Chapter 3

Ecology of Freshwater Systems

To assess properly whether or not a watercourse or water body is polluted or potentially could become polluted, you will need to know the basic ecological principles covered in this chapter.

Freshwater systems can be divided into lentic (standing) and lotic (flowing) water. Lotic systems are less prone to stress from sediment, nutrients, and pesticides because the running water flushes away pollutants. Lentic bodies, such as ponds and lakes, are more prone to pollutant stress because they retain many pollutants within their system. Impounded or dammed rivers flush out pollutants at rates which are between those for lakes and free-flowing rivers.

Lentic Systems (Lakes or Ponds)

The naturally occurring geologic process whereby lakes fill with sediment and eventually become dry land is termed "lake succession." Sediment is deposited concentrically from the outer edges to the center of the basin. Thus, a transect from the shoreline to the lake center crosses successively younger geologic sediment deposits. This concentric or horizontal zonation of sediment is reflected in concentric bands of vegetation.

Rooted aquatic plants progressively encroach toward the center from the shoreline. Large plants (macrophytes), such as cattails, alligator weed, and smartweed, generally occur in a band along the water's edge. Floating, leaved, emergent plants, such as waterlilies and American lotus root, (fig. B–7; see appendix B) occur in the bottom muds at shallow depths (0–5 feet). These plants are flanked on the inside (toward the lake/pond center) by a band of submerged rooted weeds, such as watermilfoil, coontail, and pondweed (fig. B–7). The submerged plants usually grow to a depth of about 10 feet, depending upon wave action and turbidity of the water. The region of open water is inhabited by nonrooting plants of two types, (1) microscopic floaters or plankton species (fig. B–1 to B–6), and (2) macroscopic floating species, such as duckweed (ref. 3–1, 3–2).

Associated with lake succession is eutrophication or lake enrichment by nutrients. The nutrient load of a water body is not directly observable. However, since nutrients stimulate plant growth, the biomass (total weight) of lake or pond aquatic vegetation can serve as an indirect indicator of nutrient levels. Since plants serve as food for animals, an abundance of plants often means there will be an abundance of fish and other animals. The biomass of plants and animals living in a given water body area in a unit of time is called "biological productivity."

Lentic (standing) waters are classified in biological productivity terms as: (1) "oligotrophic" (young, low productivity); (2) "mesotrophic" (middle aged, medium productivity); or (3) "eutrophic" (old, high productivity) (ref. 3–3).

Oligotrophic lakes are those which are young, geologically speaking, or are located in an infertile watershed. They are characterized by low levels of nutrients and consequently low levels of biological productivity. Having a low volume of plants (phytoplankton) contained in a large volume of water, these water bodies appear crystal clear. Since there is not much plant food at the base of the food chain, top predators, such as prized sport fish, are not abundant. Lake Superior, Lake Tahoe, and Crater Lake are examples of oligotrophic lakes. In these deep blue, clear waters fish can be seen at considerable depths from the surface.

Mesotrophic lakes are the so called "middle-aged" lakes which have a greater amount of nutrients per unit volume of water compared to oligotrophic lakes. They are more productive and have quite an abundance of organisms that are high on the food chain. For example, a 50 million pound catch of the highly edible lake trout, whitefish, blue-pike, and walleye from Lake Erie was recorded in 1920. Many of the lakes, bays and estuaries prized for their fisheries are mesotrophic (ref. 3–4, 3–5).

Eutrophic lakes have great productivity and high nutrient turnover. Water quality in these lakes with excessive nutrients can deteriorate so much that the lakes become unfit for human use. Human-induced (cultural) eutrophication may result in unsightly scums of surface algae, dead fish, and weeds washed up in mounds along the shoreline. The noxious smell of rotten eggs may result from hydrogen sulfide bubbling to the surface from the decaying organic matter.

The process of natural versus human-induced eutrophication and the presence of eutrophication indicators are discussed in more detail in Chapter 5.

Lotic Systems (Streams or Rivers)

As with plants and animals, watercourses progress through a natural life cycle from youth to old age. A young stream flows in a fairly straight path and cuts deeply into its parent soil material. In hilly terrains, it produces a narrow V-shaped valley with steep-sloped banks. As the stream matures, its path begins to meander, cutting into adjacent slopes and widening the valley. By old age, the stream has created a broad V-shaped valley and meanders back and forth within a broad flood plain (ref. 3–6).

Thus, a stream is not static, but is a delicately balanced system, ever changing in response either to natural events or to human activities. In a well-balanced "ideal" condition a stream has smooth, gentle banks—well vegetated banks free from erosion or failure—and a channel bed that is neither scouring nor building up with sediment. However, this situation seldom occurs in nature. Instead, we find streams in a continual state of adjustment, responding to the environment. It is not uncommon to find in riparian (stream bank) areas, cattle-grazing, fallen trees, or debris. Fallen trees or debris can deflect water from its main course, causing it to undercut the bank and lose vegetation. Protective vegetative cover in the watershed may be lost as land is converted to cropland or to urban development. The watercourse's adjustment to these ecological disturbances usually occurs not just at the site of the disturbance, but in domino-like fashion along a significant stretch downstream from the activities (ref. 3–7).

A watercourse adjusts to environmental effects by changing the shape of its bed, banks, or both. In an unbalanced condition, the bed will be either degrading (being scoured out) or aggrading (depositing excess sediment). Either situation is unstable and can lead to significantly adverse conditions. For example, if the bank toe is eroding, bank failure can result. If the streambed is rising, channel capacity will be reduced. In the next flood, the stream will attempt to stabilize and restore itself to its original capacity by scouring out the bed and in many cases eroding the banks as well (ref. 3-7).

Watercourse bottom materials (substrates) will vary depending upon regional geology and topography. In steep terrain, swiftly flowing waters often cut deep channels and keep the streambed scoured of sediments. By contrast, slowly flowing streams in level terrain are usually characterized by shallow beds and substrates composed mainly of sediment. Exceptions exist to the above situation, reflecting the geology of a region. For example, there are some high-velocity watercourses possessing fine bottom materials and some low-velocity watercourses with coarse bottom materials.

In general, stream flow or velocity varies according to the shape, size, slope, and roughness of the channel. Velocities range from slow (0.1 m/sec or 0.3 ft/sec); to moderate (0.25–0.5 m/sec or 0.8–1.6 ft/sec); to swift (1.0 m/sec or 3.2 ft/sec), depending on channel characteristics. Stream velocity determines in large measure the type of bottom materials present, which in turn influence the kinds and number of organisms that can live on the streambed. Erosion of sand and gravel river beds occurs at velocities greater than 1.7 m/sec (5.6 ft/sec). Gravel settles at velocities ranging from 1.2-1.7 m/sec (3.9-5.6 ft/sec). Sand settles at velocities of 0.25-1.2 m/sec (0.8-3.9 ft/sec), and silt and organics deposit when velocities drop to 0.2 m/sec (0.7 ft/sec) and less (ref 3-8).

Biology of Streams

Watercourses having cobble and gravel beds (i.e., those that are degrading or eroding) support the greatest diversity of invertebrate life. The cobble or gravel bottom is stable and provides hiding places that bottom-dwelling animals need for protection. Usually, these streams have alternating pools (deep, slow-moving water) and riffles (shallow, fast-moving water). The greatest insect production occurs in riffles with rocks of 6 in. to 12 in. on a side (ref. 3–9).

