Chapter 14 Environmental Concerns

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652.1400 General

Irrigation brings many benefits to individuals, communities, and regions, but it also brings environmental concerns. Many environmental concerns are local. Some are larger in scope; such as coastal zones, river basins, and regional and even international. Irrigation planners and decisionmakers need to have a basic understanding of the general processes by which irrigation water can affect soil, water, air, plant, and animal resources. Human considerations (social, cultural, and economic) should involve both present and future conditions.

Most farmers are good environmentalists. They are faithful stewards of soil, water, air, plant, and animal resources, and truly desire to help maintain a good overall environment and quality of life. Others, many of whom recognize only one or a few specific resources, should have concerns for environmental quality and long-term farm production.

652.1401 Environmental impacts

Negative and positive environmental impacts are caused by irrigation. These impacts include:

- Transport of chemicals
- Consumptive use by plants
- Pollution hazards by fertilizers, pesticides, fuels, and other contaminants
- Obstructed wildlife migration patterns

Negative irrigation impacts to the environment can be insignificant or large. Water pollution problems from individual irrigated farms may appear small, but when combined with adjacent farms, the problem can be large. With new project development or major changes to existing systems, mitigation may be necessary. Providing an environmental assessment as part of the irrigation system planning process can identify both negative and positive impacts. Farmer's irrigation decisions should be based on knowing potential impacts and how much they affect the environment. See chapter 15 for planning tools including environmental assessment aids.

(a) Transport of chemicals

Water can transport chemicals through the soil and off the field. Inefficient and nonuniform onfarm irrigation can provide excess surface water runoff (tailwater) and deep percolation. For best uniformity, some deep percolation is generally required.

Runoff water from irrigation can carry sediment from soil erosion, nutrients, pesticides, animal waste, and other soil surface pollutants into surface water. Runoff from irrigation can augment surface water flows to provide water for fish, wildlife, irrigated areas, and other downslope land uses, such as wetlands. However, in most cases quality of water from irrigation runoff is lower than that of the original supply. Pollutants can result in damages to other downslope irrigated areas, to fish, wildlife habitat, cities, and industries.

Proper soil, water, and plant management can minimize these effects. Runoff from irrigated cropland is designated by EPA as a nonpoint source pollutant; therefore, discharges do not require a discharge permit. Deep percolation can carry nutrients and pesticides that have become a part of the soil-water solution to local ground water aquifers. Certain chemicals contained in ground water can become hazardous when consumed by humans and livestock. Irrigation water can help metabolize wastes applied to land into plant usable nutrients and soil amendments.

(b) Consumptive use by plants

Water consumptively used by plants is not available for other instream uses. To understand the impacts on instream flows, ground water, and springs, consumptive use, nonconsumptive use, and local water right laws must be understood as they apply to mining and to agricultural, municipal, and industrial uses.

(c) Pollution hazards by chemicals

Care in handling and storage of fertilizers, pesticides, fuels, lubricants, and solvents is necessary to avoid polluting ground and surface water. This applies to both commercial and on-farm operations. Care must be taken to prevent chemical and fuel spills at chemical and fuel storage facilities, chemical mixing areas, chemical application equipment wash areas, and especially at the irrigation pumping plant site. Spills of these materials onto the ground surface can infiltrate the soil or be flushed off the surface with irrigation water or precipitation.

(d) Impacts to wildlife

Some open channel irrigation water conveyance systems can obstruct normal wildlife migration patterns. Large concrete lined canals are hazardous to some wildlife (also humans and domestic pets) unless precautions are planned and incorporated so that they can exit once they have entered (by choice or accidentally). This is a concern in arid areas where the canal water may be the only water available for some distance.

In some areas, canal seepage and deep percolation in fields can dissolve naturally occurring toxic soil elements, such as salts and selenium. The toxic elements in the soil-water solution can then move into ground and surface water.

