Chapter 8 Project and Farm Irrigation Water Requirements

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652.0800 General

The previous chapters of this Guide focused on individual fields where the water supply and other conditions do not limit operation of on-farm irrigation systems. Where water for multiple farms is supplied by an offsite group, a water distribution system and schedule for the irrigated area must be developed. It is desirable to have an adequate source of water available and supplied to each irrigated parcel in a timely manner for the crops selected. Various methods have been employed to accomplish this distribution. Crop irrigation water requirements and water supply are primary considerations.

Experience in planning, design, operation, and management of existing projects is desirable. When formulating a project, a thorough multidisciplinary evaluation is needed to obtain the most technically appropriate, economical, and environmentally sound solution. The project must be manageable and reasonable to operate and maintain. It must also be socially acceptable and meet today's standards.

This chapter provides concepts that illustrate the use of irrigation water requirement principles when planning and designing irrigation projects. This is not a design guide for irrigation delivery systems. Refer to other appropriate guidelines for more information on project design. The Natural Resources Conservation Service (NRCS) reference *Economic and Environmental Principles and Guidelines for Water Related Land Resource Implementation Studies* provides detailed guidelines for documentation. Section 652.0808 describes in detail a planning outline that will assist planning staffs with irrigation project planning. The intensity of investigations required varies with the level of planning, scope, and significance of the project. Generally, preliminary planning is less intensive than planning for investigation and evaluation of the selected alternative. Many computer programs are available to perform various parts of project evaluation. Their use is encouraged.

An irrigation project is defined as blocks of irrigated land within a defined boundary, developed or administered by a group or agency. Water is delivered from a source to individual turnouts via a system of canals, laterals, or pipelines. The irrigated block generally involves many farms that can have multiple fields per farm. Irrigation water requirements used for designing, managing, or upgrading irrigation projects are similar to an on-farm analysis. With projects, the analysis is expanded to include all landowners, cropland area, crops, and irrigation systems. General examples are provided to illustrate the procedure. Irrigation projects should distribute the available water supply to irrigators in an equitable and dependable manner. The irrigator should be aware of flow rates and frequencies of available water in their own terms. In some areas, a visual understanding is as important to the water user as is an actual flow in gallons per minute (gpm), cubic feet per second (ft^3/s), miners inches, or local measurement terms.

Project irrigation water requirement analysis include:

- Determining irrigable lands and project impacts on natural resources.
- Determining water availability.
- Determining crop irrigation water requirements.
- Determining on-farm irrigation water requirements.

Determining irrigable lands and project impacts on soil, water, air, plants, animals, and local people (SWAPA+H)—A field analysis should be made to determine suitability of irrigable lands. Basic are a quality soil survey and 1- to 5-foot contour topographic maps. To support estimates for soils interpretations, irrigation related field and laboratory tests may be needed. The information can include bulk densities to help determine available water capacity, field tests to determine soil intake characteristics, specific ranges in salinity levels, and types and concentration of toxic elements. Other considerations include internal drainage capability, water table existence and depth, soil erodibility, farmability, and onsite and offsite environmental concerns (wildlife, water quality, air quality).

Determining water availability—This includes the source, quantity, timeliness, location, quality, and water right availability.

Determining crop irrigation water requirements —Composite or weighted crop ET values are developed for on-farm seasonal and peak use periods. These values are then compiled and weighted to represent the entire project area. Percent of area of each crop is determined. Effective precipitation and ground water contribution during the growing season is accounted for as a reduction of required seasonal crop ET and net irrigation requirement (NIR). An analysis should provide a project wide seasonal and peak *net irrigation water requirement.*

Determining on-farm irrigation water requirements—Overall farm irrigation efficiencies of all water beneficially used on the farm are combined to determine project gross water delivery requirements. Irrigation efficiencies for single irrigation events as well as full season must be recognized. Project water requirements are typically based on full season irrigation efficiencies. Application of irrigation water includes some unavoidable losses. Because of the many factors associated with irrigation systems, management, and climate, applying irrigation water at 100 percent efficiency is currently unachievable. Beneficial uses of water can include:

- providing for crop ET,
- reasonable losses resulting from application and distribution inefficiency,
- leaching of excess salts, and
- climate control for crops (i.e., frost protection, slowing of bud development, slowing of ripening process, seed germination, crop cooling, plus others).

652.0801 Project objectives

Project wide benefits, impacts, and objectives are considered in the project irrigation water requirement analysis. Sponsors (landowners) must have a net economic benefit from irrigated cropland to continue farming. The group, district, or company that delivers the irrigation water must deliver water at a reasonable unit price to the user, but still cover short- and long-term costs. Economic analysis procedures for project development and operations are not described in detail in this chapter. Typically, it is a very complex process using project specific criteria. See chapter 11 for economic evaluations for on-farm irrigation systems. Issues of economics and flexibility must ultimately be considered in irrigation project development and operation. Ultimate size of project is generally limited by available water supply, soils, topography, purpose of applying water, and economics.

Irrigation projects provide and affect far-reaching social, economic, and environmental impacts to surrounding communities as well as to the region. Some benefits of an irrigation project are:

- Value of cropland is increased.
- Crop diversity is allowed.
- Additional labor is required for on-farm crop production.
- Additional businesses are needed to support irrigation and farming equipment.
- Additional processing and transportation facilities for agricultural products are necessary.
- Many other less tangible values change including aesthetics and community economic stability.

Water development facilities, such as reservoirs, open canals, laterals, and farm ponds, draw many and varied wildlife. Consideration should be given to habitat requirements associated with specific wildlife; i.e., canal and ditchbank vegetation as well as odd shaped areas.

Without consideration and careful planning, irrigation project activities can negatively impact water quantity and quality, wetlands, fisheries, and wildlife. Certain pesticides and other toxic elements found in some irrigation drainage and tailwater (runoff) can negatively impact certain waterfowl and fish. Tailwater collection and reuse facilities should be considered. However, with proper and careful planning, negative impacts can be mitigated with establishment or enhancement of areas specifically for wildlife, augmentation of water supplies, and establishing and maintaining public recreation facilities.

The planning process requires assessment of the impacts, and Resource Management System (RMS) planning requires quality criteria be established and met for all resources. In most cases, if the correct assessments are done and proper alternatives chosen, mitigation is not necessary because adverse impacts are collectively avoided with established quality criteria.

652.0802 Requirements

(a) System capacity requirements

Determining required distribution system capacities is generally the most difficult process in computing irrigation supply needs. Irrigation systems should supply enough water over prolonged periods to satisfy the difference between crop evapotranspiration (ET) demand, rainfall, and ground water contribution. The most conservative method of designing system capacity requirements is to provide enough capacity to meet maximum expected or *peak* crop ET rates. With projects, this is generally done on a monthly basis. For high value crops, meeting weekly *peak* crop ET may be necessary where a very high level of water management can be provided.