The presence of larval insect species, such as stoneflies, caddisflies, and mayflies in riffle areas of cobble/gravel bottom streams, is an indicator of "clean" water. Although the presence of these species indicates "clean" waters, absence of these species does not always mean polluted water. There are many reasons why the species might be absent. For example, they may have been exterminated by a recent flood or drought and not have had time to recolonize. Or recolonization may be impossible due to limited flight range of the insect or simply because there may be no individuals available to recolonize the location. No single insect or other invertebrate by itself can indicate pollution, but a group or association of indicator organisms can indicate the presence or absence of pollution (ref. 3–10). Refer to appendix A for biological index methods.

Aggrading or depositing streams with silt or mud bottoms support invertebrate species, such as tube-building worms, burrowing mayflies, "blood worm" midges (chironomids), mussels, and clams. The deepest parts of very large rivers, such as the Mississippi and its large tributaries, support few, if any, bottom-dwelling species because their silty bottoms are unstable.

Intermediate between cobble/gravel and mud/silt streambeds are sandy beds. Sandy bottoms support very few, if any, invertebrate species because shifting sands provide few stable surfaces to which organisms can attach.

Watercourses with slow, relatively clear waters or pools support the greatest amount of plant growth. Plants common to these waters include submerged periphyton species, such as algal or vegetative masses growing on bottom substrate materials, on twigs, or on larger rooted aquatic plants. Rooted aquatics can be either submergent species, such as *Elodea* (American waterweed), or emergents, such as the broad leaved species of *Potamogeton* (pondweed) (fig. B–7) and *Nasturtium* (watercress). These species root in the fine sediments of pools or along stream margins (ref. 3–1).

The kind and amount of aquatic vegetation in watercourses or bodies depend on a variety of factors, including flow rate, bottom type, sunlight amount, nutrient levels, and water depth. While the amounts of nutrients coming from agricultural lands might be significant, any pollutional effects from the nutrients might be minimized or "masked" by too little sunlight reaching aquatic plants for photosynthesis. Reduced sunlight can be caused by many factors, including heavy siltation of the water, dense vegetative canopy over watercourses, depth of water, etc.

Watercourses may be classified on the basis of the type of fishery they support. There are cold water, cool water, and warm water fisheries. Cold water fish include salmonid species, such as trout and salmon (fig. B–12), which are members of the trout family. These species occur in well oxygenated streams that have a swift current. Trout grow best in waters between 50 and 65 degrees Farenheit. They are insect-feeders, eating species such as mayflies and stoneflies.

The smallmouth bass (fig. B–12) is typical of cool water fisheries and is found in lower stream reaches that are marginal for trout. The bass prefer a habitat of riffles and deep pools. Home range is normally restricted to one pool where the bass feed on insects or crayfish flushed out by turtles and bottom-feeding fishes.

Where water temperatures are higher, warm water species, such as largemouth bass, crappie, bluegill, and catfish are found (fig. B–12). The largemouth bass is a predator that feeds on almost any animal which swims or falls in the water (fish, crayfish, large insects, frogs, snakes, mice). It is one of the most popular warm water fish in North America. These fish are mainly invertebrate eaters except for the catfish, which eats both plants and animals (ref. 3–11, 3–12). See appendix B for fish illustrations and descriptions.

Chapter 4

Sediment

In the United States today, watersheds are adversely affected by agriculturally related pollutants. Sediment, probably the most common and most easily recognized of the nonpoint source pollutants, ranks first in quantity among pollutants contributed by agriculture to receiving waters. Cropland erosion accounts for 40 to 50 percent of the approximately 1.5 billion tons of sediment that reaches the Nation's waterways each year. Streambank erosion accounts for another 26 percent (ref. 4–1). The amount of sediment eroding from agricultural areas is directly related to land use—the more intensive the use, the greater the erosion. For example, in a given locality more sediment erodes from row crop fields than from pastures or woodlands.

Sediment lost from agricultural sites varies significantly with the presence or absence of management practices. Figure 4–1 shows that considerably more sediment is lost from agricultural land in row crops without management practices than in row crops with management practices. The least amount of sediment is lost from agricultural lands that have conservation cropping systems, i.e., practices such as cover crops and conservation tillage (ref. 4–2).

Sediment Indicators for Receiving Waters

1. Turbidity (Refer to Field Sheet 1A, rating item 1, figure 4–2.)

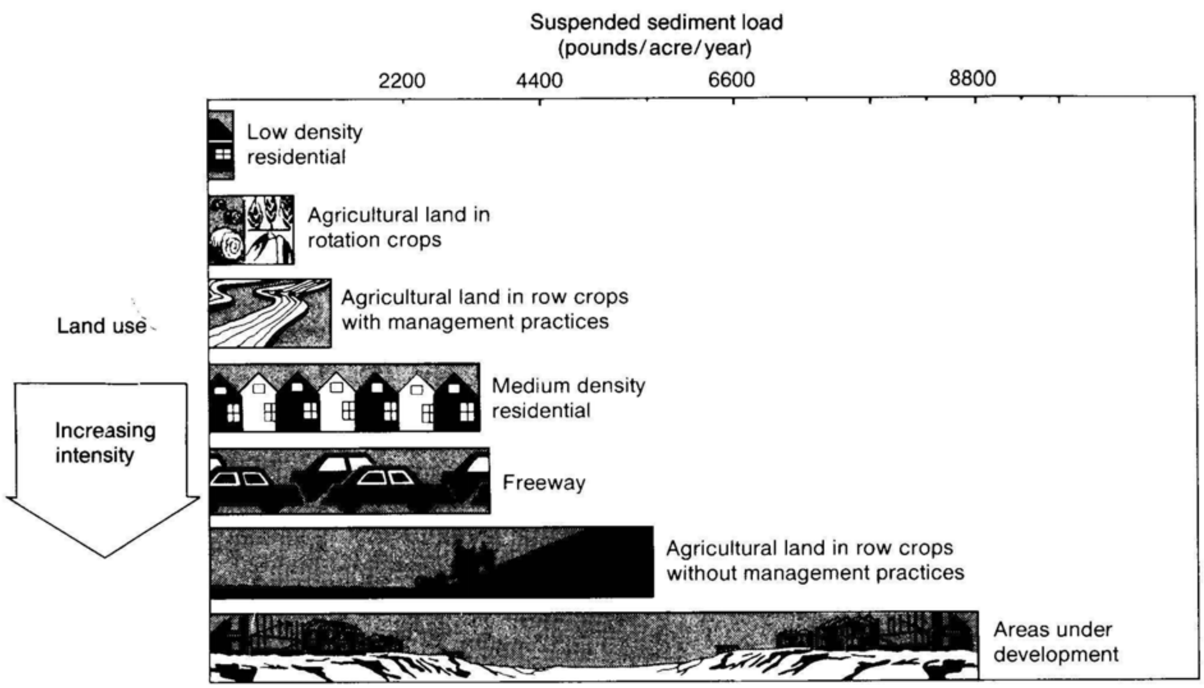
To assess sediment pollution, it is necessary to observe receiving waters during or immediately following a storm event. Sediment-laden runoff, whether from overland flow or bank erosion, muddies receiving waters, and turbidity in the form of suspended solid matter increases. As turbidity increases, light penetration decreases, making objects less visible at greater depths.

