any illegal drug should inform upper level management. If the supervisor *observes* an employee selling, purchasing, transferring, using or possessing illegal drugs while on the job, he or she will call the appropriate law enforcement official, and place employee on suspension for that day. The supervisor will then confer with upper level management about the nature of offense and action to be taken.

General Information

It is extremely important that use of alcohol or drugs does not in any way seriously interfere with employee job performance; adversely affect job performance of another employee; endanger his or her own health or safety, or the health or safety of others; and, interfere in any way with job activities. All districts in the United States with Federal Contracts must have a drug policy and education program.

18. EMPLOYEE EVALUATION

Purpose

To provide an annual review of employee performance. This review will assist both employee and supervisor for development, counseling, and compensation review.

Policy

All employees will be evaluated annually against the specified written standard that is correlated to their job description. This standard is provided to each employee so that he or she will know exactly what is expected.

A special appraisal and review is required 1 month before the end of a 6-month probationary period for new-hires and reclassified employees.

19. COUNSELING/DISCIPLINARY ACTION

Purpose

To establish policy on dealing with employee behavior and job performance problems, and provide appropriate guidelines to assist supervisory personnel.

Policy

Behavior Problems

The following are causes that are considered a reason for employee discipline and in some cases, will lead to counseling, disciplinary action, or suspension.

Fraud in securing appointment.
Incompetence.
Inefficiency.
Inexcusable neglect of duty.
Insubordination.
Dishonesty.
Under influence of alcohol or illegal drugs while on duty.
Addiction to use of narcotics or habit-forming drugs.
Inexcusable absence without leave.
Conviction of a felony or conviction of a misdemeanor involving moral turpitude.
Immorality.
Discourteous treatment of the public or other employees.
Improper political activity.
Misuse or theft of organization property.
Violation of organization rules, regulations, or policies.
Refusal to take and subscribe any oath or affirmation that is required by, or in connection with, employment.

Other failure of good behavior either during or outside of duty hours that is of such a nature that it causes discredit to the organization or his or her employment or creates a conflict of interest.
Falsifying records.
Either sale, purchase, transfer, possession, or consumption of alcoholic beverages or illegal drugs, or use of drugs that impair the senses or ability to perform the job during work hours or on organization premises.
Excessive tardiness.
Possession of firearms or explosives while on duty or on organization premises.
Violation of safety rules, policies, or procedures or other failure to perform work in a safe manner.

Causes for Suspension

Under the influence of alcohol or drugs while on duty, possession of firearms or explosives, or reporting to work without required safety apparel.

Counseling

When job performance requires improvement or conduct (attendance, punctuality, attitude, insubordination) is unsatisfactory, but disciplinary action is not then warranted, supervisor is required to complete a counseling statement.

This form provides a consistent and uniform approach and is used in lieu of a memorandum. The statement is retained in employee personnel file for 5 years. If no related corrective disciplinary measures are recorded during that time, the statement is removed and destroyed.

Procedure

Normally, corrective or disciplinary actions will be administered by either a verbal discussion with the employee or a written notice, depending on length of suspension. The supervisor can administer any action that he or she feels is warranted by the circumstances.

A supervisor can suspend an employee without pay (for 10 working days or less). The employee will be requested to leave, will be given reason for suspension, and will be informed that he or she has the right to appeal (within 10 working days after date of suspension) in writing to upper level management and in turn to Board of Directors.

20. PROBLEMS AND COMPLAINTS

Purpose

To provide a procedure by which an employee can exercise his or her right to discuss problems or complaints with management and receive a just and fair solution.

Policy

If an employee has a work-related problem or complaint, he or she has a right to resolve the matter by performing the steps as outlined. In this regard, the division head will permit an employee a reasonable amount of working time to prepare and present the matter. The employee will not be penalized in any way when using this process to resolve a problem.

Procedure

The employee will discuss the matter with the supervisor within 5 working days. If the matter involves the supervisor, an employee may turn to the next higher level of management.

If the immediate supervisor fails to resolve the matter, the employee completes a Complaint Form for submittal to the next level of management within 5 calendar days after discussion with supervisor.

The Manager has 10 calendar days to render a decision. If at that time the employee disagrees with the decision, he or she may make a formal appeal to the Board of Directors within 10 days. The Board of Directors' decision is final.

21. SERVICE AWARDS

Purpose

To establish recognition of employee tenure with the organization.

Policy

In recognition of service with the organization, an employee is awarded a specific service award for continuous service. Continuous service is measured from original date of hire to present date; however, breaks in service are deducted from date of hire to determine length of service to be considered.

Year	*Typical award*
5	Certificate of Appreciation
10	Plaque of Appreciation
15	3-Piece Pen/Pencil Set with organization emblem
20	Engraved watch

22. PAY DAYS

Purpose

To designate days on which paychecks are issued.

Policy and Procedures

All employees are paid on the 20th and 5th day of each month, or last working day preceding these dates when dates occur on Saturday, Sunday, or observed holiday (other districts pay monthly or on other dates within the month). The check issued on the 20th covers period from 1st through 15th, and check issued on 5th day of the month covers period of 16th through last day of previous month.

Employees who leave the organization may receive their final pay on next regular payday following termination, providing they have been checked out by their supervisor and have complied with termination requirements.

Pay for "new hires" is computed on an hourly basis for actual total hours worked if they begin work after the first day of a pay period. The amount of pay, however, cannot exceed their semimonthly salary.

23. LEAVE POLICY

Purpose

To establish annual and sick leave policy.

Policy

Employees accrue 8 hours annual leave and 6 hours sick leave per pay period.

Both annual and sick leave are accrued during the probationary period. While sick leave may be used whenever needed, an employee can be granted LWOP for extenuating circumstances.

If a holiday falls on a regularly scheduled day off, the probationary employee receives credit for 8 hours of annual leave (unless holiday falls on a Saturday), and may use his or her credit of 8 hours on annual leave during his probationary period.

An employee who is on probation is not eligible for a "floating" holiday; however, employee is eligible for all other observed holidays.

24. BUSINESS EXPENSES

Purpose

To provide a procedure for reimbursement of approved business expenses.

Policy

An employee required to incur approved business expenses can charge expenses to their personal credit cards or pay cash. The employee will complete an Expense Claim Form for reimbursement.

In some circumstances, a travel advance may be authorized by an approving official to avoid an undue hardship on the employee.

An employee cannot have the organization billed directly for business expenses except when employee is issued a credit card. Expenses of a spouse are not covered and will not be reimbursed.

25. OVERTIME

Purpose

To identify reimbursable expenses when an employee is required to work *unscheduled* overtime. Unscheduled overtime is defined as work other than regular scheduled hours.

Policy

When an employee is required to work unscheduled overtime, meals and mileage are reimbursable.

Meals

Meal expenses are reimbursed provided unscheduled overtime worked extends beyond 4 hours, employee actually takes time off for such a meal, and time off is not charged as time worked. If unscheduled overtime extends beyond 8 hours, employee is entitled to reimbursement for two meals.

Mileage

An employee working unscheduled overtime is reimbursed for use of his or her personal automobile at the appropriate rate per mile.

Procedure for Reimbursement

Employee reports expenses on an Expense Claim Form and forwards it to supervisor for approval. Supervisor approves the reimbursement and transmits the form to the Accounting Department for payment.

26. OVERTIME/PREMIUM PAY

Purpose

To provide guidelines and procedures for payment of work in addition to regularly scheduled time.

Policy

Overtime Pay

Employees required by their supervisor to work over 8 hours in one day, or during all or part of a day in addition to those regularly scheduled, are paid 1½ times normal rate for the additional time worked. Overtime is reported in quarter-hour increments.

If an employee is requested to work overtime in addition to his regularly scheduled working hours, minimum paid is 2 hours at overtime rate even though the 2 hours may overlap into regularly scheduled working hours.

Overtime is computed from the time the employee arrives at the jobsite or office and ends at the time he or she leaves the jobsite or office.

Holiday Pay

If additional hours are on a holiday, employee is paid at twice the normal rate. If a holiday falls on a Sunday and day of observance is Monday with additional hours worked on one or both of these days, employee is paid twice his or her normal hourly rate for Monday hours only.

Sunday Pay

If additional hours worked are on a Sunday, employee is paid at 1½ times his or her normal rate. If the hours are part of a regularly scheduled work week (10-4 work schedule), employee is paid at 1¼ times normal rate.

Effect of Absence

Paid time from work during any scheduled work day is counted as hours worked for purpose of determining overtime pay. If an employee works while on approved annual leave, leave is cancelled and he or she is paid at normal rate.

Compensatory Time

The organization does not provide compensatory time off.

APPENDIX C. JOB DESCRIPTIONS

ASSESSMENT CLERK I

Primary Function

Under the supervision of the Assistant Assessor, prepares the assessment roll, maintains property records, and calculates and collects the assessments.

Distinguishing Features

Assessment Clerk I is the entry level classification in this series. Individuals in this class receive training and experience and work under close supervision. As knowledge and skills are gained, assignments become progressively more varied and difficult.

Assessment Clerk II is the skilled level classification in this series. Individuals in this class are expected to perform the assigned duties related to the assessment process, with minimum supervision, exercising some latitude for independent judgment.

Examples Of Work Performed

Maintains and updates all records, files, and maps necessary to process assessments.
Collects and processes assessment receipts.
Prepares and files Certificates of Sale, Redemption Receipts, and Collectors Deeds.
Prepares and/or types correspondence, reports, and other data.

Classification Requirements

Education and Experience

Any combination of education and experience that has led to the acquisition of the knowledge and abilities as indicated below. Typical ways of acquiring such knowledge and abilities are the following.

Completion of the twelfth grade, or equivalent.

Knowledge and Abilities

General Knowledge of

Modern office practices and procedures.
Filing procedures.
Correct spelling, grammar, and punctuation.

Ability to

Operate office equipment, such as a typewriter, calculator, and microcomputer.

AUTOMOTIVE MECHANIC

Primary Function

Under the supervision of the Shop Supervisor or Equipment Mechanic, repairs, overhauls, and maintains (predictive and preventive) automobiles, light trucks, and various heavy-duty, portable, and stationary engines.

Distinguishing Features

Automotive Mechanic is a skilled level classification. This classification is distinguished from the Equipment Mechanic classification in that the Equipment Mechanic works on heavy-duty automotive vehicles and mobile earth-moving and load-lifting equipment.

Examples Of Work Performed

Performs predictive and preventive maintenance work on various engines, automobiles, and light trucks.

Repairs or replaces defective or worn parts and accessories.

Inspects and diagnoses mechanical and electrical malfunctions in automobiles, light trucks, and various heavy-duty, portable, and stationary engines.

Performs major and minor engine tune-ups.

Overhauls engines, transmissions, differentials, braking, and steering systems.

Responds to field service calls to repair disabled vehicles.

Classification Requirements

Education and Experience

Any combination of education and experience that has led to the acquisition of the knowledge, skills, and abilities as indicated below. Typical ways of acquiring such knowledge, skills, and abilities are the following.

1. Completion of the twelfth grade, or equivalent, and four years of experience as a general automotive mechanic; or
2. Attainment of journey level status as an automotive mechanic.

Knowledge, Skills, and Abilities

Thorough Knowledge of

Methods, materials, tools, and equipment used in the overhaul, repair, and maintenance of automobiles, light trucks, and various heavy-duty, portable, and stationary engines.
Operating characteristics of automotive equipment.

Working Knowledge of

Use, adjustment, and care of test equipment and hand and power tools common to the trade.
Vehicle service manuals.

Skill in

Testing, diagnosing, and making repairs to automobiles, light trucks, and various heavy-duty, portable, and stationary engines.
Using a variety of garage equipment, tools, and automotive diagnostic instruments.
Reading and interpreting mechanical drawings and specifications.

Ability to

Diagnose and correct equipment malfunctions.
Develop schedules and records system for use in an equipment maintenance and repair program.
Operate material-handling equipment.

CHIEF OF MAINTENANCE

Primary Function

Under the direction of the General Manager, plans, organizes, and directs all maintenance work for the district, including the district's pipelines, canals, pumping plants, and field facilities.

Distinguishing Features

Chief of Maintenance is a single position classification appointed by the Board of Directors. The individual in this class is responsible for managing the activities and staff of the Maintenance Division. The individual in this class plans, organizes, and supervises the areas of preventive and corrective maintenance and emergency repair of the district's water distribution system, drainage collector system, Pleasant Valley Pumping Plant, and Coalinga Canal.

Examples Of Work Performed

Through subordinate supervisors, plans, organizes, staffs, controls, coordinates, and directs the activities and staff of the Maintenance Division to render efficient, economical, and timely maintenance of the district's field facilities.

Formulates and directs the implementation of specific goals, objectives, priorities, and policies, and develops standards and guidelines for diverse maintenance activities.

Develops and controls budget for the Maintenance Division.

Recommends and participates in the development of district goals, objectives, priorities, and policies.

Determines the cost effectiveness of work performed by district personnel and by outside contacts and recommends appropriate action to provide and maintain service in the most cost effective manner.

Ensures that adequate supervision and personnel are available to handle emergencies on a 24-hour-per-day basis.

Monitors improvements to equipment, materials, tools, and procedures.

Serves as District liaison or representative on committees, commissions, task forces, and at meetings.

CLASSIFICATION REQUIREMENTS

Education and Experience

Any combination of education and experience that has led to the acquisition of the knowledge and abilities as indicated below. Typical ways of acquiring such knowledge and abilities are the following.

A bachelor's degree in Engineering, Business Administration, or a related field, or equivalent, and 5 years of broad and extensive experience managing a work force performing construction and maintenance work of water distribution facilities, including underground pipeline systems and/or pumping plants.

Knowledge and Abilities

Thorough Knowledge of

Principles, methods, and techniques of the development and implementation of a coordinated program for the maintenance and repair of the district's physical facilities.
The applicable safety and accident procedures of the California Occupational Safety and Health Act.
The applicable California General Industrial Safety Orders.

Working Knowledge of

Management principles and practices.
Budgeting principles and practices.

General Knowledge of

Computer technology as applied to maintenance and construction work.

Ability to

Plan, organize, and coordinate maintenance activities of an organization.
Supervise, through subordinate supervisors, a group of professional, technical, and office support employees.
Effectively deal with others as a representative of the district.
Analyze organizational and administrative problems and work cooperatively with administrators to improve effectiveness of the district's operations.
Develop and effectively use all available resources.
Make innovative changes in work methods, techniques, and procedures.
Operate material-handling equipment.

CHIEF OF OPERATIONS

Primary Function

Under the supervision of the General Manager, plans, organizes directs, controls, and supervises the District's field operations and office water marketing activities and assists in determining current and future water and water operation needs of the District.

Distinguishing Features

Chief of Operations is a single position classification appointed by the Board of Directors. The individual in this class is responsible for planning, directing, and reviewing, through subordinate supervisors, the day-to-day activities of employees involved in water marketing and scheduling activities and the operation and maintenance of water and power meters.

Examples Of Work Performed

Recommends and participates in the development of District goals, objectives, priorities, and policies.

Develops and controls the budget and formulates and oversees the implementation of specific policies and long-range plans for the District.

Directs Operations Division activities in the marketing and control of agricultural and nonagricultural water supplies, including the purchasing, marketing, and delivery of water.

Interprets management policies and procedures to subordinates and ensures that they are understood and followed.

Develops and implements work and cost control procedures and standards.

Works with the fiscal division to facilitate timely water purchases.

Represents the district at various general and technical meetings.

Participates in the negotiating of cooperative arrangements with others.

Monitors improvements to equipment, materials, and procedures.

Responds to emergency situations and coordinates the systematic shutdown of the system or a portion of the system with other agencies.

Assists in developing and implementing district policies.

Classification Requirements

Education and Experience

Any combination of education and experience that has led to acquisition of the knowledge and abilities as indicated herein. Typical ways of acquiring such knowledge and abilities are the following.

A bachelor's degree with major work in engineering, agriculture, business administration, or a related field, or equivalent, and five years of experience in the field of water management.

Knowledge and Abilities

Working Knowledge of

Principles of administration, operation, and management practices applicable to large agricultural water delivery organizations contracting with the Federal or State Project.
Operations of the Central Valley Project and the State Water Project.
Reclamation law.
Principles of supervision and budgeting.

Ability to

Effectively assist in evaluating ongoing operations and programs that develop plans to improve their effectiveness and efficiency.
Develop and maintain effective working relationships with various District personnel, the public, and governmental representatives.
Make field investigations.

DISPATCHER CLERK

Primary Function

Under the supervision of the Assistant Maintenance Superintendent, operates a mobile radio base station, interoffice radio, and telephone console system; and performs a variety of clerical work.

Distinguishing Features

Dispatcher Clerk is a single position classification. The individual in this class performs duties involving constant interaction with the public and/or other employees, either in person or over the radio-telephone, telephone, or other related equipment. Successful performance of the work requires tact, courtesy, and, in emergency situations, a skill in dealing with more than one individual at one time.

Example Of Work Performed

Receives, distributes, and transmits interoffice and mobile radio and telephone messages.

Receives, sorts, logs, distributes, and dispatches mail and documents.

Procures, stores, and distributes office supplies.

Gathers and summarizes statistical information.

Classification Requirements

Education and Experience

Any combination of education and experience that has led to the acquisition of the knowledge and abilities as indicated below. Typical ways of acquiring such knowledge and abilities are the following.

A combination of two years of experience either as a Maintenance Worker-Trainee, Maintenance Worker I, Operator Trainee, or Operator I with the District.

Knowledge and Abilities

General Knowledge of

Standard office practices and procedures.

Ability to

Learn to accurately perform basic clerical tasks.
Learn to operate a mobile radio base station and related equipment.

ELECTRICIAN I

Primary Function

Under the supervision of the Electrical Supervisor, maintains, repairs, and installs electrical circuits, motors, controls, and equipment used in a water distribution system and related facilities.

Distinguishing Features

Electrician I is the skilled level classification in this series. Individuals in this class are fully competent to install, maintain, repair, and otherwise work with both low and high voltage equipment. The work covers the entire trade and individuals often work independently due to the diverse nature of the work and the distances between the facilities involved.

Electrician II is the lead level classification in this series. Individuals in this class provide lead supervision and coordination of a crew and are responsible for planning, directing, and assisting the day-to-day activities of skilled and semiskilled level workers.

Electrical Supervisor is the supervisory level in this series. Individuals in this class are responsible for directing the work of skilled and semiskilled level workers performing field and shop maintenance, installation, calibration, and repair work on a wide variety of electrical and control equipment.

Electrician's Helper is the semiskilled level classification in this series. Individuals in this class perform routine electrical repair and maintenance assignments and assist in the more complex work. This classification is distinguished from the Electrician I classification in that the Electrician I performs a broader range of skilled work, requiring a higher degree of trade knowledge, and works under less supervision.

Electrician-Trainee is the entry level classification in this series. Individuals in this class receive training and experience and learn to perform basic electrical duties under close supervision. Upon completion of the training, individuals are expected to advance to Electrician's Helper.

Examples Of Work Performed

Inspects, maintains, repairs, installs, overhauls, and tests a variety of electrical equipment and appurtenances.

Performs troubleshooting and diagnostic work on a variety of electrical equipment.

Installs conduit and pulls wire for motors, control panels, lighting fixtures, outlets, and other purposes.

Makes cable splices of various sizes and difficulty.

Classification Requirements

Education and Experience

Any combination of education and experience that has led to the acquisition of the knowledge, skills, and abilities as indicated below. Typical ways of acquiring such knowledge, skills, and abilities are the following.

1. Completion of the twelfth grade, including one year of high school level algebra, or its equivalent, and three years of experience as an Electrician's Helper with the District; or

2. Completion of the twelfth grade, including one year of high school level algebra, or its equivalent, and attainment of journeyman level status as an electrician in general electrical installation and repair work, including high voltage.

Knowledge, Skills, and Abilities

Working Knowledge of

The National Electrical Code and relevant Safety Orders.
The use and operation of measuring and testing devices, hand tools, and equipment of the trade.
Principles of electrical installation, maintenance, operation, and testing.
Shop drawings and electrical wiring diagrams.
Trigonometric functions.
Equipment service manuals.

Skill in

Installing, maintaining, and repairing electrical wiring, motors, and other electrical equipment.
Reading and interpreting electrical wiring diagrams.

Ability to

Climb stationary ladders up to and including 100 ft in height.
Work suspended above ground level (approximately 45 ft) in a bosun chair or aerial lift.
Work in excavations (approximately 20 ft below ground level).
Learn the operation and maintenance of mechanical equipment.
Differentiate colors.

EQUIPMENT OPERATOR

Primary Function

Under the supervision of a Maintenance Supervisor, operates and makes minor adjustments and repairs to a variety of mobile earth-moving and load-lifting equipment which is used in the construction, maintenance, and repair of water distribution facilities and property.

Distinguishing Features

Heavy Equipment Operator is a skilled level classification. Individuals in this class operate a variety of pieces of equipment skillfully and safely in a variety of field locations and situations. Successful performance of the work requires the use of initiative and independent judgment as assignments are often performed without direct supervision.

Examples Of Work Performed

Checks job site for potential hazards, determines precautions necessary for safe equipment operation, and analyzes work assigned and recommends equipment and methods to perform the work.

Scarifies and windrows existing surfaces, spreads base and surfacing materials, and moves and distributes soil and rocks to a predetermined horizontal and vertical alignment.

Drives heavy equipment while moving to and from job locations or while loading and unloading equipment on and off trucks during such movements.

Operates heavy equipment in excavating trenches, lowering and lifting pipe and other materials, backfilling and moving dirt, rolling street surfaces, and grading roads and small areas.

Gives directions to workers who perform work in conjunction with the operation of the equipment.

Makes operating adjustments and may make minor repairs to the equipment in the field such as changing teeth on buckets, tightening loose bolts, or tightening loose coupling on hydraulic lines.

Reports the necessity for major repair work and assists in repair work in the field when necessary.

Maintains assigned equipment in a clean and orderly condition.

Reads grade stakes and set out ditch lines.

Classification Requirements

Education and Experience

Any combination of education and experience that has led to the acquisition of the knowledge, skills, and abilities as indicated below. Typical ways of acquiring such knowledge, skills, and abilities are the following.

1. Four years of experience in the regular operation of a variety of heavy construction equipment, including backhoes, rubber-tired or track-type tractors, front-end loaders, motor graders, and hydraulic motor cranes; or

2. Attainment of recognized journeyman level status as a Heavy Equipment Operator.

Knowledge, Skills, and Abilities

Working Knowledge of

The operation, work methods, and limitations of heavy construction equipment of the type indicated.

California Vehicle Code and Construction Safety Orders pertaining to the operation and transportation of such equipment.

General Knowledge of

The service requirements of gasoline and diesel engines and heavy construction equipment.
Underground pipelines and other utility cables.
Survey stakes, elevations, and grades.

Skill in

Operating a variety of heavy construction equipment, including motor graders, backhoes, and a variety of tractors in a safe and efficient manner.
Making minor adjustments and repairs, if necessary.
Reading survey stakes, elevations, and grades.

Ability to

Recognize the need for major equipment repairs and hazardous operating conditions and take the necessary precautions.

MAINTENANCE PLANNER

Primary Function

Under the supervision of the Assistant Chief of Maintenance, plans and schedules the construction, maintenance, and repair work of civil, electrical, and mechanical facilities and secures, coordinates, directs, and organizes equipment, materials, and crafts to do such work.

Distinguishing Features

Maintenance Planner is the skilled level classification in this series. Individuals in this class are responsible for planning, scheduling, directing, and coordinating work to be done on the District's facilities. These responsibilities include the securing and organizing of the equipment, materials, and crafts to do the work.

Assistant Maintenance Planner is the entry level classification in this series. Individuals in this class receive training and experience and, under close supervision, perform basic duties involved in the scheduling and planning of work to be done on the District's facilities.

Examples Of Work Performed

Schedules work, estimates time, and prepares weekly work schedule sheets.

Determines tasks to be performed by each craft and secures materials.

Implements and maintains the computerized work order system.

Develops historical records of repetitive maintenance work to standardize material needed and man-hour requirements and develops and maintains time-slotting standards for nonrepetitive maintenance work.

Reviews work orders for completeness, priority, and cause coding.

Reviews labor backlog data.

Inspects job sites for unusual work conditions.

Assists in establishing and operating an effective preventive maintenance program.

Maintains equipment data cards.

Classification Requirements

Education and Experience

Any combination of education and experience that has led to the acquisition of the knowledge, skills, and abilities as indicated below. Typical ways of acquiring such knowledge, skills, and abilities are the following.

1. Completion of the twelfth grade, or its equivalent, and four years of experience in water distribution system construction and maintenance work and two years of experience as a Maintenance Planner-Trainee with the District; or
2. Completion of the twelfth grade, or its equivalent, and fours years of experience in water distribution system construction and maintenance work and two years of storekeeping experience in which the major duties involved the receipt, storage, and issuance of materials, supplies, or equipment.

Knowledge, Skills, and Abilities

Working Knowledge of

Basic mathematics.

The identification and uses of construction equipment, tools, and supplies used in a water distribution system.

Civil, electrical, and mechanical construction and installation drawings.

Skill in

Operating material-handling equipment.

MAINTENANCE WORKER I (Preventive Maintenance)

Primary Function

Under the supervision of a Maintenance Supervisor, performs construction, maintenance, and repair work on water distribution and related facilities.

Distinguishing Features

Maintenance Worker I (Preventive Maintenance) is the second level classification in this series. Individuals in this class are assigned a variety of the routine tasks related to the construction, maintenance, and repair of water distribution and related facilities. As experience is gained and skills increase, assignments will carry greater responsibilities and independence from close supervision.

Maintenance Worker II (Preventive Maintenance) is the lead level classification in this series. Individuals in this class provide lead supervision and coordination of a crew involved in the construction, maintenance, and repair of water distribution and related facilities.

Maintenance Supervisor is the supervisory level classification in this series. Individuals in this class are responsible for planning, assigning, directing, coordinating, and evaluating the activities of crews involved in the construction, maintenance, and repair of water distribution and related facilities.

Maintenance Worker-Trainee is the entry level classification in this series. Individuals in this class receive training and experience in the construction, maintenance, and repair of water distribution and related facilities.

Examples Of Work Performed

Cuts, burns, chemically sprays (using hazardous chemicals), and disposes of aquatic and vegetative growth.

Cleans trashracks and moss screens.

Repairs compacted earth embankments and bituminous road surfacing.

Lubricates, services, removes and installs, disassembles, repairs, and reassembles butterfly, check, and gate valves, air compressor units, and other mechanical facilities.

Inspects, services, and adjusts traveling water screens and disposes of moss.

Inspects district headworks structures and pumping plants.

Performs scheduled lubrication of pumps, valves, air compressors, and other mechanical equipment.

Initiates work orders for repairs to equipment.

Classification Requirements

Education and Experience

Any combination of education and experience that has led to the acquisition of the knowledge, skills, and abilities as indicated below. Typical ways of acquiring such knowledge, skills, and abilities are the following.

1. One year of experience as a Maintenance Worker-Trainee with the district; or
2. One year of experience in general industrial repair work.

Knowledge, Skills, and Abilities

Working Knowledge of

Basic mathematics.
Elementary civil and mechanical drawings.

Skills in

Operating material-handling equipment.

Ability to

Climb stationary ladders up to and including 100 ft (30.5 m) in height.
Work suspended above ground level (approximately 45 ft [13.7 m]) in a bosun chair or aerial lift.
Work in excavations (approximately 20 ft [6.1] below ground level).
Work in buried dewatered pipelines 3 ft (0.9 m) to 13 ft (4.0 m) in diameter.

OFFICE ASSISTANT I

Primary Function

Under the supervision of the Supervisor of Office Services, performs a variety of clerical duties, including the operation of office machines and equipment.

Distinguishing Features

Office Assistant I is the entry level classification in this series. Under close supervision, individuals in this class perform routine and repetitive duties. As experience and proficiency are gained, duties become more varied and difficult while close supervision decreases.

Office Assistant II is the second level classification in this series. Under general supervision, individuals perform duties of average difficulty and exercise some latitude for independent judgment.

Office Assistant III is the skilled level classification in this series. Individuals in this class are cross-trained to work as relief computer operators. In addition, their work involves more complex and specialized clerical duties.

Examples Of Work Performed

Operates a variety of mail room equipment, such as letter openers, postage machines, and postage scales.

Assembles and organizes outgoing mail, determines proper class and correct postage to affix, and processes mail through appropriate inserting and stamping equipment.

Maintains various mailing lists.

Operates offset duplicating, collating devices, and other related equipment to produce a variety of printed materials.

Operates equipment to trim, drill holes, staple, and bind printed materials and pads forms as instructed.

Using hazardous chemicals, handles and mixes various chemicals and inks.

Cleans, lubricates, adjusts, and makes minor repairs to office equipment and machines.

Orders, receives, stores, and issues office supplies and equipment.

Collects and distributes interoffice mail.

Makes deliveries and pickups of supplies, parts, correspondence, and mail.

Assists in conducting periodic inventories of office supplies and equipment.

Classification Requirements

Knowledge and Abilities

General Knowledge of

Modern office practices, procedures, machines, and equipment.

Ability to

Learn and remember names, locations, routes, and procedures.
Learn the operation and adjustment of a variety of mail room and duplicating equipment.
Perform basic clerical work.
Load and unload materials of various bulk and weight, including lifting objects weighing up to 30 lbs (13.6 kg).
Stand and maintain mobility for several hours.

SENIOR ENGINEER

Primary Function

Under the general direction of the Assistant Chief Engineer, supervises and performs engineering and technical work of considerable complexity in the planning, design, construction, and operation of the district's facilities.

Distinguishing Features

Senior Engineer is the third level classification in the engineering series. Individuals in this class require an extensive engineering background in progressively difficult assignments and receive assignments in broad and general terms, have considerable latitude for unreviewed actions and decisions, and provide functional leadership for various phases of district engineering projects. Responsibilities involve relatively independent and extensive contacts with other organizational units and agencies.

Assistant Engineer is the second level classification in the engineering series. Individuals in this class perform the more difficult or complex phases of an engineering project and may act as a leader on specific and recurring projects of moderate size. The duties require a knowledge of the principles and practices of engineering and skill in the application of such principles in solving engineering problems.

Junior Engineer is the entry level classification in this series. Individuals in this class require a knowledge of engineering fundamentals. Work assignments are received in specific terms and are subject to frequent review while in progress and upon completion, except where tasks to be performed fall within well defined areas covered by established standards, policies, and procedures. As experience and proficiency are gained, assignments become progressively more diversified and difficult while exercising increasing independence of judgment.

Examples Of Work Performed

Plans, assigns, and supervises the work of other engineers, technicians, and consultants engaged in planning studies, project development, and preparation of designs, specifications, contract and bid documents, estimates, and reports.

Plans, prepares, coordinates, and administers construction contracts and agreements.