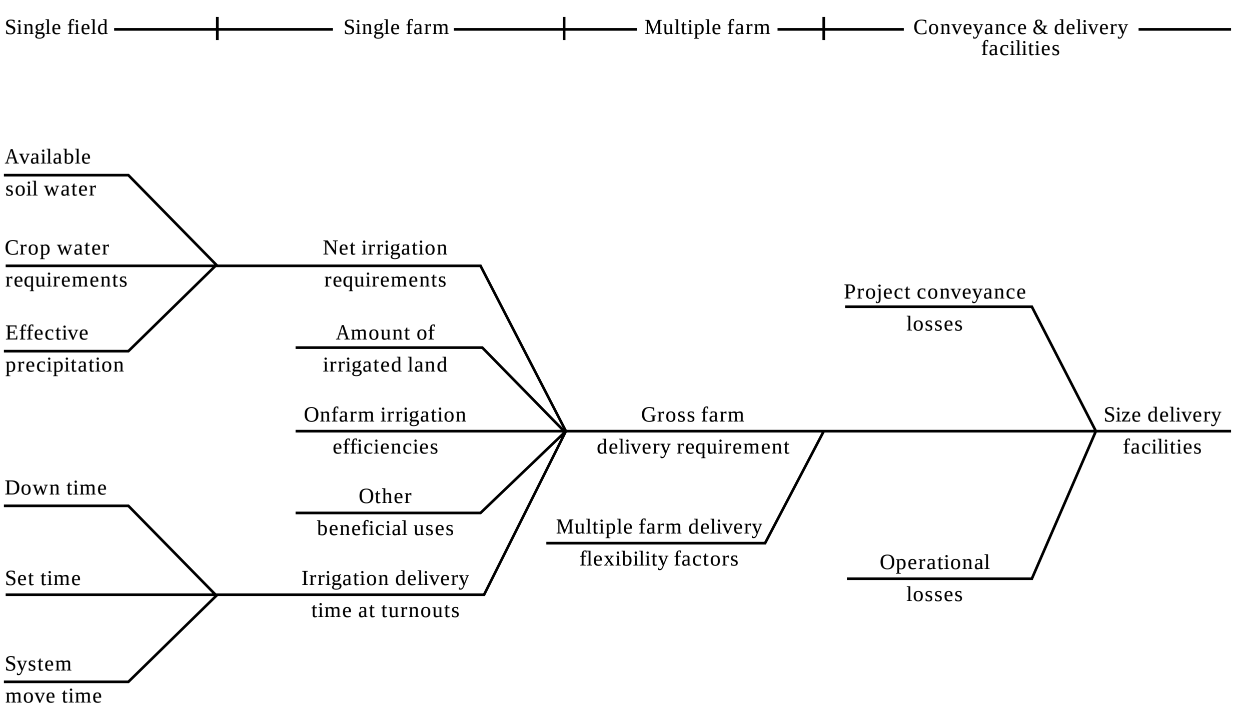
A frequency distribution analysis of mean daily crop ET (daily crop ET vs. frequency, by some time period) can display risks involved in providing something less than meeting peak crop ET 100 percent of the time. Using an example crop in California:

> Supplying water for a 95 percent probability (19 of 20 years) requires system capacity to meet a mean daily crop ET = .23 inches per day. By reducing system capacity to meet a mean daily crop ET = .20 inches per day, an 85 percent probability (17 of 20 years) can be met. The reduction in system capacity may be economically justified.

In areas where rainfall provides a substantial portion of crop water needs, a frequency analysis of precipitation should be performed. See additional information in National Engineering Handbook (NEH), Part 623, Chapter 2, Irrigation Water Requirements, pp 2–187 to 2–226.

Figure 8–1 displays the general procedure used by the Bureau of Reclamation to size delivery systems for projects. The flexibility factor displayed accounts for the type and management of the delivery system. The factor is the ratio of the actual delivery compared to the minimum continuous delivery requirement. A flexibility factor greater than 1.0 provides excess capacity so that individual irrigators can better manage their water; i.e., irrigation scheduling program and improved uniformity of application because of the opportunity to use larger heads of water with surface irrigation. Either upstream or downstream water surface control in canals and main laterals can be used to assist delivery system automation. With open conveyance systems, it has been shown that controlling the water surface elevation upstream of the farm delivery measuring device and headgate contributes greatly to accurate water deliveries. Accurate farm deliveries benefit both the irrigator and the delivery organization.

Figure 8–1 Processes involved in determining project irrigation water requirements and sizing facilities



(b) Alternative delivery schedules

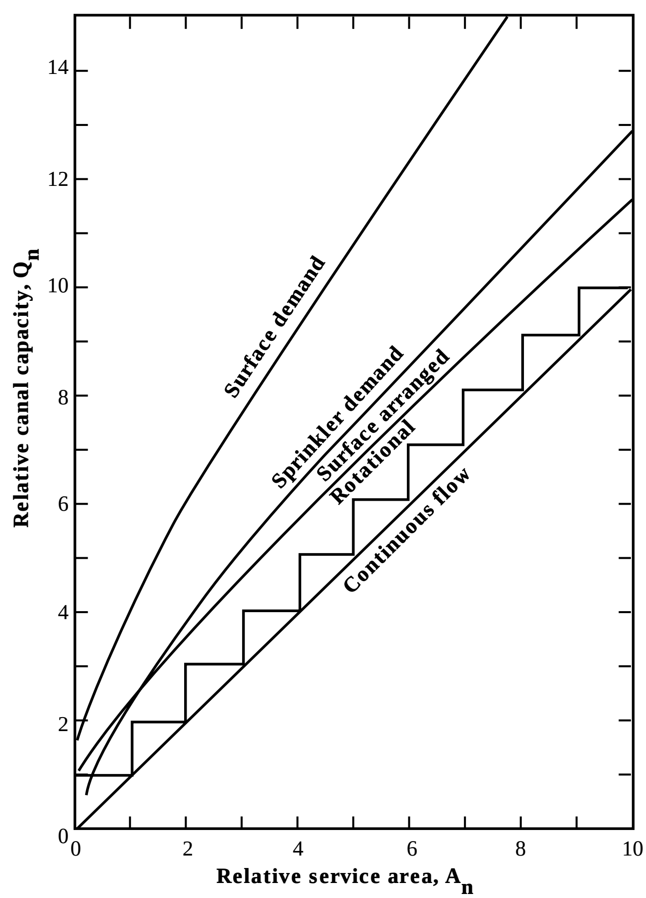
Alternative delivery schedules should be evaluated for sizing main canals and pipelines. A slight increase in capacity can provide much improved delivery flexibility and scheduling and be quite reasonable in cost. With new installations, increased pipeline and canal capacities often can be built with minimal increase in cost.