If the receiving waters appear turbid, the cause must be determined. Problem sources may be overland flow paths or channels that drain from fields and pastures into receiving waters. The muddier (thicker and denser) the overland flows, the greater the sediment load. Evidence of bank erosion should be noted.

If receiving waters are turbid, but runoff water from overland flow is essentially clear (e.g., runoff from a densely vegetated pasture), and there appears to be no bank erosion

Figure 4-1

Sediment Losses Related to Land Use Practices.



Source: Wisconsin Department of Natural Resources, Ref. 4-2.

Figure 4-2

Sediment Page 1 of 2

FIELD SHEET 1A: SEDIMENT
INDICATORS FOR RECEIVING WATERCOURSES AND WATER BODIES

Evaluator ______ County/State ______ Date ______

Water Body Evaluated ______ Water Body Location ______ Total Score/Rank ______

Rating Item	Excellent	Good	Fair	Poor
	(Circle one number among the four choices in each row which BEST describes the conditions of the watercourse or water body being evaluated. If a condition has characteristics of two categories, you can "split" a score.)			
1. Turbidity (best observed immediately following a storm event)	-- What is expected under pristine conditions in your region. -- Clear or very slightly muddy after storm event. -- Objects visible at depths greater than 3 to 6 ft. (depending on water color). -- OTHER 9	-- What is expected for properly managed agricultural land in your region. -- A little muddy after storm event but clears rapidly. -- Objects visible at depths between 1½ to 3 ft. (depending on water color). -- OTHER 7	-- A considerable increase in turbidity for your region. -- Considerable muddiness after a storm event. Stays slightly muddy most of the time. -- Objects visible to depths of ½ to 1½ ft. (depending on water color). -- OTHER 3	-- A significant increase in turbidity for your region. -- Very muddy—sediment stays suspended most of the time. -- Objects visible to depths less than ½ ft. (depending on water color). -- OTHER 0
2. Bank stability in your viewing area	-- Bank stabilized. -- No bank sloughing. -- Bank armored with vegetation, roots, brush, grass, etc. -- No exposed tree roots. -- OTHER 10	-- Some bank instability. -- Occasional sloughing. -- Bank well-vegetated. -- Some exposed tree roots. -- OTHER 7	-- Bank instability common. -- Sloughing common. -- Bank sparsely vegetated. -- Many exposed tree roots & some fallen trees or missing fence corners, etc. -- Channel cross-section becomes more U-shaped as opposed to V-shaped. -- OTHER 4	-- Significant bank instability. -- Massive sloughing. -- No vegetation on bank. -- Many fallen trees, eroded culverts, downed fences, etc. -- Channel cross-section is U-shaped and stream course or gully may be meandering. -- OTHER 1
3. Deposition (Circle a number in only A, B, C, or D)	SELECT 3A OR 3B OR 3C OR 3D			
3A. Rock or gravel streams OR	A. For rock and gravel bottom streams: -- Less than 10% burial of gravels, cobbles, and rocks. -- Pools essentially sediment free. 9	A. For rock and gravel bottom streams: -- Between 10% & 25% burial of gravels, cobbles, & rocks. -- Pools with light dusting of sediment. 7	A. For rock & gravel bottom streams: -- Between 25% and 50% burial of gravels, cobbles and rock. -- Pools with a heavy coating of sediment. 3	A. For rock & gravel bottom streams: -- Greater than 50% burial of gravels, cobbles and rocks. -- Few if any deep pools present. 1
3B. Sandy bottom streams OR	B. For sandy streambeds: -- Sand bars stable and completely vegetated. -- No mudcaps or "drapes" (coverings of fine mud). -- No mud plastering of banks; exposed parent material. -- No deltas. 9	B. For sandy streambeds: -- Sand bars essentially stable and well, but not completely, vegetated. -- Occasional mudcaps or "drapes." -- Some mud plastering of banks. -- Beginnings of delta formation. 7	B. For sandy streambeds: -- Sand bars unstable with sparse vegetation. -- Mudcaps or "drapes" common. -- Considerable mud plastering of banks. -- Significant delta formation. 3	B. For sandy streambeds: -- Sand bars unstable and actively moving with no vegetation. -- Extensive mudcaps or "drapes." -- Extensive mud plastering of banks. -- Extensive deltas. 1
3C. Mud-bottom streams OR	C. For mud bottom streams: -- Dark brown/black tanic-colored water (due to presence of lignins and tanins). -- Abundant emergent rooted aquatics or floating vegetation. 9	C. For mud bottom streams: -- Dark brown colored water. 7	C. For mud bottom streams: -- Medium brown water, muddy bottom. 3	C. For mud bottom streams: -- Light brown colored, very muddy bottom. 1

Figure 4-2

Sediment Page 2 of 2

FIELD SHEET 1A: SEDIMENT, Continued
INDICATORS FOR RECEIVING WATERCOURSES AND WATER BODIES

Rating Item	Excellent	Good	Fair	Poor
3D. Ponds	-- Ponds essentially sediment free. -- No reduction in pond storage capacity. -- OTHER 9	-- Ponds with light dusting of sediment. -- Very little loss in pond storage capacity. -- OTHER 7	-- Ponds with a heavy coating of sediment. -- Some measurable loss in pond storage capacity. -- OTHER 3	-- Ponds filled with sediment. -- Significant reduction in pool storage capacity. -- OTHER 1
4. Type and amount of aquatic vegetation & condition of periphyton (plants, growing on other plants, twigs, stones, etc.)	-- Periphyton bright green to black. Robust. -- Abundant emergent rooted aquatics or shoreline vegetation. -- In ponds, emergent rooted aquatics (e.g. cattails, arrowhead, pickerelweed, etc.) present, but in localized patches. -- OTHER 9	-- Periphyton pale green and spindly. -- Emergent rooted aquatics or shoreline vegetation common. -- In ponds, emergent rooted aquatics common, but confined to well-defined band along shore. -- OTHER 7	-- Periphyton very light colored or brownish and significantly dwarfed. -- Sparse vegetation. -- In ponds, emergent rooted aquatics abundant in wide bank; encroachment of dry land species (grasses, etc.) along shore. -- OTHER 5	-- No periphyton. -- No vegetation. -- In ponds, emergent rooted aquatics predominant with heavy encroachment of dry land species. -- OTHER 2
OPTIONAL: 5. Bottom stability of streams	-- Stable. -- Less than 5% of stream reach has evidence of scouring or silting. -- OTHER 9	-- Slight fluctuation of streambed up or down (aggradation or degradation). -- Between 5-30% of stream reach has evidence of scouring or silting. -- OTHER 7	-- Considerable fluctuation of streambed up or down (aggradation or degradation). -- Scoured or silted areas covering 30-50% of evaluated stream reach. -- Flooding more common than usual. -- More stream braiding than usual for region. -- OTHER 3	-- Significant fluctuation of streambed up or down (aggradation or degradation). -- More than 50% of stream reach affected by scouring or deposition. -- Flooding very common. -- Significantly more stream braiding than usual for region. -- OTHER 1
OPTIONAL: 6. Bottom dwelling aquatic organisms	-- Intolerant species occur: mayflies, stonefiles, caddisflies, water penny, riffle beetle and a mix of tolerants. -- High diversity. -- OTHER 9	-- A mix of tolerants: shrimp, damselflies, dragonflies, black flies. -- Intolerants rare. -- Moderate diversity. -- OTHER 7	-- Many tolerants (snails, shrimp, damselflies, dragon flies, black flies). -- Mainly tolerants and some very tolerants. -- Intolerants rare. -- Reduced diversity with occasional upsurges of tolerants, e.g. tube worms and chrionomids. -- OTHER 3	-- Only tolerants or very tolerants: midges, craneflies, horseflies, rat-tailed maggots, or none at all. -- Very reduced diversity; upsurges of very tolerants common. -- OTHER 1