652.1402 Irrigation water management

Proper irrigation water management is essential to minimize negative irrigation caused impacts to the environment. Even the best irrigation system can be mismanaged. Well planned and fully implemented irrigation water, animal waste, pest, and nutrient management plans reduce or help prevent ground water and surface water quality pollution problems associated with irrigation. Proper irrigation water management includes:

- An irrigation system that is suitable to the site.
- Good irrigation system operation techniques that optimize distribution uniformity.
- Proper irrigation scheduling and adequate irrigation system maintenance.

652.1403 Pollution delivery process

The process by which a pollutant is detached and delivered to ground or surface water (and into air) takes place in three basic stages: availability, detachment, and transport. A water pollution hazard exists **only** when a pollutant is **available** in some form at the field site, becomes **detached,** and is **transported** to a receiving water body.

Pollution concerns from irrigation activities result from using an unsuitable irrigation system, using poor operation techniques, or making poor irrigation water management decisions, especially when matching irrigation applications to pesticide and fertilizer applications. However, if excess fertilizers and persistent pesticides are available, a potential pollution opportunity exists even when good irrigation water management is practiced.

(a) Availability

Pollutant materials must be available in a form that has the potential to become a concern. The quantity and nature of the material influence its availability. For example, soil is usually available to provide sediment downstream, either as deposition or suspended particles. Chemicals, fertilizers, and pesticides vary not only in quantity, but in degree of their availability. Availability is often measured in half life (half life is when 50 percent of the original chemical is still available).

The amount and placement of chemicals (availability) at the time a runoff or deep percolation event occurs are significant. The partitioning of a chemical between water and soil determines its availability to be carried by soil erosion, by deep percolation, or by some other pathway.

Phosphate placed on the soil surface can be present in surface runoff. If placed below the soil surface, phosphates are typically not available except when severe soil erosion takes place. Nitrates that have leached below the plant root zone are available for deep percolation. Manure left on the soil surface is available as a downstream pollutant when surface runoff occurs. Pesticides with a short half-life are available for a shorter time than more persistent (longer half-life) compounds, such as chlorinated hydrocarbons.

(b) Detachment

Pollutant materials must be detached from their original location (or made mobile) before they can become a pollutant in receiving water. The detachment process is either physical or chemical. Chemical pollutants are grouped into three basic categories based on their sorption characteristics: strongly sorbed, moderately sorbed, nonsorbed. Sorption refers to absorbed and adsorbed chemicals.

Absorption, dissolving and detachment of chemicals in the soil mass and water, is dependent on:

- Type of chemical and concentration in soil water solution
- Strength of ionic bonding to soil particles
- Quality of irrigation water and soil-water solution as to type and concentration of chemicals (salinity, pH), soil texture, organic matter content, soil erodibility, temperature, biological activity, pesticide persistence

The negative impact of applying chemicals (and water) can be minimized by using a suitable irrigation system with good operation techniques and proper irrigation water management. Suitability generally refers to how uniform a planned amount of water can be applied across a field.

Highly soluble chemicals are easily detached (by dissolving or being released) by surface runoff and by water percolating through the soil. Because of strong ionic bonding to soil particles, phosphorus moves primarily with soil particles in surface runoff. The quantities and kinds of chemicals adsorbed to sediment are affected by soil chemistry, amount and availability of chemical(s), and amount of soil erosion that occurs. Solid particles are physically detached by sprinkler droplets (and raindrops) and by surface runoff (shear stress). Coarse soil materials are easily detached, but do not transport readily except on steeper slopes. Manure on the soil surface is easily detached. Fine soil materials are more resistant to detachment, but once detached are readily transported.

(c) Transport

With respect to irrigation, agricultural pollutants are typically transported in water as surface runoff or deep percolation. However, some substances are lost through wind drift and volatilization when using sprinkle irrigation systems for chemigation or application of liquid waste or manure slurry. Manure on the soil surface can be transported in field runoff as solid particles in suspension or as part of the water solution. The particular pathway by which a pollutant leaves the field depends on the soil, hydrology of the field, irrigation system used, and level of irrigation water management. Timing and rates of fertilizer and pesticide application (including the relationship to irrigation applications) and the interaction of the applied chemical with water and soil are also important.