To develop and maintain good irrigation scheduling programs, an arranged or demand type delivery schedule is necessary. Continuous and rotational type delivery schedules limit on-farm irrigation scheduling. Relative canal capacity versus relative service area for different water delivery schedules and irrigation systems is displayed in figure 8–2 (Albert J. Clemmens, ASCE, I and D Division Proceedings, 1987). Note in table 8–1, the increase in canal capacity from a rotational delivery system to an arranged delivery system would be about 16 percent. This can represent only a few inches of water depth in a canal at little increased cost. Often with new installations, increased pipeline and canal capacity can be built with minimal increase in cost. With larger capacity pipelines, there may be no increase in cost because standard pipeline diameters are readily availability and used.

Table 8–1 Example of relative canal capacities with different water schedules, for greater than 5 deliveries per lateral

Delivery schedule	Normal area of irrigation delivery 40 acres	80 acres
	gpm	gpm
Continuous flow (at 10 gpm per acre)	400	800
Rotational	500	900
Arranged—surface (basins)	580	950
Demand—sprinkler	700	1,080
Demand—surface	950	1,500

Figure 8–2 Relationship between relative service area and relative canal capacity for different irrigation schedules for greater than 5 deliveries per lateral (demand and arranged schedules at 90% performance level; An = normal area of irrigation per delivery, Qn = normal or guaranteed minimum delivery rate)



(c) On-farm irrigation water requirement

Chapter 4 and NEH, Part 623, Chapter 2, Irrigation Water Requirements describe methodology for determination of crop ET and crop water requirements. A computer spreadsheet is a good tool to evaluate and summarize all parameters for a desired period. Typical crop rotations are used to develop multicrop water requirements. The evaluation is usually done monthly to provide a basis for monthly storage or diversion and delivery needs. Parameters and steps used for a typical on-farm analysis include:

- Crop evapotranspiration (ET_c)—Determine a weighted crop ET including all crops grown. This should be based on various climatic areas in the project if the differences are sufficient. Often small valleys adjoining larger valleys have different microclimates.
- Effective precipitation (P_e)—Determine weighted effective precipitation for each climatic area.
- Ground water contribution—Determine weighted contribution to plant growth by the water table.
- Net Irrigation Water Requirement (IR)—Determine weighted net irrigation water requirements for all crops grown. Water needed and used for climate and salinity control (auxiliary water) must be included. The formula below is used to calculate the net irrigation water requirement.
- Application efficiencies—Estimate typical overall on-farm efficiencies based on method and system of water application and management. Other factors include typical soil intake characteristics and available water capacity (AWC), typical field size, shape and slopes, net applications, and climatic factors. Water losses to deep percolation and runoff must be estimated. In some project areas, all or part of this water can be available to downslope water users. Seasonal irrigation efficiencies must be established and used rather than single event application efficiencies. It may be advantageous to use realistic estimated monthly irrigation efficiency values rather than one value for the entire season. Typically irrigation efficiencies are lower during spring and fall when less water is required by crops.
- Gross irrigation requirement—Determine weighted gross irrigation water requirements for all crops grown in the project area, by irrigation method and system. Net application per irrigation is a major factor in application efficiencies especially for surface irrigation. The formula to determine gross irrigation requirement is shown below.

Net Irrigation Water Requirement:

$$\text{Net IR} = ET_c - P_e - \text{Ground water contribution} + \text{Auxiliary water needs}$$

Gross Irrigation Requirement:

$$\text{Gross Irrigation Requirement} = \frac{\text{Net irrigation water requirement}}{\text{Seasonal irrigation efficiency}}$$

(d) Project irrigation water requirements

The on-farm water requirement data must now be expanded project wide. If the on-farm typical weighted irrigation water requirement represents the entire project area, then all laterals and canals are sized accordingly, with the irrigated area controlling. Often, specific crops are grown in specific climate, soils, or geographic areas in the project, even to the extent that a single irrigation method and system may be used. For example, micro irrigation systems are well adapted to providing irrigation water to vineyards or orchards on rocky hillsides. Typical gross irrigation water requirements must then be established for those specific areas. Parameters for expanding on-farm data to project wide use include:

- Water requirement—Water delivery requirements need to be established using a planned water delivery schedule and applying management flexibility factors. Flow requirements by lateral or canal are established, based on weighted gross irrigation water requirement on a per acre basis.
- When sizing public water distribution laterals, remember peak water use for a specific crop can affect only one, two, or portions of several laterals. Averaging peak consumption across the entire area may not be realistic.
- Project efficiencies—Project water conveyance and control facility losses must be analyzed when determining delivery capacities. These losses can be as high as 50 percent or more in long, unlined, open channels in alluvial soils.
- In some existing water districts or companies, flow through or "management" water constitutes over 30 percent of the canal capacity. Flow through water is either returned to natural water courses as operational spills or added to downstream water deliveries. With today's technology, simple automatic gate/valve control devices can limit flow through water to less than 5 percent.
- Tailwater redistribution—Collection of field runoff from surface irrigation systems can be redistributed to meet lower elevation project water requirements, if allowed by state law. Quality of runoff is typically less than that diverted at the source. Irrigation tailwater may contain nutrients, pesticides, and, when surface irrigating, highly erosive soils and sediment. Reuse of runoff water should be strongly considered rather than allowing the flow to enter public water. By reusing runoff water either on the farm where it originated or on farms (fields) at a lower elevation, overall water use efficiency can be improved and diversion flow, pumpage, or storage reduced. (For more information, see chapter 7). Tailwater collection, redistribution, and proper irrigation water management need to be part of a resource plan that meets FOTG quality criteria for all resources.

652.0803 Project conveyance, distribution, and delivery facilities

Typically, delivery canals and laterals are located to provide complete control of water delivery to users. Main canals are generally installed on relatively flat grades for ease of control, to reduce water control structures, and to maximize the area irrigated using gravity flow delivery. However, pumping can be economical for delivery of water to areas at higher elevation.

Sufficient elevation drop along a distribution canal or lateral often allows replacement of the open channel with a pressurized irrigation pipeline. Benefits as well as negative impacts must be assessed as part of the planning process. In some areas, sufficient elevation drop can be available to deliver pressurized water to operate low to moderate pressure sprinkler heads and for low pressure micro systems. Local wildlife can suffer when all existing open canals, laterals, and farm ditches are replaced with buried conduits. Mitigation of lost wet areas because of lining or installing conduits should be considered. An environment assessment (EA) or environmental impact statement (EIS) may be needed to adequately assess potential impacts. National Environmental Protection Act (NEPA) policies and regulations may apply for project analysis where potential effects on the environment can occur and federal funding is involved.