TOTAL [ ]

1. Add the circled Rating Item scores to get a total for the field sheet.
2. Check the ranking for this site based on the total field score. Check "excellent" if the score totals at least 32. Check "good" if the score falls between 21 and 31, etc. Record your total score and rank (excellent, good, etc.) in the upper right-hand corner of the field sheet. If a Rating Item is "fair" or "poor," complete Field Sheet 1B.

RANKING	Excellent (32-37) [ ]	Good (21-31) [ ]	Fair (9-20) [ ]	Poor (8 or less) [ ]
OPTIONAL RANKING (with #5 OR #6)	Excellent (40-46) [ ]	Good (26-39) [ ]	Fair (11-25) [ ]	Poor (10 or less) [ ]
OPTIONAL RANKING (with #5 AND #6)	Excellent (48-55) [ ]	Good (31-47) [ ]	Fair (13-30) [ ]	Poor (12 or less) [ ]

(e.g., banks well vegetated), the turbidity may be due to stirred-up mud deposits of the stream bottom. This is common in regions characterized by muddy-bottom streams. In this situation, the regional environmental quality would be considered "excellent" despite the muddiness because conditions match what is expected under pristine conditions in that particular geographic region.

2. **Bank stability** (Refer to Field Sheet 1A, rating item 2, figure 4-2.)

To determine if streambanks are contributing sediment to receiving waters, look for the following indicators:

- Evidence of bank instability—cracks, rills, and gullies.
- Evidence of bank sloughing or chunks of soil dropping into the stream.
- Extent of vegetative protective cover or "armoring."
- Extent of exposed tree roots, fallen trees, missing fence posts, etc.
- The appearance of the channel in cross-section (adapted from Keown, ref. 3-7).

3. **Deposition** (Refer to Field Sheet 1A, rating item 3, figure 4-2.)

Watercourses are distinguished on the basis of their type of bottom substrate—rock, gravel, sand, or mud. Deposition occurs when water flow is insufficient to remove sediment entering receiving waters.

Note that this field sheet gives four choices for deposition. Items 3A, 3B, and 3C refer to streams or flowing waters, while item 3D refers to ponds or stationary waters.

Indicators of deposition vary with the type of bottom substrate. In rock and gravel streams, the relative degrees of burial of gravels, cobbles, and rocks in riffle (fast-flowing, shallow) areas are important as well as the thickness of sediment coatings in pool areas (see item 3A). For sandy streambanks the condition and stability of sandbars and the presence and frequency of mudcaps (drapes), mud plastering, and delta formation are important (see rating item 3B). For mud-bottom streams, water color is especially important (rating item 3C). In this case, it is essential to be familiar with waters of your region. You can gain familiarity with the "normal" color of local streams quickly by several onsite visits before and immediately following a storm event. Finally, indicators of pond degradation are thickness of the sediment coat and the relative degree of reduction in permanent pond storage capacity (see rating item 3D).

4. **Type and amount of aquatic vegetation and condition of periphyton** (plants growing on other plants, twigs, stones, etc.) (Refer to Field Sheet 1A, rating item 4, figure 4-2).

In those waters where aquatic vegetation is typical of that expected under pristine conditions in your geographic region, sediment load may become great enough to interfere with plant growth and reproduction. For example, periphyton (small aquatic plants that grow on submerged plants, twigs, stones, etc.) may create a "dusting" or coating on aquatic plants, reducing their photosynthesis. Sediment (silt) may also accumulate on aquatic plants and add to the poor environmental conditions. Aquatic plants may appear to be paler green and more spindly than the robust green condition that is found where light penetration is maximal. Where there is considerable sediment deposition, aquatic plants may never reach full size and are not able to reproduce. Eventually, as occurred in the Chesapeake Bay, an entire population of aquatic plants may smother and die.

5. **Bottom stability of watercourses** (Refer to Field Sheet 1A, rating item 5, figure 4-2).

In instances where historical records are available, bottom stability might serve as an indicator of sediment pollution. For example, aggradation (raising of streambeds) is an indicator of sediment deposition. Deposition is sometimes greatly accelerated by logjams or other stream obstructions. These obstructions can slow water to an extent that sediment that usually is flushed through the system has time to settle out. Given enough time, this type of deposition can lead to a significant rise in the streambed with a number of attending consequences. One consequence is that the flow becomes shallow and spreads out over a wide area, resulting in increased flooding and increased stream "braiding," the formation of many small rivulets. It may also result in the death of economically valuable bottomland hardwood trees. In such instances, it may be necessary to dredge or dynamite a channel to restore water flow to its original depth. An increased need for dredging is a good indicator that sediment deposition has increased (ref. 4-3).

Chapter 5

Nutrients

Natural and Human-Induced (Cultural) Eutrophication

Eutrophication is a natural aging process that occurs as a lake or pond becomes increasingly enriched with nutrients. The rate of eutrophication varies, depending upon the relative fertility of the watershed. It proceeds most slowly in big lakes situated in relatively infertile watersheds and most quickly in small ponds in fertile surroundings.

Eutrophication can be natural or human-induced (fig. 5–1). Eutrophication, resulting from human activity, such as fertilizing fields or converting forest or pasture to cropland, is termed human-induced (cultural) to distinguish it from natural eutrophication. In most instances, the rate of human-induced eutrophication is many times faster than the natural process. For example, in a span of about 25 years (1950-1975), Lake Erie aged to about the same degree under human influences as would have occurred in 15,000 years naturally (ref. 5–1). Today, some 75 percent of the large lakes in the United States are considered to be eutrophic (ref. 5–2).

Eutrophication rates are increased by agricultural inputs of nutrients—phosphorus and/or nitrogen. Usually, these inputs come from either fertilizer runoff or erosion from fields or pastures.

Indicators of Excessive Nutrient Input for Receiving Waters

****LIMITATIONS OF NUTRIENT FIELD SHEET 3A****

Nutrient indicators may not be perceptible in certain watercourses, especially if flow is 0.5 feet per second or greater or if sediment "masks" the effects of nutrient enrichment. Appendix A contains a procedure ("Floating Body Technique") that can be used to obtain water flow rate velocity. With rapid water flow, a watercourse could be rated "good" or "excellent" according to the 3A Nutrient Field Sheet (fig. 5-2), when in fact it could contain high nutrient levels.

In the above situations it may be advantageous to use the 3B Nutrient Field Sheet first to determine if present agricultural management practices may be contributing to nutrient enrichment in the nearby watercourse.