Directs a variety of analyses related to water quality or wastewater treatment.

Reviews and interprets bacteriological, biochemical, microbiological, or chemical tests and data, and develops water quality and wastewater treatment standards.

Provides leadership as a Project Engineer on major engineering projects.

Prepares or reviews initial studies and drafts of environmental impact assessment reports.

Classification Requirements

Education and Experience

Any combination of education and experience that has led to the acquisition of the knowledge, skills, and abilities as indicated below. Typical ways of acquiring such knowledge, skills, and abilities are the following.

A bachelor's degree in Civil, Mechanical, or Agricultural Engineering curriculum which is accredited by the Accreditation Board for Engineering and Technology, and 5 years of civil, mechanical, or agricultural engineering experience, 3 years of which must have involved the performance of increasingly difficult engineering work related to the planning, design, construction, and operation of pipeline distribution system or related hydraulic structures.

Knowledge, Skills, and Abilities

Working Knowledge of

Civil engineering principles, practices, and terminology with particular reference to a water supply and wastewater treatment utility.
The principles of hydraulic and hydrographic design, materials, engineering, and soil mechanics, and structural engineering.
Engineering mathematics and statistical analysis techniques.
Engineering economics.

General Knowledge of

The fundamentals of specification writing and building codes and regulations.

Skill in

Inspecting contractor construction projects and existing water storage facilities.
Conducting engineering studies and evaluations.
Preparing, negotiating, and administering contracts and agreements.

Ability to

Direct the work of others and evaluate consultant proposals and proposed revision to procedures, methods, and equipment.
Evaluate ongoing operations and develop plans to improve their effectiveness and efficiency.

WAREHOUSEMAN I (Male or Female)

Primary Function

Under the supervision of the Warehouse Supervisor, assists in the receipt, storage, handling, and issuance of materials, supplies, and equipment; performs varied clerical work including data entry; and stages work materials.

Distinguishing Features

Warehouseman I (Male or Female) is the entry level classification in this series. Individuals in this class receive training and experience in warehouse duties and perform basic duties under supervision.

Warehouseman II (Male or Female) is the skilled level classification in this series. Individuals in this class are fully trained to assist the Warehouse Supervisor in the daily operation of the District's central warehouse, including training and supervising other workers.

Warehouse Supervisor is the supervisory level classification in this series. The individual in this class is responsible for the overall operation of the District's central warehouse. Responsibilities also include the gardening and building maintenance work involved at the Five Points Shop and Field Office.

Examples Of Work Performed

Performs clerical duties.

Gathers and stages materials in accordance with work order requirements.

Picks up and delivers supplies.

Updates computerized inventory system.

Initiates replacement requests when supplies reach the reorder point.

Maintains storage areas in a clean, orderly, and safe manner.

Loads and unloads materials.

Assists in the receiving, storing, transporting, issuing, and salvaging activities at the District's central warehouse.

Assists in inventory control and physical inventories.

Assists in maintaining stock within prescribed service levels.

Classification Requirements

Education and Experience

Any combination of education and experience that has led to the acquisition of the knowledge, skills, and abilities as indicated below. Typical ways of acquiring such knowledge, skills, and abilities are the following.

One year of experience in general storekeeping or warehouse work using a computerized inventory control system.

Knowledge, Skills, and Abilities

Working Knowledge of

Methods, practices, and equipment used in the receipt, storage, handling, issuing, and preservation of materials and equipment.
Stock levels and reorder points.
Inventory control techniques.
Telephone techniques.
Purchasing cycle as is applies to warehousing activities.

Skill in

Operating a calculator.

Ability to

Perform difficult clerical work.
Follow inventory control procedures.
Maintain inventory records and cost data.
Update the computerized inventory system.

Distinguish and identify specific types of materials.
Operate material-handling equipment.
Operate a typewriter.

WATER DELIVERY CONTROLLER II

Primary Function

Under the supervision of the Supervising Water Delivery Controller, performs duties related to water ordering and water delivering activities, including water use accounts and relations.

Distinguishing Features

Water Delivery Controller II is the skilled level classification in this series. Individuals in this class perform difficult duties, including responding to water user inquiries and complaints in a satisfactory manner. Individuals exercise judgment in determining appropriate actions to take in dealing with water users and others.

Senior Water Delivery Controller is the lead level classification in this series. Individuals in this class provide lead supervision and coordination of other workers and are responsible for planning, directing, and assisting in the day-to-day activities of the water marketing functions.

Supervising Water Delivery Controller is the supervisory classification in this series. Individuals in this class plan, organize, coordinate, and direct the activities related to the marketing and delivery of water. Individuals in this class are responsible for the development and maintenance of good business relations with water users, enforcement of district regulations regarding use of water, and the effective coordination of water marketing activities within the district and with others.

Water Delivery Controller I is the entry level classification in this series. Individuals in this class receive training and experience and, under close supervision, perform most duties involved in the water marketing functions.

Examples Of Work Performed

Advises water users of policies, rules, procedures, and legal requirements relating to the delivery of water.

Responds to and resolves water users' complaints or inquiries and contacts water users to settle overdue accounts.

Receives and processes requests for closing down of individual water deliveries and laterals and coordinates shutdown with the affected water user.

Receives, processes, and approves water orders with applications to determine eligibility, and assembles data for use in preparation of monthly water bills.

Prepares various reports and records pertaining to water deliveries.

Communicates information to, and receives information from, field operations personnel, maintenance personnel, water users, landowners, and various other outside agencies.

Classification Requirements

Education and Experience

Any combination of education and experience that has led to the acquisition of the knowledge, skills, and abilities as indicated below. Typical ways of acquiring such knowledge, skills and abilities are the following.

1. Two years of experience as a Water Delivery Controller I with the district; or
2. Three years of experience in which a major portion of the duties involved mathematical calculations and record keeping.

Knowledge, Skills, and Abilities

Working Knowledge of

Modern office practices, procedures, and equipment.
Water district operations and billing procedures.

Skill in

Operating a calculator.
Preparing reports and maintaining records.

Ability to

Listen, interpret, and handle water user inquiries.
Interpret and apply district regulations and procedures.
Develop and maintain effective working relationships with water users, landowners, and representatives of other agencies and groups.

APPENDIX D. BUDGET GUIDELINES

1. PREPARATION GUIDELINES

Inflation

In preparing a budget for the next fiscal year, the requestor should take into account that the budget will be for item(s) that will be purchased as much as 15-18 months later, and provide for inflation on item(s) to be purchased.

There is no set rate for inflation. The cost of some budgeted items may remain constant, others may decrease in price, and still others can rise, sometimes as high as 50 to 100%. The frequent user or requestor is probably the best person to estimate price direction and degree of change. Other sources that can be used to determine price direction and percentage change might include the following.

- Inventory records that show past purchases of the item and unit cost.
- Copies of past materials requests that show the purchase order number and unit cost.
- Purchasing copies of all purchase orders (maintained in numerical sequence).
- Paid invoices in the fiscal division's records.
- Discussion with supplier.
- Discussion with purchasing agent.

Failure to provide for future price increases can delay purchasing budgeted item(s) should the budget be short of funds for the item(s). This is especially true in instances of large dollar value items and capital assets.

Rounding

All budget accounts and subaccounts should be rounded up to the nearest $100.

Impacts on Other Budgets

In preparing division budgets, plans of one division may have impacts on another division. Review proposed budgets in sufficient time to discuss impacts or possible impacts with other divisions and still provide sufficient time to properly plan and prepare the budgets. Some typical examples of items that might impact other divisions are the following.

- New hires—These should be discussed with the personnel department to cover any advertising needs for position desired.

- Additional mailings—This should be discussed with the administration department, which needs to budget for clerical time, supplies, and postage.
- Large purchases—These items should be discussed with the purchasing department regarding the impact on the freight and/or advertising budgets.

The list can be endless. Each division head should discuss plans with other division heads, as they would expect to hear about any plan that might impact budget.

2. CODES

One method that can be used to develop a budget code would be to use five numeric characters and one alpha character. These characters would always be in the same sequence as follows:

1 A 10 11

Each character or set of characters would be unique to allow a computer to assemble the budget data in a uniform manner. Many expense types may have only one subexpense (normally No. 99) which is added only to provide uniformity to the total budget process.

The characters in the sequence identify the following:

Character	*Represents*
1	Division
A	Department within the division
10	Expense type (capacity to 100).
	Subexpense is a further breakdown of expense type (capacity to 100 for each expense type).

The need to expand, add, or delete authorized budget codes should be discussed with the accounting department.

All subexpense codes are usually established at the request of a division or department so that certain types of expenditures can be monitored. These should be reviewed on a periodic basis to ascertain if the expenditures are still needed or can be combined with another subexpense. Each additional subexpense in use makes it more difficult to handle the budget and to verify that purchase requests or invoices are properly coded. This affects the division, department, accounting, and purchasing.

Another important point, when requesting that an expense be subexpensed into various accounts, is that all divisions and departments using that expense type must convert to the new subexpense sequence. Thus, a request may very well affect all divisions and departments. Be sure the requested information is really needed and that it cannot be obtained elsewhere.

Once a request for additional subexpense codes are approved and entered or a consolidation of accounts occurs, department budgets will reflect the new codings. Each department is then responsible to see how the change affects that department and to take appropriate steps to familiarize personnel of the charge.

All documents relating to budgets being received from departments must have an authorized six character budget code. This would include all items such as materials requests, manual purchase orders, invoices, and requests for checks. Items received by the fiscal division without proper budget codings will be returned to the originator.

Following is a list of expense codes that will be used in the budgeting process with descriptions and/or examples of the types of items to be budgeted.

00—Salaries and Wages

Along with the annual budget request forms, the fiscal division will give each division a list showing the cost of maintaining all present full-time personnel for the next fiscal year. The accounting department must be notified of any proposed personnel changes so that the necessary payroll adjustments can be made.

All funds added for new hires, part-time wages, reclassification, etc., must be added by each department using current salary rates. The accounting department will adjust the amounts later if a cost-of-living adjustment is made.

All budgeted amounts other than those for part-time help are for specific positions only. Funds saved because of vacant positions, late hires, etc., cannot be used for other purposes without board or committee approval.

Types of Items to Be Included

Salaries—Permanent employees
Salaries—Part-time employees
Salaries—Temporary employees
Amounts for hires through temporary employment agencies

Types of Items Excluded

Consultants—Use expense code 26
Legal and accounting—Use expense code 25
Premium pay—Use expense code 01
Contract services—Use applicable expense code

01—Premium Pay

Use this expense code to budget all overtime, Sunday, and holiday pay. Budgeted amounts must be separated for full-time and part-time employees. Each department that anticipates having employees who will earn premium pay must have money budgeted in the correct account. If not, numerous problems can develop if payroll is run with premium pay for an employee in a department that does not have the proper budget account preestablished.

02—Distribution System Maintenance

This expense code can be used to budget for all repair costs and other direct costs of maintaining the distribution system. All inventory items should be included in the central warehouse budget while other items such as concrete, gravel, outside service, etc., should be included in each department's own budget.

Items purchased for new construction are charged into this expense code when purchased; however, the costs are later transferred to the new construction budget codes. Therefore, all amounts for new construction supplies should be budgeted in expense code 93 or 94.

Types of Items Included

Repair parts
Oil and lubricants (nonvehicular only)
Equipment rentals
Outside services

Types of Items Excluded

Tool repair—Use expense code 03
Boundary markers—Use expense code 08
Rags—Use expense code 08
New construction—Use expense code 93 or 94
Film purchase and processing—Use expense code 08

03—Small Tool and Equipment Expense

This expense code should be used for all small tool and equipment purchases up to a given set amount. Appropriate taxes should be added to all costs when determining whether or not an item exceeds the limit. If the total is greater than the established amount, the item should be budgeted a capital asset. Equipment should include all types of shop equipment, field equipment, etc. All small tool repair and equipment repairs are also budgeted within this expense code regardless of the tool or equipment costs. Excluded are repairs to vehicles and other types of rolling equipment repairs that are budgeted under expense code 04.

Each department is responsible for budgeting its own requirements in this budget category.

Types of Items Included

Tool boxes
Hammers
Wrenches
Sledges
Shovels

Rakes
Porta desks
Drill presses
Sanders
Vises
Analyzers
Voltage meters
Annual crane inspections

Types of Items Excluded

Vehicle repairs—Use expense code 04
Trailer repairs—Use expense code 04
Backhoe repairs—Use expense code 04
Office equipment—Use expense code 10 or 22

04—Vehicle and Rolling Equipment Repair

Subexpense codes 01 to 49 are for use in budgeting repair parts and should be used by the central warehouse only. Subexpense codes 50 to 90 are for outside services and should be included in the auto shop budget. Parts such as batteries, tires, oil changes, car washes, and other outside services for vehicles at the Fresno office should be budgeted by the department to which assigned. Field departments with credit cards should budget for any of the above items that may be charged to the credit cards. Accounting will budget for the maintenance of the pool cars.

Types of Items Excluded

Lathe repairs—Use expense code 03
Engine analyzer repairs—Use expense code 03
Jack repairs—Use expense code 03

05—Vehicular Gas, Oil, and Other Fuels

All bulk gasoline and diesel purchases should be budgeted by the auto shop; however, departments with vehicles at other locations should budget for any bulk fuel withdrawals as well as for credit card purchases. Field departments with credit cards should also budget the required amounts.

The auto shop should budget for all vehicular oil and other lubricants except those charged to credit cards.

Types of Items Excluded

System maintenance lubricants—Use expense code 02
Fuels for weed control—Use expense code 02

06—Safety and Employee Comfort

All inventory items in this budget category should be budgeted by the central warehouse. Yearly shoe and uniform allowances for eligible employees should be budgeted by the department to which eligible employees are assigned. Be sure to allow for new hires.

Preemployment medical exams should be budgeted by each department for known hires, replacements, etc., and given to the personnel department for inclusion in its budget. Additionally, the personnel department should budget a contingency amount for employee turnover, unexpected retirement, etc. Each department should budget for required annual physical exams.

Fire extinguisher purchases, inspections, and rechargings are budgeted in the budget of the complex in which they are located. Costs related to all vehicular fire extinguishers should be included in the operations or maintenance budgets.

Amounts for safety education such as posters, film rentals, etc., will be budgeted by the office engineering department.

Each department is responsible for budgeting their own non-inventoried specialty items.

Items to be Excluded

Outside safety seminars—Use expense code 14
Safety tools—Use expense code 03

07—Building Utilities

This expense code is used to budget for all gas and electricity needed to operate facilities other than water delivery or drainage equipment.

08—General Supplies

This expense code is used to budget for supplies that are needed in day-to-day functions of any particular job and do not belong in any other expense category. The supplies may be applicable to any one department or job or to various departments. These supplies differ from system maintenance and other repair parts and supplies in that the supplies do not go to the direct repair or maintenance facilities, but are used to assist in the task.

Items in this category should be budgeted by the central warehouse if kept in inventory, or by each individual department if not.

Types of Items Included

Wipe rags
Hand soap
Welding rods
Film purchases and processing
Boundary markers

Types of Items Excluded

Small tools—Use expense code 03
Equipment—Use expense code 03
Office supplies—Use expense code 10 or 22

09—Telephone

All telephone expenses should be budgeted by the administrative service department with the exception of any leased lines necessary for the computer, which should be budgeted by the computer services department. Telephone costs at other locations should be included in the budgets for those locations. The telephone answering service is budgeted by the operations division. The administrative services department should be notified of any new telephone equipment that needs to be budgeted.

Types of Items Excluded

Leased alarm lines—Use expense code 02
Telephone equipment—Use expense code 90

10—Field Office Expenses

Inventory type items such as pencils, tablets, staples, tape, etc., are budgeted by the administrative services department; however, each field office should budget its own items in this expense code. The subcode for small equipment purchases should be used for purchasing office equipment costing less than a set amount including tax.

11—Computer Costs

All computer costs including maintenance, leases, software fees, etc., are budgeted by the computer services department. Only outside computer costs should be budgeted by each individual department. Computer equipment that becomes part of the total system such as terminals, software, etc., should be budgeted as capital assets regardless of their cost. Computer equipment is budgeted in expense code 22 if cost is less than a set amount, including tax or as a capital asset if the cost is greater than the set amount.

12—Power Purchases

All power costs for operating both temporary and permanent water delivery or drainage facilities are budgeted by the operations department.

Types of Items Excluded

Building utilities—Use expense code 07 or 010

13—Water Purchases

All amounts for water purchases are budgeted by the water management department.

14—Schools and Seminars

This line item is budgeted by each individual department. All training costs are charged to the department to which the employee is assigned regardless of the type of training received.

Types of Items Included

Special training school costs
Seminar registration fees
Conference registration fees

Types of Items Excluded

Meals—Use expense code 29
Transportation—Use expense code 29
Lodging—Use expense code 29

15—Radio Expense

All radio expenses including maintenance agreements should be budgeted by the field operations department. Other departments should notify the field operations department of budget changes to maintenance costs such as additional maintenance agreements for new radios, transfers of radios between vehicles, etc.

Costs of new radios or other radio equipment including sales tax and installation charges should be budgeted as capital assets regardless of cost because this equipment becomes a part of the total communications system.

16—Freight Expense

All freight expense amounts are budgeted by the purchasing department. Any other department anticipating the purchase of large items or items that may be costly to ship should notify the purchasing department so that the required additional funds can be budgeted.

17—Advertising and Public Notices

Costs of publishing invitations to bid should be budgeted by the purchasing department; however, other departments must notify the purchasing department when anticipating purchases for any items costing enough to require publication.

Funds for publishing job notices for new hires, replacements, etc., are budgeted by the personnel department; however, other departments must notify the personnel department of anticipated new hires, retirements, etc., as well as the type of advertising (local, regional) required for each position.

Specialty items such as assessment and water user notices should be budgeted by the appropriate department.

Types of Items Included

Legal notices
Water user notices
Assessment notices
Job notices
Invitations to bid

18—Employee Relations

All costs for employee relations should be budgeted by the administrative services department.

21—Outside Printing

Each department should budget for its own outside printing requirements. Accounting should budget for the printing of water invoices which are used jointly with the water management department. The public relations department should budget for the printing of newsletters, annual reports, etc., while the administrative services department should budget for the outside printing of any forms used by all departments.

Types of Items Included

Maps
Forms
Checks
Invoices

Types of Items Excluded

Preprinted forms—Use expense code 22
In-house printing—Use expense code 22
Advertising—Use expense code 17

22—Office Supplies

All general office supplies such as pencils, tablets, staples, tape, etc., should be budgeted by the administrative services department. Specialty items such as drafting supplies, accounting ledgers, and small equipment purchases should be budgeted by individual departments as required. Small equipment purchases where the value, including tax and installation charges, exceed a specific amount should be budgeted as capital assets.

The administrative services department should budget for all maintenance contracts and fees on general office machines such as calculators and typewriters and should be notified of any anticipated additions by other departments. Each individual department should budget for the maintenance of specialized office equipment such as check protectors, computer equipment, etc.

Types of Items Excluded

Special printed forms—Use expense code 21

23—Postage and Postal Permits

All amounts in this expense code are budgeted by the administrative services deparment; however, other departments should forward information as to any changes in the quantities or frequencies of period mailings or of any other unusual or new mailings.

Types of Items Included

Post Office Box rentals
Bulk mailing permits
Express mail
Master replenishment
Postage due

Types of Items Excluded

Nonpostal permits—Use expense code 40

24—Dues, Subscriptions, and Publications

All recurring yearly dues are budgeted by the accounting department. Individual departments should budget for magazine subscriptions and other publications that need to be purchased.

Types of Items Included

Dues
Books
Newspapers
Magazines
Periodicals
Repair manuals
Operation manuals

Types of Items Excluded

Other publications—Use expense code 17
Notice publications—Use expense code 17

25—Legal and Accounting

This expense code is for use only by the legal and accounting departments to budget for outside legal fees and annual audit as well as any other legal aid or accounting services.

26—Consultants

This expense code can be used by any departments requiring outside consultants.

28—Election Expenses

This expense code is for use by the administrative services department to budget for all anticipated election-related expenses. These expenses include items such as postage, outside computer services, consultants, etc., even though these types of items would normally be classified elsewhere.

29—Subsistence and Travel

This expense code should be used by all departments as required to reimburse employees for business-related travel expenses. It should also be used for mileage and meal expenses related to unscheduled overtime. Other items such as the purchase of materials or supplies cannot be charged to this account and *should not* be claimed for reimbursement as part of a claim for personally incurred expenses.

Types of Items Included

Airline tickets
Taxi fares
Car rentals
Mileage reimbursements
Meals, including guests
Lodging

Types of Items Excluded

Registration fees—Use expense code 14
Materials and supplies—Use applicable expense code

30—Charters and Tours

This expense code is for use by the public relations department to budget expenses related to giving the district group tours.

Types of Items Included

Bus charters
Air charters

Tour lunches

Types of Items Excluded

Travel expenses
Luncheons
Meeting room rental

32—Insurance

For use by the accounting department for payment of all district insurance policies except those related to employee benefits.

Types of Items Included

Liability
Bond
Forgery
Boiler and machinery
Data processing

Types of Items Excluded (Expense Code 33)

Workers' compensation
Health
Dental
Life
Disability

33—Fringe Benefits

For use by each department to budget fringe benefits for its personnel. The accounting department will furnish a list giving the amount to be budgeted for present full-time personnel as of budgeting time as well as percent of salary to be used for calculating fringe benefit costs for reclassification, new hires, part-time, premium pay, etc.

Please see the commentary under 00—Salaries and Wages for additional information regarding cost-of-living adjustments, employee transfers, and excess money.

34—Ground-Water Observation

This expense code is for all repair parts and other direct costs associated with ground-water observation.

35—Drainage System Maintenance

This expense code is for all repair parts and other direct costs of maintaining the drainage system. All inventory items should be budgeted by the central warehouse, while other items such as contract services should be included in each user department's budget.

Types of Items Included

Cathodic protection
Repair parts
Equipment rental
Contract services

36—Drainage Studies

This account is for all costs associated with drainage studies.

Types of Items Included

Geological investigations
Reports
Contract services
Maps
Studies

37—Participation—Other Districts

This account is for participation in the costs of other entities and agencies sponsored by this organization.

39—Right-of-Way Expenses

This account is for miscellaneous costs directly associated with right-of-way acquisitions.

Types of Items Included

Acquisition fees
Title fees
Crop damages

Types of Items Excluded

Office supplies—Use expense code 22
Outside printing—Use expense code 21
Notary fees—Use expense code 40

40—Miscellaneous

This expense code is for items not covered within any of the other expense codes. It should be used sparingly for one-time and normally low-cost items only. It cannot be used to supplement other expense codes without board transfer approval.

Types of Items Included

Licenses
Permits

Types of Items Excluded

Annual crane inspections—Use expense code 03
Film purchases and processing—Use expense code 07

50—Reserve Contributions

This budget is for the accounting department to budget annual contributions to reserves.

90—Capital Assets

For budgeting purposes, a capital expenditure is an item costing $1,000 or more with a useful life expectancy beyond 1 year. Permanent improvements to buildings, shops, etc., are also capital assets if cost exceeds $1,000 or more. To determine if the item costs more than $999, include sales tax, freight, discounts, etc., in the purchase price.

Telephone, mobile and desk radios, and all computer equipment that becomes a part of the total system should be budgeted as capital assets. All software purchases should also be budgeted as capital assets.

Please contact the accounting department when there is a doubt as to whether an item is a capital asset or not.

All computer equipment including line printers, CRT terminals, etc., are budgeted by the computer services department. If you anticipate a need for these types of items, you must notify the computer services department so the item(s) can be included in its budget.

Vehicles reaching mileage of approximately 80,000 miles should be referred to the auto shop supervisor to determine whether or not a replacement is needed.

Periodically, items classified as capital assets will unexpectedly need to be replaced for various reasons. Because these needs cannot be anticipated, the accounting department will budget a contingency amount for emergency replacement of small equipment costing between $1,000 and $2,500. Funds will be transferred to other departments when required. Replacement of items costing more than $2,500 will have to go through the normal budget transfer/augmentation process.

93 (94)—New Construction

Amounts should be budgeted in these expense codes by departments expecting to purchase materials or services or to incur other costs related to the construction of new facilities. However, actual expenditures for materials, rock and gravel, equipment rental, outside services, etc., should be charged to the applicable subcode under expense code 02—System Maintenance, as though being used for maintenance rather than construction.

No purchases should be charged directly into expense code 93, as these funds are authorized for use only by the accounting department. The accounting department will later transfer charges appearing on work orders with a new construction charge code to these expense codes while crediting the system maintenance budget account that they were originally charged to.

Typically, account 93 will end up reflecting all charges for new construction other than employee labor, labor overhead costs, and equipment charges.

96—Repayment

This expense code is for use only by the accounting department to budget for repayment of construction contracts.

97—Bond and Interest Redemption

This expense code is for use by the accounting department to budget for bond redemption costs.

3. BUDGET MAINTENANCE

Accrual accounting merely means that income is recorded as earned rather than when received. For instance, at month end, water users are billed for water used that month. The sale (income) is recorded in the records at the end of the month even though it will not be actually received for 2 or 3 weeks. By recording the sales at end of month, the money is "accrued" as income so that the records will match month income to month expense, i.e., costs for water for that month.

The same holds true on the expense side of the books. The expense is accrued when it is incurred. From an accounting standpoint, an expense is incurred when a service is performed or merchandise is received and the organization is obligated to pay. The "accrual" method puts the expense in the month (or year) that it was incurred. A purchase order only "commits" funds without regard to when the expense will be incurred.

Services or merchandise received on or before end of fiscal year are expensed and budget charged in year received. Receipts on or after beginning of new fiscal year are chargeable to new year budget. It is incumbent upon the personnel in charge of ordering or controlling a budget to plan enough in advance so that receipts occur in the year desired.

A purchase request submitted 30 days prior to end of fiscal year to use up remaining budgeted funds and not affect next year budget would be hard pressed to justify that it should be charged to the prior year's budget. This is especially true when the merchandise is received 15 days into the new fiscal year, and if historically the material had a 45-day delivery time. The receipt of items or services requested, not issuance of the purchase order, controls the budget charge.

In order to alleviate some problems associated with receipts near year end, and to lessen year end purchasing burden, only emergency-type orders and purchase order worksheets (POWs) should be processed 20 days prior to end of fiscal year.

Budget Transfers

Budget transfers between like expense types can be made at any time without prior audit and budget committee approval regardless of the subexpenses involved. The only exceptions to the above rule are salaries and wage, and capital asset expense codes which require that the amount transferred also be within the same subexpense code.

Any transfers meeting the above requirements can be made between any two departments whether or not the departments are in the same division. As with budgeting, transfers can be made only in $1,000 increments.

Any department needing funds must find another department within or outside of its own division that has excess funds that can be transferred and meet the above requirements. The accounting department should then be notified of the desired transfer so that a "Budget Transfer Authorization Form" can be prepared. The accounting department will then prepare and route the authorization form to the person who is authorized to give up the funds for his or her signature. Upon receipt of the signed authorization act in the accounting department, the transfer will be made between the affected departments.

The accounting department may be able to assist in determining which division or department, if any, might have excess funds in the expense category interested.

Budget transfers cannot be made between unlike expense types without manager, audit and budget committee, and board approval. The requirements for this type of action are detailed in the following section.

Budget Augmentation

Occasionally, circumstances might arise when it becomes necessary to seek authorization to transfer funds between unlike expense types or seek augmentation to the budget without an available source of funds. The latter should be done only after all efforts to find the necessary funds in other budget accounts (all departments in all divisions) have proven unsuccessful, and a determination has been made that the item requiring the funds cannot wait for the new budget year.

In either case, a memorandum to the chief accounting officer, through the manager, should be prepared detailing circumstances surrounding the proposed expenditure and an estimate of required funds by budget expense code and subexpense code. If the requested action is a transfer, also give detail such as expense code, subexpense code, and dollar amounts for the budgets to be reduced. The memorandum should be discussed with the manager before being sent to the chief accounting officer.

After approval by the manager, the request will be taken to the audit and budget committee and ultimately to the board of directors. The division head should attend the committee meeting to discuss the request with the committee.

APPENDIX E. WATER SERVICE

TERMS AND CONDITIONS OF WATER SERVICE

Following is an example of "Terms and Conditions for Agricultural Water Service," adopted by the board of directors of a large water district and is presented here an as example of such. Each district will need to develop its own appropriate terms and conditions of service.

1. The allocation and furnishing of water to, and its use by, the applicant shall be subject to all regulations of the board of directors of the district as the regulations may now or hereafter be amended or adopted. In the event of a conflict between the terms and conditions set forth herein and the regulations, the latter shall control.

2. All water delivered shall be made upon a request by the applicant or his authorized representative for the delivery of a stated amount to a specific parcel of land. The request shall be made within the time and in the manner prescribed by the district.

3. The water will be furnished by the district subject to the terms and conditions of the contract or water right between the district and the supplier under which said water is made available to the district and if, in the exclusive judgment of the district, the water and facilities for its delivery are available: Provided, that the district will use its best efforts, to the extent that it has water and capacity available, therefore, and taking into account the requirements of other water users to receive water from said facilities, to provide such water in the manner and at the times requested. The district may temporarily discontinue water service or reduce the amount of water to be furnished to the applicant for the purpose of such investigation, inspection, maintenance, repair, or replacement as may be reasonably necessary of any of the district facilities necessary for the furnishing of water to the applicant. Insofar as feasible, the district will give the applicant notice in advance of such temporary discontinuance or reduction, except in case of emergency, in which event no notice need be given. No liability shall accrue against the district or any of its officers or employees for damage, direct or indirect, because of the failure to provide water to the applicant as a result of system malfunctions, interruptions in service necessary to properly operate and maintain the water distribution system, or other causes.

4. By ordering and taking delivery of water from the district, the applicant assumes responsibility for, and agrees to hold the district harmless from, all damage or claims for damage that may arise from his or her furnishing or use of the water after it leaves the district facilities.

5. The water furnished by the district is not in a potable state, and the district does not warrant the quality or potability of water so furnished. The applicant shall be responsible for any water treatment, including but not limited to filtration and chlorination, which is required to make the

water usable for the purpose to which it is to be put or which is required by federal, state, or local law or regulation. By ordering and taking delivery of water from the district, the applicant assumes responsibility for, and agrees to hold the district harmless from, damage or claims for damage arising out of the unpotability of water furnished by the district.

6. All water will be measured by the district with meters installed by it, and such measurements shall be final and conclusive.

7. Charges for agricultural water, including power surcharges, if any, hereinafter referred to as "water charges," shall be at the rates established by the board of directors.

8. The payment of water charges or related penalties or interest shall be made at the district's office. When any deadline established herein falls on a Saturday, Sunday, or holiday, it shall be extended to the next working day.