Objectives for conveyance, distribution, and delivery facilities should include:

- Maximizing irrigated acres within physical, environmental and economic limits
- Minimizing land disturbance by minimizing excessive cut and fill areas for conveyance system facilities
- Providing complete control of all water by:
  - — Reducing canal seepage. Install channel linings or pipelines to reduce seepage losses in high water loss soils.
  - — Reducing operational spills. Use appropriate distribution system water management to minimize management or flow through water. Consider semiautomation or full automation as a management tool.
  - — Using adequate water measuring devices to measure flows in all diversion, division, and delivery facilities. Equitable delivery of water according to water rights and delivery schedules is essential for user harmony. Maintaining an adequate record of water diverted and delivered is also essential. Irrigation organizations that have installed water measuring devices on lateral and farm turnouts typically experience from 20 to more than 40 percent increase in usable water. It is human nature to provide *a little more water than required* to minimize complaints. Ditch riders (person controlling delivery) tend to open the gate a little more when they are uncertain about flows. Accurate water measurement is essential for high level on-farm water management. See discussion on water measuring devices in chapter 9.
  - — Installing, operating, and maintaining adequate structures for grade control, water level control, and delivery. (See USBR reference Design of Small Canal Structures). Consideration should also be given to automation of control structures and valves (see USBR reference Canal Systems Automation Manual, 1991). With a fully automated system, almost immediate adjustments can be made to increase or decrease water availability in a canal or conduit system when changes are made in water delivery to the user. This may require increased capacity in main canals or conduits. Semiautomation can be very cost effective.
  - — Providing a water delivery schedule to the user that promotes good irrigation water management and water conservation. As mentioned before, consideration should be given to an arranged or demand type delivery schedule so the irrigation decision-maker can receive water according to plant needs.

- Small storage and regulating reservoirs can be located within the irrigated area to temporarily store water discharging from canals and laterals when severe changes in delivery rate(s) occur, or when excess water is available. These small reservoirs help prevent operational spills of excess water that cannot be stored within the main canal system. They balance out, and generally reduce overall diversion requirements. Water levels in these reservoirs tend to fluctuate widely as inflow and outflow change rapidly. An added advantage occurs when the water source is a long distance from the irrigated area. A canal or pipeline can contain (store) several acre feet of water that must be delivered, stored, or spilled when many irrigators discontinue irrigation, for example to harvest alfalfa hay, or during an unexpected short rainy period. Check structures or valves should be used to contain or discharge (into protected watercourses) excess water that cannot be placed in regulating reservoirs.

652.0804 Irrigation delivery system automation

Water conveyance facilities can be automated to deliver irrigation flow rates *on demand* for most users. Typically only a slight to moderate increase in canal or pipeline capacity is required. Facilities that measure and control water surface elevation (or pressure) are generally quite simple. Headgates and valves can be calibrated to control water surface elevations within 0.01 feet.

With automation, irrigation delivery systems can operate at capacity with limited manual adjustments. Water deliveries can be interrupted by the user without jeopardizing the main delivery system. Automation encourages better user understanding of plant water needs. When manual water deliveries are changed in 12- or 24-hour increments, fine tuning water applications to meet actual plant water need becomes more difficult. With automation, water can be changed at any time.

With most delivery systems, at least semiautomation of key headgates or valves is appropriate and cost effective. Labor to change headgates is reduced.

Experience has shown that controlling the hydraulic grade line (water surface elevation in open channels) immediately upstream of farm turnouts provides the most accurate water deliveries with the least labor. Also downstream water surface control on laterals makes it easier to divide water between a few users.

Typically, less water is diverted when agricultural water delivery systems are automated, mainly because of more precise control. Automation of urban water systems often use more water because it is delivered by a time clock.

Downstream water control can provide flexible and demand operation. Any change in flow rate within the system causes upstream gates or pumps to make a corresponding adjustment automatically, until eventually the gates or pumps at the far upstream supply point respond. Therefore, downstream control is limited to canals or laterals, including pump systems, which have a flexible supply of water. Downstream control canals usually are supplied from a regulating reservoir, but pumps or wells conjunctively used can supply some of the flexibility where multiple pumps are used. An example of the latter may be where the water source is a multipump pumping plant at a river or reservoir.

With downstream control, the water surface or pressure leaving the structure is controlled. A constant water surface elevation or pressure is maintained at some point downstream of the control facility regardless of the number of turnouts opened.

The nature of automated upstream control is to pass all problems downstream while maintaining turnout flow rate control for all upstream users. With upstream control, the water surface (or pressure) entering the facility is controlled by opening or closing a gate to a lower ditch or pipeline. In open channels, broadcrested weirs can be used to provide constant discharge at a given upstream water surface elevation.

Energy for opening and closing small to very large gates can use water pressure (head), gravity, electric, or pneumatic energy.

Floats, pressure tapes, pressure transducers, sonic transmitters, and air bubblers are used to sense the water surface elevation. A stilling well is necessary if the water surface fluctuates more than the open/close gate tolerance. Typically, the water surface sensing unit requires very little energy. A 12 volt DC, deep charge car type battery, or 115 volt AC is generally used.

652.0805 Water budget

A project wide water budget can be an effective tool to analyze total water needs versus total water availability. A water surplus or deficit is readily recognized. A budget can show diversion, pumping, or storage requirements for any selected time period. Typically, a month-by-month analysis is used for the growing season or entire calendar year. Water budgets can be developed for specific items. For example, budget(s) may be developed for: individual system peak crop ET, project wide average crop ET, project wide peak crop ET, water quality management, or water conservation. Often a variety of crops with peak water use requirements occurring at different periods of the growing season are grown to reduce peak water delivery needs. Parameters that might apply to a project wide water budget include:

- Weighted crop ET requirement.
- Effective precipitation that changes soil moisture within the plant root zone.
- Ground water contribution to plant water needs.
- Net irrigation water requirement (to make up soil moisture deficit).
- Irrigation efficiency (accounting for unnecessary irrigations, losses to deep percolation and runoff).
- Auxiliary water requirement (leaching for salinity control; climate control such as frost, cooling, or humidity; seed germination).
- Gross irrigation water requirement.
- Water conveyance system losses (evaporation, phreatophyte plant use, seepage, operational spills).
- Diversion, pumping, and storage requirements.

The following example and data displayed in figure 8–3 are an example water budget for a sprinkle irrigation project. Design single event irrigation application efficiency of a sprinkler system can be 65 to 70 percent or higher. For the total irrigation season project wide, it is assumed in this example that an overall average of 55 percent is more typical. Project wide efficiencies are typically lower because of nonmeasured water delivery, extra irrigations, conveyance facility seepage and leaks, and deliveries and irrigation application not according to plant needs. A weighted crop ET is determined that would represent an average for crops irrigated in a project.