Additionally, it may be necessary to conduct or have conducted nutrient chemical analyses or to contact the State water quality agency to get nutrient values for the watercourse being examined.

Figure 5-1

Advanced Eutrophication of a Pond.

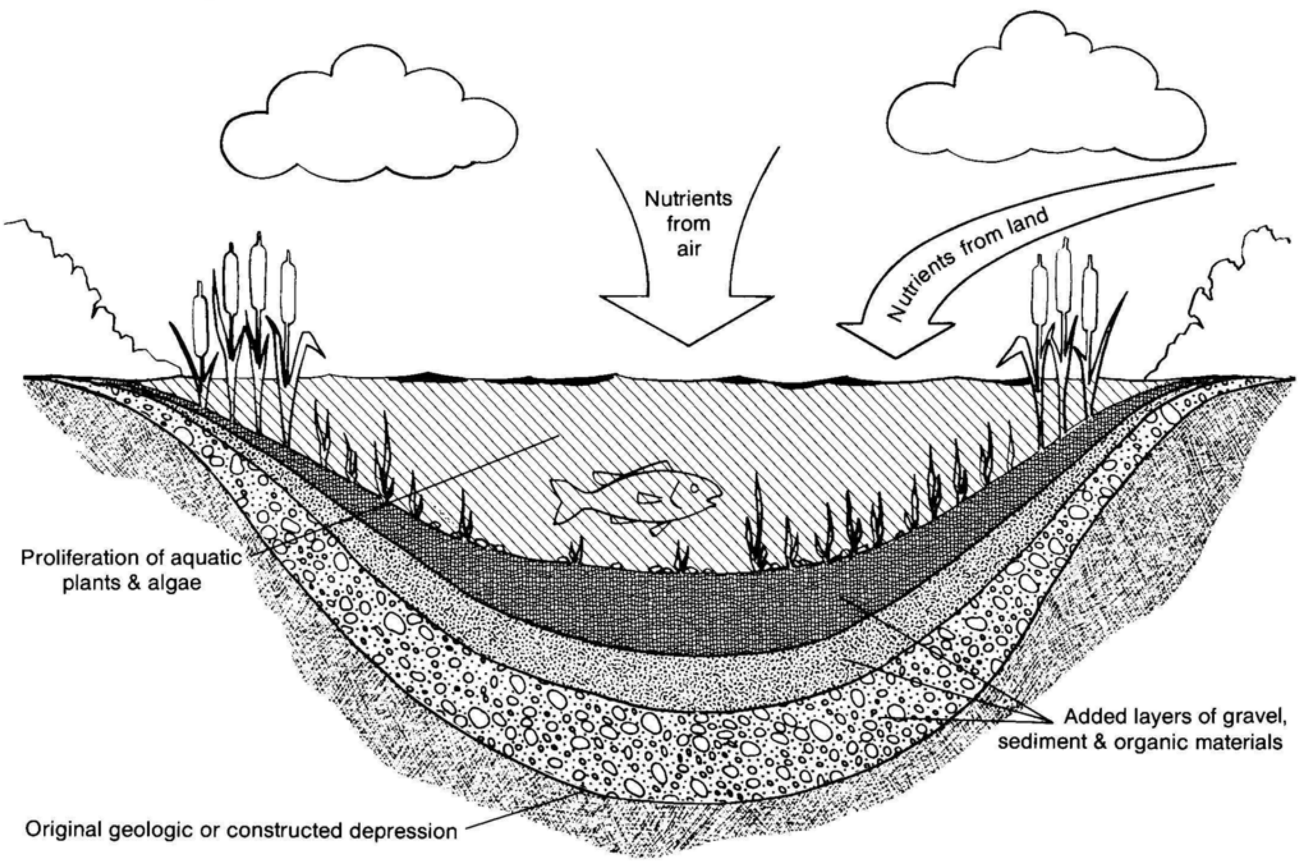


Figure 5-2

Nutrients

FIELD SHEET 3A: NUTRIENTS
INDICATORS FOR RECEIVING WATERCOURSES AND WATER BODIES*

Evaluator ____________________ County/State ____________ Date ____________
Water Body Evaluated ____________ Water Body Location ____________ Total Score/Rank ____________

(Circle one number among the four choices in each row which BEST describes the conditions of the watercourse or water body being evaluated. If a condition has characteristics of two categories, you can "split" a score.)

Rating Item	Excellent	Good	Fair	Poor
1. Total amount of aquatic vegetation at low flow or in pooled areas. Includes rooted and floating plants, algae, mosses & periphyton	Little vegetation, uncluttered look to stream or pond. OR What's expected for good water quality conditions in your region. Usually fairly low amounts of many different kinds of plants. OTHER 10	Moderate amounts of vegetation. OR What's expected for good water quality conditions in your region. OTHER 6	Cluttered weedy conditions. Vegetation sometimes luxurious and green. Seasonal algal blooms. OTHER 3	Choked weedy conditions or heavy algal blooms or no vegetation at all. Dense masses of slimy white, greyish green, rusty brown or black water molds common on bottom. OTHER 0
2. Color of water due to plants at base or low flow	Clear or slightly greenish water in pond or along the whole reach of stream. OTHER 9	Fairly clear; slightly greenish. OTHER 6	Greenish. Difficult to get pond sample without pieces of algae or weeds in it. OTHER 3	Very, very green pond scums. Pea green color or pea soup condition during seasonal blooms of microscopic algae in ponds. "Oily-like" sheen when pea soup algae die off. OTHER 0
3. Fish behavior in hot weater fish kills, especially before dawn	No fish piping or aberrant behavior. No fish kills. OTHER 9	In hot climates, occas-sional fish piping or gulping for air in ponds just before dawn. No fish kills in last two years. OTHER 5	Fish piping common just before dawn. Occasional fish kills. OTHER 3	Pronounced fish piping. Pond fish kills common. Frequent stream fish kills during spring thaw. Very tolerant species (e.g. bullhead, catfish). OTHER 0
4. Water use impacts; health effects for whole sub-watershed	None. OTHER 8	Minimal, such as reduced quality of fishing. OTHER 7	A couple of the following: Algal clogged pipes. Algal related taste, color, or odor problems with human or livestock water supply. Cattle abortion. Reduced recreational use due to weedy conditions, decay, odors, etc. OTHER 4	Several of the following: Algal clogged pipes. Algal related taste, color, or odor problems with human or livestock water supply. Cattle abortion. Reduced quality of fishery. Reduced recreational use due to weedy conditions, decay, odors, etc. Blue babies—incidence of methemoglobinemia due to high nitrate levels. Property devaluation. OTHER 2
5. Bottom-dwelling aquatic organisms	Intolerant species occur: mayflies, stonefiles, caddisflies, water penny, riffle beetle. High diversity. OTHER 9	Intolerants common. A mix of tolerants: shrimp, damselflies, dragonflies, black flies. Moderate diversity. OTHER 7	Mainly tolerants: snails, shrimp, damselflies, dragonflies, black flies. Mainly tolerants, but some very-tolerants. Intolerants rare. Reduced diversity with occasional upsurges of tolerants, e.g. tube worms, and chironomids. OTHER 3	Mainly very-tolerants: midges, craneflies, horseflies, rat-tailed maggots, or no organisms at all. Very reduced diversity, upsurges of very-tolerants common. OTHER 1

*The effects of nutrients may be "masked" by high sediment loads, creating sufficient turbidity to shade light-dependent aquatic vegetation. This may cause aquatic vegetation, a water quality indicator, to die and disappear from the watercourse. To obtain accurate nutrient levels in high sediment situations, chemical testing may be necessary. Under these circumstances you should contact a local or other water quality specialist.