Pollutants are generally transported to receiving water by surface runoff and deep percolation. Practicing good water management provides little opportunity for applied and naturally occurring chemical and organic wastes to move with surface runoff or through the soil profile to ground water. Some runoff from graded furrow and border irrigation systems is necessary to make the most uniform application of irrigation water to all parts of the field.

In practice, deep percolation and lateral translocation can occur with all irrigation methods and systems except subirrigation where water movement is primarily upward. Where operation and management of the system are poor, excess deep percolation and runoff probably have the best opportunity to occur with surface irrigation methods. However, it should be strongly emphasized that when adequately designed, operated, maintained and managed, surface irrigation systems can provide good uniformity and low pollution potential. A poorly designed, operated, maintained, and managed micro or sprinkle irrigation system also has high potential for providing excess deep percolation and runoff.

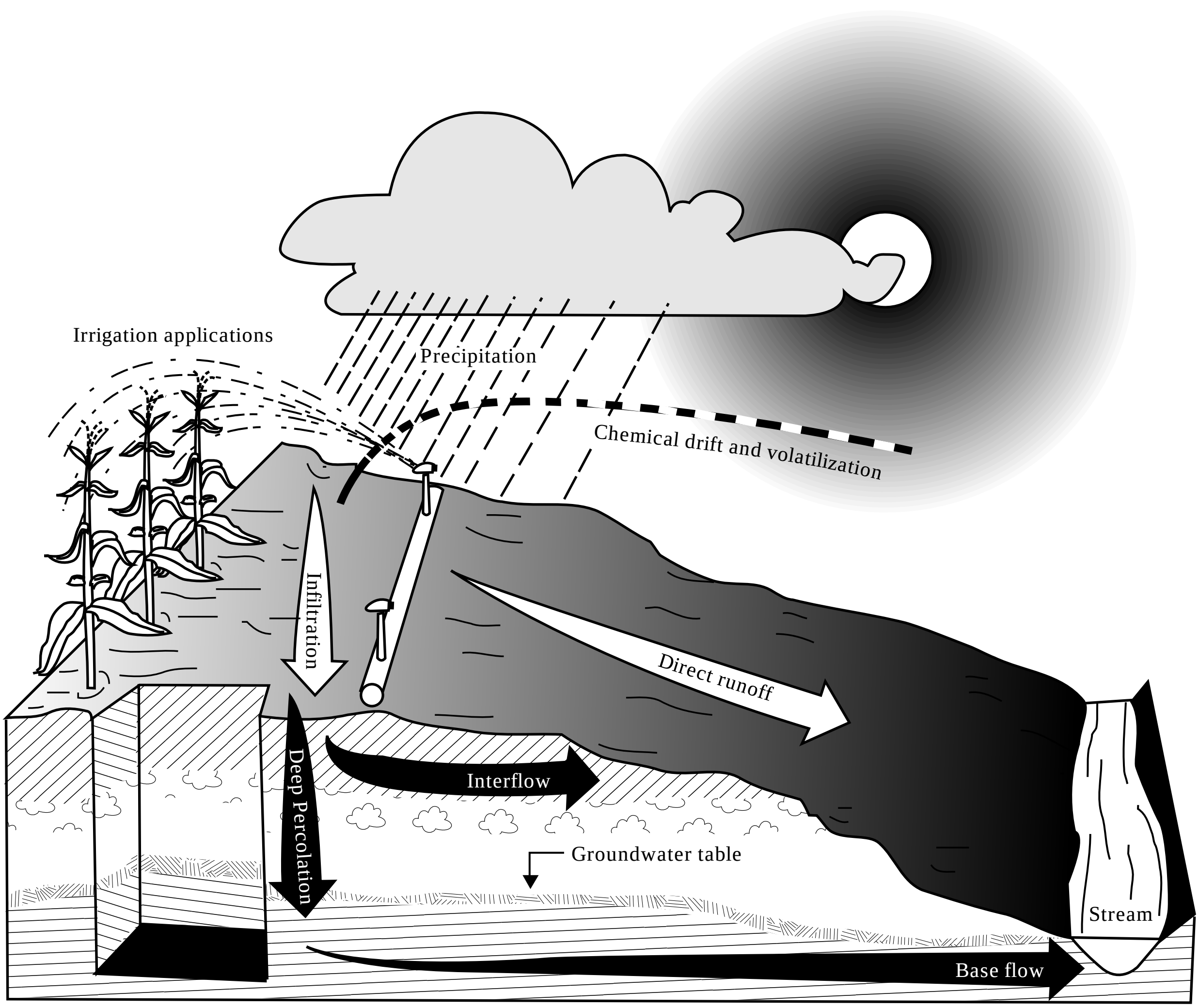
Deep percolation carries dissolved substances, such as nitrates or pesticides in original form or in a metabolized form. The metabolized form of some chemicals can have a much longer half-life than the original chemical and may be either less or more toxic or mobile in the soil-water solution.