9. As a condition of the district continuing to furnish water, applicant shall pay each month (January through August, inclusive) for 12½% of all water allocated for his use during the calendar year, or an amount based on his actual water use, whichever is greater. Any payments for water used that cumulatively exceed the applicant's cumulative obligation for allocated water shall be credited toward the applicant's next succeeding 12½% allocation payment(s). Said monthly payments shall be made by the 25th of each month. Water charges not paid by that date shall be delinquent: Provided, that payments postmarked on or before the 25th shall be deemed to have been received by said date.

10. All claims for overcharges or errors must be made in writing and filed with the district within 10 days after the date the bill is received by the applicant.

11. On the 26th day of each month, a penalty of 10% of that month's water charges that became delinquent on the preceding day shall be added to the water charge and penalties and interest, if any, due and owing to the district, the total of which are hereinafter referred to as "unpaid charges." Prior unpaid charges shall bear interest at a monthly rate of 1½%. Interest shall not, however, accrue after the unpaid charges have been added to and become a part of the annual assessment levied on the land by the district. All payments and credits will be applied to the earliest unpaid charges.

12. On the 1st of the month following that in which the unpaid water charges for agricultural water service become delinquent, such service shall be discontinued.

13. The amounts due to the district as a result of the allocation or furnishing of water, which amounts become delinquent prior to December 1, and the penalties and interest relating thereto which remain unpaid at the time of the filing of the district's assessment book with the tax collector of the district in January of the following year may be added to, and become a part of, the annual assessment levied by the district on the land that received the water. The district shall give the owner of the land notice of the delinquency prior to its addition to the annual assessment. The amounts so added shall be a lien on the land and impart notice thereof to all persons. Should said assessment become delinquent, penalties and interest will be added thereto as provided by law.

14. Agricultural water service shall not be provided to any parcel of land for which the assessment, standby charges or water charges, or other special charges are a lien on the land.

15. Agricultural water service shall not be provided to any person who owes the district delinquent water, standby or other special charges, or penalties or interest on such charges, notwithstanding the fact that the unpaid charges have been added to the assessment(s) on the parcel(s) for which they were incurred.

16. In the event water service hereunder is discontinued as a result of nonpayment of water charges, all unpaid charges for such service that are due the district from the person in default must be paid before water service can be restored.

17. By applying for a water allocation or taking delivery of agricultural water from the district, the applicant agrees to these terms and conditions of service.

18. The district may modify or terminate these terms and conditions: Provided that such modifications or termination are prospective only and notice thereof is given prior to the effective date by mail to the applicant.

WATER-ORDERING PROCEDURES

The following water ordering procedures were written to meet the needs of a large water district and are presented only as an example of such procedures. Each district will have to develop unique procedures to fit the needs of that district.

1. Water must be ordered not later than 9 a.m. the day before the water delivery is to start, except a water order for Monday must be placed by 10 a.m. the preceding Saturday.

2. An order must be placed at the district office, Monday through Friday between the hours of 8 a.m. and 5 p.m., and Saturdays between 8 a.m. and 3 p.m. During other hours, emergency messages may be left by telephoning the district office or by communicating with district personnel engaged in water delivery operations in the field.

3. Water may not be turned on until the water order is approved by authorized district personnel at the main office. Normally, if the order is placed directly with the main office, it will be approved at that time. If the order is given to a field representative of the district, it will be approved as soon as possible.

4. All water deliveries should be adjusted, turned on, or shut off as close to 8 a.m. as possible, except in the case of deliveries through district pump lines where all increases in flow should be made between the hours of 9 a.m. and 10 a.m.

5. Any shutoff, delay, or variation from the scheduled delivery of water for more than 2 hours must be reported to the district office immediately.

RECORD PREPARATION

The following is a list of basic rules used by one agency for keeping water records. Examples 1 through 5, which are referred to below, can be found in Fig. E-7.

General

1. The ditchtender will measure and record the discharge for all measuring devices that are running water when he arrives and when he leaves the device. If there is no change, only one entry is required (example 2).
2. Ditto marks will not be used on the records. An entry will be made for each day water is running (example 2).
3. All on's and off's on the record sheets will be marked with the words "on" and "off" (example 2).
4. No entries will be made between the off's and on's when the water is not running.
5. The loss allowance on a one-unit delivery lateral will be shown in a circle or brackets on the top line of the order column (example 3).
6. All discharges that have been affected by weeds, power outages, etc., shall be explained by a note in the order column (example 2).
7. The water balance for units with more than one turnout will be recorded on the last sheet in the turnout numbering sequence.
8. The water balance for units in combination will be recorded on the last unit and the numbering sequence of the combination.
9. All entries for a turnout will be recorded in the ditchtender's records before he leaves that turnout.
10. A water request card is required for all turn on's, turn off's, and changes. The only exception, with prior approval of a watermaster, will be for deliveries to units which have been combined for water record purposes at the end of a lateral without a wasteway when the total order of the combination does change.
11. Carry the daily delivery to two decimal points and enter to the nearest lower 0.05. For instance, in example 1, 1.53 should be entered as 1.50, and in example 2, 2.01 should be entered as 2.00.
12. Never charge the farmer for more water than he orders. If he receives less than he ordered, charge him for what he receives.
13. Do not charge the farmer for the first day his water is turned on, but charge him for the day when water is turned off (example 2). (Applies only to 24-hour, fixed-delivery duration).
14. Never make any deliveries until you receive written notice from your watermaster or branch office that the user has paid all necessary water charges and is eligible to receive water.
15. Never deliver more water than has been paid for or than has been authorized by your supervisor.
16. Do not deliver water ordered for one turnout through another turnout unless a combination is approved. If in doubt, consult the watermaster.

17. If a weir is installed at the end of a delivery lateral, it is to be used for loss measurements only. The water for the unit will be measured over the original device constructed at the head of the delivery lateral.

Water Delivery Record

1. A water delivery record will be kept for each farm unit.
2. The entries for weirs, constant head orifices, and meter gates will be recorded as shown in example 1.
3. The "Order or Remarks" column may be maintained in one of two ways, or a combination of the two as directed by your watermaster. The two methods are shown in example 2. This column will also be used for loss and explanation notes.
4. Turn on and turn off will be recorded as shown in example 2.
5. When reporting changes or adjusting flow outside of the tolerance limits, the measurement when the ditchtender arrives will be shown on the left side of a slash, and the measurement when leaving will be shown on the right side as shown in example 2.
6. Explanatory notes may be recorded as shown in example 2.
7. Loss notations for end delivery lateral may be recorded as shown in example 3.
8. On Sunday or on any other day that the turnout is not visited, a dash should be entered in the head and gate opening column, and the assumed water delivery should be recorded as shown in example 4.
9. Changes from one measuring device to another that are made by a farm operator on end deliveries under combination when total flow is not changed may be handled as shown in example 5. The letters OC stand for operator change. The agency using the form shown in Fig. E-7 operates on a 2-week billing period. This is done because all water must be paid for in advance, and the ditchtender's records should not go for longer than 14 days without the totals being checked with adding or posting machines.

Lateral Diversion Record

Instructions for preparation of the typical lateral diversion record (Fig. E-1) are as follows.

1. A lateral diversion record sheet will be kept for any measuring device which leads to two or more units where there is a possibility of loss in the lateral system.
2. All on's and off's on the diversion sheet will be marked with the words "on" and "off."
3. Measuring devices with two measuring gates will be recorded on one diversion sheet. A notation will be added to the bottom of the sheet stating that there are two gates in the measuring device. The gates on the device are to be opened an equal amount unless otherwise noted in the explanation column.
4. When a lateral has a farm unit turnout between its turnout gate and measuring device, the diversion record will be kept only for the lateral measuring device.

5. On Sunday, or on any other day that the structure is not visited, enter a dash in the head and gate opening columns and record assumed discharge.

Lateral Wasteway Record

General rules for the preparation of typical wasteway records (Fig. E-2) are as follows.

1. A wasteway record will be kept for each wasteway.
2. An entry will be made for each day including Sunday. If no water is estimated for the next 24 hours, enter 0 (zero).
3. The flow recorded on the wasteway sheet may not be the measured flow but the estimated average flow in the wasteway for the next 24-hour period.

Monthly and Yearly Record

All organizations usually are required to prepare summaries of their records. This may be a relatively simple document or it may be quite comprehensive, depending upon the purpose for which the record is intended or used. The "Monthly Water Distribution" report (Fig. E-8) is one of the more comprehensive. It provides a monthly summary of the quantities of water used and how it was distributed. The several columns can be used as follows.

1. Diverted from stream—The total quantity of water diverted for all purposes except sand sluicing, power production, and other nonirrigation purposes. This includes water diverted from the natural flow of the stream or directly into the distribution system from reservoirs that are not a part of the distribution system.
2. Inflow from reservoirs and other sources—A quantity of water delivered to the distribution system that is not accounted for in the column headed "Diverted from streams." Sources of water include inflow from reservoirs in the distribution system, return flows from higher project lines, and water pumped or diverted from wells, drains, and lakes.
3. Delivered to reservoirs—A quantity of water that is delivered through the distribution system into the distribution system storage or regulating reservoirs.
4. Net supply—The total quantity of water used. It is obtained by adding the values shown in the columns entitled "Diverted from stream" and "Inflow from reservoirs and other sources" and subtracting the values shown in the column "Delivered to reservoirs." The net supply must be accounted for in the columns entitled "Main canal waste," "Main canal losses," and "Delivered to laterals."
5. Main canal waste—The quantity of water wasted through waterways from the main canal.
6. Main canal losses—The quantity of "net supply" not accounted for as "Main canal waste" or "Delivered to laterals." The sum of the values for "Main canal waste" and "Delivered to laterals" subtracted from the

values shown in the "Net supply" column should equal the "Main canal losses."

7. Delivered to laterals—The quantity of water diverted from the main canal for all purposes. All diversion from the main canal including those made to individual water users are considered to be "Delivered to laterals."

8. Lateral waste—The quantity of water wasted through wasteways from the lateral system.

9. Lateral losses—The quantity of water "Delivered to laterals" that cannot be accounted for as "Lateral waste," "Nonirrigation deliveries," and "Delivered to farms." This value is obtained by subtracting the sum of the "Lateral waste," "Nonirrigation deliveries," and "Delivered to farms" from the values shown on "Delivered to laterals."

10. Nonirrigation deliveries—The quantity of all water deliveries made except those delivered to the farms for irrigation use. This includes deliveries for municipal and industrial uses and water delivered to the farms for use as spray water, stock water, and cistern and domestic water. A supplemental sheet detailing the types and amounts of nonirrigation deliveries may be needed.

11. Delivered to farms—The quantity of water under the subcolumn "Total" is the total amount of all water delivered to the farms for irrigation use. The values in subcolumn "Per acre" (square meter) are calculated by dividing the values for the "Total" by the number of acres (square meters) irrigated as shown at the top of the form. In checking the water distribution form, it should be ascertained that all waters accounted for in the columns are balanced.

The values shown as "acre-feet per acre" (cubic meters per square meter) for each column on the penultimate line of the form are calculated by dividing the total seasonal water quantity by the acres (square meters) irrigated.The values shown on the lower line as "Percent net supply" are calculated by dividing each column total by the total of the "Net supply" column.

The values shown as "Area irrigated" in the form heading should be the number of acres (square meters) to which irrigation water was supplied during the season. Quantities of water shown that are not measured should be footnoted as estimates.

In areas where water tables are high or where ground water is used to supply irrigation water, records of pumping rates and volumes should be kept along with periodic measurement of ground-water levels. In areas where drainage systems are important, measurement of drainage quantity and quality should be measured and recorded. The recording intervals needed depend a great deal on the nature and magnitude of the drainage problem.

Water Supply Reports

Another report useful in the planning of operations is the water supply report. Two typical forms for such a report are shown in Figs. E-9a and E-9b. Information reported on Fig. E-9a includes both reservoir and irrigation data that can be used in planning distribution. Information to be reported would be as follows:

1. *Reservoir elevation*—The elevation in feet (meters) and the date and time of the observation. Actual time of observation should be entered and not a scheduled time.

2. *Active storage*—Total water in active storage in thousands of acre-feet (thousands of cubic dekameters, dam3) as of the end of the month whether operated by the operating agency or under the control of other agencies that furnish water.

3. *Monthly total*—Inflow and outflow expressed in thousands of acre-feet (thousands of dam3); if monthly runoff at important gaging stations is available, it should be entered under "Remarks" where needed to present an adequate picture of water supply conditions. Forecasts of the probable runoff by river basins, if desired, can also be given under "Remarks."

4. *Outlook*—Estimates of current water outlook should apply to the current water year. The terms described in the current water outlook should take into account not only current and potential inflow but also storage on hand in relation to current and prospective demands. The following terms are frequently used to define the estimates of the current water outlook:

Above normal (Abv)—Abundant water available for all usages and for increased holdover storage where applicable, or where all streamflow to which the development is entitled cannot be used profitably.

Normal (Nor)—Sufficient water for mature crops on all lands normally under irrigation with or without drawing upon holdover storage; where no storage is included, sufficient water for mature crops within the streamflow rights.

Subnormal (Sub)—Insufficient water to mature all crops even by drawing upon holdover storage or by using other valid complaints from farmers regarding water deliveries, in order to determine the success of the operators in meeting needs.

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DIVERSION RECORD

APPENDIX E
FIGURE E-1

Ditchtender ______________________ Period ____________ To ____________ Incl.

Lateral						
Measure Ditch Size Type						
Previous						
YEAR	GAUGE	SEC. FT. (m^3/s)	GAUGE	SEC. FT. (m^3/s)	GAUGE	SEC. FT. (m^3/s)
THURSDAY						
FRIDAY						
SATURDAY						
SUNDAY						
MONDAY						
TUESDAY						
WEDNESDAY						
THURSDAY						
FRIDAY						
SATURDAY						
SUNDAY						
MONDAY						
TUESDAY						
WEDNESDAY						

APPENDIX E
FIGURE E-2

LATERAL WASTE RECORD

Ditchtender ______________________________ Period ____________ To ____________ Incl.

Lateral						
Measure Ditch Size Type						
Previous						
YEAR	GAUGE	SEC. FT. (m^3/s)	GAUGE	SEC. FT. (m^3/s)	GAUGE	SEC. FT. (m^3/s)
THURSDAY						
FRIDAY						
SATURDAY						
SUNDAY						
MONDAY						
TUESDAY						
WEDNESDAY						
THURSDAY						
FRIDAY						
SATURDAY						
SUNDAY						
MONDAY						
TUESDAY						
WEDNESDAY						

LUNF75

APPENDIX E
FIGURE E-3

DAILY WATER DELIVERY RECORD

MONTH ____________________

WATER USER ______________________

GATE OR METER NUMBER ____________________

DATE	TIME	METER READING	ACRE FEET	FLOW FT^3/S	D.W.R. FT^3/S	REMARKS
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
TOTAL			WATER USE	AMOUNT DUE		

APPENDIX E
FIGURE E-4

WATER USER LEDGER

ADDRESS & FARM UNIT DATA   BLOCK & FARM UNIT   OPERATOR & ADDRESS

FARM UNIT NO.	PURCHASES	DATE THIS PERIOD ENDED	WATER USE THIS PERIOD	WATER USE TO DATE	BALANCE AFTER THIS PERIOD	TOTAL PURCHASES

LUNF69

APPENDIX E
FIGURE E-5

ABSTRACT OF WATER LEDGERS

ICX ____________ RIDE NO. ____________ WATERMASTER SECTION ____________

FARM UNIT NUMBER	PURCHASES	DATE THIS PERIOD ENDED	WATER USE THIS PERIOD	WATER USE TO DATE	BALANCE AFTER THIS PERIOD	TOTAL PURCHASES

NOTE: All quantities in second-feet days (one cu ft per second for 24 hours)

SYMBOLS:
BQ - BASE QUANTITY
SU - SUPPLEMENTAL
1E - FIRST EXCESS
2E - SECOND EXCESS
A - COMBINED OPERATION
TP - TESTING PERIOD WATER
7000 - PART-TIME TURNOUT
9000 - MUNICIPAL & INDUSTRIAL WATER CONTRACT

APPENDIX E
FIGURE E-6

LUNF70

REPORT OF WATER USED

(This is not a Bill for collection)

All quantities are in second-feet-days. One second-feet-day = 1.9835 acre-feet (2448 m^3)

FARM UNIT NO.	PURCHASES	DATE THIS PERIOD ENDED	WATER USE THIS PERIOD	WATER USE TO DATE	BALANCE AFTER THIS PERIOD	TOTAL PURCHASES

It is very difficult to gravity irrigate without some waste water. However, you should avoid excessive waste that washes good topsoil from your farm, erodes waste water channels and causes you to buy additional water. See your County Agent or Soil Conservationist for ideas in conserving water.

APPENDIX E
FIGURE E-7

WATER DELIVERY RECORD

Day	Head	Opening	Measured discharge	Hours run	Daily delivery	Balance	Order or remarks
			Example 1				
Mon.	.45	Weir / ----	2.00	24	2.0	10.00	
Tue.	.20	CHO / .48	3.00	24	3.00	10.00	
Wed.	5"	Meter gate / 4-1/2"	1.53	24	1.55	10.00	
			Example 2				
Mon.	on/.20	on/.20	On/1.00	----	----	10.00	+ 1.0 or on/1.0
Tue.	.20	.20	1.00	24	1.00	9.00	
Wed.	.20	.20/.40	1.00/2.01	24	1.00	8.00	
Thur.	.20	.40	2.01	24	2.00	6.00	
Fri.	.18/.20	.40	1.90/2.01	24	1.90	4.10	weeds in back gate
Sat.	.20/off	.40/off	2.01/off	24	2.00	2.10	2.0 or 2.0/off
			Example 3 (Weir)				.50
Mon.	.45	----	2.00	24	1.50	10.00	
			Example 4 (CHO)				
Sat.	.20	.48	3.00	24	3.00	9.00	
Sun.	----	----	----	24	3.00	6.00	
Mon.	.20	.48	3.00	24	3.00	3.00	
			Example 5 (Weir)				
Mon.	.45	----	2.00	24	2.00	12.00	
Tue.	.28	----	1.00	24	1.00	11.00	OC
Wed.	.28	----	1.00	24	1.00	10.00	
Thur.	.37	----	1.50	24	1.50	8.50	OC

APPENDIX E
FIGURE E-8

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

MONTHLY WATER DISTRIBUTION

Project ______________ Acres Irrigated ______________ Year ______

QUANTITIES IN ACRE-FEET (CUBIC METERS)

MONTHS	DIVERTED FROM STREAM[1]	INFLOW FROM RESERVOIR AND OTHER SOURCES	DELIVERED TO RESERVOIR[2]	NET SUPPLY[3]	MAIN CANAL WASTE	MAIN CANAL LOSSES	DELIVERED TO LATERAL[a]	LATERAL WASTE	LATERAL LOSSES	NON-IRRIGATION DELIVERIES[4]	DELIVERED TO FARMERS[b]	
											TOTAL	PER ACRE
January												
February												
March												
April												
May												
June												
July												
August												
September												
October												
November												
December												
Total												
Acre Ft. per acre												
Percent net supply												

1. Diversion amount exclusive of waste of head gates for sand sluicing, etc.
2. Reservoirs connected with distribution system only
3. Diversions plus inflow for reservoirs and other sources less delivery to reservoirs
4. Do not include power

a) Measured at ______________

b) Measured at ______________

APPENDIX E
FIGURE E-9a

WATER SUPPLY REPORT

To ☐ ____________________ Region ____________________

☐ ____________________ Project ____________________

☐ ____________________ (Copy) Water Supply Prospects At End Of ____________________

RESERVOIR DATA

RESERVOIR	RESERVOIR ELEVATION		ACTIVE STORAGE 1,000 A.F.	MONTHLY TOTAL		OUTLOOK (ABV, NOR, SUB)	PRECIPITATION	
	FEET	DATE AND TIME		OUTFLOW 1,000 A.F.	INFLOW 1,000 A.F.		INCHES	PERCENT OF NORMAL

REMARKS

SUBMITTED BY

____________________ NAME ____________________ TITLE ____________________ DATE

APPENDIX E
FIGURE E-9b

WATER YEAR ENDING SEPTEMBER 30	PROJECT						
	RESERVOIR						
	DAM						
	ACTIVE CAPACITY			TOTAL CAPACITY			
	ACTIVE STORAGE END OF MONTH		OUTFLOW	INFLOW		CURRENT WATER OUTLOOK	INDUSTRIAL SUPPLY OUTLOOK
UNITS 1,000 ACRE FEET	WATER YEAR			CURRENT	AVERAGE		
OCTOBER							
NOVEMBER							
DECEMBER							
JANUARY							
FEBRUARY							
MARCH							
APRIL							
MAY							
JUNE							
JULY							
AUGUST							
SEPTEMBER							
TOTALS							

APPENDIX E
FIGURE E-10

NOTICE OF SYSTEM SHUTDOWN

Dear Water User:

It will be necessary for Lateral (Watercourse, Distributary, or Canal) ____

____

to be shut down at ________________ on ________________ for repair work which cannot be delayed. We hope to complete the necessary work within ________ days, although it may take a longer time. We will, however, make every effort to get this portion of the water delivery network back in service as soon as possible. You will be notified within a few hours after service is again available. No delivery from that lateral may be turned on until you receive this confirmation.

DAILY WATER REQUESTS

AREA ______________ DATE ______________

WATER USER	GEOGRAPHIC LOCATION	NUMERIC CODE	TYPE ORDER	C.F.S.	TIME	DESCRIPTION OF SERVICE AREA	CROP	PLANT DATE

APPENDIX E
FIGURE E-12

COMPLAINT FORM

Name of Complainant ____________________

Address ____________________

Phone ____________________ Date of occurrence __________

Nature of complaint including location ____________________

____

____

Action taken to correct problem ____________________

____

____

Was the action sufficient to satisfy the **complainant's** problem:

Yes No

What further action is recommended ____________________

____

____

____

Date ____________________ Signed ____________________

Person taking complaint

Comments by Division head ____________________

____

____

Date ____________________ Signed ____________________

____

____

Comments by Manager ____________________

____

____

Date ____________________ Signed ____________________

APPENDIX E
FIGURE E-13

APPLICATION FOR WATER DELIVERY OUTLET
AGRICULTURAL USES
(LANDOWNER)

The undersigned, being the owner(s) of the following described property lying with the (hereinafter referred to as the Agency):

hereby request(s) that an outlet be constructed by the Agency as a part of its irrigation system to permit service of water, as water is available, for agricultural uses from the Agency system. Said outlet is to be located ____.
The size shall be ______________________________.

The undersigned hereby agrees to pay the actual cost of construction of the outlet to, and as determined by, the Agency. Said construction cost shall be payable upon completion of the installation and within thirty (30) days after demand by the Agency.

It is further understood and agreed that, if said charge is not so paid, it will be added to and collected as part of the annual assessment levied on the above described land and shall comprise a lien upon said land to the extent and in the manner provided in the law.

The imposition of the charge provided for herein shall not be construed as preventing the establishment and collection of other and additional standby or water charges by the Agency for water supplied through such outlet.

It is further understood and agreed that the operation of said outlet will be only to provide water for agricultural purposes in a manner consistent with Agency regulations.

In the event said outlet is not used for a period of five (5) years, the Agency reserves the right to remove the service facilities. The cost of such removal shall be borne by the Agency, and the facilities which are removed shall remain the property of the Agency.

The owner(s) hereby agree(s) to convey to the Agency, at such time as requested by the Agency, any easements necessary for the installation, operation, and maintenance of said outlet.

The terms of this application shall be binding upon the successors in interest and assigns of the undersigned with respect to the above described real property.

Dated ________________ Signed ____________________________

Date outlet completed ___________ Date charges paid ___________

APPENDIX E
FIGURE E-14

WATER DELIVERY OUTLET - INSTALLATION

As Built Data | Sketch

Landowner: ____________________

Lessee: ____________________

Delivery No. ____________________

Meter No. ________ Meter size ______

Field elev. ________ Date __________

Location in feet from section corner: ____________________

N: _____ S: _____ E: _____ W: _____

Remarks: ____________________
____
____
____

Bench Mark Data:

Bench mark No. ____________________

Description: ____________________
____
____
____

Bench mark elevation: ____________________

Date: ____________________

Datum: ____________________

Scale

APPENDIX F. SAFETY

INTRODUCTION

The district's public safety and employee safety policies must adhere to all federal, state, and local laws and regulations. The board of directors should ensure that the district's policies provide specific application of these laws and regulations to the irrigation and drainage system under the board's authority.

Two examples of safety policies are presented in this appendix. One is the policy for public safety, and the other is a project employee safety policy for an operating U.S. Bureau of Reclamation project.

POLICY FOR PUBLIC SAFETY AT RECLAMATION FACILITIES

1. Introduction

Personal safety has always been a vital concern of the Bureau of Reclamation (Reclamation). There has always been a strong mandate to protect the general public at Reclamation-owned facilities. In the past, many of Reclamation's structures and appurtenant facilities were constructed in remote areas, not easily accessible to the public, and therefore posed less of a safety problem.

As the population of the West grew and urban areas expanded into the areas under Reclamation jurisdiction, these facilities posed potential hazards to the public. To minimize these hazards, Reclamation has adopted and updated standardized Bureauwide policy on public safety at its facilities.

2. Objective

The objective of this policy is to establish acceptable standards that can identify potential hazards, minimize the risk of personal injury and loss of life, and reduce the liability to the operating entities and Reclamation. To accomplish this, all Reclamation-owned facilities shall be comprehensively reviewed to identify potential hazards. Types of signs and/or barriers and safety devices necessary to comply with this will be identified and implemented.

3. Major Structures

The Regional Director has primary responsibility for minimizing risk to the general public at all major structures under his jurisdiction. To accomplish this, safety devices, signing, access restrictions, and changes in the use patterns or operational practices may be required.

3.1. Dams

The need for restricted areas shall be evaluated on a case-by-case basis. All restricted areas shall be fenced and appropriately signed to prohibit public access. These signs shall warn of all potential hazards and state the action required to avoid the hazard.

Dam embankments which provide public vehicle access shall be provided with guardrail protection equivalent to the protection specified by applicable county, state, or federal regulations. Guardrails shall be installed where automobiles are allowed to drive or park near sharp inclines or vertical dropoffs.

3.2. Spillways

These structures, regardless of size, shall be restricted to authorized personnel only due to the potential to sustain injury and/or loss of life. Fencing, guardrails, signs, and buoy lines shall be installed at key locations along, adjacent, above, and below the spillway. This includes the inlet, spillway bridge, chute, and stilling basin area.

1. Inlet Channel

Inlet channels to spillways will be cordoned off by a log boom or safety line floating across the entire section. The line will be kept afloat by brightly colored buoys readily visible from the water and shore. Signs prohibiting fishing, swimming, and boating will be posted on the buoys. Where the top of the inlet walls are less than 42 in. (1067 mm) above the ground, chain link fences shall be installed on top of the wall in a manner to preclude a person from standing on top of the wall inside the fence. The fence shall not extend below the maximum of water surface elevation.

2. Chute

Chute walls shall be fenced along each side of the structure if they present a potential danger to the general public. Signs shall be posted along the fence warning of the potential dangers.

3. Stilling Basin

Where the top of the walls are less than 42 in. (1067 mm) above the ground, guardrails or chain link fence shall be installed on top of the wall to preclude a person from standing on top of the wall inside the fence.

4. Discharge Channel

For gated spillways, signs warning of sudden high flows shall be posted at all public access locations, as far downstream of the stilling basin, as rapid increases of water surface elevation are expected to occur. Gated spillways that are remotely controlled or open automatically shall be provided with a high water alarm system.

5. Bridges

Bridges shall have guardrails or fencing. Load limit or speed limit signs shall be clearly posted.

C. Outlet Works

All portions of the outlet works, including the intake structure, chutes, shafts, control house, auxiliary power supply facilities, stilling basins, and discharge channels shall be considered restricted areas and prohibit public access.

1. Intakes

Intakes shall have a safety line with readily visible buoys near the intake. Signs prohibiting boating, fishing, skin or scuba diving, and swimming inside the restricted area shall be clearly posted on the buoys.

2. Chute

The outlet works chute is to be completely fenced and signs warning of potential high flows posted every 100-ft (30.5 m) along the fence.

3. Stilling Basin

The stilling basin is to be fenced to prevent access from shore. Signs prohibiting fishing, boating, and swimming in the basin area and warnings of sudden high flows are to be posted on both the inside and outside of the fence. Buoys with a safety line will be placed at the entrance of the basin to prohibit entry by watercraft.

4. Discharge Channel

Discharge channels shall have signs warning of sudden high flows placed at public access locations, as far downstream from the stilling basin as rapid increases of water surface elevation are expected to occur. Outlet works that are remotely controlled shall be provided with a high water alarm system.

D. Tunnel Intakes

Tunnel intakes can be submerged or nonsubmerged, and should be clearly identified by use of signs, buoys, fencing, and guardrails, to warn the public.

1. Submerged

Buoys and safety cables shall be placed around the mouth of the tunnel intakes at distances that allow a watercraft to overcome the pull of the current at maximum flows. Signs warning of a submerged tunnel are to be posted on the buoys. If the tunnel is accessible by land, access roads shall be gated and the area around the tunnel fenced. The fences shall be posted with signs warning of a submerged tunnel intake. Roads adjacent to any submerged tunnel shall be equipped with a guardrail and signs warning of the potential danger, even where steep slopes or other natural barriers may preclude access. The signs shall be posted at such a distance from the tunnel to allow a car to reduce its speed before reaching the vicinity of the submerged tunnel.

2. Nonsubmerged

Buoys shall be placed around the mouth of the intake tunnel at suitable distances that would allow a watercraft to overcome the pull of the current at maximum flows. Signs warning boaters of the current will be posted on buoys. Land access to tunnels shall have, at a minimum, guardrails with fencing in areas of heavy use. Guardrails and fences shall be posted with signs warning of the danger of the tunnel intake and strong current. A safety line with floats shall be strung across the mouth of the channel.

E. Roads

All roads shall be posted with speed limits and hazard signs. Curves will be posted with appropriate speed limit signs. All signs and posted speeds shall conform to the local State transportation department, except where U.S. Department of Transportation rules differ, in which case Department of Transportation guidelines will be followed.

F. Powerplants and Pumping Plants

These facilities, in addition to the switchyards, transmission lines, forebays, afterbays, and any bypass structures, shall remain inaccessible to unauthorized personnel due to the hazardous conditions prevalent at these locations. Fencing and signs shall be posted at these sites indicating restricted areas. Road signs shall be designed and installed in accordance with ANSI D6.1, "Manual on Uniform Traffic Control Devices." An exception to this criteria would be where powerplants or pumping plants are open to the public, and guided or self-guided tours are authorized. The areas open to the public shall be clearly identified by signs indicating that guided or self-guided tours are available.