1. Add the circled Rating Item scores to get a total for the field sheet. TOTAL [ ]
2. Check the ranking for this site based on the total field score. Check "excellent" if the score totals at least 38. Check "good" if the score falls between 23 and 37, etc. Record your total score and rank (excellent, good, etc.) in the upper right-hand corner of the field sheet. If a Rating Item is "fair" or "poor," complete Field Sheet 3B.

RANKING Excellent (38-45) [ ] Good (23-37) [ ] Fair (9-22) [ ] Poor (8 or less) [ ]

1. **Total amount of aquatic vegetation** (Refer to Field Sheet 3A, rating item 1, figure 5–2.)

Aquatic vegetation must be supplied with a sufficient quantity of nutrients to grow and reproduce. Vegetative growth in many waterways and bodies is held in check by a limited amount of an available nutrient, i.e., the limiting nutrient. Typically, waters are phosphorus limited, although in some areas the waters naturally contain high phosphate levels and nitrogen is the limiting nutrient.

Agriculturally related inputs of phosphorus, nitrogen, or both to nutrient-limited waters promote aquatic plant growth. With minimal additions of nutrients, plants may appear even more robust and luxurious than usual. For example, watercress that has additional nutrients may be darker green than normal. By contrast, moderate amounts of nutrients may result in noticeable increases in plant biomass. Stands of watercress under this condition might enlarge considerably in surface area. Heavy additions of nutrients can stimulate weedy proliferations or extensive algal blooms. Sometimes this potential is not realized, such as when sediment loads are so great that light becomes the limiting factor for plant growth. In this instance, sediment masks the expected effects of nutrient enrichment.

When a watercourse or water body regularly displays symptoms of heavy nutrient enrichment, such as extensive algal slimes (scums) or weedy proliferations, it is labelled "eutrophic." It is common for these eutrophic waters to be clogged with vegetation. In general, standing bodies of water are more prone to eutrophication than flowing waters, although even streams may appear quite clogged during periods of low flow.

Many types of aquatic vegetation, such as watermilfoil and many algae, die back at the end of summer in response to unidentified seasonal environmental influences. When significant masses of vegetation die simultaneously, the biochemical oxygen demand (BOD) of the water increases dramatically and the amount of dissolved oxygen (DO) drops precipitously as oxygen-requiring (aerobic) micro-organisms begin the process of decomposition. These lowered DO levels stress all aquatic organisms, both animals and plants, and may lead to fish kills and the elimination of all vegetation. This is discussed further in the next section.

2. **Color of water** (Refer to Field Sheet 3A, rating item 2, figure 5–2).

Excessive growth of microscopic plants or algae (phytoplankton, figs. B–1 to B–6) often manifests itself as a change in the color of the water. Ponds in particular might assume a deeper color of various shades of green, blue-green, red, gray, or yellow depending upon the phytoplankton species present. Blue-green algae can undergo tremendous growth in numbers when phosphorus is added, so that the water can become like pea soup. Furthermore, blue-greens can survive nitrogen deficient conditions because they are able to utilize atmospheric nitrogen in much the same manner as soil bacteria in the nodules of legumes. In addition, many blue-greens secrete toxins or foul-tasting chemicals, making them most unattractive as food to other organisms.

Animal plankton (zooplankton— small, floating or feebly swimming animals), such as water fleas, rotifers, and copepods, which usually graze on the phytoplankton (plant plankton) avoid blue-green algae. As a result, blue-green algae can grow unchecked by predators until the algae die in massive amounts. The decay of algal overgrowths leads to fluctuating oxygen levels and to periodic oxygen depletions (anoxia) that sometimes result in fish kills (fig. 5–3). During extended periods of anoxia, vegetation of all types is destroyed during the nights, when photosynthesis does not occur (ref. 5-3).

3. **Fish diversity, behavior and fish kills** (Refer to Field Sheet 3A, rating item 3, figure 5–2.)

Nutrient enrichment can lead to the simplification of food webs by the elimination of sensitive species, which are the least able to cope with adverse conditions. Long-lived organisms that reproduce slowly and require extended periods of stable conditions fare worst in unstable eutrophied waters. In particular, fish populations often shift from dominance by larger, top predator game species to dominance by smaller, less desirable forage (rough) species. For example, in Lake Erie the long-lived highly edible sport fish, such as lake trout, whitefish, pike, and walleye, were replaced by "rough" fish—carp, smelt, drum, and alewives (fig. B–12, ref. 5–1.)

Sensitive species, such as sport fish, decline because they cannot tolerate the periodic episodes of:

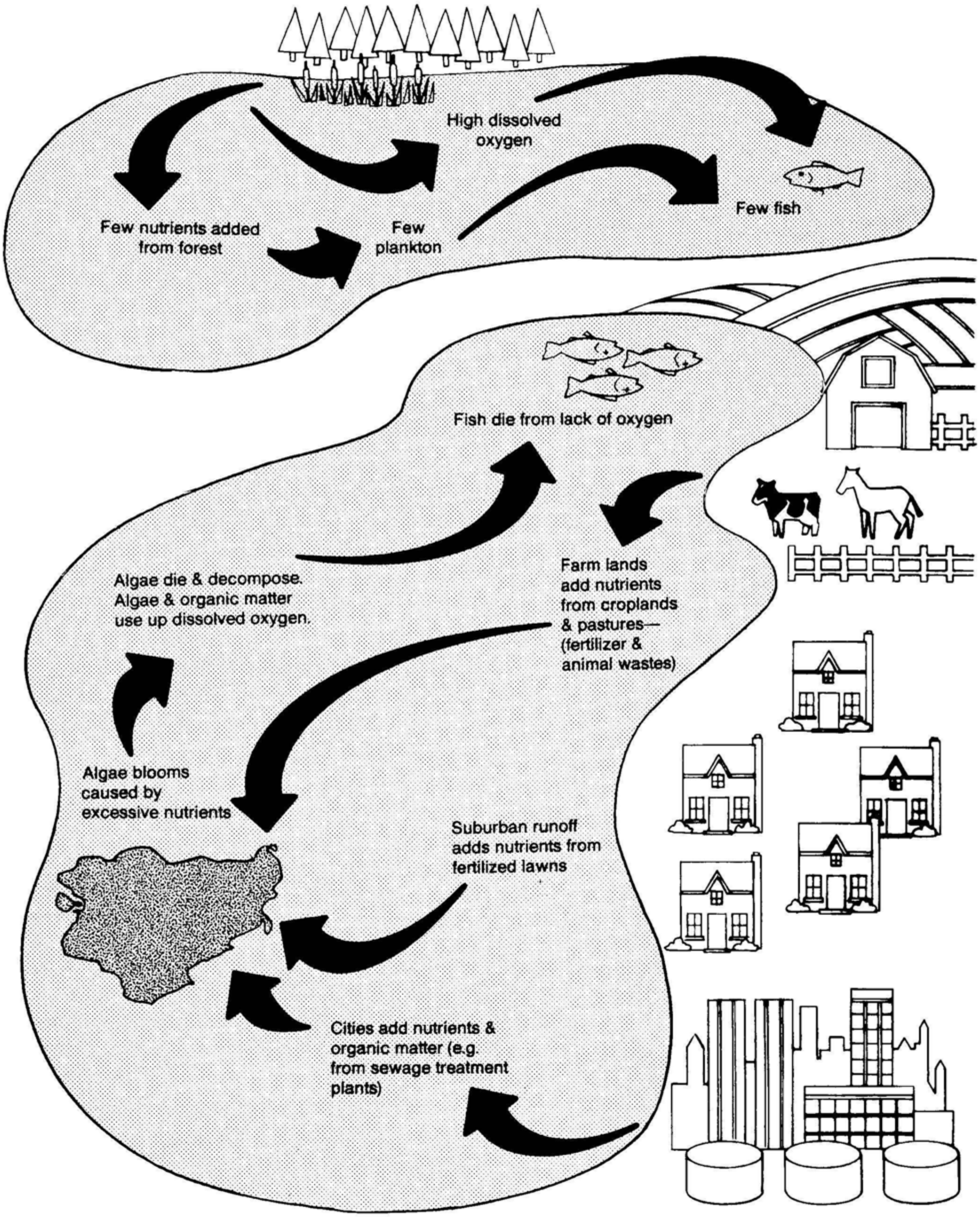
- Low dissolved oxygen levels (anoxia) due to the decomposition by micro-organisms of massive amounts of dead plants;
- Toxicity due to the release of the poisonous gases (hydrogen sulfide and methane) by anaerobic micro-organisms during anoxic conditions;
- Toxicity due to secretions from some blue-green or dinoflagellate algal blooms; or
- Some combination of the above activities with other major agricultural pollutants (adapted from Luoma, ref. 5–3).