Given: Area = 1,000 acres
Seasonal on-farm irrigation efficiency = 55%
Seasonal weighted crop ET = 28.0 acre-inches per acre
Monthly crop ET effective precipitation (Pe) as shown
Root zone moisture level assumed at full AWC at start of season

Figure 8–3 Example project water budget

Item	April	May	June	July	Aug	Sept	Oct	Total
For 1.0 acre	------------------ (acre-inches / acre) ------------------							
Crop ET	1.4	2.5	5.6	6.8	6.0	4.5	1.2	28.0
Pe	2.5	2.1	0.7	0.2	0.4	1.0	1.5	8.4
Net IR	0.0	0.4	4.9	6.6	5.6	3.5	0.0	21.0
Gross IR	0.0	0.7	8.9	12.0	10.2	6.4	0.0	38.2
Losses:								
From Excess Precip. 1/	1.1						0.3	1.4
From Excess Irrig. 2/		0.3	4.0	5.4	4.6	2.9		17.2
Total 3/								**18.6**
For 1,000 acres	---------------------- (acre-ft) ----------------------							
Crop ET	117	208	467	567	500	375	100	2,334
Net IR	0	33	408	550	467	292	0	1,750
Gross IR	0	58	742	1,000	850	533	0	3,183
Losses:								
From Excess Precip. 1/	92						25	117
From excess Irrig. 2/		25	333	450	383	242		1,433
Total 3/								**1,550**

1/ Where effective precipitation (P_e) exceeds crop evapotranspiration (ET_c), the excess effective precipitation infiltrates into the soil and is assumed to go to deep percolation.
2/ Where Pe is less than crop ET, losses or excess is due to irrigation.
3/ Represents total water losses due to both inefficient irrigation and excess effective precipitation. For offsite determination of impacts on water quality, further partitioning may be desirable to determine how much is lost to each individual item (i.e., Deep Percolation , Runoff , and for Spray and Drift). This requires a monthly soil-water and crop-water balance analysis. This is suitable for planning purpose where only historical normal temperature and precipitation data are available. Where local real time climate data are available, the water balance analysis process discussed and calculated in NRCS (SCS) SCHEDULER would be appropriate for daily decisions.

652.0806 Water source

Irrigation water may be from direct gravity diversion or pumping from natural streams, springs, or sloughs; ground water using wells; lakes and reservoirs; or a combination of these. In addition to irrigation project needs when using a reservoir, storage may include municipal, recreation, fire protection, fishery and wildlife, sediment retention, flood protection, downstream natural stream flow augmentation, and power generation.

Determining if water is available and can be used for irrigation purposes is necessary before spending much time on project planning. This may require a preliminary hydrologic analysis and search of issued state water rights. A permit may be required to divert surface water, install wells and pumps, and to store and beneficially use public water. Typically, detailed plans for irrigation storage reservoirs are required and must be approved by a state regulatory agency before construction starts.

652.0807 Evaluating alternatives and selection

Keeping objectives of sponsors and the community in mind and evaluating alternatives (including economical, social, and environmental impacts) are probably the most important part of a project analysis. This step requires a multidiscipline approach that should involve landowners, engineers, agronomists, biologists, economists, water quality specialists, social science specialists, and others. See section 652.0809 and the NRCS National Planning Procedures Handbook for a more detailed discussion of the planning process. Parameters and steps for evaluating alternatives leading up to a selection should include:

- Sponsors identify goals and objectives.
- Identify community concerns and objectives.
- Research applicable local laws and regulations.
- Establish project specific quality criteria.
- Environmental assessment and impacts of each alternative component and cumulative effects of components for each alternative are considered; including soils, water quality and quantity, air quality, plants of concern, and animals (including fishery, wildlife, and endangered species). People including cultural resources and social impacts of alternatives are also a consideration.
- Benefits for each alternative that reaches final consideration. Some alternatives drop out early for obvious reasons; i.e., costs, extreme negative resource and social impacts.
- Fishery and wildlife impacts and mitigation needs.
- Project costs for each alternative that reaches final consideration.
- Interim cost versus benefit analysis, and economic impacts on landowner, community, and region.
- Selection of best alternative, based on objective(s) and goals of sponsors, that meets established quality criteria.
- Operation and maintenance.

652.0808 Project cost and benefits

A detailed project benefit-cost analysis is developed for the selected alternatives. Depending on need, a benefit-cost analysis can be limited to individual landowners and their ability to pay the cost of water and make a net profit with irrigation improvements. Current and reasonable values must be assigned to all components of the project.

Project costs:

- Engineering planning and design, contract administration, construction inspection, permits.
- On-farm land preparation, irrigation system(s), and distribution facilities.
- Cost of water to landowner, which include costs of:
  - — Conveyance, distribution and delivery facilities and all associated structures.
  - — Water source—diversion facilities, wells and pumps, storage reservoir.
  - — Fishery and wildlife mitigation, maintaining or reconstructing wetlands.
  - — Management, operation and maintenance of facilities (buildings, staff, equipment)

Note: For a total project benefit-cost analysis, costs must also include all landowner ownership and operation expenses.

Project Benefits:

- Economic, social, and environmental benefits for on-farm, community, and regional levels.
- Power generation revenue (as applicable).
- Other benefits including fishery, wildlife, and recreation use of reservoirs and open canals.

It may be difficult and time consuming to determine all impacts on soil, water, air, plants, animals, and humans (SWAPA+H). For a true benefit-to-cost analysis, dollar values need to be assigned to community benefits including aesthetics, nongame wildlife, environment, social welfare, and economic improvement to community, state, and region. Other Federal, state, and local agencies can be sources of data.

652.0809 Planning process for irrigation projects

The NRCS National Planning Procedures Handbook (September 1993) provides guidance in using the NRCS planning process to develop, implement, and evaluate project plans. The purpose of the planning and implementation process is to:

- Provide methodology that helps planners work effectively with sponsors to identify opportunities and needs and to solve identified resource problems or concerns.
- Help sponsors recognize and understand natural resource conservation principles, concerns, and problems. Resource treatment and effects are considered for each alternative.
- Develop and evaluate alternatives that lead to decisions to implement and maintain conservation treatments and management for the project.
- Enable sponsors to achieve their objectives as well as meet social, legal, and program requirements.
- Help sponsors develop a plan that meets established project specific quality criteria including environmental concerns.
- Assess the effectiveness of installed practices in meeting the goals and objectives of the sponsors while solving problems and impacts on environmental values.