At all powerplants or pumping plants, fire exits, fire protection equipment, and physical hazards shall be identified in accordance with ANSI 253.1, "Safety Color Code for Marking Physical Hazards," or NFPA N. 101, "Life Safety Code."

1. Switchyards

All switchyards will be completely fenced, gated, and locked. The fencing will have a barbed wire overhang to discourage climbing. Warning signs indicating *High Voltage* and *No Trespassing* are to be posted on all four sides of the fenced enclosure.

2. *Transmission Lines*

Horizontal and vertical clearances for these lines shall conform to the National Electrical Safety Code, ANSI C2. However, care is to be taken that horizontal clearance is such that any special equipment necessary for the particular structure can operate safely within the clearance. Clearances for lines will be clearly marked on poles and/or towers.

3. *Forebays, Afterbays, and Bypass Structures*

Inlets and outlets to these structures are to be marked with buoys and safety float cables. Access to these structures shall be discouraged by the use of buoys with signs warning of fluctuating water surface and sudden increases or decreases in releases. High water alarm systems (sirens, lights, etc.) shall be installed at the afterbay of powerplants with their meaning posted on buoys and guard fences.

4. *Powerplants and Pumping Plants*

Perimeter security fencing shall be installed where necessary to prohibit public access to these facilities. Appropriate signs shall be posted around the perimeter fencing.

IV. Minor Structures

There are numerous minor structures operated by the various water user entities and Reclamation. Many of these structures pose similar hazardous problems and require warning signs and devices to identify and warn of potential hazards.

A. Canals

All canals shall be evaluated to determine the safety measures necessary to protect the public. Canals shall be fenced where justified. Signs shall be posted prohibiting swimming and other water-related activities.

Concrete-lined canals having a vertical lining height of 30 in. (762 mm) or more, and with a width greater than 10 ft (3048 mm), shall be equipped with escape ladders. Ladders will be installed opposite each other at 750 ft (230 m) intervals on each side of the canal, and immediately upstream of siphons, checks, and similar structures, in conjunction with nets or safety cables.

1. *Operation and Maintenance Roads*

Where public use is prohibited, signs shall clearly state *No Trespassing* and shall be gated and locked. If public access is allowed (e.g., fishing), and speed limit signs shall be posted at all gates. Entrances shall be gated and all hazards plainly marked (e.g., soft shoulder).

2. *Check Structures, Drop Structures, Wasteways*

Public access to check structures, drop structures, and wasteways shall be prohibited. Large structures shall be enclosed by fencing with barbed wire overhangs, and access to the canal lining shall be restricted by wire-type extensions. The ponds above check structures are very attractive as swimming sites, but are very dangerous due to water depth and the likelihood of a person being drawn through an open check bay by high velocities. Such locations shall be posted with signs pointing out these potential hazards.

Rectangular section drops and chutes of 10 ft (30 m) depth or more shall be fenced or have guardrailing constructed along each side of the structure. Wasteways may require safety net or cable and drop-line devices across the water prism upstream from the intake of the structure with ladders on both sides to facilitate escape from the water.

3. *Diversion Structures and/or Headworks*

The area around the headworks of a canal or a diversion structure shall be posted with signs warning of high flows and turbulence. Safety lines with floats will be installed and attached to ladders providing escape from the canal. The area around the headworks and diversion structures will be fenced in a manner similar to check structures to prevent public access.

4. *Siphons*

All siphons over 30 in. (762 mm) shall be protected by a safety line with buoys and escape ladders installed at the inlet of each siphon. Additional safety devices to be used are as follows.

a. *Safety rack.* Safety pipe racks shall have approximately 9 in. (230 mm) clear spacing between pipes and be installed on a 4:1 or flatter slope. This device shall be used in small canals and where maintenance problems associated with weeds are not severe.

b. *Safety nets.* Safety nets shall be used in small canals where safety rack installations are not deemed advisable.

c. *Safety cables.* Floating cables shall be used in large canals where excessive spans limit the use of the safety rack or safety net.

d. *Guardrails.* Guardrails, in conjunction with pipe racks, shall cross the siphon transition headwall and extend the length of the transition on both sides of the canal. The railing shall be 42 in. (1067 mm) high with the metal posts embedded in the concrete.

e. *Fences.* Safety fencing, in conjunction with safety nets or cables, shall be a minimum of 6 ft high (3.6 m), chain link fence with barbed wire overhang above it. The fencing shall extend across the transition headwall and along each side to the anchor posts of the safety net or cables; except that where connection is made to an existing fence higher than 4 ft (1.2 m), a fence of equal height shall be provided. The net, rack, or cables shall be attached to a ladder on either side to provide for escape. Signs shall be posted along the fence warning of high flows and turbulence.

5. Bridges

Foot and vehicular bridges shall have guardrails equivalent to the standards of the maintaining entity.

Operating bridges and farm bridges that carry extremely wide farm machinery may be constructed without a regular guardrail to permit the passage of machinery. However, the curb guard shall always be used and special precautions taken to ensure that the side limits of the bridge are plainly visible to anyone approaching it. Guardrails shall be installed on the shoulders of ramp approaches to bridges.

In addition, load limits and speed limits will be clearly posted as well as other specialized information (such as "One Lane Bridge").

A safety line with floats will be installed 75 ft (23 m) downstream from the bridge and attached to escape ladders on each side of the canal.

B. Diversion Dams

A safety line with buoys shall be provided upstream of spillways, sluiceways, and headworks. Appropriate signs warning of danger from falling or fast flowing water shall be posted at these locations. Generally, the above structures as well as cable ways are considered restricted areas, and shall be fenced and have *No Trespassing* signs indicating the hazards.

V. Other Areas of Concern

A. Landslides

All active landslides are considered hazardous areas and shall be appropriately identified. Signs warning of the potential danger due to further slippage shall be posted a sufficient distance from the hazardous area. Inactive slide areas shall also be identified and signed.

B. Public Utilities

Power, water, oil, gas, and communication lines should be marked with the owner's name. If the lines are buried, signs shall be posted warning of the buried cable and giving a number to call.

Overhead utility lines crossing an operating road shall be posted in both directions and adequate distances from the line to allow vehicles traveling at the posted speed limit to stop. Any lines erected on U.S. lands must be checked for minimum clearance based on the National Electrical Safety Code, ANSI C2, and those clearances shall be plainly marked on the pole. Maximum safety clearance shall be in accordance with Constructions Safety Standards. High voltage or explosive lines, whether buried or otherwise, shall be marked as hazardous and owner identified.

VI. Identification, Review, and Replacement

A. Identification

Each region shall make a comprehensive review of all facilities in their area of responsibility to determine where safety devices or signs are needed, using the above criteria. Based on these findings, the Regional Director shall be responsible to program nonreimbursable funds for initial installation of all safety devices and signs.

B. Review

Each project and water user entity shall be responsible for review of all safety devices and signs on an annual basis. In addition, Reclamation examiners performing the periodic review of operation and maintenance examination at Reclamation facilities shall assess damaged or missing safety devices and signs and shall make recommendations to the Regional Director regarding replacement or repair.

C. Replacement

Anytime the warning or safety devices become worn, lost, or no longer legible, replacement or repair will be required. Responsibility for replacement or repair lies with the operating entity. Funding for such expenditures shall be a normal operation and maintenance expense.

PROJECT SAFETY POLICY

The basic Department Safety Policy Requirements are contained in Reclamation Instructions. These requirements and standards enable the Bureau to conform to the regulations promulgated by the U.S. Department of Labor, Safety and Health Provisions for Federal Employees. Further requirements are given in the Bureau Construction Safety Standards.

A. Purpose

The Project Safety Policy is to ensure the safety and health of employees of the Willows Office (CVP) against specific and/or identifiable occupational hazards in a manner consistent with the directives and in conformance with the Federal Regulations and Reclamation Instructions.

B. Responsibilities

1. The Project Superintendent, through supervisory personnel shall ensure the implementation and enforcement of this policy.

2. All supervisory personnel shall be responsible for ensuring that all employees under their supervision are thoroughly acquainted with this policy by reviewing it periodically with each employee and further, that

effective implementation of this policy and any supplements will be accomplished within 30 days following the date of release.

3. Employees are expected to observe all safety regulations and to comply with safety instructions given to them by their supervisors. Each employee is responsible for ensuring his own safety; for carrying out his work in a manner not endangering fellow employees, and for promptly reporting unsafe conditions, accidents, and injuries to his supervisors.

C. Personal Protective Equipment

Employees shall be responsible for wearing the protective equipment required by the work being performed or that is required by this policy. Failure or refusal to wear the required protective equipment shall be grounds for disciplinary action in accordance with existing personnel procedures. Employees shall immediately notify their supervisors of equipment that does not meet standards or is in such condition that it does not provide the intended protection.

1. Minimum Wearing Apparel for Field Personnel

All field employees will wear as minimum protection, full length pants and shirt or T-shirt (shirt sleeves must cover the shoulders). Cutoffs, tank tops, or modified shirts are not acceptable for outer wearing apparel. Footwear shall be standard water repellent, leather, 6 in. (152 mm) shoe or 8 to 10 in. (203 to 254 mm) boot, unless otherwise approved in writing by the Project Superintendent. Dress oxfords, sandals, or canvas tennis or deck shoes are not acceptable.

2. Requirements for Use of Basic Protective Equipment

Head Protection

a. Employees working in areas where there is a possible danger of head injury from impact from falling or flying objects from electrical shock shall wear protective helmets.
b. Project personnel shall be furnished and shall wear protective helmets under the following conditions.

  (1) All project construction sites.
  (2) All O&M activities involving construction and maintenance activities, the Corning Canal pumping plant, and all facilities related to operation of Red Bluff Diversion Dam upstream of the velocity barrier. Exceptions are interiors of shops, offices, and designated parking areas. Hardhats are to be worn when working around boom trucks, cranes, any overhead equipment, and when operating or working around heavy equipment.
  (3) All drilling sites and around active drill crew operations.
  (4) All electrical switchyards and substations.

(5) Whenever visiting non-project construction activities or other non-project activities requiring such protection.
(6) Any areas designated by signs as hardhat areas.
(7) Areas not listed above where there is a reasonable probability of injury that could be prevented or moderated by such protection.

c. Protective helmets used on this Project shall conform to ANSI Z89.2 standards and may be of the following types and class.

Type 1—helmet, full brim
Type 2—helmet, brimless and peak
Class B—high voltage protection

There shall be no holes through the shell of the helmet for any purpose. Any helmets with cracks, holes, deep scars, or appearing to be brittle will be replaced immediately. If particular exposure requires accessories, such as welding helmets, face shields, or others, a Class A helmet conforming to ANSI Z89.1 may be used if a suitable Class B helmet is not available. Class A helmets will not be worn around high voltage electrical equipment.

3. Eye Protection

a. Employees working in areas where there is a reasonable probability of eye injury shall wear safety glasses or other equivalent eye or face protection.
b. Project personnel shall be furnished and shall wear appropriate face or eye protection when exposed to eye hazards such as but not limited to the following.

(1) Welding, burning, sledging, chipping, drilling, riveting, caulking, grinding, wet or dry sandblasting, hammering, chiseling, punching on metals, wood, stone, masonry, concrete, or any other work where there is a possibility of eye injury from flying particles of any size or velocity. Protection is also required under all conditions where power impact tools are used.
(2) Babbitting, soldering, pouring lead joints, casting molten metal, handling hot tar, asphaltic materials, hot oils or liquids, and other molten substances.
(3) Handling of acids, caustics, hot liquid, creosote, spray paints, poison compounds, pesticides, weed oils, weed sprays, and other dangerous liquids.
(4) Areas not listed above where there is a reasonable probability of injury that could be prevented or moderated by such protection.

c. *Prescription Safety Glasses.* Prescription-ground safety glasses may be purchased for employees who wear corrective glasses and are engaged in eye hazardous duties. Any employee requiring prescription glasses shall obtain prescription forms from the Procurement Branch. The prescription itself must be obtained at the employee's own expense from an optometrist or opthomologist of the employee's choice. Shaded or photogray lenses *may* be purchased provided the examiner so prescribes.

d. *Plano Glasses.* Plano clear or shaded safety glasses will be issued in accordance with existing property procedures.

e. *Goggles, Face Shields, etc.* Other face and eye protective equipment such as side shields for glasses, goggles, and face shields shall be stocked as needed by each supervisor.

4. Foot Protection

a. Employees exposed to potential foot hazard conditions shall wear appropriate leather type safety footwear. Safety-toed footwear must comply with the criteria for ANSI 24.1 75 lb (165 kg) test, have non-skid soles for general use or oil resistant soles for those exposed to oily or wet surfaces and may be obtained by submitting a requisition through the employee's supervisor to the Procurement and Property Branch. A pair of shoes may then be purchased in accordance with existing policy. Generally only one pair of safety shoes per 12 month interval may be purchased.

b. Supervisors shall be responsible for ensuring that protective footwear is worn in the designated foot protection areas and may approve the use of protective footwear for employees working in areas where protective footwear is recommended.

c. As a minimum protection, safety-toed footwear shall be required in the following designated activities or work areas.

 (1) All drill crew operations.
 (2) All concrete and soils testing operations.
 (3) All warehousing activities.
 (4) Heavy equipment maintenance and repair.
 (5) All O&M maintenance activities.

d. Employees entering, for short durations, places or areas designated as foot protection areas shall, while in the designated areas wear foot protection. Metal toe guards that fit over the shoe will be stocked at fixed worksites such as maintenance and repair shops, warehouse, and laboratories for use by visitors required by Reclamation Instructions.

5. Hearing Protection

All employees working in areas where noise levels exceed the permissible limits and exposure times as set forth in Reclamation Instructions, shall wear appropriate ear protective devices. A sound level meter is available to measure the noise levels in any questionable areas.

Certain O&M areas, as determined by sound level meter tests, are posted showing hearing protection requirements. Helpers, visitors, or bystanders are subject to the above provisions.

6. Respiratory Protection

Respiratory protective devices shall be MESA or NISOH approved. Use and type of equipment shall conform to Reclamation Instructions, and the codes contained in ANSI Standard Z8.8.2.

1. Cartridge or Filter-Type Respirator

All employees working in atmospheres contaminated with toxic gases, fumes, mist, vapors, or dust exceeding respective threshold limit values shown in the latest edition of the ACGIH publication entitled "Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment" shall use approved respirators. This type of respirator will not be used in atmospheres containing airborne contaminants that include the following.

a. Exceed concentrations recommended in respirator approval certification.
b. Are of high toxicity.
c. Do not provide adequate warning to the senses.
d. Can be absorbed through the skin.
e. In atmospheres immediately dangerous to life or deficient in oxygen (below 19.5%).

2. Air Line Respirators

Employees working in confined areas where high concentrations of toxic substances are present in the atmosphere, but are not immediately hazardous to life shall wear air line respirators. This includes, but is not limited to spray painting of lead base or highly toxic paints and sandblasting. Air furnished to the respirator must be clean and free of oil, water scale, or other extraneous matter, carbon monoxide, and other gaseous contaminants.

3. Self-Contained Breathing Apparatus

All employees working in atmospheres immediately hazardous to life or on rescue squads entering burning enclosures shall wear a self-contained breathing apparatus. No employee shall enter such atmosphere unless accompanied by another employee equipped with an apparatus.

Employees will not be permitted to use self-contained breathing apparatus or other respiratory devices for use in atmospheres immediately hazardous to life unless they have received 4 hours of initial training on the equipment and a 2-hour refresher course annually.

7. Fluorescent Vests

Employees working around large haulage equipments, on or near public roads, in large game hunting areas during open season, and flagmen shall wear safety color fluorescent vests or a fluorescent coat, shirt, or poncho of equal or greater reflecting area.

8. Chain Saws

Employees operating chain saws shall wear chaps that meet the requirements of the U.S. Forest Service, safety-toed shoes or equivalent protection, goggles, face shield, and adequate hearing protection.

9. Personal Flotation Devices

All employees on rafts, in skiffs or boats, or working over or near water where danger of drowning exists shall wear U.S. Coast Guard approved personal flotation devices. Flotation devices may not be required when employees are protected by safety belt and lifelines or adequate guardrails as determined by the Project Superintendent.

D. Requirements for Pesticide Applications

Employees who handle, mix, or apply pesticides shall be properly trained pesticide applicators and shall follow the instruction on the manufacturers labels and materials safety data sheets for the product being used. Suitable safety equipment, as required for the product, will be used during the handling, mixing, and/or application of pesticides. Safety equipment shall include, but not be limited to, rubber boots, coveralls, rubber gloves, goggles or face shield, and respirator appropriate for the materials being used.

1. Other Protection Required

a. Sufficient washing facilities including soap, individual towels, and hot water shall be provided wherever mixing and/or handling concentrates is performed. In addition, such washing facilities shall be readily available to personnel performing spraying functions for cleanup at the end of the shift.
b. A deluge-type shower shall be provided at locations where handling, storage, and/or mixing of solutions is performed.
c. Eye flush fountains, either fixed or portable, shall be provided at all locations where handling, storage, mixing, and/or spraying is performed.

The foregoing requirements are consistent with the regulations promulgated by the California Food and Agriculture Code, Article 23, Pesticide Worker Safety.

E. Motor Vehicle Operation

The Bureau requirements for the motor vehicle licensing are set forth in the Department of Interior Regulations and the Office of Personnel Management Regulations. An employee operating a government-owned or leased motor vehicle, a private vehicle on official duty or mobile equipment of any type, must possess a valid State Of California driver's license and a U.S. Government Motor Vehicle operator's identification card showing the type of equipment the employee is qualified to operate. The possession of this card verifies that he or she meets the prescribed physical standards, has demonstrated ability to operate the assigned vehicle, and has supervisory authorization to do so. The card is valid for three years and then must be renewed.

The card will be suspended or revoked if employee's state operator's license is suspended or revoked. Depending upon the circumstances in each case the card may also be suspended or revoked if the employee:

(a) Is involved in an accident while operating a motor vehicle on government business and is found to have been at fault and seriously negligent.
(b) Is convicted of operating a motor vehicle while under the influence of alcohol or drugs.
(c) Is convicted of leaving the scene of an accident.
(d) Improperly operates the vehicle.
(e) Fails to meet the required physical standards of the operation of motor vehicle.
(f) Is convicted of moving violations.

If the employee's card has been revoked or suspended he or she will not be issued a new operator's identification card and be authorized to operate a motor vehicle until he or she has demonstrated driving competence by a road test, completion of driver training, current physical examination, restoration of state driver's license (if applicable), and/or other requirements as may be necessary.

1. Vehicle Occupant Restraining Systems

Operators and passengers of motor vehicles and mobile equipment must wear the occupant restraining devices (seat and/or shoulder belts) whenever the vehicle is in motion. As this is a mandatory requirement throughout the Bureau of Reclamation, an operator shall not put a vehicle in motion until all occupants are protected by restraint systems. Operator shall notify supervisor of any malfunctioning restraining devices. Disciplinary action will be taken for failure to use restraining devices.

2. Parking Brakes

It is the responsibility of the operator to follow proper parking procedure when exiting the motor vehicle or mobile equipment for any reason. The proper procedure is:

(a) Set the parking brake.
(b) Place the transmission in park or the lowest gear depending on type of transmission.
(c) Turn off engine.

Disciplinary action will be taken for failure to follow proper parking procedures.

F. Accident Prevention, Investigation, and Reporting

Effective accident prevention training is a constant and continuing responsibility of Bureau supervisors, carried out through the media of safety meetings, safety seminars, indoctrination of new employees, educational releases, and day- to-day supervision. Each supervisor is responsible for training their employees to work safely, for correcting unsafe acts and hazardous conditions, for investigating and reporting all accidents, and taking all necessary precautions to protect their employees, the public, and property as outlined in the Reclamation Instructions.

1. Accident Reporting

The following types of accidents and incidents shall be investigated immediately following their occurrences.

a. Any injury, occupational diseases, or death connected with performance of work by employees or other personnel under Bureau jurisdiction.
b. Any fire or property damage regardless of the amount of damages.
c. Any mobile equipment or motor vehicle accident involving Bureau, GSA motor pool vehicles, or vehicles privately owned or commercially leased when used on official business.
d. Any public injuries, deaths, or property damage relative to Bureau property and activities.

2. Report Form for all Accidents/Incidents

The proper form should be used to report all accidents and incidents enumerated in Reclamation Instructions, with exception of minor injuries requiring only onsite first aid treatment. (See Figs. F-5 [a and b] of this Appendix.)

3. Procedure in Case of an Accident

When an accident occurs the following procedure shall be followed.

a. First aid shall be administered as soon as possible.
b. The immediate supervisor shall be notified without delay. If the injured employee is able, he or she should personally report the

accident. If he or she is not able, other workers at the scene should do so.

c. Names of witnesses of the accident shall be noted.
d. If injury warrants, medical or hospital treatment shall be secured.
e. The proper reports shall be filled out and submitted.

It is the responsibility of the immediate supervisor to submit all forms to the proper authority within a reasonable time (usually *two* working days) and obtain and submit any follow up data (medical reports, doctor's statements, etc.). Specific forms and reporting procedures are explained in the directive from Assistant Regional Director, Administration on Reporting Procedures for Workers Compensation.

**REPORT OF
SAFETY MEETING**

**APPENDIX F
FIGURE F-1**

EMPLOYER	
JOB LOCATION	
NUMBER OF EMPLOYEES PRESENT	DATE
ACCIDENTS REVIEWED	
SUBJECTS DISCUSSED	
SUGGESTIONS/RECOMMENDATIONS	
ACTION TAKEN/SUPERVISOR'S COMMENTS	
SUPERVISOR'S SIGNATURE	

APPENDIX F
FIGURE F-2

EMPLOYEE SAFETY TRAINING REPORT

EMPLOYEE ______________________________ DATE ______________

CLASSIFICATION ____

DEPARTMENT ____

TYPE OF TRAINING: GROUP ☐ INDIVIDUAL ☐

SUBJECT(S) COVERED: ____

____

SPECIAL WORK TOOLS OR EQUIPMENT INVOLVED: (IF ANY) ______________

____

____

____

SAFETY EQUIPMENT USED: (IF ANY) ______________________________

____

____

INSTRUCTIONS GIVEN BY: ______________________________

TRAINING RECEIVED BY: ______________________________
(EMPLOYEE'S SIGNATURE)

MINUTES OF SAFETY COMMITTEE MEETING — APPENDIX F FIGURE F-3

☐ CENTRAL COMMITTEE ☐ DEPARTMENTAL COMMITTEE	DEPT. (If applicable)	DATE OF MEETING	TIME OF MEETING
CHAIRMAN	SECRETARY		DATE OF NEXT MEETING

COMMITTEE MEMBERS AND GUESTS	NAME	POSITION
PENDING BUSINESS	GENERAL	
PRIOR RECOMMENDATIONS	COMPLETED SINCE LAST MEETING	
	UNDER CONSIDERATION	
	DROPPED (Recommendation number, reason)	
ACCIDENTS AND NEW RECOMMENDATIONS	ACCIDENTS (Date, name, and description)	
	NEW RECOMMENDATIONS	
OTHER SAFETY ACTIVITIES	NEW	
	ITEMS THAT SHOULD RECEIVE PUBLICITY	

FOR COMMITTEE USE: ☐ Reviewed Department Inspection Reports ☐ Copy Sent To Central Committee

APPENDIX F
FIGURE F-4

REPORT OF UNSAFE CONDITION

I would like to report what I belive to be a hazard to life, limb, personal and/or District property. ______________________________
(Employee)

Specifically (hazard described in detail as follows, including exact location): ______________

____

____

____

____

Corrective Action Taken: ______________________________

____

____

____

By: ______________________________
Supervisor Department Date

Action Taken or Recommendation: ______________________________

____

____

____

By: ______________________________
Upper Level Supervisor Department Date

Comments, Safety Officer: ______________________________

____

Suspense Date of Correction: ______________________________

Date Correction Completed: ______________________________

APPENDIX F
FIGURE F-5a
DRIVER'S REPORT OF ACCIDENT

Company ____________________ Policy No. ____________

Address ____________________

Date of Accident ____________

Time ________ ☐ AM ☐ PM Day of Week ________

Place of Accident ____________

____

Road Conditions ____________

Weather Conditions ____________

Your Direction ________ Speed ________

Direction of Other Car ________ Speed ________

Police Report Taken? ________ Rept No. ________

Name of Police Department ____________

Policeman's Name ____________

Badge Number ____________

Was Summons Issued? ________ To Whom? ________

INJURED PERSONS

Name ____________

Address ____________

Nature & Extent of Injury ____________

____

____

Name ____________

Address ____________

Nature & Extent of Injury ____________

____

____

Name ____________

Address ____________

Nature & Extent of Injury ____________

____

____

YOUR VEHICLE (Veh. No. 1)

Owner ____________

Address ____________

Make, Model, and Year ____________

Vehicle Number ____________

Vehicle Lic. No. ________ State ________

Driver ____________

Driver's Address ____________

Driver's Lic. No. ________ State ________

Damaged Part(s) of Car ____________

____

OTHER VEHICLE (Veh. No. 2)

Address ____________

Make, Model, and Year ____________

Vehicle Number ____________

Vehicle Lic. No. ________ State ________

Driver ____________

Driver's Address ____________

Driver's Lic. No. ________ State ________

Insurance Co. ____________

Damaged Part(s) of Car ____________

____

OTHER VEHICLE (Veh. No. 3)

Address ____________

Make, Model, and Year ____________

Vehicle Number ____________

Vehicle Lic. No. ________ State ________

Driver ____________

Driver's Address ____________

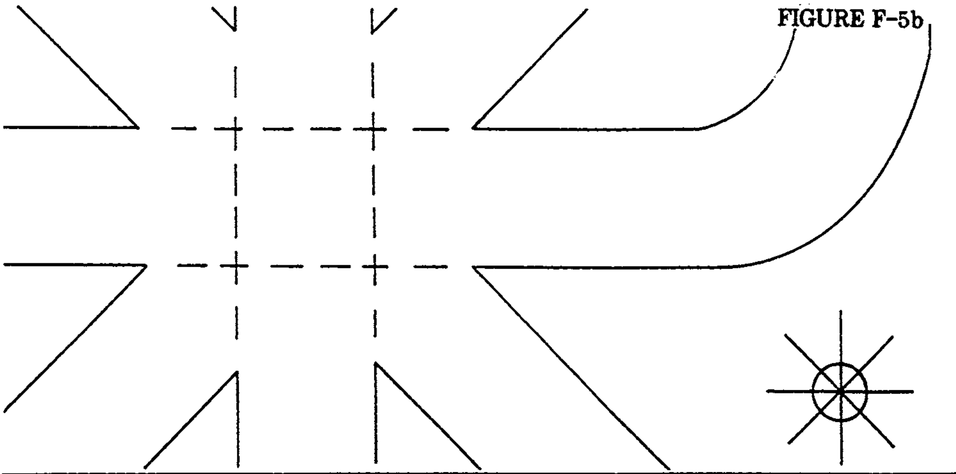
Driver's Lic. No. ________ State ________

Insurance Co. ____________

Damaged Part(s) of Car ____________

____

APPENDIX F
FIGURE F-5b



On the above diagram, show the position of each car at the time of the accident. Use rectangles or squares to indicate each car and number them (Veh. No. 1, Veh. No. 2, etc.). Indicate the direction of travel of each by arrow. Indicate traffic signs or signals. Also, indicate "North" on the diagram. Show any stationary objects involved in the accident.

NARRATIVE REPORT: Briefly describe accident; add pertinent comments not covered on first page.

APPENDIX F
FIGURE F-6A

SUPERVISOR'S ACCIDENT REPORT

Incident No.____________

(To be completed immediately after accident, even when there is no injury)

1. Name and address of injured (or ill) person ________________

2. Birthdate ________________ SSN ________________ Sex ________

3. Date of hire ________________ Monthly wage ________________ Employee's phone no. ________

4. Date last worked ________________ 5. Time on present job ________ 6. Title/occupation ________________

7. Department ________________ 8. Date of accident ________ 9. Time ________

10. Accident category (check) ☐ Motor Vehicle; ☐ Property Damage; ☐ Fire; ☐ Other ________________
(If motor vehicle accident, complete form WWD 135 also.)

11. Severity of injury or illness ☐ Non-disabling; ☐ Disabling; ☐ Medical Treatment; ☐ Fatality; ☐ First Aid

12. On employer's premises? ☐ Yes ☐ No 13. Location ________________

14. Name and address of Physician ________________

15. Has employee returned to work? ☐ Yes, date returned ________________ ☐ No, still off work ________

16. If hospitalized, name and address of hospital ________________

17. Nature of injury or illness? ________________

18. Part of body affected? ________________

19. Degree of disability? ________________
(Temporary Total; Permanent Partial; Permanent Total)

20. Causative agent most directly related to accident? (Object, substance, material, machinery, equipment, conditions) ________________

____

____

Was weather a factor? ________________

21. Unsafe mechanical/physical/environmental condition at time of accident? (Be specific) ________________

____

____

22. Unsafe act by injured and/or others contributing to the accident. (Be specific; must be answered) ________________

____

____

Personal factors (Improper attitude, lack of knowledge or skill, slow reaction, fatigue) ________________

____

____

(over)

APPENDIX F
FIGURE F-6B

24. Personal protective equipment required? (Protective glasses, safety shoes, safety hat, safety belt) ______

Was injured using required equipment? ______

25. What can be done to prevent a recurrence of this type of accident?
(Modification of machine; mechanical guards; correct environment; training) ______

______

______

26. Detailed narrative description (How did accident occur; why; objects, equipment, tools used, circumstance, assigned duties. Be specific.)

______

______

______

(Use additional sheets as required)

27. Witnesses to accident ______

______

Date prepared ______ Signature of Foreman/Immediate Supervisor ______

Department ______

SUPERVISOR'S APPRAISAL AND RECOMMENDATION

a. In your opinion, what action on the part of injured (or ill) person or others contributed to this accident? ______

______

______

b. Your recommendation ______

______

Date ______ Signature of Supervisor ______

FOR SAFETY OFFICE USE ONLY

Date of review ______

Reportable to SCIF: ☐ Yes ☐ No

Recordable to CAL/OSHA: ☐ Yes ☐ No

Comments ______

______

______

______

______

APPENDIX F
FIGURE F-7

LUNF 85

REPORT OF DAMAGE TO FACILITIES

(Use Reverse Side if Necessary)

1. DATE OF DAMAGE: ______________________ TIME: ______________________

2. FACILITY: ______________________

3. LOCATION: ______________________

4. DESCRIPTION OF DAMAGE: ______________________

____

____

5. DAMAGE CAUSED BY:

A. TYPE OF EQUIPMENT: ______________________

B. OWNER & ADDRESS: ______________________

C. OTHER FACTS: ______________________

____

____

6. PROPOSED METHOD OF REPAIR: ______________________

____

7. EMERGENCY REPAIRS REQUIRED: ______________________

8. ESTIMATED COST OF DAMAGE OR REPAIRS: ______________________

9. REMARKS: ______________________

____

DATE OF REPORT: ______________________ SIGNED: ______________________

FOR OFFICE USE ONLY	BY	DATE
10. NOTICE TO INS. AGENT (WHEN REQ'D):		
11. NOTIFICATION LETTER OUT:		
12. WORK ORDER NUMBER: ________		
13. DATE REPAIRED:		
14. LETTER/INVOICE OUT NO.: ________		
PAYMENT RECEIVED:		

Field Supervisor ______________________

Ass't Chief Engineer (office) ______________________

File: ______________________

COMMENTS: ______________________

APPENDIX G. MAINTENANCE MANAGEMENT (Johnston 1987)

Maintenance is a major challenge to top management. When there is an indication that basic maintenance objectives are not being met, improvements must be made in organizational structure: work order systems, estimating methods, planning and scheduling procedures, preventive maintenance, or material management. Following is a description of a functioning maintenance management organization for a large district that has hundreds of pumps, valves, meters, and pieces of mobile equipment.