Exhibit 14–1 displays the factors affecting chemical pollutant availability, detachment, and transport. Figure 14–1 displays the pathways through which substances are transported from irrigated cropland to become water pollutants

Exhibit 14–1 Factors affecting chemical pollutant availability, detachment, and transport

Availability	Soil, land use, substance input, management practices.
Detachment	Irrigation application rate, furrow and border inflow stream rates, soil erodibility, soil bonding of chemicals, and surface condition (cover, residue, clodiness, surface depressions).
Transport	Runoff energy, runoff volume, sediment particle size and specific gravity, organic matter of surface soil, water holding capacity of upper soil profile and vadose zone, infiltration of soil surface, hydraulic conductivity characteristics of soil profile and vadose zone, and chemical properties of soil profile and vadose zone.
Site	Undulating topography, vegetation in flow path, distance of flow path to surface stream and/or depth to water table, concentration in water of particulate, organic and inorganic materials.

Figure 14–1 Pathways for transportation of substances to receiving water



652.1404 Type of pollutants

Pollutants can be put into three basic categories—particulates, organics, and inorganics. Table 14–1 displays examples of the more common pollutants. All can be transported by water, and a few can be transported by air. Odors associated with organic and inorganics are definitely problems to people, and irrigation activities (both water and air) can be the carrier. Examples include sprinkle application of animal waste, sprinkle and aerial application of pesticides, volatilization of nitrogen in urea, and ammonia forms from animal waste and fertilizers.

At a soil-water nitrogen concentration of 20 ppm (20 mg/L), each acre-inch of deep percolation represents about 5 pounds of nitrate-nitrogen lost per acre. Applying fertilizer in excess of plant needs, along with over irrigation on all or parts of a field, is perhaps the greatest cause of ground water and surface water pollution. Where ground water is used as an irrigation watet source, it can also be a valuable source for supplying nitrate needs for crop growth. With an annual irrigation application rate of 24 inches per acre, and 20 ppm, this resource can provide approximately 120 pounds of nitrate-nitrogen per acre. Water should not be used for human consumption at nitrate concentrations of more than 10 ppm (10 mg/L).

Table 14–1 Common pollutants

Particulates	Organics	Inorganics
Sediment	**Livestock waste**	**Chemicals**
sand	manure	fertilizers—nitrates, phosphorus, potassium
silt	bedding and litter material	pesticides—herbicides, insecticides, fungicides, miticides, nematicides
clays	spilled and undigested feed	
	fecal coliform	**Salts**
	Plant residue	sodium, calcium, magnesium, potassium, carbonates, bicarbonates, sulfates, chlorides
		Other
		boron, arsenic, selenium, heavy metals, engine fuel, lubricants, pumping engine exhausts

652.1405 Conservation practices for pollution control and reduction

Potential pollutants can be controlled or eliminated by:

- Reducing or eliminating the source
- Reducing availability
- Decreasing detachment or transport process

The role irrigation water management plays in the movement of contaminates by excess deep percolation and surface runoff on irrigated cropland cannot be overstressed. An adequately designed, operated, maintained, and managed irrigation system is essential for minimizing pollution potential. Applying the correct amount of water according to crop needs is a necessary part of proper irrigation water management for controlling pollution.