(a) Watershed-based planning

The watershed-based planning approach provides a comprehensive process that considers all natural resources in the watershed (project) as well as social, cultural, and economic factors. The process tailors workable solutions to ecosystem needs through the participation and leadership of sponsors. The watershed approach follows the established planning process and empowers local people to recognize problems and opportunities and find workable solutions for resolving issues and attaining goals related to ecosystems. This approach provides a forum for successful planning and conflict resolution. The result is a watershed plan that is a clear description of resource concerns, goals to be attained, and identified sources for technical assistance, education assistance, and funding assistance from Federal, State, and local entities for implementing solutions.

(b) Project planning relationships

Project planning relationships are displayed in figures 8–4 (steps 1–4) and 8–5 (steps 5–9).

Figure 8–4 Resource planning process for project plan—steps 1–4

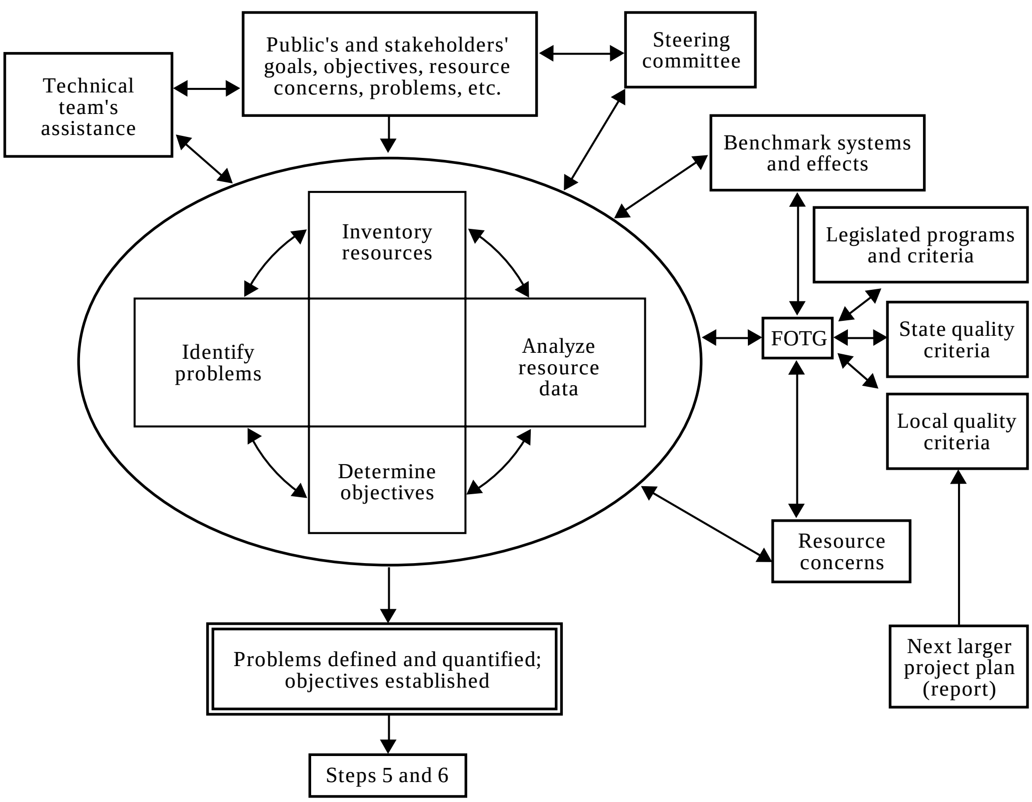
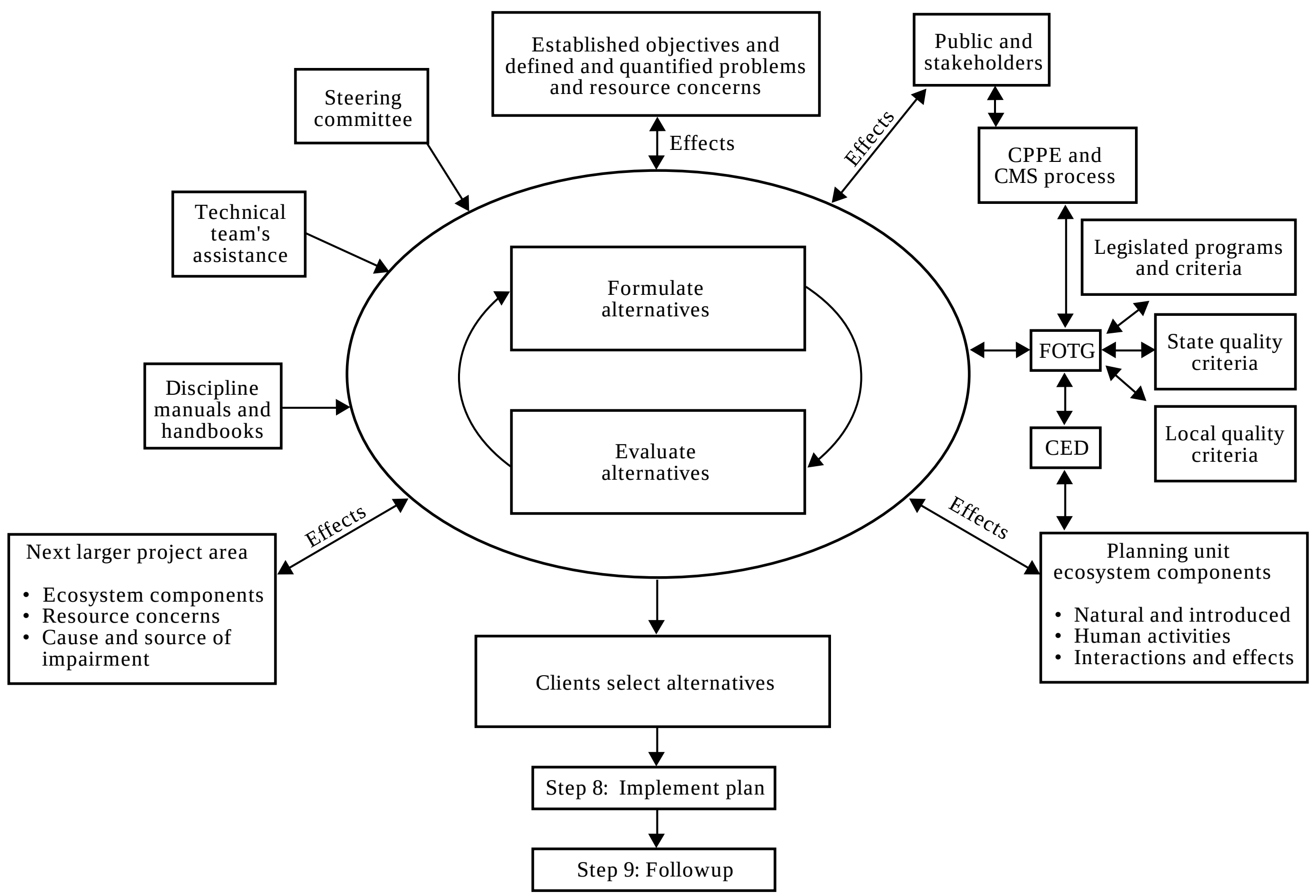


Figure 8–5 Resource planning process for project plan—steps 5–9



(c) Outline for irrigation project planning

The following outline is a guide for inventorying, investigating, and analyzing physical resources for a project. It can assist planning personnel with irrigation aspects of planning a project. Adherence to the principles of the outline will help ensure a uniform approach in estimating physical feasibility, benefits, effects, and impacts at the various stages of progressive planning.