Many districts do not have facilities that will require all personnel described herein to adequately manage a maintenance program. However, all of the functions described should be conducted for an adequate maintenance program, even though many of the jobs may be completed by one or just a few persons using fewer or less detailed forms. Districts with large amounts of mechanical equipment often find it beneficial to provide employees with a short course on maintenance management.

Some of the material presented in the maintenance management section of this manual was developed from such a course (Juul 1976). The person that maintains any irrigation system must rely on the support of operators, engineers, and administrative and financial personnel, along with management, including board of directors, to effectively carry out the work.

PERSONNEL

A large maintenance organization is generally headed by a maintenance manager. This position is listed in the detailed organizational chart (Fig. A-3a of Appendix A). The basic responsibilities of the maintenance manager should be to see that the following are done.

All facilities are maintained in good operating order within established rules, regulations, and budgets of the organization.

The preventive maintenance program is administered properly, minimizing breakdowns and unplanned shutdowns.

Adequate engineering advice is provided, and specifications for facilities and equipment are developed to allow all other maintenance personnel to keep all facilities operating in an efficient manner.

The purchasing of supplies and materials are made in a timely manner.

In addition to the maintenance manager, key persons in the maintenance organization could also consist of a maintenance planner, assistant chief engineer (maintenance), supervisor of preventive maintenance, supervisor of general maintenance, purchasing agent, warehouse supervisor, maintenance clerk, and maintenance workers, depending on the size and scope of activities of the group. See Appendix A for their placement in an organization chart of a large operating water district.

These positions may be combined in several different combinations when workloads are not sufficient to require all of the listed positions. The thing to remember is that in order to have a good maintenance program, all of the work must be done regardless of how many persons are involved.

BASIC MAINTENANCE WORK ORDER SYSTEM

The principal objectives of a maintenance work order system are to do the following.

Provide a method for controlling maintenance work and total maintenance costs.

Provide a means for proper authorization, planning, scheduling, and execution of maintenance work.

Provide an efficient method for management review of the maintenance work.

Assure that work requested is performed in the most efficient manner and at the lowest cost.

The basic policies and principles of the system should be that:

Work done by maintenance personnel will be done only by written work order.

All work requests will be estimated, authorized, and scheduled.

Originator will specify date when the work must be complete.

Work orders will be signed by originator and/or his or her supervisor upon completion of the work to acknowledge acceptance.

All jobs estimated to cost more than some amount (for example, $1,000), and all work contracted or done by non-organization forces will be reviewed and authorized by the maintenance manager.

All work will be prioritized.

No work will be scheduled for completion until all materials are on hand.

The work priority assigned a job will depend on severity of the problem and urgency. Work priorities can be divided into numerous classifications. However, three classifications will generally cover most needs pertaining to any repair of irrigation system malfunctions. The three basic maintenance work priorities are the following.

Priority 1. Emergency work that needs to be completed as soon as possible. Crews should be assigned immediately, and work should continue around the clock until complete and facilities are back in service. Overtime is automatically authorized.

Priority 2. Work is usually urgent and needs to be completed within 1 week. Work is done during normal working hours until the job is complete. Overtime is not automatically authorized but may be used if necessary.

Priority 3. Work is regularly scheduled and/or seasonal. Work should be completed as directed by normal work schedule. Priority 3 work is all work that is not classified as priority 1 or 2.

Processing Maintenance Work Order

A maintenance work order (MWO) form is used to request work (Fig. G-1) and is written when any facility fails or any work is necessary. The MWO is initiated by the person that discovers needed work, usually an operations or preventive maintenance person, and becomes part of the work backlog. The work is scheduled in accordance with its priority and requested completion date. This basic document originates work; collects labor, service, and material costs of a job; and serves as a record of work done.

The MWO should be a prenumbered, 4-copy form. The originator must supply the basic information needed to initiate estimate, procure materials, schedule, and perform the work required. This information includes the following.

1. Originator's name.
2. Work priority code.
3. Current date.
4. Location of work.
5. Date work should be completed.
6. Detailed description of the work.
7. Special conditions.

The originator should retain copy 4 of the MWO and send the first three copies to his or her supervisor. The supervisor approves and dates the MWO and routes it to the maintenance planner.

The maintenance planner will review the MWO and check the planners work order log to ensure that there has not been a previous request for the same work. The planner will then consult with the maintenance supervisor and/or visit the worksite to verify that the work description is correct and complete.

If a previous MWO has been filed for the same work, the second MWO is returned to originator with an appropriate explanation regarding priority and/or completion date of previous MWO along with any required revisions. If the MWO is an original, it is added to the planners work order log and weekly work scheduling system.

The planners work order log (Fig. G-2) is a hand-written record maintained by the Planner to determine status of any MWO without examining the more detailed weekly work scheduling system report which is used to record the status of all pending MWO's.

Prior to scheduling the weekly work, the Planner:

1. Identifies the lead maintenance department and each maintenance department that will need to perform work described.

2. Estimates type and number of hours of labor and needed equipment for each maintenance department. The estimates are based on job history for each particular category of work. The job history record must be maintained so that estimates regarding the time it takes to do various types of work can be refined as more and more work of each type is completed. The development of job history records is explained in the timekeeping section of this appendix.

3. Enters information on the weekly work scheduling system. The weekly work scheduling report (Figs. G-3a, G-3b, and G-3c) is coded to specify why each MWO is not scheduled for completion during any given week.

4. Lists materials needed on materials list form (Fig. G-4). Warehouse personnel are responsible for procuring materials for each MWO by withdrawing items from stock using a stock withdrawal card (Fig. G-5) or requesting that items not in stock be purchased using a materials request form (Fig. G-6).

The stock withdrawal card allows a computerized inventory system to be automatically updated for material costs to be charged to each work order, and material costs to be charged to appropriate maintenance department budgets.

When nonstocked material is ordered, the MWO number is indicated on materials request form. When material arrives, purchase order number and MWO number is marked on the material as it is set aside for each MWO. Also, as material is received and staged, purchase orders are closed, and the Planner is advised that materials are available for that MWO.

Adequate warehouse space is needed to provide for complete staging of materials. If adequate space for staging is not available, the maintenance supervisor should withdraw materials from stock when assigned to the scheduled job. See maintenance recordkeeping section of this appendix for a description of procedure used to purchase nonstocked items.

5. Describes special or safety instructions that should be followed by maintenance personnel.

6. Uses weekly work scheduling report to schedule priority 3 MWO's at least 1 week in advance, but only after all materials are available.

Priority 1 and 2 work, leave, training, preventive maintenance, and supervision is anticipated on work scheduling sheet (Fig. G-7). This sheet is used to determine number of hours available to work on priority 3 jobs, schedule jobs for next workweek, and distribute to various departments for job execution.

Work is normally scheduled for particular days of the week so that equipment, materials, and manpower are coordinated with all operations and maintenance departments involved in completing the work required under the MWO. A planning worksheet (Fig. G-8) is used to schedule different departments and special equipment that will be needed each day of the week.

If additional priority 1 or 2 work is assigned, it is assigned for immediate execution or scheduled for the next day. Other work that would have been carried out by workers assigned priority 1 and 2 work is held in the backlog file for future normal scheduling. Backlog work may be normal, seasonal, or preventive maintenance-type work.

Completing Work Described on MWO

When work is scheduled, the planner retains copy 3 of the MWO and sends copies 1 and 2 to the lead maintenance supervisor. When the maintenance supervisor receives the MWO as an assigned job, regardless of priority, maintenance personnel should check that needed materials have been assembled by the warehouse and are ready to go. If materials have not been staged, maintenance and warehouse personnel should work together to withdraw and assemble needed materials from inventory. The maintenance personnel should prepare any special tools necessary, collect materials, and proceed to jobsite.

The maintenance supervisor has the responsibility to see that all labor and equipment usage pertaining to each MWO is recorded properly as follows: Each maintenance person should record his or her time daily on daily timesheets (Fig. G-9). All equipment usage should be recorded daily on an equipment usage report (Fig. G-10). Charges should be made to the MWO for which the work is being done. Once work for any given MWO is finished, the maintenance supervisor must complete the MWO. The completion report should include the actual hours of equipment and labor required to complete the job, materials used, an assigned cause code, any additional work done and, if necessary, a record of pertinent measurements and clearances. Copies 1 and 2 of completed MWO should be returned to the planner.

The Planner retains copy 1 of the MWO with all backup material for a permanent record of the completed job. Copy 3 is destroyed, and copy 2 is returned to the originator through his or her supervisor so that the originator will know what has been done. The originator may either retain or destroy copy 2.

Costs for labor, equipment, and materials can be tabulated to each MWO and used to generate the following.

1. Cost center reports (Fig. G-11) which allot costs of work by type, area of service, type of facility, or other type of breakdown desired.
2. Invoices for billable work (Fig. G-12a).
3. Monthly work order reporting (Fig. G-12b).
4. Detailed work order reports (Fig. G-12c).

Maintenance Flowchart

The maintenance flowchart shown in Fig. G-13 describes the work order process from the time work order is initiated until there is notification that the work is complete.

Linear Responsibility

A chart showing the linear responsibility of the maintenance work order system is presented in Fig. G-14.

MAINTENANCE RECORD KEEPING

All work orders must be assigned a cause code before the work order is filed away. The following cause coding is recommended.

Code	*Cause*
A	Safety
B	Normal wear
C	Abnormal wear, faulty material, substandard equipment
D	Outside cause, operator error, overload
E	Maintenance error
F	Corrosion
G	Acts of God, frost damage, flood damage, etc.
H	Vandalism
I	Alteration—Productivity improvement
J	Alteration—Product quality improvement
K	Alteration—Maintenance improvement
L	Alteration—Environmental
M	Undetermined cause

It is possible to have two causes for the same job like B-K, i.e., replace a worn-out part with a different (stronger) part to avoid repeated failures.

Standing Work Log

A standing work log (Fig. G-15) is used for miscellaneous jobs of less than 4-hour duration. Each maintenance worker should retain a supply of these forms. Priority codes and cause codes are listed on the form for ready reference.

Purchasing Nonstocked Items

When nonstocked items are requested by warehouse personnel through issuance of a materials request form, purchasing agent issues a purchase order which shows the following.

Purchase order number
Order date
Date material is needed
Number of units ordered
Description of material ordered
Unit cost

Total cost per item
Taxable total cost (if applicable)
Amount of tax
Total cost of purchase order including tax

TIME KEEPING

The maintenance work order system is tied into the financial accounting system by the timekeeping system. This consists of reports of regular work time and overtime work charged to specific accounting codes. These reports substantiate regular and overtime payrolls and provide cost data on each cost center for budget and control purposes. The maintenance cost codes should be developed for:

Labor—Regular
Labor—Overtime
Labor—Contract or temporary
Supplies
Repair parts and repairs
Equipment type
Lubricants
Other

A daily timesheet (Fig. G-9) should be used to record regular time and overtime for work carried out under respective work order numbers. The time worked should be entered on the timesheet daily by each employee. The employee should record date, regular hours, and overtime hours worked under each work order number. Summaries can then be prepared to show how labor costs have accrued to the various jobs.

WORK SCHEDULING

In order to schedule work, it is important to estimate both the time necessary to do the work and time available. The following discussion describes procedures for estimating such time. First, all maintenance work should be divided into two groups.

Repetitive work is done over and over using similar equipment.

Nonrepetitive work is work done infrequently and where little or nothing is gained by keeping files on established methods and time used.

It is difficult to establish a meaningful historical record (standard) for a repetitive job unless:

The job has been identified and assigned a code number.
The job is described in detail and can be recognized by the planner.
The materials and spare parts used are identified and specified.
The best method has been identified and specified.
The tools, special material handling equipment, and safety instructions are stated.

The crew size is specified.

DEVELOPING JOB HISTORY RECORDS

Maintenance supervisors and planners should collect this information on repetitive jobs. The planners should keep ring binders with master copies of all repetitive jobs giving aforementioned information and average actual time to perform these jobs. It is important that methods and crew sizes are checked and optimized. With computerized system, this is done automatically.

Copies of the master copies will minimize future planning and estimating work of all repetitive work. Basically, a set of pre-made work orders and bill of materials for all repetitive work can be created. This process should allow the planners to concentrate on nonrepetitive work.

It is more difficult to estimate nonrepetitive work, but it must be done. All nonrepetitive jobs should be estimated using the slotting method which is simply placing each type of job in slot category depending on the length of time it takes to do the work.

The following time slots are recommended for nonrepetitive work:

A = 0-4 person-hours	"A" average to be calculated
B = 4.1-8 person-hours	"B" average to be calculated
C = 8.1-16 person-hours	"C" average to be calculated
D = 16.1-32 person-hours	"D" average to be calculated
E = 32.1-64 person-hours	"E" average to be calculated
F = 64.1-128 person-hours	"F" average to be calculated
G = 128 person-hours	"G" average to be calculated

The planners will assign a time slot to each craft (all planned work orders). The actual time taken will be recorded on the work order.

The maintenance clerks should tabulate actual times for all A, B, C, D, and E jobs for each craft, and monthly calculate the moving 5-month average. A computer will do this automatically.

To get the system started, it is recommended that average time slot values be developed by taking at least 2 months of completed work orders and sorting these work orders by actual time taken, i.e., collect all jobs charged with 0 to 4 person-hours and average actual time taken. Repeat the process for all jobs charged with 4.1 to 8 person-hours, and so on. These averages will be adjusted as work is done.

These average values should also be suited for determining backlog, weekly work program, and general cost estimating.

It is expected that average time values should be reduced as supervision and planning improve. The greatest single factors will be the preplanning of material requirements, selection of appropriate skill positions, assignment of correct crew size (do not use two people when one could do it), and increased supervision.

As explained previously, maintenance planners need to schedule work on a weekly basis and should process all work orders as each work order is authorized. The planners should discuss repair and maintenance methods and manpower problems with the maintenance and operations supervisors.

Maintenance planners prepare the weekly schedule based on meetings between operations and maintenance. The foremen proceed with work based on planners' recommended daily and weekly schedules modified by day-to-day emergencies and other nonscheduled activities. Engineering representatives should attend the planning meetings when maintenance is scheduling system alterations or construction.

During the meeting, work is selected from the backlog to correspond with person-hours available for scheduled work as determined in developing the weekly work program. The primary considerations in selection of jobs for the weekly schedule are the following.

Date of request.
Equipment availability.
Degree of urgency considering both production and maintenance requirements.
Coordination and availability of crafts.
Overall cost considerations.

All jobs selected are doublechecked for material availability and conformance with production schedules, planned shutdowns, and coordination of available men/women. Whenever possible, jobs should be selected and arranged to enhance productivity, such as a combination of jobs having similar characteristics to reduce travel and/or preparation time.

BACKLOG

Backlog is the amount of maintenance work that is pending completion. The amount of backlog work as determined on a weekly basis indicates whether or not the maintenance staff is adequate to perform the required maintenance work. A backlog of 8 to 10 weeks work is normal.

The size of the maintenance work force, required overtime, and need for outside contract labor must be considered as functions of estimated backlog of maintenance and construction work.

Maintenance manpower planning is based on weekly preparation and analysis of proposed department capacity. The departmental capacity should be calculated as follows.

Calculate total number of person-hours available for each department.
Add average number of outside contracted person-hours for each department, if any.
Add average overtime for the department.
Subtract average absenteeism for the department.
Subtract expected vacation hours for the department.

This will give total weekly capacity for each department, but not capacity available for planned work as contained in the backlog.

Capacity must be reserved for work not included in the normal backlog. This will include the average weekly amount as follows.

Required priority 1 (emergency) work.
Required priority 2 (urgent) work.
Preplanned preventive maintenance work.
General troubleshooting and routine work.

The 5-week moving average of these values should be calculated. Then, total reserved time should be subtracted from the gross capacity to get net capacity for each department. The net capacity for planned backlog work is a key figure for scheduling planned work.

The planned person-hours scheduled should be based on a 5-week moving average of actual time charged, modified to include known information on expected availability for the planning week (such as vacations, shutdowns, absenteeism, and special contracting agreements).

Five percent of available hours and 10 percent of available hours for priority 1 and 2 work, respectively, are subtracted from total available person-hours. Also, preplanned routine work, troubleshooting, and inspections are subtracted in order to get the expected amount of person-hours available for planned (priority 3) work. The backlog trend is of the greatest importance to maintenance management. Increasing backlog indicates insufficient manpower, reduced performance, too many new projects, or increased failure rate of the equipment, i.e., poor preventive maintenance.

Decreasing backlog indicates improved performance or surplus manpower and suggests reduction in overtime, elimination of outside contract labor, or work force reduction. It might also show an opportunity to take on new projects or complete deferred maintenance work. The ideal backlog situation will be achieved when all crafts have 8 to 10 weeks of backlog.

The actual person-hours used are noted at the end of the week by analyzing time charges. Variances are calculated. The following weeks work program is based on the analysis of variances and past performance. It is a tool for forecasting required nonscheduled person-hours (priorities 1 and 2, plus routine work) and total person-hours available for scheduled activities.

The available weekly capacity should also be adjusted for planned shutdowns.

SUPPLIES AND MATERIALS CONTROL

A key to maintaining any irrigation water delivery system is having the supplies and materials on hand or available to properly maintain the system. Certain maintenance personnel should be delegated the responsibility for seeing that supplies and materials are made available.

Control of supplies and materials is the responsibility of the warehouse supervisor. A tabulation showing a recommended delegation of those responsibilities is presented in Fig. G-16. Also shown are those persons that need consulting before any specific action is taken and those that need to be informed of the specific action.

Specific limits of authorization should be established in regard to allowing authorization of expenditures by maintenance personnel. These limits should be clearly known throughout the organization. A typical example of such levels of authorization follows. The amounts are shown in U.S. dollars, but appropriate amounts could be established in any currency.

Authorization by (1)	Repair of equipment or facilities (2)	Modification of equipment or facilities (3)
Maintenance foreman	Up to $200	0
Maintenance engineer or maintenance supervisor	Up to $5,000	Up to $500
Maintenance manager	Up to $10,000	Up to $1,000
Top management	Up to $20,000	Up to $10,000

In addition to the forms and computer reports previously discussed, warehouse personnel use several forms to control and monitor flow of supplies and materials from the vendor to user. Some typical forms used in such control are the following.

Inventory Control Form. If the inventory control system is not computerized, a form such as the one shown in Fig. G-17 should be used to monitor receipts and disbursements of item purchases. A computerized form is shown as Fig. G-18. Specific vendors should be listed along with expected cost of item.

Request for Quotation Form. Fig. G-19 is a form used to obtain written quotes for items or services of higher value or where larger quantities of items are purchased.

PREVENTIVE MAINTENANCE

The primary objective of preventive maintenance (PM) is to minimize failure of equipment and facilities as much as possible. This is done by scheduling equipment or facility repairs in advance of failure. A PM program can be based on one of three types of records—equipment history, inspections, and diagnostics.

Equipment History

An equipment history PM program would be one established upon the record of repairs made on each piece of equipment or facility because of a failure of that piece of equipment or facility. A good PM program can be fully implemented from equipment history records when there is knowledge about the following.

Time intervals between different failures.
Repair or replacement parts required.
Labor requirements.

This information will also allow annual budgets, repair material inventories, and work force requirements to be developed. Figs. G-20 and G-21 are samples of maintenance record forms that should be used to record the work that is done on a particular piece of equipment or facility. It is important that a separate form be filled out for each piece of equipment or facility. The form should be used to record the following.

Make, size, type, and serial number (if applicable) for each piece of equipment, facility, or item.
Organization identification number.
Work order number under which repair was done.
Work priority assigned.
Complete description of work.
Cause code.
Work hours.
Equipment, labor, material, and other repair costs.

It is important, that in the case of a pipeline failure, for example, that class of the pipe be included on the record. In addition, in order to establish a meaningful inspection or maintenance record, an exact update of the machinery, electrical equipment, or facility specifications must be included.

Advantage

Accurate as maintenance programs can be customized to requirements of each facility or piece of equipment.

Disadvantages

May require a long time to reach full implementation because some failures may not occur for 15 to 20 years.
Allowing failures to occur is generally more expensive than repairing equipment before failure.

Inspections

An inspection PM program would be one established upon examining equipment and facilities for signs of impending failures so that repairs can be scheduled to avoid the failures. Such a program is most important for organizations that operate a considerable amount of mechanical equipment (pumps, motors, valves, slide gates, electrical controls, and related facilities) that cannot be inspected easily without either shutting down the facilities or planning an extensive inspection program. For example, a 3-year inspection plan could be implemented.

The organization would then dewater and inspect one-third of its facilities every year. Detailed inspection reports would illustrate damage to the facilities and current dimensional specifications of the equipment. Figs. G-22 through G-31 are inspection report sheets for various types of irrigation system equipment and structures.

These inspection sheets must be customized for each piece of equipment or structure inspected. Work orders are initiated for all equipment found in poor or fair condition immediately upon inspection with completion dates set in accordance with the need. In addition, operations personnel should conduct ongoing inspections of the district facilities each time they travel along the system.

Advantages

Allows for quicker implementation of maintenance programs.
Prevents costly failures from occurring.
Allows scheduling of maintenance activities.

Disadvantages

Requires shutdown of the system or facilities for inspection.
Does not provide the most accurate indication about condition of the equipment or facilities with regard to potential failure.

Diagnostics

A diagnostics PM program would be one established using testing instruments to detect impending failures of equipment or facilities. This type of program works best where there are large amounts of pumps and for electrical equipment. Figs. G-32 through G-41 of Appendix G shows sample diagnostic reports that must be developed to implement a diagnostics PM program. A diagnostics PM program is a program that requires a continuous effort to analyze efficiency and condition of the irrigation system.

Advantages

Provides for a quick implementation of maintenance.
Provides an accurate indication of internal condition of machinery, equipment, and facilities.
Minimizes down time and costly failures.

Disadvantages

Has a relatively high implementation cost.
Requires specialized equipment.
Requires that personnel be trained to use the equipment.

Each organization should select the appropriate type or combination of PM programs needed for the type of facilities operated and personnel available. It is essential that personnel assigned to PM work be allowed to do the PM work and not be scheduled to do other maintenance work just because "nothing will happen if the PM is not done this time."

Figs. G-42 through G-44 of Appendix G are samples of PM inspection sheets that should be completed at regularly scheduled times and routed to files through the maintenance planner and maintenance superintendent. Fig. G-45 shows a delivery site maintenance request form.

APPENDIX G
FIGURE G-1

EL-29 (11-82)
Bureau of Reclamation

SHEET OF

DENVER OFFICE
RESEARCH LABORATORY SHOPS

WORK ORDER

SHOP WORK ORDER NO.		DUE DATE		ESTIMATED COSTS	
CHARGE TO:					
			ORIGINAL	REVISED	REVISED
COST CENTER:	JOB NO:		DATE		
PROJECT NAME			LABOR		
FOR INFORMATION CALL:		EXT.	MATERIALS		
DELIVER TO:		EXT.	OTHER*		
CODE	BLDG	ROOM	TOTAL		

*INCLUDES SHOP DESIGN COSTS

DESCRIPTION OF WORK:

(CONTINUED ON REVERSE SIDE F NECESSARY)

REQUESTED BY: (Authorized Signature)	DATE	WORK COMPLETED DATE:	
ASSIGNED TO: (Shop)	DATE	WORK ACCEPTED BY: (Signature)	DATE

(LABORATORY SHOPS COPY)

(LEL-1)

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PLANNERS WORK ORDER LOG

APPENDIX G
FIGURE G-2

DATE	WORK ORDER NUMBER	LOCATION	DESCRIPTION	WORK WANTED	PRIORITY	SECTION	COMPLETED

APPENDIX G
FIGURE G-3a

```
                    WEEKLY WORK SCHEDULING      06-18-86  15:38
SECTION 3E MAINT.
WEEK OF  06-16-86   PERSONNEL 16 EMPLOYEES

     TOTAL AVAILABLE MAN HOURS

          REGULAR TIME                               640.00
          OVERTIME                                      .00
          LEAVE                                       42.00-


               NET AVAILABLE MAN HOURS               598.00


     NOT AVAILABLE FOR SCHEDULING

          PRIORITY 1                                  12.00
          PRIORITY 2                                  24.00
          SAFETY TRAINING                               .00
          OTHER 1   9450: ADMIN. & SUPERVISION       200.00
          OTHER 2   92000 SUPERVISION                 40.00
          OTHER 3                                       .00
          OTHER 4                                       .00
          OTHER 5                                       .00

               TOTAL NOT AVAILABLE HOURS             276.00-

               MAN HOURS AVAILABALE FOR SCHEDULING  296.00
```

APPENDIX G
FIGURE G-3b

WEEKLY WORK SCHEDULING 06-18-86 15:38

SECTION 3E MAINT.
WEEK OF 06-16-86 PERSONNEL 16 EMPLOYEES

WORK ORDER	DESCRIPTION LOCATION	JOB CODE	EST HRS	HRST REMAIN	PTY	SUPV APRV DATE	REQUEST COMP DATE	REVISED COMP DATE	HOLD CODE	DESCRIPTION
07011	REMOVE GRAFFITI, REG. TANKS/E VARIOUS LOC.	3E	48.00	48.00	3	04-26-86	10-27-85			
07006	BACKFILL EROSIONS/E 2R-B PP	3E	48.00	48.00	3	09-25-85	11-08-85	11-30-86	03	WAITING FOR LINE TO GO DOWN
07007	BACKFILL EROSIONS/E 14R-C PP	3E	48.00	48.00	3	09-25-85	11-15-85	03-31-88	03	WAITING FOR LINE TO GO DOWN
01045	GRADE SILT/E INLET CANAL (6-1, 7-1 & 7-2 PP)	3E	29.08	29.08	3	11-04-85	12-01-85		04	OTHER
01122	FAB & PLACE PAD, WASH RACK/E FPSFO YARD	3E	192.00	90.00	3	11-22-85	12-22-85			
03995	REPAIR GRO. VALVE/E 23-4.1	3E	48.00	48.00	3	04-09-85	12-31-85	12-31-88	03	WAITING FOR LINE TO GO DOWN
00846	ACCUM. COSTS, LAND APPL., DR/E INTERIM DRAINAGE PROJECT AREA	3E	375.00	27.50	3	09-27-85	12-31-85			
07466	REPAIR RECIRC. STACK/E 17L HDWKS	3E	24.00	24.00	3	01-28-86	02-14-86	11-30-88	03	WAITING FOR LINE TO GO DOWN
07480	REPAIR RECIRC. STACK/E IL HDWKS	3E	24.00	24.00	3	01-28-86	02-14-86	03-31-87	03	WAITING FOR LINE TO GO DOWN
00907 110+44 BK	RAISE M.H. VAULT/E	3E	24.00	24.00	3	01-29-86	02-14-86		02	AWAITING 7R STA. MATERIALS
00899	REGROUT MANHOLE, DR./E DR. 136.0-34n	3E	48.00	48.00	3	01-23-86	02-24-86			

APPENDIX G
FIGURE G-3c

```
SECTION 3E MAINT.       WEEKLY WORK SCHEDULING        06-18-86    15:38
WEEK OF  06-16-86       PERSONNEL 16 EMPLOYEES

                        * * * B A C K L O G   A N A L Y S I S * * *

                           50 OPEN WORK ORDERS     4,114.00 ESTIMATED HOURS

                          124 HOLD WORK ORDERS     5,065.08 ESTIMATED HOURS

                        TOTAL WORK REQUIREMENT     9,179.08 ESTIMATED HOURS

                               AVAILABLE HOURS      296.00

                           BACKLOG EQUIVALENCY       31.0  WEEKS
```

APPENDIX G
FIGURE G-4

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MATERIALS LIST

Sheet ______ Of ______

Prepared by: | Date: | Work Order No.:

Item No.	Description	Part No.	Quantity	Unit	Unit Price	Amount	P.O. No.	Remarks

APPENDIX G
FIGURE G-5

STOCK WITHDRAWAL CARD

Date ____________________ Stock No. __ __ - __ __ - __ __ __ __ - __

Location __ __ - __ __ - __ __

Quantity __ __ __ Unit of Issue __ __ __

Description ____

Division/Section __ __ Employee No. __ __ __ Work Order No. __ __ __ __ __

Withdrawal ☐ Return ☐ Supervisor Init. __________ WWD No. __ __ - __ __ - __ __ __ __

Data Entered By ____________________ Date Entered ____________________

APPENDIX G
FIGURE G-6

MATERIALS REQUEST

DEPARTMENT ____________________ DATE WANTED ____________________

REQUESTER ________ DATE ________ AUTHORIZED ________ DATE ________ WAREHOUSE ________ DATE ________

SHIP TO LOCATION ☐ FRESNO OFFICE ☐ F.P.S.F.O.