(a) Pollution control

(1) Reduction of source

Source reduction is reducing availability of chemicals through proper nutrient and pest management.

(i) Nutrient management**—**Less fertilizer is generally applied if a nutrient management plan is followed. A soil testing program can show residual amounts of fertilizer available, thereby avoiding overapplication. This reduces the *extra* that was historically applied to account for *losses* and helps balance the total fertilizer needs and availability (including residual amounts in the soil profile) for average crop yield, not maximum yield.

(ii) Pest management**—**Less pesticide is generally applied if a pest management plan is followed. Evaluation of soil, site conditions, application methods, and the choice of pesticide is stressed to reduce hazards of potential pollution. Application of pesticides should be coordinated with irrigation applications to allow necessary time to be effective in controlling pests without being washed from the surface of leaves by spray. Better control and timing of application typically results in less pesticide use with chemigation.

Field scouting techniques and proper pesticide application timing and rates based on pest threshold levels can reduce potential for leaching and runoff.

Using SCS SCHEDULER software, or some other technique, to calculate growing degree days can reduce the amount of pesticide applied by more accurately predicting insect hatch and propagation.

(2) Reduction of availability

The irrigation decisionmaker can optimize nutrient availability by:

- Managing fertilizer through proper rates and timing
- Monitoring the buildup of available nutrients in the crop root zone
- Incorporating fertilizers
- Using proper irrigation water management

Where excess nitrates have accumulated in the soil profile below normal rooting depths for shallow rooted crops normally grown, then salvage crops with deep rooting characteristics should be grown until the accumulation of nitrates is consumed. Minimization of deep percolation losses is essential.

(3) Reduction in detachment

The loss of nutrients and pesticides by detachment of soil particles (i.e., erosion) is important for inorganic chemicals whose major environmental chemical forms are strongly or weakly held by soil particles. Phosphorus is tightly bonded to soil particles; therefore, it is not readily detachable except where soil is detached by water erosion. Phosphorus becomes part of the surface water pollution process mostly as a result of precipitation, runoff, irrigation related soil erosion, sediment deposition, and suspended sediment in surface water.

Increased soil organic matter decreases the potention for detachment of nutrients and pesticides. Decreasing deep percolation losses can decrease nitrate movement. Inorganic forms of nitrogen are not tightly bonded to soil particles. They dissolve easily and readily become part of the soil-water solution. Nitrates are very mobile and move readily with deep percolation as part of the soil-water solution.

Erosion control is an essential component of a resource plan. If quality criteria are met for erosion control, irrigation induced erosion, sediment transport, and water leaving the field should be at acceptable levels to prevent significant loss of nutrients or pesticides.

(4) Reduction in transport

The importance of the transport process in the loss of pollutants (including salts) from irrigated cropland is a function of the affinity of the chemical form of the nutrient or pesticide for soil particles. Chemicals that dissolve readily are transported easily with excess irrigation water. Reducing deep percolation by using adequately designed, operated, maintained, and managed irrigation systems is essential to reducing transport potential. Chemigation near the end of an irrigation application helps keep chemicals near the soil surface.

Phosphorus typically is transported with detached and transported soil particles in surface runoff because of strong bonding with soil particles. Reduced irrigation induced soil erosion on the field and opportunity for off-field transport of sediment are essential. Onfield soil erosion with furrow irrigation systems can be controlled by:

- Using proper furrow inflow streams, reducing irrigation grades
- Maintaining crop residue on the soil surface with adequate crop rotations and conservation tillage methods and equipment
- Reducing tillage operations

Where onsite erosion control practices are adequate, off-field sediment movement can be reduced with vegetative filter strips at the lower end of fields and by installing and maintaining sediment collection basins. On highly erosive soil, often the only solution to eliminate irrigation induced erosion and resulting pollution may be changing to permanent vegetative crops (grass, alfalfa-grass, and clover-grass) or collecting and redistributing sediment. Almost all soils contain some clay particles. Colloidal clays stay in suspension much longer than do silts and sands; therefore, overflow from sediment ponds can contribute to downstream suspended sediment pollution.