The outline is not intended to indicate a fixed chronological order or procedure. Many of the investigations may be carried on concurrently. Perform only those items described in the outline that are directly applicable to appraise the capability of satisfying a component need. The procedural outline is subject to additions or deletions should a particular project warrant.

Intensity of investigations required for various outline components varies with the level of planning and the scope and significance of the project being planned. Generally, the lowest intensity is associated with preapplication planning level. It increases to full intensity for investigation of the selected plan.

The procedural outline does not describe program requirements or format for plan preparation. It provides an orderly format for planning, implementation and evaluation. As a part of the planning process, it provides an orderly format for organizing information to facilitate comparison of alternatives. It also provides guidance for writing of plans, organizing supporting documentation, and facilitating reviews.

Step 1. Identify problems and concerns (scoping process)

An interdisciplinary team should review sponsors application and gather and review existing information about the project area and ecosystem(s). They should:

- Determine environmental, social, economic, and cultural resources in the area. Other agencies and specific interest groups are good sources for information.
- Make a field review of the project area with specific interest in sponsors concerns, but look at all natural resources.
- Obtain input from the public, other agencies, and special interest groups. This is generally best done at one or more public meetings. All personnel or groups affected by the project should be interviewed for their real (or perceived) concerns and problems. Small groups can be effective in identifying resources of concern.

Step 2. Determine objectives

Help sponsors develop project planning goals and objectives based on needs and values regarding the use, treatment, and management of available resources, both onsite and offsite. Establish project specific quality criteria for resources of concern. Use or enhance FOTG quality criteria.

Step 3. Inventory resources

Review goals and objectives determined in step 2 as related to land uses, production goals, and problem solving. Tailor inventory detail to expected complexity of resource setting. This can be accomplished using the scoping process. Review with sponsors the purpose and importance of the inventory process, what should be done, how much time will be required, and what documentation will be provided.

Develop Plan of Work (POW) outlining; list of tasks, discipline, time frame to do task, and expected product for each task.

Have sponsors assist throughout the inventory process as much as possible.

Suggested inventory procedure outline:

A. Develop project base map
   1. Identify cultural features, communities, roads, railroads, public and private utilities, climatic stations, sloughs, ponds, streams, lakes, key points where resource data have been collected, wildlife preserves, parks
   2. Topography or elevations typically one to five contour intervals

B. Overlay maps
   1. Soils
   2. Farm boundaries, irrigation organization boundaries
   3. Water rights by year established (if appropriate)
   4. Skeletal outline
      a. Project conveyance facilities including canal and pipeline locations and delivery points
      b. Drainage facilities—surface and subsurface
      c. Reservoirs
      d. Diversion points
      e. Wells
      f. Water control structures, measuring devices
   5. Irrigation service areas
      a. Present
      b. Potential
   6. On-farm irrigation methods, systems, or both

C. Conservation farm maps
   1. Skeletal outline of farm distribution system and field layout. Inventory may be by farm, group of farms, project, or sample area as determined by intensity of study and variation of conditions. Delivery location(s) and amount of water delivered are shown for each farm.

D. Soils
   1. Description of soil series, surface textures, management groups
      a. Acreage and location
      b. Soil moisture storage management groups
      c. Intake characteristics
         (1) Furrow, rill, corrugation
         (2) Border, basins
         (3) Sprinkler
      d. Soil chemistry; i.e., salinity, sodicity, pH
      e. Erodibility designation or group from both water and wind
      f. Water table depth by month, season

E. Crops
   1. Crops grown including time of year
   2. Acres of each crop
   3. Acres by irrigation method and/or system(s)
   4. Growing season with planting and harvest dates for multiple cropping

F. Water supply
   1. Quantity records—historical or probability
      a. Reservoir storage availability
      b. Direct stream diversion
      c. Ground water including depth
   2. Quality records
      a. Chemical and mineral content
      b. Sediment content and type
      c. Temperature, if a factor
   3. Water rights
      a. Listing of water rights as to source
      b. Priorities by date
      c. Seasonal volume, flow rate, or both
      d. How administered (state, irrigation organization, group, water user)
   4. Competing water uses from the same source

G. Climatic records (mean monthly and seasonal, or monthly for historical period)
   1. Temperature maximum, minimum, average daily, and growing degree days, if available
   2. Precipitation—effective precipitation during growing season
   3. Humidity
   4. Wind—speed and prevailing direction, by month or season
   5. Pan evaporation
   6. Solar radiation
   7. Percent probable sunshine

H. Energy sources
   1. Type—electric, natural gas, diesel, gravity, solar
   2. Availability—brownouts, lightening
   3. Cost, rates and power interruption potential

I. Project conveyance facilities
   1. Canals, laterals, pipelines, etc., including shape, location and size
   2. Capacity - based on size, shape, and conveyance gradient or elevations
   3. Length(s)
   4. Conveyance losses (preferably measured)
      a. Seepage
      b. Evaporation
      c. Evapotranspiration—stream side vegetation, submersed and floating aquatic weeds
      d. Operational and management spills and other losses

5. Method of delivery
    a. Continuous flow
    b. Rotation
    c. Demand, including elapsed time between request and delivery. Is quantity variable? Is delivery period (time) variable? Can user request variable time and amount?
    d. Combination
6. Water measuring facilities
    a. Canal and lateral division boxes
    b. Pipeline division points
    c. Pumping plant discharge
    d. Farm deliveries
7. Geology

J. Project runoff and wastewater disposal including reuse facilities
1. Type
2. Capacity
3. Location of disposal facilities and areas, outlets, pump back or reuse facilities and areas
4. Real or anticipated effects of runoff and wastewater disposal.