OTHER ☐ ____________________

ITEM NO.	QUANTITY	UNIT	DESCRIPTION	W.W.D. STK. NO.		EXPENCE CODE	MIN	MAX	EST. UNIT COST	P.O. NO.	DATE
1											
VENDOR NO.				FOR:							
			MFG PT NO	AUTO.	ORDER	WK ORDER					
			MFG	YES	NO						
2											
VENDOR NO.				FOR:							
			MFG PT NO	AUTO.	ORDER	WK ORDER					
			MFG	YES	NO						
3											
VENDOR NO.				FOR:							
			MFG PT NO	AUTO.	ORDER	WK ORDER					
			MFG	YES	NO						
4											
VENDOR NO.				FOR:							
			MFG PT NO	AUTO.	ORDER	WK ORDER					
			MFG	YES	NO						
5											
VENDOR NO.				FOR:							
			MFG PT NO	AUTO.	ORDER	WK ORDER					
			MFG	YES	NO						

ITEM NO.	SUGGESTED VENDOR	ITEM NO.	SPECIAL INSTRUCTIONS

APPENDIX G
FIGURE G–7

WORK SCHEDULING SHEET

PLANNER ____________________ WEEK STARTING ____________________

SECTION PVPP (3C) PERSONNEL ____________________

	PRI	MAN HOURS SCHEDULED		MAN HOURS ACTUAL		VARIANCE
A. AVAILABLE MAN HOURS						
1. Regular Time						
2. Overtime						
3. Leave		( )				
4.						
NET AVAILABLE MAN HOURS						
B. NOT AVAILABLE FOR SCHEDULING						
1. Priority 1		( )				
2. Priority 2		( )				
3. Priority 3		( )				
4. Priority 4		( )				
5. Safety Training		( )				
6. 93003 PVPP, PM		( )				
7. 93004 Coalinga Canal, PM		( )				
8. 93007 PVPP, Operations		( )				
9. 93000 Supervision		( )				
10. 93001 Supervision		( )				
11. 92000 Supervision		( )				
12.		( )				
C. MAN HOURS AVAILABLE FOR SCHEDULING						
D. WORK ORDERS SCHEDULED	PRI	*		**		
1. 93005 PVPP Gen. Maint.	3					
2.						
3.						
4.						
5.						
6.						
7.						
8.						

CURRENT BACKLOG (WORK ORDERS) = ____________ MAN HOURS

CURRENT BACKLOG EQUIVALENT TO (____________) / ( ) = ____________ WEEKS OF BACKLOG

*(✓) Indicates scheduled completion. **(✓) Indicates Actual Completion.

APPENDIX G
FIGURE G-8

PLANNING WORK SHEET

SHEET ________ OF ________

W.O. NO. ____________ PLANNER ____________ DATE ____________

JOB DESCRIPTION ______________________________

____

____

LEAD SECTION ____________ MATERIAL REQUIRED? ☐ YES ☐ NO

SECTION	CHRONOLOGICAL LIST OF JOB DUTIES	EQUIPMENT		MAN HOURS
		TYPE	HOURS	

SECTION						TOTAL HOURS
MAN HOURS						

APPENDIX G
FIGURE G-9

DAILY TIME SHEET

NAME	DATE	SUPERVISOR
EMPLOYEE NO.		

WORK ORDER NO.	REG. HRS.	O.T. HRS.	SUN. HRS.	HOL. HRS.
	.	.	.	.
	.	.	.	.
	.	.	.	.
	.	.	.	.
	.	.	.	.
	.	.	.	.
	.	.	.	.
	.	.	.	.
	.	.	.	.
	.	.	.	.
TOTAL	.	.	.	.

APPENDIX G
FIGURE G-10

EQUIPMENT USAGE REPORT

Report By: ______________________ Equipment No. ______________________

DATE	W.O. NO.	DESCRIPTION OF WORK	TOTAL HOURS

APPENDIX G
FIGURE G-11

WORK ORDER BY COST CENTER REPORT FEBRUARY 03-01-86 10:09

COST CENTER: 02C3 WRK ORD/DESC./LOC.	NO/DESCRIPTION	PTY	STAT	LABOR CUR/YTD	EQUIP	MATLS	P.C.CHG	YTD TOTAL
00892 REPAIR A.R. VALVE/E 208-1.8 STA. 9+00+/-	02-C3-CC00 DISTR SYSTEM VALVES	3	OPEN	142.10 487.20	110.25	9.24	.CO	261.59
00901 REPAIR PL/E 28R STA. 24+73+-	02-C2-CC00 PIPELINES	3	OPEN	243.60 243.60	256.00	.00	.CO	499.60
00909 REPAIR A.R. VALVE/E 33-7.5	02-C3-CC00 DISTR SYSTEM VALVES	2	OPEN	395.85 395.85	416.00	31.24	.CC	843.09
00919 REPAIR PL/E 14R STA. 467+00	02-C2-CC00 PIPELINES	2	OPEN	487.20 487.20	512.00	333.29	.CC	1,332.49
01123 REPAIR TELE. CABLE/D 18 MAIN LINE	02-10-CC00 DIST SYSTEM ELECT FAC.	1	OPEN	2,637.60 7,487.10	2,348.75	564.81	.CC	5,551.16

APPENDIX G
FIGURE G-12a

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DATE
INVOICE NO.
PROJECT NO.
LOCATION

QUANTITY	UNIT	DESCRIPTION	UNIT PRICE	TOTAL COST
			TOTAL DUE	

CUSTOMER COPY

MONTHLY WORK ORDER REPORTING - MAY 06-06-86 15:35

REGULAR WORK ORDERS
STATUS OPEN

W.O. NUM	PTY	DATE	DESCRIPTION LOCATION WWD FIELD OFFICE, FPSFO	WWD EQUIP NUMBER	DESCRIPTION	BILL IND	REQ COMP DATE	L SEC	A B EST	O R ACT
01122	3	11-22-85	FAB & PLACE PAD, WASH RACK/E FPSFO YARD	06-02-0000	BUILDINGS & STRUCTURES	NO	12-22-85	3E	96.00	102.00
								3L	48.00	38.00
								3D	6.00	17.00
								3F	6.00	2.00
01134	3	09-16-85	ELECT DOCUMENTATION, PC'S/D PLANTS & SHOP	01-13-0000	ELECTRICAL FACILITIES	NO	12-31-85	3D	192.00	157.00
01169	3	06-20-85	REPAIR PUMP/F 15R U#1	01-03-0294	VERTICAL PUMP	NO	08-02-85	3F	192.00	.00
01195	3	07-03-85	REPAIR PUMP/E 25/L U#2	01-03-0102	VERTICAL PUMP	NO	07-31-85	3D	2.00	.00
								3F	192.00	.00
01586	3	05-28-86	INSTL SERIES "6" CONTROLLED/D 16R-A PP	01-13-0000	ELECTRICAL FACILITIES	NO	06-30-86	3D	48.00	46.00
01587	3	05-28-86	REPAIR LMT CONTROL 30X/D 16R-A PP	01-05-5000	PUMP DISCHARGE CONTROL VALVE	NO	06-28-86	3D	12.00	6.00
03047	3	08-18-88	REPLACE BADGER METERS/F VARIOUS, DELIVERY SITES 7L	07-05-0000	VERTICAL FLOW	NO	12-09-83	3E	192.00	74.00
								3L	48.00	16.00
								3F	192.00	145.50
03213	3	09-22-88	INSPECT AND REPAIR, INTERIOR/K 26R TERM, TANK	02-09-0000	DISTR SYSTEM REG TANKS	NO	01-31-84	3K	48.00	.00

APPENDIX G
FIGURE G-12b

APPENDIX G
FIGURE G-12c

DETAILED WORK ORDER REPORT

06-16-86 10:26

WORK ORDER	DESCRIPTION LOCATION	PTY	WWD EQUIP NUMBER	DESCRIPTION	SUPV APR REQ COMP ACT COMP	BILL PM?	STAT	HOLD/CAUSE DESCRIPTION	TOTAL COST
07288	REPAIR PUMP/L 1R-2.0B U#4	3	01-03-0185	CENTRIFUGAL PUMP	04-28-86 05-17-86 06-06-86	N N	C		1,776.65

* L A B O R   D E T A I L *

SECTION	EST HRS	ACT HRS	RATE	CHARGED	
3L	12.00	36.00	19.80	712.18	
3F	6.00	25.00	20.80	520.00	
				TOTAL LABOR	1,232.80

* M A T E R I A L S *

STOCK ID	DESCRIPTION	QTY	UNIT COST	CHARGED	
01-03-0078	NIPPLE GALV 3/8" DIA X 2"	2	.94	1.88	
01-05-0005	ADAPTER MALE PVC 1/2" DIA TXS	2	.21	.42	
01-05-0097	REDUCER PVC 1/2" x 3/8" S X T	2	.40	.80	
05-07-0003	SLEEVE SHAFT STAINLESS STEEL	2	86.89	173.78	
05-07-0041	WEAR RING CASE BRONZE CASE	2	34.20	68.40	
05-07-0046	BEARING INBOARD 6AD14	1	56.39	56.39	
05-07-0050	GASKET STUFFING BOX 6AD14	4	1.14	4.56	
05-07-0051	O-RING STUFFING BOX 6AD14	4	3.45	13.80	
05-99-0011	O-RING 1-3/4" x 2" x 1/8"	2	.30	.60	
05-99-0252	PACKING PUMP MECHANICAL 3/8"	1	168.22	168.22	
			TOTAL MATERIALS		488.85

* E Q U I P M E N T *

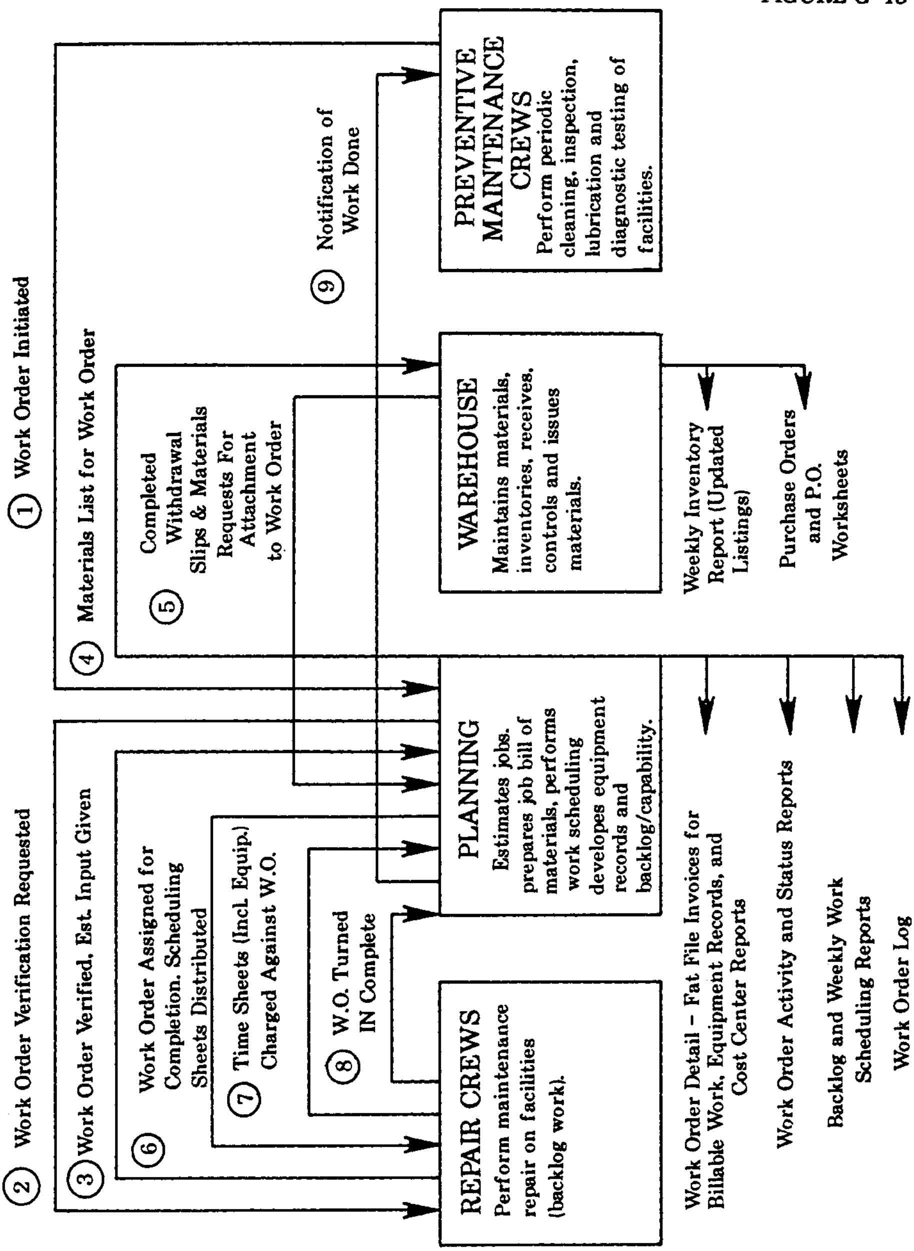
CODE	DESCRIPTION	ACT HRS	RATE	CHARGED	
391	CHEV. METER TRUCK	5.00	11.00	55.00	
			TOTAL EQUIP		55.00

* P U R C H A S E   O R D E R   C H A R G E S *

		CHARGED	
SYSTEM PO	03664	665.20	
SYSTEM PO	03794	95.40	
		TOTAL PURCHASE ORDER	760.60

APPENDIX G
FIGURE G-13

MAINTENANCE FLOWCHART



APPENDIX G
FIGURE G-14

LINEAR RESPONSIBILITY CHART	WORK ORDER SYSTEM							
Prepared	Approved							
Date								
Activity / POSITION	ORIGINATOR OF WORK ORDER	OPERATIONS SUPERVISOR	MAINTENANCE SUPERVISOR	MAINTENANCE PLANNER	MAINTENANCE MANAGER	WAREHOUSE SUPERINTENDENT	Other Positions	
Originates	RESP	APP	INF					
PRIORITY	INF	RESP	CON	CON	INF			
CAUSE CODING	INF	INF	RESP		INF			
ESTIMATE WORK			APP	REC	RESP			
WEEKLY WORK PROGRAM		INF	RESP	REC	APP			
DALY WORK PLAN	INF	INF	RESP	INF				
CHECK MATERIAL AVALABLITY			INF	RESP		CON		
SUPPLY MATERIALS	INF		CON	INF		RESP		
DO THE WORK	INF		APP	INF			CRAFTS PERSONS	RESP
QUALITY OF WORK			APP				CRAFTS PERSONS	RESP
COMPLETION OF WORK	INF	INF	INF	INF			CRAFTS PERSONS	RESP
MAINTENANCE BUDGET			CON	INF	RESP		ACCOUNTING	CON
BACKLOG CONTROL		INF	APP	RESP	INF			

REC-recommends APP-approves CON-consulted INF-informed RESP-responsible

APPENDIX G
FIGURE G–15

LUNF 96

STANDING WORK LOG

STANDING WORK LOG					WEEK OF		
NAME					EMPLOYEE NO.		
1	DATE	ORIGINATOR	DESCRIPTION			PRIORITY	DATE REQ.
	LOCATION				DATE COMPL.	REG. HRS.	O.T. HRS.
			CAUSE CODE	EQUIP. NO.	W.W.D. NO.		
2	DATE	ORIGINATOR	DESCRIPTION			PRIORITY	DATE REQ.
	LOCATION				DATE COMPL.	REG. HRS.	O.T. HRS.
			CAUSE CODE	EQUIP. NO.	W.W.D. NO.		
3	DATE	ORIGINATOR	DESCRIPTION			PRIORITY	DATE REQ.
	LOCATION				DATE COMPL.	REG. HRS.	O.T. HRS.
			CAUSE CODE	EQUIP. NO.	W.W.D. NO.		
4	DATE	ORIGINATOR	DESCRIPTION			PRIORITY	DATE REQ.
	LOCATION				DATE COMPL.	REG. HRS.	O.T. HRS.
			CAUSE CODE	EQUIP. NO.	W.W.D. NO.		
5	DATE	ORIGINATOR	DESCRIPTION			PRIORITY	DATE REQ.
	LOCATION				DATE COMPL.	REG. HRS.	O.T. HRS.
			CAUSE CODE	EQUIP. NO.	W.W.D. NO.		
6	DATE	ORIGINATOR	DESCRIPTION			PRIORITY	DATE REQ.
	LOCATION				DATE COMPL.	REG. HRS.	O.T. HRS.
			CAUSE CODE	EQUIP. NO.	W.W.D. NO.		
7	DATE	ORIGINATOR	DESCRIPTION			PRIORITY	DATE REQ.
	LOCATION				DATE COMPL.	REG. HRS.	O.T. HRS.
			CAUSE CODE	EQUIP. NO.	W.W.D. NO.		
8	DATE	ORIGINATOR	DESCRIPTION			PRIORITY	DATE REQ.
	LOCATION				DATE COMPL.	REG. HRS.	O.T. HRS.
			CAUSE CODE	EQUIP. NO.	W.W.D. NO.		

PRIORITY CODE: 1. Immediate & O.T. 2. Within one week – By date required

CAUSE CODE: 01. Normal Wear 02. Abnormal Wear 03. External Cause 04. Alterations 05. New Construction or Fabrication 06. Safety

NOTES: 1. Entries from WORK LOG to TIME SHEET shall be: W.O.No. 94000 – For miscellaneous activities and repairs 2. Use and attach Materials List

APPENDIX G
FIGURE G-16

DELEGATION OF RESPONSIBILITY FOR SUPPLIES AND MATERIALS

Function	Maintenance Engineer	Maintenance Supervisor	Maintenance Planner	Purchasing Agent	Warehouse Superintendent	Appropriate Maintenance Department
Develop Specifications	R	I	I	I		
Establish Standard Order Quantity		R	I	I		C
Determine Leadtimes		I	I	R		
Determine Suppliers		I	I	R		C
Maintain Stock Records		I	I	C	R	
Develop Stock Controls		I	I	C	R	
Determine Order Quantity		I	I	C	R	
Establish Prior Order Timing		I	R	I	C	
Issue: Purchase Requisitions						
Class I & II		I	R	C	I	
Class III		I	I	C	R	
Order		I	I	R	I	
Expedite Orders		I	I	R		
Receive Orders		I	I	I	R	I
Store Goods			C		R	
Issue: Shop Requisitions						
Standard			R			I
Non-Standard			I			R
Returns			I			R
Issue for Use					R	I

R - Responsible C - Must be consulted before action I - Must be informed of action

APPENDIX G
FIGURE G-17

INVENTORY CONTROL
Receipts and Disbursements

VENDORS		VENDORS		Cost Price
1.	2.	3.	4.	

Date	P.O. No.	Bal. on Ord.	Rec.	Used	Shop Work Ord.	Bal. in Stock	Unit Cost	Ext.	Date	P.O. No.	Bal. on Ord.	Rec.	Used	Shop Work Ord.	Bal. in Stock	Unit Cost	Ext.

Remarks		Used on	Lead	Min.
			Unit	Max.
Det. No.	Pr./No.	Description	Loc.	

APPENDIX G
FIGURE G-18

WEEKLY INVENTORY REPORT BY ITEM DESCRIPTION
NON-OFFICE ITEMS ONLY

05-06-86 15:38

DESCRIPTION	STOCK NO LOCATION	EXP REORD? CODE	QTY	STK BAL REOR PT	COST EA LOW STK	VALUE	ORD QTY PO NO	GRP	ORDER DATE DATE REC'D	YTD USE AV/MONTH	DATE LAST USE COMMENT
FUSE 15000V 5 AMP TYP 200	13-06-0042		YES	19	4.17	79.23	0	EA	11-23-83	0	12-07-84
	20-C8-13	02-30	5	10	11				01-6-84	.00	
KEARNEY CAT#11005											
FUSE 2 AMP	13-06-0200-C		YES	5	1.58	7.90	0	EA	00-00-00	0	12-07-84
	20-C8-07	02-23	9	1	3				04-14-83	.00	
BUSS BBS-2											
FUSE 2400 VOLTS 130 AMPS	13-06-0167		YES	1	174.97	174.97	1	EA	05-06-86	3	04-24-86
	10-03-04	02-30	1	2	3		0-03674		00-00-00	.17	ON ORDER
ALLIS-CHALMERS CAT# 24FM3X4											
FUSE 2400 VOLTS 170 AMPS	13-06-0168		YES	12	290.00	3,480.00	0	EA	00-00-00	0	00-00-00
	30-30-83	02-30	1	2	3				12-15-82	.00	
ALLIS CHALMERS CAT# 24FM6X4											
FUSE 2400 VOLTS 200 AMPS	13-06-0169		YES	10	290.00	2,900.00	0	EA	00-00-00	0	00-00-00
	30-30-90	02-30	1	2	3				12-15-82	.00	
ALLIS CHALMERS CAT# 24FM9X4											

APPENDIX G
FIGURE G-19

REQUEST FOR QUOTATION

Sheet ________ of ________

Date ____________________ 19 ______

Quotation No. ______________________________ Return by ____________ A.M./P.M. ____________________ 19 ______

Delivery desired at F. O. B. point ____

in ______________________________ calendar days from date of order.

Quote ON THIS SHEET your price for material, supplies or services listed below. Quotations submitted on other than district forms may be rejected. Provisions not included in this Request for Quotation may render a quotation unacceptable.

ITEM	QUANTITY	UNIT	DESCRIPTION	UNIT PRICE	AMOUNT
SUBTOTAL					
Sales (or Use) Tax					
Freight Charge					
Other Applicable Charges (specify)					
TOTAL					

TAXES: Prices quoted by the bidder shall be exclusive of Federal excise taxes pursuant to the exemption of political subdivisions of a State by Federal law. Copy of the Federal Exemption Certificate will be furnished upon request.

DUTIES: Prices quoted by the bidder shall include all applicable duties.

DISCOUNT: Above prices subject to cash discount of .... % .... days after delivery.

F. O. B.: Above material can be furnished at F. O. B. point in .... calendar days from date of order.

PRICES: Prices are firm for .... calendar days after closing date.

The bidder by signing this quotation agrees to furnish the materials listed above at the time, place, terms and prices set hereon, and subject to all conditions made a part of this quotation and specifications.

Name of Firm ______________________________________

Signature ____________________________ Date ______________

Title ______________________________________

IMPORTANT INSTRUCTIONS TO BIDDERS

The right is reserved to award in whole or in part or to reject all quotations. Delivery date may be taken into consideration in making award. Quotations must be submitted in sealed envelope showing bidder's name, quotation number and time of opening. This quotation shall remain effective and subject to acceptance by District for the number of calendar days in which prices are stated to be firm.

Questions concerning the conditions or specifications shall be directed to the Purchasing Agent.

APPENDIX G
FIGURE G-20

LUNF 101

MAINTENANCE RECORD

EQUIPMENT, FACILITY or ITEM	WWD NO.	LOCATION	INITIAL COST

DATE	WORK ORDER NO.	PRIORITY	DESCRIPTION OF WORK	CAUSE CODE	MAN HOURS	MAINTENANCE COST			
						EQUIPMENT	LABOR	MATERIAL	ACCUMULATED

APPENDIX G
FIGURE G–21

LUNF 102

EQUIPMENT REPAIR ORDER

DATE	MILEAGE	EQUIPMENT NO.	AUTHORIZED BY	MECHANIC

SERVICE REQUESTED A B C OTHER: ______________________

SERVICE PERFORMED: ______________________

TOTAL HOURS REQUIRED FOR SERVICE ______________

PARTS

QUAN.	PART NO.	DESCRIPTION	PRICE		P.O. NO.	INVOICE NO.

SUBTOTAL FROM ADDITIONAL PARTS		
TOTAL PARTS		

APPENDIX G
FIGURE G-22

PUMPING PLANT
TRIENNIAL INSPECTION

P.P.: ____________
Inspection By: ____________
Date: ____________

1. CONCRETE SUMP — CONDITION

A. Structural (Cracks, settlement) — Good Fair Poor
Comments: ____________

B. Downstream Ladder (Material, corrosion) — Good Fair Poor
Comments: ____________

C. Upstream Ladder (Material, corrosion) — Good Fair Poor
Comments: ____________

D. Miscellaneous Metal (Corrosion, metal loss) — Good Fair Poor
Comments: ____________

2. RESERVOIR

A. Earthwork (Cracks, erosion, subsidence) — Good Fair Poor
Comments: ____________

B. Hypalon Lining (Holes, rips) — Good Fair Poor
Comments: ____________

C. Inlet Structure (Cracks, settlement) — Good Fair Poor
Comments: ____________

D. Slide Gate (Operation, seating) — Good Fair Poor
Comments: ____________

E. Ladder (Material, corrosion) — Good Fair Poor
Comments: ____________

F. Interior Overflow Structure — Good Fair Poor
Comments: ____________

G. Exterior Overflow Structure — Good Fair Poor
Comments: ____________

GOOD - Concrete sumps considered to be in a good condition exhibit no visual signs of settlement, no cracking of the overall structure around wall mountings or anchor bolting of various equipment, (shrinkage cracks are acceptable), or no repairs required.

FAIR - Concrete sumps considered to be in a fair condition exhibit cracks from 1/32 to 1/16 inch in width, visual signs of settlement, or repairs required within 2 years.

POOR - Concrete sumps considered to be in a poor condition will exhibit cracks from exceeding 1/16 inch in width; failed or unsafe wall mounting or anchoring of access, control, and other facilities.

RESERVOIRS

GOOD - Reservoirs considered to be in a good condition will exhibit only shrinkage cracking in inlet and overflow structures; no erosion, cracking, or subsidence of earthwork; no holes or rips in the hypalon lining; and no repairs required.

FAIR - Reservoir considered to be in a fair condition will exhibit cracking or erosion of earthwork; holes or rips in the hypalon lining above the waterline; cracking in concrete inlet and overflow structures from 1/32 to 1/16 inch in width; visual signs of settlement of concrete inlet and overflow structures.

POOR - Reservoirs considered to be in a poor condition will exhibit subsidence of earthwork, holes or rips in the hypalon lining below the waterline, cracking in concrete inlet and overflow structures exceeding 1/16 inch in width, or repairs required within 6 months.

APPENDIX G
FIGURE G-23

TRAVELING WATER SCREEN TRIENNIAL INSPECTION

Location: ____________ Inspection By: ____________
WWD No.: ____________ Date: ____________
Hour meter: ____________

CONDITION

1. DRIVE SPROCKET (Alignment and wear) — Good Fair Poor
   Comments: ____________

2. DRIVEN SPROCKET (Alignment and wear) — Good Fair Poor
   Comments: ____________

3. DRIVE CHAIN (Alignment, tension, and wear) — Good Fair Poor
   Comments: ____________

4. HEAD SHAFT SPROCKETS AND TAKEUP BEARING (Bearing and insert wear) — Good Fair Poor
   Comments: ____________

5. BASKETS AND FABRIC (Corrosion and wear) — Good Fair Poor
   Comments: ____________

6. FRAME (Corrosion, material loss) — Good Fair Poor
   Comments: ____________

7. BOOT CASTING (FMC only – wear) — Good Fair Poor
   Comments: ____________

8. BOOT PLATE (Corrosion, wear, and sediment buildup) — Good Fair Poor
   Comments: ____________

9. BASKET CHAIN GUIDES (Corrosion and wear) — Good Fair Poor
   Comments: ____________

10. FOOT SPROCKETS AND SHAFT (Corrosion, bearing, and sprocket wear; depth of grooves on Rex spocket) — Good Fair Poor
    Comments: ____________

11. BASKET CHAIN (Corrosion, roller wear – measure maximum longitudinal movement) — Good Fair Poor
    Comments: ____________

12. WOOD SEAL STRIPS (Alignment and wear) — Good Fair Poor
    Comments: ____________

13. BOLTS, NUTS, WASHERS (Corrosion, missing) — Good Fair Poor
    Comments: ____________

GOOD – Traveling water screens considered to be in a good condition will have all mechanical components running true and/or parallel to each other; fabric bolting in place and fabric intact; grooves in foot sprockets less than 1/8-inch depth; no metal loss due to wear or galvanic corrosion exhibited by structural members; no repairs required.

FAIR – Traveling water screens considered to be in a fair condition will have a worn drive and/or driven sprocket; loose drive chain (requires tightening or link removal); a takeup bearing which is noisy; uneven wear on head shaft sprocket inserts; missing fabric bolts; holes in fabric; foot sprocket wobble (indicates bearing wear); a clearance exceeding 1/8 inch between baskets and the wood strips; metal loss due to wear or galvanic corrosion less than 30 percent of the cross-sectional areas of any structural member of the frame, or less than 1/4 inch in depth on the boot plate; a clearance from 3/8 to 5/8 inch between basket lips and the boot; grooves in the foot sprockets from 1/8 to 1/4 inch in depth; longitudinal movement in the basket chain rollers from 1/8 to 1/4 inch; repairs required within 2 years.

POOR – Traveling water screens considered to be in a poor condition will have a cracked or broken drive and/or driven sprockets; takeup bearing rotating in housing; a broken drive chain; head shaft sprocket inserts worn to the head of the fastener; fresh wear on the basket lips or side plates (indicates the need for an adjustment on the basket chain); metal loss equal to or exceeding 30 percent of the total cross-sectional area of any structural member of the frame due to galvanic corrosion; broken boot casting; a clearance of less than 3/8 inch between the basket lips and the boot plate; metal loss in the boot plate due to mechanical wear or galvanic corrosion exceeding 1/4 inch in depth; longitudinal movement in the basket chain rollers exceeding 1/4 inch; failed wood strips; or repairs required within 6 months.

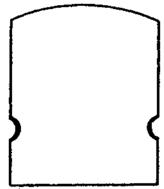
APPENDIX G
FIGURE G–24

AIR CHAMBER INSPECTION

Location: ____________ Inspection By: ________
Task No.: ____________ Date: ____________

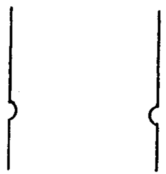
CONDITION

1. EXTERIOR (Sketch Coating Deficiencies)



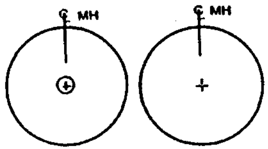
Condition of Coating: Good Fair Poor
Comments (Appearance): ________

2. INTERIOR (Sketch Coating Deficiencies)



Condition of Coating: Good Fair Poor
Comments (Appearance): ________

3. INTERIOR BOTTOM AND TOP (Sketch Coating Deficiencies)



Condition of Coating (Bottom): Good Fair Poor
Condition of Coating (Top): Good Fair Poor
Comments (Appearance): ________

<u>GOOD</u> – Tank structures considered to be in a good condition will have the linings intact and free of voids with small, tight blisters acceptable; coatings firm, intact, and free of voids with isolated nicks or indentations acceptable; no metal loss due to corrosion on interior and exterior surfaces; slight sediment buildup; repairs not required.

<u>FAIR</u> – Tank structures considered to be in a fair condition will have bare metal not exhibiting metal loss on interior surfaces above the waterline; bare metal pitting due to corrosion, and/or peeling or flaking coating on exterior surfaces; graffiti on exterior surfaces; sediment buildup not sufficient to cause immediate pump damage; repairs required within 2 years.

<u>POOR</u> – Tank structures considered to be in a poor condition will have perforation or near perforation at or below the waterline; bare metal on interior surfaces at or below the waterline; metal loss due to corrosion on interior surfaces; loose blistering or peeling.