Maintaining ground cover to filter potential pollutants and prevent soil erosion can provide a reduction of chemical availability, detachment, and transport. Implementing necessary component practices identified in resource plans, such as conservation tillage helps maintain crop residue on soil surface and improve soil condition. Vegetative cover and water management practices can reduce or eliminate irrigated related soil erosion. Plant and maintain vegetative filter strips at lower end of irrigated fields to reduce water velocity and to filter sediment. Also consider using sediment collection basins at lower end of fields as a best management practice.

(5) Controlling pollution from animal waste

Animal waste (manure) is a valuable resource for crop production. It contains not only nutrients, but also organic material. A basic principle is that if animal waste is used to the maximum extent possible, few pollutants are discharged to receiving water. Animal waste is applied as liquids, slurries, or solids.

A properly designed, operated, maintained, and managed waste management system reduces or eliminates deep percolation and surface runoff of applied nutrients. A properly designed, operated, maintained, and managed irrigation system is often a part of waste management systems. In some cases. two separate systems may be necessary.

Runoff from waste application should be nonexistent. Vegetative filters at the lower end of fields efficiently trap water transported waste particles with attached nutrients and allow more time for infiltration of runoff. Filter strips must be used in combination with other applied practices.

Little (if any) reduction in water soluble nutrients and chemicals is experienced by surface water passing through and leaving a filter strip. Water quality problems related to animal waste application sites can be effectively solved by using water management practices that reduce the availability of pollutants for transport during runoff events. These practices include:

- Providing a suitable site (crop, soils, and slope)
- Applying waste with a suitable irrigation system
- Not exceeding soil intake rate(s)
- Providing proper timing of waste application
- Providing uniform waste and water applications

(i) Application rates—The rate at which animal waste is applied should be based on soil nutrient levels, nutrient needs of the crop, and available nutrients in the waste. Both nitrate and phosphorous requirements should be considered in determining proper application rates.

Soil infiltration rates using effluents are generally less than the infiltration rate for clean water. Waste effluent should be applied at a rate less than that of the soil infiltration (plus surface storage) rate for the effluent being applied. Split application also helps.

***(ii) Timing of waste applications*—**To maximize plant use and reduce potential for deep percolation and runoff losses, applications of animal waste should coincide as nearly as possible with crop needs. Sufficient water must be available to optimize plant use of applied waste.

Rate and timing of waste applications with an irrigation system can be controlled by the kind and amount of nutrients in the waste or by the amount of water applied. Typically waste application should occur near the end of the irrigation set. Waste applications during nongrowing seasons should be controlled by the capacity of the soil profile containing plant roots to store both the applied nutrients and water. Surface incorporation of wastes also helps.

***(iii) Frequency of waste application*—**The frequency of waste applications can vary considerably. During the irrigation season, waste applications should coincide with planned irrigations. Liquid waste high in phosphates should be applied in the first part of the irrigation application period to allow infiltration. Animal waste high in nitrates should be applied near the end of the irrigation set. Clear water should pass through the system for 5 to 15 minutes following waste application to purge the irrigation system of waste material and to wash off plants. In either case, the amount of applied water should not exceed the capacity of the soil to store applied water within the plant root zone.

(6) Tools for planning and followup

Portable state-of-art test kits and instruments for field use are readily available. They can be extremely useful as planning and application tools that provide almost instantaneous information. Examples of field instruments and uses are:

- Determining soil and irrigation water salinity levels; i.e. electrical conductivity of soil-water extract (EC_e) and irrigation water (EC_i).
- Determining nitrogen content of animal waste.
- Quick readings of in situ soil moisture; i.e., neutron moisture gauges (probes), tensiometers, TDR probes, electrical resistance blocks, feel and appearance of soil, and Speedy Moisture Meter.
- Determining sediment concentration in surface runoff using Imhoff cones.
- Quickly and easily determining stream flow using digital current meters.
- Measuring stream flow depth using resistance tapes or pressure transducers.
- Collecting, storing, and transferring field data using data loggers.
- Providing on-the-spot analysis and information using laptop computers and portable printers.