The loss of species diversity, as sensitive species die, is undesirable for both economic and ecological reasons. The loss of sport fish from a lake may constitute a major economic loss to sport fishermen and local businesses dependent upon the fishermen.

Ecologically, simplification of a food web is a "warning signal" or indicator that the whole ecosystem is unhealthy and may be in jeopardy. An unhealthy system is more vulnerable than a healthy "diverse" system to further disruptions or disturbances, whether natural or caused by human activities.

Figure 5-3

The Eutrophication Process.



Fish kills can occur in ponds that receive excessive nutrient inflows. Three common scenarios for eutrophied ponds are described below, namely:

- Floating Plant (macrophyte) Infestation
- Algal Mats (filamentous) Infestation
- Pea Soup (phytoplankton) Infestation

Floating plant (macrophyte) infestation. In the summer months, floating plants, such as duckweed (*Lemna*, fig. B–7), can proliferate in ponds enriched by the runoff from fertilized fields or pastures. If left unchecked, these plants can multiply and cover the entire pond surface. When this happens, light cannot penetrate through the surface plant cover. Without light, the naturally occurring phytoplankton (microscopic algae) at the base of aquatic food chains cannot carry on photosynthesis, and little or no oxygen is produced. The protective cover of floating plants also reduces wave action, an important source of oxygen. Oxygen is depleted by the respiration of plants, animals, and micro-organisms.

Hot weather intensifies the problem by accelerating both the rate of respiration of the organisms and the chemical oxidation of many substances. Eventually, fish and other oxygen-requiring (aerobic) organisms suffocate from a lack of dissolved oxygen, and fish kills occur.

Algal mat (filamentous) infestation—fish piping common. Many farmers routinely treat ponds for floating plants before the plant populations reach nuisance proportions. However, some ponds that appear "clear" (you can see to the bottom) will have significant amounts of filamentous algae (pond scum) growing along the bottom and sides or attached to rocks or other larger plants (fig. B–7). In response to an unidentified trigger, these filamentous algae rise to the surface in mats and die, creating decaying odors and nuisances.

The sudden existence of such large quantities of dead algae in a pond pollutes the pond by increasing oxygen-demanding organic matter, which increases the biochemical oxygen demand (BOD) of the decay micro-organisms. This results in an immediate drain on the dissolved oxygen (DO). DO levels in the pond become critical at night when photosynthesis by any remaining living plants comes to a halt. The lowest DO levels occur at dawn.

At sunrise, fish in a pond with insufficient DO can be observed congregating at the edge of the water where DO levels are highest. The fish usually assume a hanging position at approximately a 45 degree angle and pipe (suck or gulp) air. Under these critical DO concentrations, fish begin to die slowly. It takes about a week of nightly DO levels dropping to levels of less than 2.0 parts per million (ppm) to achieve a total kill.

Under highly enriched conditions, aerobic decay micro-organisms may become too overworked to handle the increased organic load and may die of suffocation when DO levels approach zero. The decomposition process is then taken over by much less efficient anaerobic bacteria that do not require oxygen. These bacteria release a gas that smells like rotten eggs (hydrogen sulfide), as well as other poisonous breakdown products. The bacteria contribute to the ultimate decline of a lake or pond, which then is most unappealing in terms of sight, smell, and taste. This situation can be particularly dangerous in lakes or ponds used as reservoirs for drinking water.

Pea soup (phytoplankton) infestation. Farm ponds, which become highly enriched with nutrients may undergo much photosynthesis and take on a pea soup appearance to a depth of more than 1 ft. During summer, in some farm ponds in the South, SCS personnel have recorded supersaturated DO levels ranging up to 28 ppm at 4 o'clock in the afternoon, dropping to near 0 ppm by an hour after sunrise of the following day. Fish kills are common under such conditions.

The organisms responsible for the fish kills in the pea soup condition are phytoplankton (small, floating plants), which are so small that they can be observed only with a microscope. The phytoplankton consist of a variety of algae, including diatoms and green and blue-green algae (cyanobacteria, fig. B–1 to B–6). Despite their small size, populations of these plankton can reach proportions that color the water pea green and thicken it to resemble soup.

4. Water use impacts (Refer to Field Sheet 3A, rating item 4, figure 5–2).

Agriculturally related nutrient enrichment and eutrophication can adversely affect a number of water uses. For example, eutrophied water can alter the color, taste, and odor of a drinking water supply. The removal of excessive algal slimes may also increase the cost of water treatment. Nuisance levels of vegetation or algae may detract from the aesthetic quality of the water, clog pipes and intakes, and reduce property values and recreational use.

Finally, high nitrate levels in drinking water are known to affect adversely the health of babies and the elderly. Babies who receive too much nitrate from the water used in preparing formula may suffer from methemoglobinemia, or blue baby syndrome. Some babies have died from this condition, when it was not treated in time. These same conditions can affect the young of cattle.

5. Bottom-dwelling aquatic organisms (Refer to Field Sheet 3A, rating item 5, figure 5–2).

As waters become increasingly eutrophied, the abundance and species composition of bottom organisms change. Waters receiving few, if any, excess nutrients from agricultural or other sources are characterized by a high diversity of bottom-dwelling organisms. Generally, in these very pristine waters, the diversity of bottom species is high, but the number of each type is low.