APPENDIX G
FIGURE G-25

PUMPING PLANT LADDERS

P.P.: ____________
Survey By: ____________
Date: ____________

Upper Ladder	Upstream Ladder		Downstream Ladder	
1. Inside to inside of sidebars	______ inches		______ inches	
2. Safety cage around ladder	Yes	No	Yes	No
3. Safety cage mounted to	Wall	Ladder	Wall	Ladder
4. Is there a landing platform (if not, ignore information requested for lower ladder)	Yes	No	Yes	No
5. High waterline between (count top rung and down)	rung & ___	& rung ___	rung & ___	& rung ___
6. Wall-mounting brackets between (count top rung and down)	rung & ___	& rung ___	rung & ___	& rung ___
	___	___	___	___
	___	___	___	___
	___	___	___	___
	___	___	___	___
7. Sidebar splices between	rung & ___	& rung ___	rung & ___	& rung ___
	___	___	___	___
	___	___	___	___
8. Wall mounting Reusable	Screws Yes	Studs No	Screws Yes	Studs No
9. Is ladder mounted to floor	Yes	No	Yes	No
10. Number of rungs	______		______	
11. Condition	______		______	

Lower Ladder				
1. Wall-mounting brackets between (count top rung and down)	rung & ___	& rung ___	rung & ___	& rung ___
	___	___	___	___
	___	___	___	___
	___	___	___	___
	___	___	___	___
2. Sidebard splices between (count to rung and down)	rung & ___	& rung ___	rung & ___	& rung ___
	___	___	___	___
	___	___	___	___
3. Wall mounting Reusable	Screws Yes	Studs No	Screws Yes	Studs No
4. Is ladder mounted to floor	Yes	No	Yes	No
5. Number of rungs	______		______	
6. Condition	______		______	

GOOD – Ladders considered to be in a good condition are structurally sound, exhibit no evidence of metal loss due to galvanic corrosion, and no repairs are required.

FAIR – Ladders considered to be in a fair condition are structurally sound, exhibit metal loss less than 30 percent of the total cross-sectional area of any rung, rail, wall-mounting bracket or bolting, splice bolting, or any other load bearing member within the framework of the ladder, mounting, or platform will constitute a poor rating and does not pose an immediate safety hazard to personnel; repairs required within 2 years.

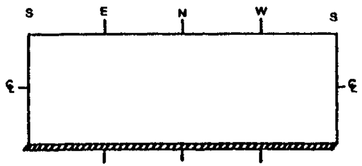
POOR – Ladders are considered to be in a poor condition if their structural integrity is questionable due to metal loss resulting from galvanic corrosion so as to pose a safety hazard to personnel using them. Metal loss which exceeds 30 percent of the total cross-sectional area of any rung, rail, wall-mounting bracket or bolting, splice bolting, or any other load-bearing member within the framework of the ladder, mounting, or platform will constitute a poor rating.

APPENDIX G
FIGURE G-26

REGULATING AND SURGE TANK INSPECTIONS

Tank No.: ______________ Inspection By: ______________
Tank Location: ______________ Date: ______________
Tank Diameter × Height: ______________

1. Exterior (Sketch ladder, manhole opening, and coating deficiencies)



Ladder: Good Fair Poor

Concrete: Good Fair Poor

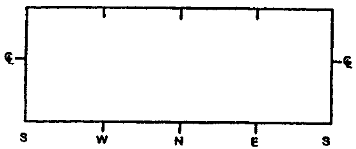
Overflow structures: Good Fair Poor

Appearance of Coating
Good Fair Poor

Condition of Coating
Good Fair Poor

Comments ______________

2. Interior (Sketch ladder, inlet/outlet openings, and coating deficiencies)

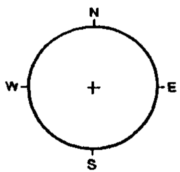


Ladder: Good Fair Poor

Condition of Coating
Good Fair Poor

Comments ______________

3. Bottom (Sketch inlet/outlet openings, coating deficiencies, and sediment)



Condition of Coating
Good Fair Poor

Comments ______________

GOOD – Tank structures considered to be in good condition will have all surfaces clean, paint intact and free of voids with small, tight blisters acceptable; coating firm, intact, and free of voids with isolated nicks or indentations acceptable; no metal loss due to corrosion on interior and exterior surfaces; slight sediment buildup; repairs not required.

FAIR – Tank structures considered to be in fair condition will have bare metal not exhibiting metal loss on interior surfaces above the waterline; bare metal pitting due to corrosion, and/or peeling or flaking coating on exterior surfaces; graffiti on exterior surfaces; sediment buildup not sufficient to cause immediate pump damage; repairs required within 2 years.

POOR – Tank structures considered to be in poor condition will have perforation or near perforation at or below the waterline; bare metal on interior surfaces at or below the waterline; metal loss due to corrosion on interior surfaces, loose blistering or peeling of the coating; sediment buildup sufficient to cause immediate pump damage or to prevent repair; or repairs required within 6 months.

APPENDIX G
FIGURE G-27

SLANTING DISK CHECK VALVE INSPECTION

Location: ____________ Sheet No. _____ of _____
Unit No. ____________ Type: ____________
Checked By: ____________ Date: ____________

CONDITION

Bushing to Disk Clearance Only — Good Fair Poor

Comments: ______________________________

____

Pin to Bushing Clearance Only — Good Fair Poor

Comments: ______________________________

____

Disk Seat Ring Condition — Good Fair Poor

Comments: ______________________________

____

Body Seat Ring Condition — Good Fair Poor

Comments: ______________________________

____

Any Other Condition That Needs To Be Noted

Comments: ______________________________

Recommendation: ______________________________

____

____

____

____

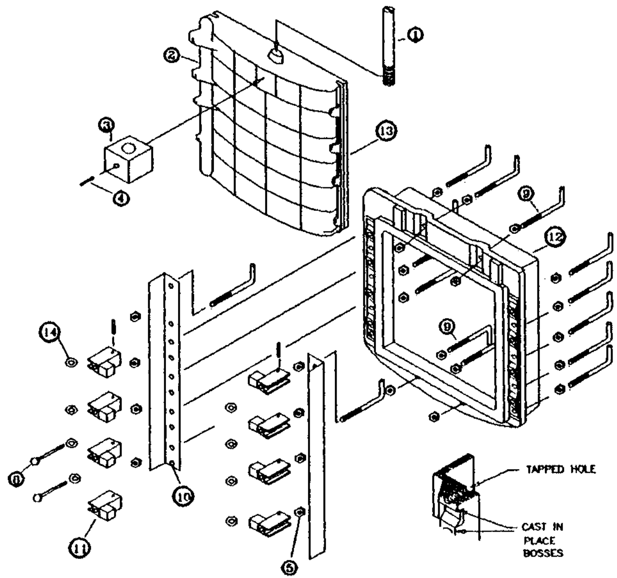
<u>GOOD</u> - Will have a 0.002- to 0.004-inch press fit between the outside diameter of the pivot bushings and the disk ear bores, a clearance between the inside diameter of the pivot bushings and the pins corresponding to a good rating as per chart below, seat rings which exhibit no scoring or washout, or repairs are not required.

<u>FAIR</u> - Will have a clearance of 0.001+ to 0.010 inch between the outside diameter of the pivot bushings and the disk ear bores, a clearance between the inside diameter of the pivot bushings and the pins corresponding to a fair rating as per chart below, seal rings which exhibit slight scoring so as not to allow enough leakage to backspin the corresponding pump unit, or repair required within 2 years.

<u>POOR</u> - Will have a clearance greater than 0.010 inch between the outside diameter of the pivot bushings and the disk ear bores, a clearance between the inside diameter of the pivot bushings and the pins corresponding to a poor rating as per chart below, beat out disk ear bores, cracked body or disk castings, seal rings which exhibit severe scoring so as to allow enough leakage to backspin the corresponding pumping unit, or repairs required within 6 months.

RATING:	GOOD	FAIR	POOR
Nominal valve size (inches)	Maximum/minimum (inches)	Maximum/minimum (inches)	Minimum (inches)
20	0.068/.053	0.073/0.068	0.073
18	.068/.058	.073/0.068	.073
16	.060/.050	.065/0.060	.065
14	.073/.058	.078/0.073	.078
12	.070/.055	.075/0.070	.075
10	.062/.047	.067/0.062	.067
8	.037/.022	.042/0.037	.042
6	.029/.011	.034/0.029	.034

APPENDIX G
FIGURE G-28



PARTS LIST	
1.	Stem, Steel
2.	Slide, Cast Iron
3.	Stem Block, Cast Iron
4.	Set Screw, S.S.T.
5.	Nuts Brass
6.	Stud Bolts
9.	Ancher Bolts, S.S.T.
10.	Guide Angles, S.S.T.
11.	Wedge Block, Cast Iron
12.	Seat, Cast Iron
13.	Sealing Surface, Machined
14.	Washers, Brass

Note : All Machine Bolts & Nuts Have Hex Heads

Body	Cast Iron (ASTM A 126 Class B)
Disk	NI-Resist Type I
Shaft	18-8 Type 304 Stainless Steel
Bearings	Silicone-Lubricated Bronze
Segments	Nickel Cast Iron

BRAND NAME: ________
LOCATION: ________ INSPECTION BY ________
SIZE: ________ DATE: ________
SERIAL NO.: ________ MODEL NO.: ________

	GOOD	FAIR	POOR	COMMENTS
1. Body				
2. Disk				
3. Rubber Seats				
4. S.S. Bolts				
5. S.S. Nuts				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				

INSPECTION TERM DEFINITION

GOOD: No variance or no significant variance from standard by measurement or sensory observation.

FAIR: Slight variance to significant variance from standard by measurement or sensory observation. Immediate repair not required. Explain the variance and indicate a date for reinspection or repair.

POOR: Excessive variance from standard by measurement or sensory observation. Immediate or near-immediate repair is required. Explain the variance and indicate the latest date that repair should be performed.

#6 GOOD+ No obvious wear; looks like new.
#5 GOOD- Slight or normal wear. No repairs needed. Year's inspection.
#4 FAIR+ Abnormal wear; should be reinspected for critical wear. (Possible affected performance.) (18 months) Write work order.
#3 FAIR- Operation affected (obvious wear); risk of breakdown (inspection in 6 months).
#2 POOR+ Machinery is failing. Needs repair as soon as possible (visual damage).
#1 POOR- Repair is needed; machinery does not work (immediate action required).

APPENDIX G
FIGURE G-29

SWING CHECK VALVE INSPECTION

Location: ______________ Sheet No. _____ of _____
Unit No. ______________ Type: ______________
Checked By: ____________ Date: ______________

CONDITION

Yoke Arm Condition — Good Fair Poor
Comments: ______________________________
____

Shaft to Yoke Arm and Keyway Condition — Good Fair Poor
Comments: ______________________________
____

Yoke Arm Pin to Disk Condition — Good Fair Poor
Comments: ______________________________
____

Disk Rubber Seat Condition — Good Fair Poor
Comments: ______________________________
____

Shaft Bronze Bushings Condition — Good Fair Poor
Comments: ______________________________
____

Any Other Condition That Needs To Be Noted
Comments: ______________________________
____

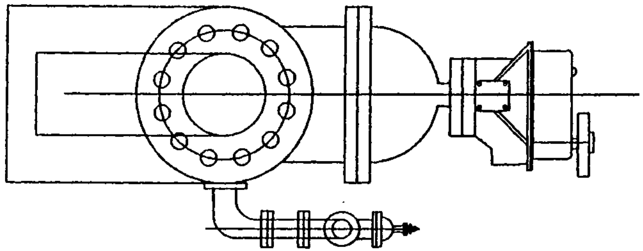
Recommendation: ______________________________
____
____
____

GOOD – Will have a clearance ranging from 0.0015 to 0.005 inch between bronze pivot bushings and shafts; no scoring of the disk seat; slight corrosion with no metal loss; no free play between mechanical components; or no repairs needed.

FAIR – Will have a clearance ranging from 0.005 to 0.008 inch between the bronze pivot bushings and the shaft; a slightly scored disk seat so as not to allow enough leakage to backspin corresponding pump unit; body, disk, and/or yoke arm castings which exhibit metal loss less than 30 percent of the cross-sectional area of the component, slight free play between mechanical components acceptable if valve is seating so as not to permit enough leakage to backspin corresponding pump unit; or repairs required within 2 years.

POOR – Will have a clearance greater than 0.008 inch between the bronze pivot bushings and the shaft; a torn or scored disk seat so as to permit enough leakage is backspin in the corresponding pumping unit; body, disk, and/or yoke arm castings which exhibit cracks or metal loss due to corrosion (metal loss must constitute approximately 30 percent of the cross-sectional area of metal components in order to warrant a poor rating); free play between the disk and yoke arm through the pin bore (indicates sloppy pin fit); independent movement between the external counterweight arm and the yoke/disk assembly (indicates a sloppy key/keyway fit between the yoke arm and the shaft); or repairs required within 6 months.

APPENDIX G
FIGURE G-30



INSPECTION TERM DEFINITION

10: No variance or no significant variance from standard by measurement or sensory observation.

11: Slight variance to significant variance from standard by measurement or sensory observation. Immediate repair is required.
Explain the variance and indicate the latest date that repair should be performed.

12: Excessive variance from standard by measurement or sensory observation.
Immediate or near-immediate repair is required.
Explain the variance and indicate the latest date that repair should be performed.

Good+ No obvious wear; looks like new.

Good− Slight or normal wear. No repairs needed. Year's inspection.

Fair+ Abnormal wear; should be reinspected for critical wear. (Possible affected performance.) (18 months)
Write work order.

Fair− Operation affected (obvious wear); risk of breakdown; (inspection in 6 months).

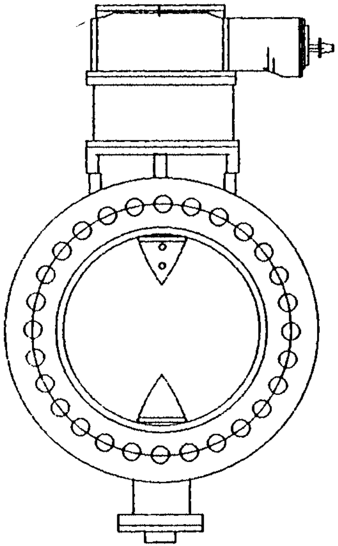
Poor+ Machinery is failing. Needs repair as soon as possible (visual damage).

Poor− Repair is needed; machinery does not work (immediate action required).

BRAND NAME: ____________
LOCATION: ____________ INSPECTION BY ____________
SIZE: ____________ DATE: ____________
MODEL NO.: ____________

	GOOD	FAIR	POOR	COMMENTS
1. Body				
2. Disk				
3. Brass Seats				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				

APPENDIX G
FIGURE G-31



Body	Cast Iron (ASTM A 126 Class B)
Disk	NI-Resist Type I
Shaft	18-8 Type 304 Stainless Steel
Bearings	Silicone-Lubricated Bronze
Segments	Nickel Cast Iron

BRAND NAME: ____________ INSPECTION BY ____________

LOCATION: ____________ DATE: ____________

SIZE: ____________ MODEL NO.: ____________

SERIAL NO.: ____________

	GOOD	FAIR	POOR	COMMENTS
1. Body				
2. Disk				
3. Rubber Seats				
4. S.S. Bolts				
5. S.S. Nuts				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				

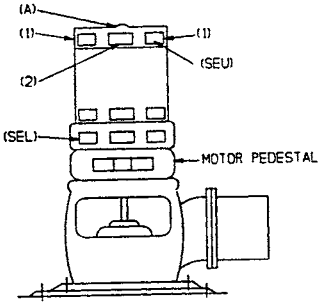
INSPECTION TERM DEFINITION

GOOD: No variance or no significant variance from standard by measurement or sensory observation.

FAIR: Slight variance to significant variance from standard by measurement or sensory observation. Immediate repair not required. Explain the variance and indicate a date for reinspection or repair.

POOR: Excessive variance from standard by measurement or sensory observation. Immediate or near-immediate repair is required. Explain the variance and indicate the latest date that repair should be performed.

#6 GOOD+ No obvious wear; looks like new.
#5 GOOD- Slight or normal wear. No repairs needed. Year's inspection.
#4 FAIR+ Abnormal wear; should be reinspected for critical wear. (Possible affected performance.) (18 months) Write work order.
#3 FAIR- Operation affected (obvious wear); risk of breakdown (inspection in 6 months).
#2 POOR+ Machinery is failing. Needs repair as soon as possible (visual damage).
#1 POOR- Repair is needed; machinery does not work (immediate action required).



VIBRATION DATA SHEET

APPENDIX G
FIGURE G-32

LOCATION ______________________ ______

WWD NO. ______________________

(1) On the motor case in a plane with or as close as possible to upper bearing.

(2) ______ do ______ , except 90° from (1).

(A) As close as possible and parallel to the vertical shaft.

(SEU) As close as possible to upper bearing.

(SEL) As close as possible to lower bearing.

PROBE AT	VELOCITY in/sec	DISPLACEMENT mils	SPIKE ENERGY g	DATE	BY	COMMENTS

PROBE AT	VELOCITY in/sec	DISPLACEMENT mils	SPIKE ENERGY g	DATE	BY	COMMENTS

APPENDIX G
FIGURE G-33

Sheet____ of ____

FIELD CORROSION SURVEY DATA

PROJECT	TEST INSTRUMENT
FEATURE	REFERENCE ELECTRODE
DATE	TESTS BY

STRUCTURE CONTACT		REFERENCE ELECTRODE LOCATION	POTENTIAL (millivolts)		CURRENT FLOW (milliamps)				NOTES
Feature (terminal box, etc.)	Location (station, etc.)				On		Off		
			On	Off	Magnitude	Direction	Magnitude	Direction	

REMARKS:

APPENDIX G
FIGURE G-34

DATA SHEET
CATHODIC PROTECTION SYSTEMS

Date ______________

Plant No. ______________ Model No. ______________ Serial No. ______________

Rated Output: Volts ______________ Amps ______________

Static Potential ______________ Anode/Cathode Voltage ______________

No. of Anodes (N) ______________ Max Allowable Current (NX3.5) ______________

Rheostat Settings ______________ "Y" Ground Strap Installed: Yes ______ No ______

Operating Mode Manual

Tap Settings		Output	
Coarse	Fine	Volts	Amps

Anode Outputs

1 ______	7 ______	13 ______	19 ______
2 ______	8 ______	14 ______	20 ______
3 ______	9 ______	15 ______	21 ______
4 ______	10 ______	16 ______	22 ______
5 ______	11 ______	17 ______	23 ______
6 ______	12 ______	18 ______	24 ______

Operating Mode Automatic

Current Limit Pot. Reset: Yes ______ No ______ IR Free Potential ______________

New Set Potential (IR Free Potential + 0.025 ± V) ______________

Output decreases as set potential is approched: Yes ______ No ______

Current "ON" potential ______________ (3.0 volts and not increasing)

Reset potential to 0.80 volts: Yes ______ No ______

Remarks: ______________

APPENDIX G
FIGURE G-35

DIFFERENTIAL RELAY TEST REPORT

LOCATION ________ CIRCUIT ________ DATE OF TEST ________

RELAY MFR ________ TYPE ________ STYLE OR MODEL NO. ________

RELAY RATING:

TAPS ______ AMPERES % SLOPE ________

C.T. MARKED RATIOS ________ ACTUAL RATIOS ________

	PHASE A	PHASE B	PHASE C
REPAY SERIAL No.			
RELAY SETTING:			
TAP-AMPERES			
SLOPES - %			
MINIMUM PICKUP CURRENT TESTS:			
RESTRAINING COIL NO. 1 AMPS			
RESTRAINING COIL NO. 2 AMPS			
RESTRAINING COIL NO. 3 AMPS			
OPERATING COIL AMPS			
MEDIUM PICKUP CURRENT TESTS:			
RESTRAINING COIL NO. 1 AMPS			
RESTRAINING COIL NO. 2 AMPS			
RESTRAINING COIL NO. 3 AMPS			
OPERATING COIL AMPS			
HIGH PICKUP CURRENT TESTS:			
RESTRAINING COIL NO. 1 AMPS			
RESTRAINING COIL NO. 2 AMPS			
RESTRAINING COIL NO. 3 AMPS			
OPERATING COIL AMPS			
OVERCURRENT OPERATING TESTS:			
A. RESTRAINING COIL NO. ___ AMPS			
RESTRAINING COIL AMPS			
OPERATING TIME — CYCLE			
B. RESTRAINING COIL NO. ___ AMPS			
RESTRAINING COIL AMPS			
OPERATING TIME — CYCLE			
CURRENT BALANCE FOR THRU PRIMARY CURRENT:			
CIRCUIT NO. 1 AMPS			
CIRCUIT NO. 2 AMPS			
CIRCUIT NO. 3 AMPS			

DO RELAYS TRIP ALL CONNECTED DEVICES?
DO OPERATION INDICATORS OPERATE?
DO AUXILIARY CONTACTS OPERATE?
*RECORD MINIMUM PICKUP AMPS

NOTE: ALL DATA ARE FOR CONDITION AS LEFT UNLESS OTHERWISE NOTED.

TRIP CIRCUIT MEASUREMENT:

MINIMUM AMPS TO TRIP ___ TOTAL RESISTANCE ___ OHMS AT __ °C

RESISTANCE OF TRIP COIL ONLY ________ OHMS AT __ °C

MAIN CONTACT GAP CLEARANCE ________ INCHES

GENERAL CONDITION OF RELAYS AS FOUND:

DUST OR DIRT INSIDE OF RELAYS? ________

CONDITION OF CONTACTS? ________

CONDITION OF PIVOTS? ________

STICKING OR BINDING OF MOVING PARTS? ________

MAGNETIC PARTICLES IN AIRGAP? ________

CONDITION OF COILS? ________

WHAT MAINTENANCE OR REPAIRS WERE FOUND NECESSARY? ________

WHAT CHANGES WERE MADE IN SETTINGS AND C.T. RATIOS? ________

REMARKS: ________

TESTED BY: ________ ASSISTED BY: ________

APPENDIX G

FIGURE G-36

_______________ FIELD DIVISION

Watt- ( ); Var- ( ) Hourmeter Test Report

Location: ______________________ ______KV: Date:__________

Meter: Ser. No. ______________ Mult. __________ K_h: __________ K_H: __________

Demand Meter: S.N.______________Mult.__________Tape Mult. __________

Rotating Std.: S.N.______________

Meter Test Data:

	Time	Reg Rdg	Counter	__Revs(Secs)	MD	Remarks
In:						
Out:						
Diff.						

Voltage: AØ ________ BØ ________ CØ ________

AMPS	P. F.	Rotations		Std.	As Found			As Left		
		Meter	Std	C. F.	Revs Std	Corr Revs	Meter C. F.	Revs Std	Corr Revs	Meter C.F.
5	1.0									
5	1.0									
2.5	1.0									
2.5	1.0									
0.5	1.0									
0.5	1.0									
5	.50									
5	.50									

NOTE: Use one line each test to record average of three or more readings.

Demand Meter Check:__________Revs Std. = __________Revs whm disc = __________Contacts

Repairs, Adjustments & Remarks: ______________________________

Tested By:______________________ Assisted By:______________________

______________________ Witness ______________________

APPENDIX G
FIGURE G-37

POWM-100
(1-64)
Bureau of Reclamation

OVERCURRENT RELAY TEST REPORT

LOCATION ______ CIRCUIT ______ RELAY MFR. ______ TYPE ______ STYLE OR MODEL NO. ______

RELAY RATING.
TIME DELAY ELEMENT ______ TO ______ AMPERES ______ CHARACTERISTIC
INSTANTANEOUS ELEMENT ______ TO ______ AMPERES ______
DIRECTIONAL ELEMENT ______ AMPERES ______ VOLTS ______ DEGREES PHASE ANGLE

RELAY SERIAL NUMBERS. PHASE A ______ PHASE B ______ PHASE C ______

C. T. MARKED RATIOS ______ ACTUAL RATIO ______ P. T. MARKED RATIOS ______ ACTUAL RATIO ______

	DATE SETTING DESIRED	19__ PHASE A	PHASE B	PHASE C	19__ PHASE A	PHASE B	PHASE C	19__ PHASE A	PHASE B	PHASE C	19__ PHASE A	PHASE B	PHASE C	19__ PHASE A	PHASE B	PHASE C
RELAY SETTING:																
TIME DELAY ELEMENT - AMP TAP																
- TIME LEVER																
- PRIMARY AMPS-KVA																
INSTANTANEOUS ELEMENT - AMPS. P. U.																
PRIMARY AMPS. KVA																
DIRECTIONAL ELEMENT - AMPS. OR VOLTS																
RELAY TESTS																
A. TIME DELAY ELEMENT - MIN. PICK-UP AMPS																
INSTANTANEOUS ELEMENT - MIN. PICK-UP AMPS																
DIRECTIONAL ELEMENT - MIN. PICK-UP AMPS																
POLARIZING AMPS. OR VOLTS																
ANGLE OF MAX. TORQUE																
B. TIME DELAY ELEMENT - OPERATING AMPS.																
POLARIZING AMPS. OR VOLTS																
OPERATING TIME - SECONDS																
C. TIME DELAY ELEMENT - OPERATING AMPS.																
POLARIZING AMPS. OR VOLTS																
OPERATING TIME - SECONDS																
D. TIME DELAY ELEMENT - OPERATING AMPS.																
POLARIZING AMPS. OR VOLTS																
OPERATING TIME - SECONDS																
E. INSTANTANEOUS ELEMENT OPERATING AMPS.																
OPERATING TIME - CYCLES																
DO TESTS AGREE WITH MFR'S. DATA ?																
DO RELAYS TRIP BREAKERS ?																
DO OPERATION INDICATORS OPERATE *																
DO AUXILIARY CONTACTS OPERATE *																

* RECORD MINIMUM PICK-UP AMPS.

NOTE. ALL DATA ARE FOR CONDITION AS LEFT UNLESS OTHERWISE NOTED.

APPENDIX G
FIGURE G-38

LUNF 105

PHASE ANGLE TEST

Name ______________ Location ______________ Date ________

W. H. Meter # ________ Type ________ A. ____ V. ____ W.____ Ph.____ Kh.____ Reading ________ MD ______

RKVA Meter ________ Type ________ A. ____ V. ____ W.____ Ph.____ Kh.____ Reading ________

CY# ________ Amp Rating ________ PT# ________ Volt Rating ________.

#________ ________ ________ ________

#________ ________ ________ ________

Billing K

WHM ________

Dom ________

RKVA ________

WH Load:______ Rev.______Sec.

KW ________

RKVA Load:______ Rev.______Sec.

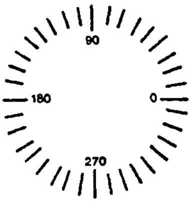
KVAR ________

Average Phase Angle

Degrees ________

S.P. F. ________

Power Factor:



$\frac{RKVA}{KW}$ = ________%

1 Rev W_1 ________Sec.
1 Rev W_2 ________Sec.

$\frac{W_1 - W_2}{W_1 + W_2} \times \sqrt{3}$ = ________ %

Volts A-B________ C-B________ AC ________ RE.A-B ________ RE.C-B________

Volts Ground A-O________ B-O________ C-O________ RE.A ________ Re.B ________ RE.C________

Phase Sequence: Test Switch ________ Reactiformer ________

Phase Angle Readings

1-A ____ Amps	1-C ____ Amps	I-A ____ Amps	I-B ____ Amps	I-C ____ Amp
E.A-B ____	____	E.A-O ____	____	____
E.C-B ____	____	E.B-O ____	____	____
E.A-C ____	____	E.C-O ____	____	____
REA-B ____	____	RE.A ____	____	____
REC-B ____	____	RE.B ____	____	____
		RE.C ____	____	____

NOTES: ________________

Tested By ________________

APPENDIX G
FIGURE G-39

MISCELLANEOUS TEST SHEET

Location .... Circuit .... Date of Test ....

Device .... Mfr. .... Style Model No. ....

Type of Test .... Rating .... Cat. Serial No. ....

Transfer Ratio: Current .... Potential .... Sec. K ....

Setting: Current .... Voltage .... Time Lever ....

Remarks: ....

Tested By: .... Assisted By: ....