K. Irrigation methods and systems
1. Irrigation method (surface, sprinkle, micro, subirrigation) and systems (furrow, border, handmove sprinkler, line source micro, etc.)
2. Acreage by method and system—Inventory by field, farm, group of farms, project area or representative sample areas, as determined by study, diversity of soils, management areas
3. Quantity of water used or applied
    a. Per irrigation or application event
    b. Per irrigation season
    c. For auxiliary use; i.e., chemigation, frost protection, temperature control, leaching
4. On-farm irrigation scheduling methods
5. Project irrigation scheduling methods

L. Return flow—tailwater, runoff usable in the project.
1. Quantity records, field measurements, sample evaluations, etc.
2. Quality records
    a. Chemical concentration
    b. Mineral content
    c. Organic content
    d. Sediment content
3. Location in the project

Step 4. Analyze resource data

Use scoping process to determine the types of analyses needed. Identified problems and concerns, sponsor’s objectives, program criteria, and environmental values to be considered. Input from sponsor, irrigation water user's interdisciplinary team, special interest group(s), public, and other agencies affected by the project is necessary. Type of planning, size, cost, potential for adverse environmental or social impact, and controversy need to be considered. Agreement by the sponsor(s) and Federal, State or local agencies is essential.

Define the existing and future resource conditions in the project area. This can help define the conditions that limit sponsors from fully realizing their objectives. Separately analyze *With* and *Without* Project Conditions. Without Project Conditions can be for existing conditions or future without project conditions. One of these is selected and used as the benchmark to compare alternatives. Typically several alternatives are analyzed, and some are eliminated before the near final selection of best alternative(s).

Analysis of resource data outline:

A. Project area to be irrigated
1. Acreage of composite groups of soils that can be managed similarly
2. Acreage by crop
3. Acreage by irrigation method and/or system

B. Crop water requirements
1. Project wide composite for different crops; i.e., weekly, monthly

C. Water supply, by days, weeks, or months as needed
1. Frequency (continuous, intermittent)
2. Historical period (including time of year)
3. Risk assessment (probability)

D. Conveyance efficiencies, by month
1. By type and condition of conveyance facility
2. By construction material; i.e., earth, concrete, PVC pipeline, steel pipeline

E. Overall application efficiencies including management
1. By irrigation method and/or system
2. By type and condition of on-farm distribution facilities

F. Crop water budget/balance, by probability, historical period
   1. Acres provided full water supply
   2. Acres provided partial water supply
   3. Water deficiencies and excesses
      a. Volume
      b. Time periods

G. Project delivery system capacity requirements
   1. Unit peak period water requirements
   2. Composite peak period water requirements
   3. Farm turnout capacity and pressure requirements
   4. Project conveyance facility capacity and pressure requirements
   5. Water measurement for division of supply for farm delivery

H. Irrigation benefits
   1. Net returns
      a. Crop yield and quality improvements, optimizing net benefits
      b. Reduced farm, irrigation, or both organization operation costs
   2. Environmental improvements
      a. Water quality improvements—reducing agricultural related chemicals, salts, sediments, and organic material in ground and surface water; reducing stream temperatures
      b. Water quantity improvements—reducing seepage and deep percolation losses thereby reducing pumping, diversion and storage requirements resulting in increased in-stream flows, decreased ground water mining
      c. Community benefits
      d. Other resource improvements—air quality, wildlife habitat

I. Review and finalize quality criteria for project with water users and nonwater users affected by the project

Step 5. Formulate project (components) alternatives

Identify practices (components) and other treatments that address the sponsors goals and objectives.

Land treatment (structural and nonstructural) as well as preventative measures should be considered. Management improvements using the existing system is always the first increment to be considered.

Develop alternatives (composite of components) as necessary.

Make a preliminary evaluation of the effects of each practice on resource concerns, problems, objectives, and environmental values.

Develop preliminary designs and cost estimates.

Compare alternative to project quality criteria.

Estimate environmental, social, economic, and human effects. Acceptability of the alternative by the sponsor, the public, and State and Federal agencies should be established. Needed measures to mitigate any potential environmental damages need to be included.

Analyze the risk and uncertainty associated with each alternative.

Use sponsor(s) and public affected by the project to help identify and formulate alternatives.

Develop benefit-to-cost analysis for selected alternative(s).

Step 6. Evaluate project (components) alternatives

Quantify effects on soil, water, air, plant, and animal resources plus social and economic considerations, both for the benchmark and each alternative. Quantification of effects should be done as agreed to by the interdisciplinary team. Evaluation detail for each alternative will vary and become more refined as needed in the selection process. The sponsors, public, and other agencies and interest groups affected by the project should be included in the quantification process.

Compare the effects of each alternative to the benchmark. Both beneficial and adverse impacts are considered.

Compare alternative to project quality criteria.

Display evaluations in a manner easily understood by the sponsor, public, special interest groups, individual landowners, and other agencies.

Step 7. Make decisions

- Assist the sponsor(s) in reviewing alternatives and evaluations.
- Provide opportunity for public response.
- Sponsor(s) review the plan, public input, obligations, and responsibilities.
- Compare selected alternative to project specific quality criteria.
- Sponsor provides a decision, with public information (and review) as necessary.

Step 8. Implement project plan

Develop Plan of Work (POW) for implementation of practices and measures. Include list of tasks, disciplines involved, and time required for preparing real property acquisition maps, acquiring necessary right-of-way, prepare design surveys, final design of construction drawings and specifications, cost estimates, bid documents, and installation sequence and schedule. Particular attention should be paid to all special environmental concerns, such as threatened and endangered species, cultural resources, and wetlands. Sponsors obtain necessary agreements, permits, and approvals.

Develop plans for any mitigating loss of environmental values that resulting from project plan implementation. If established project quality criteria was appropriate, mitigation should be minimal.

Develop Operation, Maintenance, and Replacement (O, M, and R) plan and agreement(s). Identify who will do the work and the process followed for periodic inspections and development of plans for remedial action.

Step 9. Evaluate project plan (follow-up)

Establish evaluation criteria including what use will be made of the results.

Develop POW to guide evaluation efforts. Develop by component, project, and individual discipline the products to complete the evaluation. This should include work to be performed by the sponsor, NRCS, contractor, and other agencies. The POW will vary based on the project and the purpose of the evaluation. Identify personnel who will be involved in remedial work and together develop procedures to be used, time required, and cost. Develop a schedule showing who has responsibility for a specific action, when it is to begin, when it is completed, and what is to be the product.

As identified in the Plan of Work, periodically:

- Gather information, make analyses, develop recommendations, and prepare necessary reports.
- Take necessary action as a result of the evaluation.

Examples of evaluations may include:

- Dam performance and safety inspections
- Monitoring water quality
- Performance evaluations of measuring devices, conveyance and delivery facilities, and pumps
- Delivery (conveyance) system operation and management

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