652.1406 Consrvation management plan development

The objective of conservation management planning is to assist farmers in protecting the soil, water, air, plant, animal, and human resource base. The irrigation planner must consider resource interrelationships when planning irrigation systems, and as part of the environment. A broader planning scheme is particularly important with water quality concerns. Impacts of irrigation activities can be either onsite or offsite. The NRCS National Planning Policy and National Planning Procedures Handbook provide direction for all planning activities.

Development of alternatives, selection of practices, and consideration of all costs associated with those practices must be weighed against benefits received.

An evaluation tool, such as the example in exhibit 14–2, can be used to identify and assess concerns and their level of significance during the scoping process. Intensity of the scoping of environmental concerns varies with location, problems involved, people involved, and size of planning unit (individual farm, group of farms, watershed). The scoping process should involve multidiscipline professionals.

For project level planning, the scoping process should involve landowners, public, community leaders, agencies at all government levels, and interested technical people. Concerns having less importance can be scoped out early. Institutionalized concerns should be addressed. Scoping helps to determine the level of information needed. The scoping process also helps identify significant problems or concerns on which to focus.

652.1407 Benefits

Environmental and socioeconomic benefits from irrigation can include contributions to:

- Local and national economies
- Livestock capacity
- Alternative use of potential pollutants
- Utilization of agricultural and municipal wastes
- Activities involving small farm ponds
- Activities involving large storage reservoirs
- Ground water and wet areas
- Local climate and aesthetics
- Wind erosion prevention

Irrigated cropland contributes much to local and national economies and the well being of people. Irrigation water and the resulting area of irrigated cropland provide a basis for development of communities, businesses, industry, and export. In semiarid, subhumid, and humid areas, supplemental irrigation helps assure an economic crop yield and quality during periods of less than adequate precipitation. In arid areas, most crops cannot be economically grown without irrigation water. Irrigation can reduce the potential for pollution in subhumid and humid areas by maintaining plant growth during periods of less than adequate precipitation.

Ranch livestock capacity and associated economic operations are often controlled by quantity and quality of feed harvested from irrigated fields.

Irrigation of high salt tolerant plants with high saline (or sodic) subsurface drainage effluent provides a wise alternative use of an otherwise potential pollutant. Irrigation systems can transport and apply agricultural and municipal wastes for disposal on irrigated cropland, landscaping, or turf. A larger volume of wastes can be used by irrigated crops than nonirrigated crops because of the higher use of nutrients. A better microbiological environment is provided in the upper part of the soil profile as a result of applied irrigation water.

Exhibit 14–2 Example of identified concerns

Environmental concerns	Concern	Significance	Remarks
Water quality in streams	Very high	Very high	Poor water quality results in several negative impacts.
Sedimentation	Medium	Medium	High rates of sedimentation in streams are noted.
Streambank erosion	Medium	Medium	75 percent of streambanks are unstable and eroding.
Seasonal peak flows	High	High	High peak flows prevent riparian restoration.
Low summer flows	High	High	Insufficient to allow fish to migrate.
High summer water temps	High	High	High temperatures are lethal to trout (cold water fish).
Lack of streamside vegetation	High	High	Shading of stream decreases water temperature.
Lack of wildlife & fish	High	High	Fish population is lowest on record.
Threatened and endangered species	Medium	Medium	No known threatened and endangered species are in the area.
Water rights	Very high	Very high	Pending in-stream water needs, water right holders are concerned about options to use existing available water or to develop additional water.
Watershed condition	High	High	Concern as to continued deterioration.
Weeds	Medium	Medium	Certain weeds are multiplying at an alarming rate.
Cropland erosion	Medium	Medium	Conservation practices are essential to maintain long–term productivity.
Cultural resources	Medium	High	Significant buildings and sites in upper watershed.
Private property rights	Very high	Very high	Landowners fear loss of property rights.
Wetlands	Low	Low	Limited amount in watershed and adjacent areas.
Human health and safety	Low	Low	Resource problems do not impact human health and safety.
Important agricultural lands	Low	Low	Local zoning laws protect important farm lands.
Highly erodible lands	Low	Low	Erodible lands are currently protected by CRP.
CRP contract expiration	High	High	Cropland erosion rates could increase upon expiration of contracts if annual farming is again commenced.
Other items			Include all necessary items that need scoped.