APPENDIX G
FIGURE G-40

LUNF 107

Portable Electric Power Tool Test & Inspection Report

Location ______________ Department ______________ Section ______________

Type of Tool ______________ Date of Purchase ______________ Mfr. ______________ Serial No. ______________

Rated Voltage ________ AC _____ DC _____ AC/DC _____ Hertz ______________ Phase ______________

Date of Test	Tested By	Type of Test	Applied Potential	Resistance in OHMS	Comments

APPENDIX G
FIGURE G-41

LUNF 108

PUMPING PLANT HOUSEKEEPING CHECKLIST

Plant No.________ Reviewer's Initials ________ Date ________

1. Light Fixtures:

Type Fixtures: Incandescent Mercury Vapor (Circle type)

No. needing repair: ________ ________

Type bulb: Incandescent Mercury Vapor (Circle type)

No. of bulb not working: ________ ________

	Check One			
	OK/Yes	Not OK/No	Comments	Initial & Date Resolved
2. Cabinet condition				
Doors				
- condition				
- locked				
- locks working condition				
- handles				
- gasket (weatherstrip)				
- hinges				
- ID nameplate				
- interior doors				
3. Sunshade for cabinets				
4. Sunshade for flowmeter				
5. Bird nests removed				
6. Grease and oil spots removed				
7. Trash removed				
8. Air chamber				
- Sight glasses				
- Air release valves				
- Crawl space cleanliness				
9. Recirculation structure				
10. Moss screens				
- splash nozzles working				
- stationary screen				
- gates				
- grease and oil spots removed				
11. Plant ID sign				
12. Debris or trash in area				
13. Earth, gravel, washouts				
14. Fence, gates				
15. Transformer gauges				
16. Weeds in fenced area				
17. Floatwell & Inst. shelter at reservoirs, inlets & outlets				

APPENDIX G
FIGURE G-42

HEADWORKS AND PUMPING PLANTS INSPECTION CHECKLIST

I. FENCE

A. Horizontal and vertical alignment
B. Fence-grade clearance
C. Signs
D. Grounding connection
E. Electrical bond straps
F. Gates

II. EARTHWORK

A. Cracks, erosion, subsidence
B. Gravel, surfacing
C. Riprap
D. Weeds
E. Rodents

III. HEADWORKS OR PUMP STRUCTURE

A. Exposed concrete
   Cracks, scale, spall
B. Access wells, sumps, and covers
   1. Cracks, scale, spall
   2. Corrosion of ladders and metal
C. Recirculating stand
   Appearance and condition
D. Railings
   1. Grounding connections
   2. Safety
E. Grates
   Safety

IV. STEEL CANOPIES

A. Appearance and condition
B. Grounding connections

V. AIR CHAMBER

A. General appearance, exterior
B. Grounding connections
C. Condition, interior

VI. FLOATWELL AND INSTRUMENT SHELTER

General appearance and condition

VII. INLET STRUCTURE

A. Concrete
   Cracks, scale, spall
B. Ladder
   Safety
C. Railing
   Grounding connection
   Safety
D. Slide gate

VIII. OVERFLOW SPILLWAY AND OUTLET

A. Concrete
   Cracks, scale, spall
B. Grates
   Safety

IX. MOSS SCREENS AND MISCELLANEOUS METAL

General condition and appearance

LOCATION ______________ INSPECTED BY ______________ DATE ______________

COMMENTS ____

____

____

____

____

APPENDIX G
FIGURE G-43

PUMPING PLANT ELECTRICAL P.M. CHECK SHEET

P.P. No. ____________

Date: ____________

1.	H.V. disconnect cleaned and checked	Good	Fair	Poor
2.	Main busing cleaned and checked	Good	Fair	Poor
3.	MCC panels cleaned and checked	Good	Fair	Poor
4.	Starters cleaned and checked	Good	Fair	Poor
5.	Motors meggared and recorded			
	#1 ____________	Good	Fair	Poor
	#2 ____________	Good	Fair	Poor
	#3 ____________	Good	Fair	Poor
	#4 ____________	Good	Fair	Poor
	#5 ____________	Good	Fair	Poor
	#6 ____________	Good	Fair	Poor
	#7 ____________	Good	Fair	Poor
	#8 ____________	Good	Fair	Poor
SP	#1 ____________	Good	Fair	Poor
SP	#2 ____________	Good	Fair	Poor
SP	#3 ____________	Good	Fair	Poor
SP	#4 ____________	Good	Fair	Poor
A/C A-C	____________	Good	Fair	Poor

COMMENTS ____

____

____

____

____

____

Report by: ____________

APPENDIX G
FIGURE G-44

WEEKLY PM

Headworks or PP ____
Date ____
By ____

1. PUMPING UNITS
   A. Indicate any unit with an abnormal or significant change in sound. None
   Unit Pos. ____ WWD No. ____ Describe sound ____
   B. Clean all oil reservoir and tubing as needed.
   Completed Not needed
   C. Fill all oil reservoirs. Use Lubricant #01 Completed
   D. Adjust the oil feed on all operating units to a minimum of one drop every six (6) seconds. Completed
   E. Place hand as close as possible to top bearing of motors on operating units. If any units seem to have excessive or a significant change in vibration, obtain vibration values with the vibration meter and record on Vibration Data Sheet.
   All OK Data Recorded
   F. Indicate any units that have water leaking past the oil tube tension nut assembly. None
   Unit Pos. ____ No. ____ Defer repair for 2 weeks? Yes No
   G. Indicate any units that require a change of motor bearing oil (cloudy or foamy appearance). Drain oil and fill to "normal" mark if at ambient temperature, fill is slightly above "normal" mark if at operating tmperature.
   Use Lubricant #01.
   None Unit(s) required change and was changed.
   Unit(s) requiring oil change:
   Unit Pos. ____ No. ____
   H. Add or drain motor bearing oil as necessary. Should be at the "normal" mark if at ambient temperature or slighly above the "normal" mark at operating temperature. Use Lubricant #01 for makeup.
   Completed Not required
   I. Clean inlet and outlet screen on motors to provide clear airflow.
   Completed Not required
   J. Indicate any other pumping unit maintenance work that needs to be scheduled.
   ____

2. TRAVELING SCREENS AND BUBBLER SYSTEM
   A. Clean out splash housing (call for assistance if housing needs to be entered).
   Completed Not required
   B. Clean stationary screens. Completed Not required
   C. Adjust bubbler system air supply to differential controller to a minimum of 20 lb/in². Completed
   D. In the controller panel, the air supply shutoff valve is open, the selector switch is in the "Auto" position. Yes
   E. Open differential controller drain outlet valvea and blow out moisture and sediment. Completed
   F. Drain condensate from the air receiver. Completed
   G. Manually operate compressor safety valve. Completed
   H. Start screens automatically by adjusting the purgemeter needle valves to create a differential on the scales. After the screens start, readjust the valves to return both purgemeter floats to their original balanced positions. Completed
   I. Indicate number of only spray pump not developing a minimum of 90 lb/in² at the pump manifold. All OK ____
   J. Indicate number of screen unit on which the waterspray is not developing a full pattern on the screen. All OK ____
   K. Indicate number of screen unit whose basket seal plate lips exhibit scuffs or wear (bright metal spots). All OK ____
   L. Indicate number of screen unit whose drive chain is not riding smooth and true on the driver and driven sprockets. All OK ____
   M. Indiate number of screen unit whose drive chain exceeds an amount that would allow removal of one chain link. All OK ____
   N. Indicate number of screen unit whose screen chain is not riding smooth and true on the head sprocket. All OK ____
   O. Indicate number of screen unit whose head shaft bushings appear to exhibit excessive wear. All OK ____
   P. Lubricate head shaft and chain tightener bearings. Apply greese with a paddle or bush. Use Lubricat #05. Completed
   Q. Lubricate drive chain. Apply grease with a paddle or brush. Use Lubricant #5. Completed
   R. Indicate any screen unit maintenance work that needs to be scheduled and performed.
   ____

3. AIR CHAMBER AND COMPRESSOR
   A. Indicate any broken or dirty sight gauges that need to be scheduled for maintenance. All OK ____
   B. Manually operate compresssor safety valve. Completed
   C. Maintain proper oil level between indicated high and low marks on compessor gauge. Use Lubricant #04. OK
   D. The compressor switch is in the "auto" position. Yes
   E. The compressor discharge gate valve is in open position. Yes

4. GENERAL MAINTENANCE
   A. Indicate any corroded piping or plant piping leaks requiring scheduled reapir. None
   ____
   B. Indicate any erosion, fencing repairs, or rodent control requiring scheduling. None
   ____
   C. Remove all birds nests from pumping plant. Completed
   ____
   D. Indicate housekeeping, weed control, or any work requiring scheduling. None
   ____

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APPENDIX G
FIGURE G-45.

Delivery Site Maintenance Request

Water User ______________________ Delivery ______________________

a. Leak(s) in Discharge Pipe
1. Truck filling tee .... ☐
2. Valve on truck filling tee .... ☐
3. Flange downstream of meter or meter valve .... ☐
4. Air release valve .... ☐
5. Connection to surface pipe .... ☐

B. Ditch Bank
1. Too close to meter .... ☐
2. Eroding around delivery & creating a problem .... ☐

c. Agricultural Delivery
1. Delivery inaccessible .... ☐
2. Ground valve inaccessible .... ☐
3. Dirt on meter base .... ☐
4. Install pipe support .... ☐
5. Repair pipe support .... ☐
6. Remove, replace, or modify lever operated valve .... ☐

D. M & I Meters
1. Water in meter box .... ☐
2. Oil in meter box .... ☐
3. Meter box inaccessible .... ☐
4. Meter box covered with dirt .... ☐

E. Temporary Turnouts
1. Oil leak .... ☐
2. Water leak .... ☐
3. Water leak & eroding bank .... ☐
4. Electrical hazard .... ☐

F. Other ______________________

____

____

____

Operator ______________________ Date ______________

Water User Notified

Representative ______________________ Phone No. ______________

Comments ______________________

____

____

Operations Supervisor ______________________ Date ______________

Deficiency Corrected

Date ______________ Verified ______________________

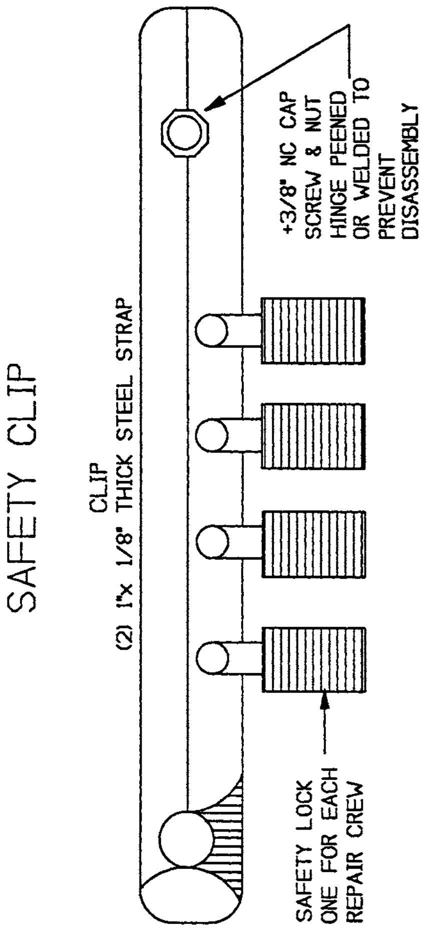
APPENDIX G
FIGURE G-46

APPENDIX G
FIGURE G-47

STATUS OF DO NOT OPERATE TAG

TAG HOLDER	DATE OUT	PERSON NOTIFIED	FACILITY AND/OR PUMPING PLANT	RETURN TO SERVICE		MALFUNCTION						
				DATE	INIT.	CONTROL VALVE UNIT #	VALVE LIMITORQUE UNIT #	CHECK VALVE UNIT #	MOTOR UNIT #	PUMP UNIT #	TAG RETURN DATE	OTHER

APPENDIX G
FIGURE G-48



APPENDIX G
FIGURE G-49

Maintenance Clearance Checklist
Lateral/Plant No. ___________

The following Maintenance Supervisors as indicated with a (√) have cleared this lateral for service on the date and time shown and have hereby notified Operations that all maintenance procedures within that Supervisor's department are completed, and that all maintenance personnel within that department are clear.

Dept.	Supervisor	Radio Call No.	√	Date	Time
3D	Bob Cooper	151	____	____	____
3E	Robert Bishop	44	____	____	____
3F	Quincy Nash	51	____	____	____
3K	Audie Trent	87	____	____	____
3L	Don Spaulding	74	____	____	____
____	________	____	____	____	____
____	________	____	____	____	____
____	________	____	____	____	____
____	________	____	____	____	____
____	________	____	____	____	____
____	________	____	____	____	____

APPENDIX G
FIGURE G-50

DAY OF USE
MAINTENANCE CHECK LIST
RO TRUCK MOUNTED CRANE

TRUCK NO. 392 MILEAGE: ______________ HOUR METER: ______________ DATE: ______________

	INSPECTION OK OR SERVICE PERFORMED	DEFICIENCY	DEFICIENCY CORRECTED	SUPERVISOR NOTIFIED
Radiator Coolant Level	☐	☐	☐	☐
Engine Oil Level	☐	☐	☐	☐
Lights & Warning Signals	☐	☐	☐	☐
Brake Operation	☐	☐	☐	☐
Hand Break Operation	☐	☐	☐	☐
Tire Inflation	☐	☐	☐	☐
Glass & Mirrors	☐	☐	☐	☐
Body Dents	☐	☐	☐	☐
Fire Extinguishers	☐	☐	☐	☐
CRANE MODEL NO. RO TC85-1 S/N 1120280029				
Hydraulic Oil Leaks	☐	☐	☐	☐
Exposed Hydraulic Hoses (Blistered, Frayed, Cut)	☐	☐	☐	☐
Hydraulic Oil Reservoir Level (All Cylinders Retracted)	☐	☐	☐	☐
LUBRICATE:				
Upper Sheave Pin	☐	☐	☐	☐
Lower Sheave Pin	☐	☐	☐	☐
Boom Topping Base Pin	☐	☐	☐	☐
Boom Topping Cylinder Pin	☐	☐	☐	☐
Turret Mounting Pin	☐	☐	☐	☐
Boom & Controls Operation for Normal Power, Response & Speed	☐	☐	☐	☐
Structure Members for Damage	☐	☐	☐	☐
Load Line for Kinks, Breaks, Damage	☐	☐	☐	☐
SAFETY DECALS				
OSHA Hand Signals: Mainframe	☐	☐	☐	☐
Caution Outrigger Clearance: Mainframe	☐	☐	☐	☐
Load Chart: Mainframe	☐	☐	☐	☐
Boom Radius-Angle Gauge: Boom	☐	☐	☐	☐
RO Decal: Boom	☐	☐	☐	☐

INSPECTION BY: ______________________________

COMMENTS: ____

____

____

APPENDIX H. LIST OF ITEMS TO BE DISCUSSED IN A "REVIEW OF OPERATIONS AND MAINTENANCE" REPORT FOR A WATER STORAGE FACILITY

Reference data (drawings and other pertinent information)
Structural performance data
Previous examinations including underwater/unwatered examinations
Date of examination and names of examining party
Facilities examined

- Dam
- Spillway
- Outlet works
- Other

Operations

- Standing operating procedure
- Communications
- Logbook
- Access
- Landslide
- Dam tender's training

Status of previous recommendations
New recommendations

Signatures

- Examiners
- Supervisors

Photographs to illustrate status and findings

Operations

Attendance at dam ______________
Dam operator's training ______________
Residence ______________

Standing Operating Procedures and Designers' Operating Criteria

	SOP	DOC
Issue and revision dates	______	______
Is copy at dam current?	______	______
Does SOP meet current guidelines?	______	______
Are SOP supporting documents available?	______	______
Are instructions adequate?	______	______
Are instructions understood?	______	______
Any changes needed?	______	______

Operating Log

Maintained at dam? ______________

Certification of SOP review and dam operator's training (dated and signed by dam operator and supervisor) ______________

All RO&M team members sign and date ______________

Team leader verify (sign and date) ______________

1. Current SOP is on hand and revisions inserted. ______________

2. Operating log signed and dated by dam operator and supervisor verifying SOP certification requirements. ______________

3. All operating procedures observed during review were in accordance with SOP. ______________

4. All SOP supporting documents available. ______________

5. Recommendation to correct deficiency in any of the above items will be made. ______________

Communications

- Type ______
  - Normal ______
  - Standby ______
- Adequacy ______

Auxiliary Power

- Test during examination ______
- Condition ______
- Adequacy ______

Access Roads

- Adequacy under adverse conditions ______

Oil Containment

- Spill Prevention Control and Countermeasure (SPCC) Plan ______

Landslides

- Restricted ______
- Signs ______

Concrete Dam

- Upstream face ______
- Downstream face ______
- Crest ______
  - Roadway ______
  - Walks ______
  - Parapet wall ______
  - Lighting, etc. ______
- Galleries ______
  - Concrete ______
  - Metalwork ______
  - Electrical ______
  - Ventilation ______
  - Drains and drainage ______
- Elevator shaft ______
  - Metalwork ______
  - Equipment ______
  - Safety inspection ______
- Abutments ______
- Foundation at downstream toe of dam ______
- Leakage around dam ______
  - Location ______
  - Amount ______
  - Measurement methods ______
- Performance instruments and devices ______
  - Uplift measurements ______
  - Drain flow ______
  - Other ______

______

______

______

Embankment Dam

- Upstream face
  - Riprap ______
  - Erosion–Beaching ______
  - Vegetative growth ______
  - Settlement ______
  - Debris ______
- Downstream face
  - Rock ______
  - Vegetative growth ______
- Crest
  - Roadway ______
  - Guardrails ______
  - Curb ______
  - Parapet wall ______
  - Settlement ______
  - Lighting ______
- Abutments ______
- Seepage and drainage
  - Location ______
  - Toe drain ______
- Measurement
  - Method ______
  - Amount ______
  - Change in flow ______
  - Records ______
- Performance instruments
  - Surface settlement points ______
  - Piezometer well ______
  - Readings ______
- Other ______

Diversion Dam

- Concrete ______
- Ogee weir ______
- Riprap ______
- Abutment walls ______
- Wingwalls ______
- Embankments ______
- Foundation at downstream toe of dam ______
- Fish ladders ______
- Leakage ______
- Embankments ______
  - Upstream ______
    - Vegetation ______
    - Riprap ______
  - Downstream ______
    - Vegetation ______
    - Rock ______

Diversion Dam – Continued

- Crest
- Canal headworks
  - Concrete
  - Gates
    - Coatings
    - Hoists
    - Operation
    - Leakage
  - Fish facilities
  - Guardrails
  - Outlet channel
  - Control structures
  - Sluiceway
    - Concrete
    - Radial gate
      - Coatings
      - Hoists and cables
      - Operation
      - Leakage
      - Handrails
      - Approach channel
      - Outlet channel
    - Gates
      - Condition
      - Hoists
      - Cables
    - Standby power
    - Other

Spillway

- Approach channel
  - Channel
  - Log boom
- Control structures
  - Crest
  - Walls
  - Apron
- Chute
  - Walls
  - Floor
  - Drains
- Stilling basin
  - Walls
  - Floor
- Outlet channel
  - Riprap
  - Erosion
  - Vegetation

Spillway - Continued

- Structural
  - Hoist deck ______
  - Bridge ______
- Gates
  - Mechanical features
    - Hoists ______
    - Cables ______
    - Gates ______
    - Protective coatings ______
- Electrical features
  - Power supply ______
  - Standby power ______
- Posted operating instructions ______ ______
- Exercising frequency ______ ______
- Automatic controls ______ ______
- Ice prevention system ______ ______
- Other ______ ______ ______

Outlet Works

- Inlet structure ______
  - Trashracks ______
  - Concrete ______
  - Gate chamber ______
  - Gates
    - Operation at time of examination ______
    - Exercising frequency ______
    - Mechanical ______
    - Electrical ______
    - Protective coatings ______
    - Posted operating instructions ______
  - Ventilation ______
  - Seepage ______
  - Concrete ______
  - Access shaft
    - Elevator ______
    - Concrete ______
    - Metalwork ______
  - Outlet conduit
    - Metalwork ______
    - Protective coatings ______
    - Concrete ______
    - Cavitation ______

Outlet Works - Continued

- Control facilities
  - Control house ____
    - Structural condition ____
      - Roof ____
      - Walls ____
    - Housekeeping ____
    - Metalwork ____
    - Protective coatings ____
    - Gates
      - Operation at time of examination ____
      - Exercising frequency ____
      - Mechanical ____
      - Electrical ____
      - Protective coatings ____
      - Posted operating instructions ____
- Chute ____
  - Floor ____
  - Walls ____
  - Drains ____
- Stilling basin ____
- Outlet channel ____
  - Vegetation ____
  - Gravel bars, etc. ____

____

____

Powerplant or Pumping Facilities

- Structural features ____
  - Building ____
    - Roof ____
    - Decks ____
    - Parapets ____
    - Walls ____
  - Substructure ____
  - Superstructure ____
- Forebay conditions ____
- Afterbay conditions ____

Major Pumping Facilities

- Structural features
  - Building (wood, concrete, metal construction) ____
    - Walls ____
    - Roof ____
    - Decks ____
    - Drainage ____
    - Crane ____
    - Doors, windows ____
    - Ventilation ____
    - Lighting ____
    - Safety ____

Major Pumping Facilities - Continued

- Forebay conditions
  - Inlet channel ____________
  - Concrete ____________
  - Riprap ____________
  - Debris or silt bars ____________
  - Trashracks ____________
  - Stoplogs and grooves ____________
  - Sump conditions ____________
  - Other metalwork ____________
- Pumping units
  - Maintenance procedures ____________
  - Vibration ____________
  - Cavitation ____________
  - Lubrication ____________
  - Bearing temperatures ____________
  - Packing box leakage ____________
  - Unit mounting and foundation ____________
  - Low water cutoff system ____________
  - Pump priming system ____________
  - Other operating difficulties ____________
- Discharge valves (manual, motor, or hydraulic-operated) ____________
  - Operation ____________
  - Vibration ____________
  - Maintenance procedures ____________
  - Lubrication ____________
  - Paint deterioration ____________
  - Unit mounting and foundation ____________
- Electrical control equipment
  - Housekeeping (clean and dry) ____________
  - Protective coatings ____________
  - Maintenance procedures ____________
  - Other operating difficulties ____________
- Afterbay conditions
  - Discharge piping ____________
    - Interior ____________
    - Exterior ____________
  - Anchor blocks ____________
  - Discharge boxes ____________
  - Flap valves ____________
  - Other metalwork ____________

Canal

- Underdrains ____________
- Subsidence ____________
- Seepage ____________
- Linings
  - Constructed joints ____________
  - Random cracking ____________
  - Joint sealers ____________
  - Silting ____________

<u>Canal-Continued</u>

- Inlet structure and checks
  - Structural features
  - Radial gates
    - Hoists
    - Cables
    - Electrical features
    - Protective coatings
    - Controls
- Turnouts
  - Gates
  - Structure
- Bridges
  - Deck
  - Railings
  - Structural features
- Operating roads
- Vegetation
- Safety features

<u>Pipelines</u>

- Structures
  - Ventilation
  - Seepage
  - Drains
  - Lighting
  - Settlement
- Chlorination stations
  - Ventilation
  - Security
  - Safety Equipment
- Alignment (below-ground pipe)
  - Surface water
  - Deeprooted vegetation
  - Subsidence
  - Surface erosion
  - Encroachment onto row
- Cathodic protection
  - System provided/need
  - Performance
  - Monitoring
- Valves air release/flow control/blowoff
  - Operability
  - Exercising
  - Corrosion/coating
  - Protection from freezing (insulation)
- Pipe
  - Lining (dewatered)
  - Corrosion/protective coating
  - Joints/couplings
  - Surface deposits
  - Cracks/separations

Bridge

Name ______________________ Group __________

Type I. Intermediate Inspection

This inspection should *not* be considered as an inspection in depth. The purpose of the Type I inspection is primarily to ensure the safety of the bridge user. This entire inspection should be properly documented. This inspection can be limited to:

Bridge supports
- Foundations ______________
- Substructures-Piers ______________
- Bridge bearings ______________
- Moving parts ______________
- Accumulation of bird nests, etc. ______________
- Visual inspection of scour protection ______________
- Protective coatings ______________

Main supporting members
- Deteriorated and/or damaged members ______________
  ____
- Live load capacity ______________

Bridge deck
- Potholes ______________
- Deterioration ______________
- Unusual roughness ______________
- Drainage ______________
- Expansion joints ______________
- Guardrails ______________
- Signing ______________

General conditions ______________

Vegetation at abutments and piers ______________

APPENDIX I. CONVERSION TABLE

International System (SI Metric)/U.S. Customary Conversion Tables

Length

To convert from (1)	To (2)	Multiply by (3)
millimeters	micrometers	1.0×10^{3}
	centimeters	0.1
	meters	1.0×10^{-3}
	mils	39.3701
	inches	0.0394
	feet (ft)	3.2808×10^{-3}
centimeters	millimeters	10.0
	meters	0.01
	mils	0.3937×10^{3}
	inches	0.3937
	feet	0.0328
inches	millimeters	25.40
	meters	0.0254
	mils	1.0×10^{3}
	feet	0.0833
feet	millimeters	304.8
	meters	0.3048
	inches	12.0
	yards (yd)	0.3333
yards	meters	0.9144
	inches	36.0
	feet	3.0
meters	millimeters	1.0×10^{3}
	kilometers (km)	1.0×10^{-3}
	inches	39.3701
	yards	1.0936
	miles(mi)	6.2137×10^{-4}
kilometers	meters	1.0×10^{3}
	feet	3.28018×10^{3}
	miles	0.6214

International System (SI Metric)/U.S. Customary Conversion Tables—(Continued)

To convert from (1)	Length To (2)	Multiply by (3)
miles	meters	1.6093×10^{3}
	kilometers	1.6093
	feet	5280.0
	yards	1760.0
nautical miles (nmi)	kilometers	1.8520
	miles	1.1508

To convert from (1)	Area To (2)	Multiply by (3)
square millimeters	square centimeters (cm^2)	0.01
	square inches (in^2)	1.550×10^{-3}
square centimeters	square millimeters (mm^2)	100.0
	square meters (m^2)	1.0×10^{-4}
	square inches	0.1550
	square feet (ft^2)	1.0764×10^{-3}
square inches	square millimeters	645.16
	square centimeters	6.4516
	square meters	6.4516×10^{-4}
	square feet	69.444×10^{-4}
square feet	square meters	0.0929
	hectares (ha)	9.2903×10^{-6}
	square inches	144.0
	acres	2.2957×10^{-5}
square yards	square meters	0.836 13
	hectares	8.3613×10^{-5}
	square feet	9.0
	acres	$2.066\ 12\times10^{-4}$
square meters	hectares	1.0×10^{-4}
	square feet	10.7639
	acres	2.471×10^{-4}
	square yards (yd^2)	1.19560
acres	square meters	4046.8564
	hectares	0.4047
	square feet	4.356×10^{4}

International System (SI Metric)/U.S. Customary Conversion Tables—(Continued)

To convert from (1)	Area To (Cont'd) (2)	Multiply by (3)
hectares	square meters	1.0×10^4
	acres	2.471
square kilometers	square meters	1.0×10^6
	hectares	100.0
	square feet	107.6391×10^5
	acres	247.105 38
	square miles (mi^2)	0.3861
square miles	square meters	258.9988×10^4
	hectares	258.9988
	square kilometers (km^2)	2.5900
	square feet	2.7878×10^7
	acres	640.0

To convert from (1)	Volume—Capacity To (2)	Multiply by (3)
cubic millimeters	cubic centimeters (cm^3)	1.0×10^{-3}
	liters (l)	1.0×10^{-6}
	cubic inches (in^3)	61.0237×10^{-6}
cubic centimeters	liters	1.0×10^{-3}
	milliliters (ml)	1.0
	cubic inches	61.0237×10^{-3}
	fluid ounces (fl oz)	33.814×10^{-3}
milliliters	liters	1.0×10^{-3}
	cubic centimeters	1.0
cubic inches	milliliters	16.3871
	cubic ft (ft^3)	57.8704×10^{-5}
liters	cubic meters	1.0×10^{-3}
	cubic feet	0.0353
	gallons	0.2642
	fluid ounces	33.814
gallons	liters	3.7854
	cubic meters	3.7854×10^{-3}
	fluid ounces	128.0
	cubic feet	0.133 68

International System (SI Metric)/U.S. Customary Conversion Tables—(Continued)

To convert from (1)	Volume—Capacity To (Cont'd) (2)	Multiply by (3)
cubic feet	liters	28.3168
	cubic meters (m^3)	28.3168×10^{-3}
	cubic dekameters (dam^3)	28.3168×10^{-6}
	cubic inches	1728.0
	cubic yards (yd^3)	37.0370×10^{-3}
	gallons (gal)	7.4805
	acre-feet (acre-ft)	22.9568×10^{-6}
cubic miles	cubic dekameters	4.1682×10^{6}
	cubic kilometers (km^3)	4.1682
	acre-feet	3.3792×10^{6}
cubic yards	cubic meters	0.7645
	cubic feet	27.0
cubic meters	liters	1.0×10^{3}
	cubic dekameters	1.0×10^{-3}
	gallons	264.1721
	cubic feet	35.3147
	cubic yards	1.3079
	acre-feet	8.107×10^{-4}
acre-feet	cubic meters	1233.482
	cubic dekameters	1.2335
	cubic feet	43.560×10^{3}
	gallons	325.8514×10^{3}
cubic dekameters	cubic meters	1.0×10^{3}
	cubic feet	35.3147×10^{3}
	acre-feet	0.8107
	gallons	26.4172×10^{4}
cubic kilometers	cubic dekameters	1.0×10^{6}
	acre-feet	0.8107×10^{6}
	cubic miles(mi^3)	0.2399

To convert from (1)	Acceleration To (2)	Multiply by (3)
feet per second squared	meters per second squared (m/s^2)	0.3048
	G's	0.0311

International System (SI Metric)/U.S. Customary Conversion Tables—(Continued)

To convert from (1)	Acceleration To (Cont'd) (2)	Multiply by (3)
meters per second squared	feet per second squared (ft/s^2)	3.2801
	G's	0.1020
G's (standard gravitational acceleration)	meters per second squared	9.8066
	feet per second squared	32.1740

To convert from (1)	Velocity To (2)	Multiply by (3)
feet per second	meters per second (m/s)	0.3048
	kilometers per hour (km/h)	1.0973
	miles per hour (mi/h)	0.6818
meters per second	kilometers per hour	3.60
	feet per second (ft/s)	3.2808
	miles per hour	2.2369
kilometers per hour	meters per second	0.2778
	feet per second	0.9113
	miles per hour	0.6215
miles per hour	kilometers per hour	1.6093
	meters per second	0.4470
	feet per second	1.4667
feet per year (ft/yr)	millimeters per second (mm/s)	9.665 14×10^{-6}

To convert from (1)	Force To (2)	Multiply by (3)
pounds	newtons (N)	4.4482
kilograms	newtons	9.8066
	pounds (lb)	2.2046
newtons	pounds	0.2248
dynes	newtons	1.0×10^{-5}

International System (SI Metric)/U.S. Customary Conversion Tables—(Continued)

To convert from (1)	Mass To (2)	Multiply by (3)
grams	kilograms (kg)	1.0×10^{-3}
	ounces (avdp)	0.0353
ounces (avdp)	grams (g)	28.3495
	kilograms	0.0283
	pounds (avdp)	0.0625
pounds (avdp)	kilograms	0.4536
	ounces (avdp)	16.00
kilograms	kilograms (force)—second squared per meter ($kgf.s^2/m$)	0.1020
	pounds (avdp)	2.2046
	slugs	0.0685
slugs	kilograms	14.5939
short tons	kilograms	907.1847
	metric tons (t)	0.9072
	pounds (avdp)	2000.0
metric tons (tonne or mega-gram)	kilograms	1.0×10^{3}
	pounds (avdp)	2.2046×10^{3}
	short tons	1.1023
long tons	kilograms	1016.047
	metric tons	1.0160
	pounds (avdp)	2240.0
	short tons	1.120

To convert from (1)	Volume per unit time flow To (2)	Multiply by (3)
Cubic feet per second	liters per second (l/s)	28.3168
	cubic meters per second (m^3/s)	0.0283
	cubic dekameters per day (dam^3/d)	2.4466
	gallons per minute (gal/min)	448.8312
	acre-feet per day (acre-ft/d)	1.9835

International System (SI Metric)/U.S. Customary Conversion Tables—(Continued)

To convert from (1)	Volume per unit time flow To (Con't) (2)	Multiply by (3)
	cubic feet per minute (ft^3/min)	60.0
gallons per minute	cubic meters per second	0.631×10^{-4}
	liters per second	0.0631
	cubic dekameters per day	5.451×10^{-3}
	cubic feet per second (ft^3/s)	2.228×10^{-3}
	acre-feet per day	4.4192×10^{-3}
acre-feet per day	cubic meters per second	0.0143
	cubic dekameters per day	1.2335
	cubic feet per second	0.5042
cubic dekameters per day	cubic meters per second	0.0116
	cubic feet per second	0.4087
	acre-feet per day	0.8107

Temperature

degrees Celsius (°C)	t_c
kelvin (K)	t_k
degrees Fahrenheit (°F)	t_f
degrees rankine (R)	t_r

$$t_c = (t_f - 32)/1.8 = t_k - 273.15$$

$$t_k = t_c + 273.15 = (t_f + 459.67)/1.8 = t_r/1.8$$

$$t_f = t_c/1.8 + 32$$

$$t_r = 1.k\ t_k = 1.8\ t_c + 491.68$$

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