On-farm irrigation systems often incorporate collection and regulation ponds either at the upper or lower end of the farm. These ponds can provide water for many other uses including family recreation, stock water, wildlife use, fishing, and fish production. On-farm ponds are valuable assets when fighting fires in rural areas.

Large multiple purpose storage reservoirs that provide for irrigation storage can also provide many other public benefits. Benefits include water-based recreation (boating, swimming, fishing, bird watching, water fowl hunting,), water for wildlife, habitat for waterfowl, flood protection, hydro power, fire protection, waterway transportation, and municipal and industrial water supply. However, large reservoirs can also prevent historical normal migration patterns of wildlife and anadramous fish and can impact cultural resources. These effects should be considered during the planning process.

Irrigation water conveyance systems (open channels) provide open water and adjacent habitat for wildlife. Canals and laterals with high seepage rates help to develop and maintain ground water and wet areas. Where water sources to ground water and wet areas are eliminated by canal linings, mitigation may be necessary. Irrigation pipelines and lined channels can reduce water lost to deep percolation.

Many irrigation organizations that deliver water in open channels also use regulating reservoirs to facilitate delivery rates, amounts, and schedules. Regulating reservoirs can provide water for many benefits besides irrigation purposes.

Large areas of irrigated cropland in arid areas can affect local climate, such as increased humidity. Higher humidity can be good to the human body. It can also be uncomfortable, especially during high crop water use periods. Air movement influences the degree of comfort relating to humidity. Irrigated cropland creates a green oasis in an otherwise barren desert. Green irrigated areas attract people and wildlife in both an urban and rural environment.

Adequate plant growth can reduce or prevent wind erosion during high wind periods on erosion prone soils. Irrigation aids plant growth during high wind periods, but only during the plant growing season. Applying water for preventing wind erosion, as a single practice to provide a wet surface to increase erosion resistance, is short lived. Soil at the surface dries rapidly under windy conditions. With an erodible soil and warm, windy conditions, a continuously moving center pivot irrigation system cannot keep the surface wet enough to prevent wind erosion.

652.1408 Costs and benefits

Economic and environmental guidelines should be used in the evaluation and selection of ecosystem based resource management systems for conservation and pollution control. An analysis of expected costs and benefits of irrigation and waste management system and associated conservation practices are frequently sufficient for the decisionmaking effort. See Chapter 11, Economics, for discussion of terms and principles used in cost analysis. Costs consist of:

- Actual cost of installing irrigation and waste management systems and associated conservation practices
- Cost of operation and maintenance of systems and practices.
- Cost of capitol (money used) used to purchase, install, and operate systems. Interest on borrowed money or money diverted from other investments is a project cost.

The number of years each system will be effective with reasonable maintenance and the rate of interest to be used are required to express the total costs in average annual terms. Typically, borrowed money for system installation is for a much shorter period than the estimated life of the system or system components. The two should not be confused.

The monetary value of benefits derived from reduction of irrigation related pollutants and improved water quality is generally difficult to determine. Cost effectiveness of each practice or a combination of practices can be used. Monetary value of cumulative effects is typically more difficult to determine.

Irrigation system improvements, improved irrigation water management, and proper nutrient and pesticide management can typically relate to:

- Decreased water requirement, which equates to reduced diversion requirements reduced pumping costs, reduced water purchased, and reduced system capacity requirement.
- Decreased use of fertilizers.
- Decreased use of pesticides.
- Increased yield or higher product quality, or both.

Decreased irrigation induced soil erosion relates to:

- Maintaining long-term soil productivity.
- Decreased maintenance costs for removal of deposited sediment in runoff collection drains, ponds, roadside ditches, and in water conveyance systems.
- Decreased use of fertilizer.
- Decreased use of pre-emergence herbicides.

652.1409 State supplement