Among bottom organisms found to be sensitive to or intolerant of nutrient excesses are mayflies, stoneflies, caddisflies, water-penny, and riffle beetles (ref. 5–4). Generally, as nutrient quantities increase, populations of these intolerant species recede. They are replaced by expanding populations of nutrient-tolerant species, such as chironomids and blackflies. The usual pattern is that as nutrients increase over time, the number of species (species diversity or richness) decreases, while the population growth of a few species increases.

An excellent tool for determining the diversity of bottom-dwelling invertebrates is the Sequential Comparison Index (SCI, appendix A), which is designed for nonprofessionals and assumes no background knowledge of biology or taxonomy (ref. 5-5). Appendix A also contains Beck's Biotic Index procedure, which requires the identification of pollution-tolerant and intolerant species to make a water quality determination. Appendix B contains pictorial keys for common invertebrates and another procedure entitled "Simple Assessment of Bottom-Dwelling Insects."

Chapter 6

Pesticides

Most agricultural pesticides are either herbicides, which make up approximately one-half of the U.S. pesticide usage, or insecticides, which make up about one-third of the pesticide usage.

Effects of Pesticides on the Aquatic Environment

The effect of a pesticide on the aquatic environment depends upon many factors, including the physical, chemical, and biological properties of the pesticide; the amount, method, and timing of application; and the intensity of the first storm event following application. In general, pesticide effects on aquatic organisms vary with the relative toxicity of the pesticide, its persistence or how long it remains active in the environment, and its tendency to accumulate in the food chain. The longer a pesticide persists in the soil, the greater the opportunity for it to be transported from the crop area to receiving waters or to ground water, or for it to affect nontarget organisms, such as animals, humans, and noncrop plants adversely.

Insecticides: Chlorinated hydrocarbon insecticides, such as DDT, which appeared after World War II, are of low-to-moderate toxicity and are termed "wide-spectrum" (i.e., they kill a wide variety of insects). These insecticides severely affected many environments, killing top-of-the-food-chain predator birds, such as the bald eagle, brown pelican, and peregrine falcon.

The most infamous of the synthetic organics was DDT. DDT is very persistent, with a half-life in sediments of greater than 10 years. The half-life is how long it takes for half of a compound to decay. Since DDT is fat soluble, it concentrates in the fat of organisms. Figure 6–1 illustrates the increase in concentration of DDD, a close relative of DDT, as DDD is passed from one organism to another up the food chain in a lake.

In some ecosystems, DDT can become concentrated at the top of the aquatic food chain in quantities great enough to interfere with reproduction or cause death. Consequently, decline or death of birds of prey at the top of aquatic food chains (e.g., bald eagle or fish hawk) may be an indicator of pesticide damage to an aquatic ecosystem.

The decline or death of sensitive fish species and other aquatic organisms also serves as an indicator of pesticide pollution. Salmonids (rainbow trout, brown trout, and salmon) are the most sensitive to chlorinated hydrocarbon pesticides. Redear sunfish, bluegill, and largemouth bass are intermediate in sensitivity, with channel catfish and black bullheads being the least sensitive (ref. 6–1).

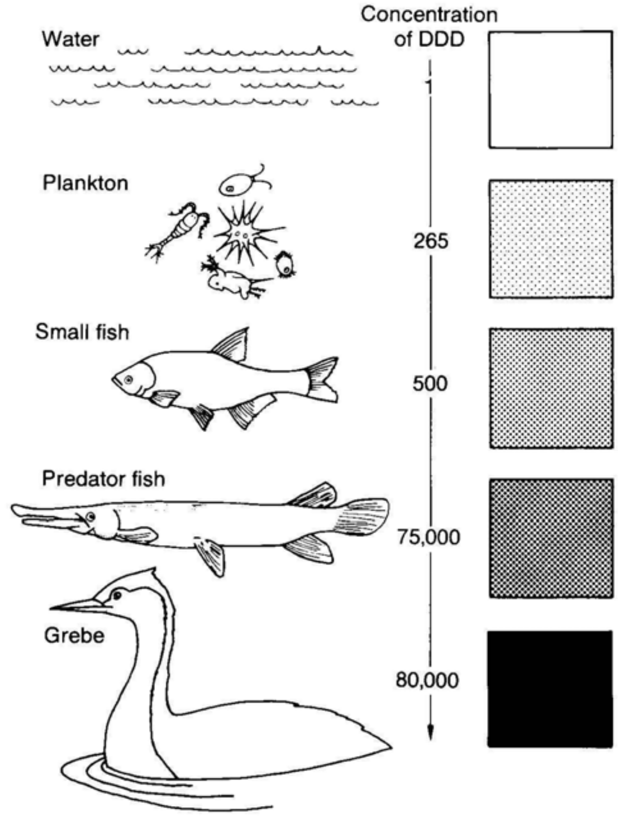
Today, most synthetic organic insecticides have been replaced by the organophosphate insecticides (e.g., malathion and diazinon) and by carbamates (e.g., carbaryl). Organophosphate insecticides are much less persistent, with half-lives from 1 to 12 weeks. The main feature of organophosphate insecticides is their rapid degradability (ref. 6–1). Some carbamates persist only a few days.

Since carbamates and organophosphates are not fat soluble, they do not concentrate in organisms nor do they accumulate up the food chains. Consequently, the compounds are much safer environmentally. However, while organophosphate compounds are safer environmentally, a toxic organophosphate compound can kill fish in a water body and quickly degrade with no detectable chemical trace a few weeks later. Fish families still show the same types of sensitivity to the organophosphates that they did to the chlorinated hydrocarbons, with salmonids being the most sensitive and catfish the least sensitive. Carbamates and organophosphates are soluble in water and can be easily transported in water. Thus, these compounds may increase the potential for ground water contamination.

Figure 6-1

Biomagnification of DDD in the Food Chain at Clear Lake, California.

Numbers are times amount in water.



(Flint and van den Bosch, 1977) (Ref. 6-10).

Herbicides: Herbicides vary considerably in their persistence. Herbicides, such as 2,4-D and alachlor, are considered to be nonpersistent, with half-lives of less than 20 days. They seldom remain in the soil for longer than a month to 6 weeks when used at the recommended levels for weed control. Atrazine is considerably more persistent, remaining in the soil for as long as 17 months. Others such as monuron, picloram, simazine, and paraquat are very persistent, remaining in the soil from 2 to 4 years. Most herbicides are nonpersistent, breaking down by the end of the growing season (ref. 6–2, 6–3).

In general, when compared to insecticides, herbicides in use today rank lower in relative fish toxicity and the potential for environmental impact. Many herbicides do not appear to have a permanent impact on aquatic ecosystems and appear to be only moderately toxic to fish.

Pesticide Indicators for Receiving Waters

1. **Presence of pesticide containers** (Refer to Field Sheet 4A, rating item 1, figure 6–2).

   Evidence of careless and haphazard disposal or dumping of pesticide containers in or near sink holes, streams, or water bodies should be a warning of possible adverse pesticide effects on the aquatic ecosystem.

2. **Appearance of nontarget vegetation** (Refer to Field Sheet 4A, rating item 2, figure 6–2).

   By definition, herbicides are toxic to plant life. Herbicides draining from agricultural fields can result in the death of aquatic vegetation. This is especially true if a storm occurs immediately following spraying and washes the newly applied pesticide into nearby waters. Also, aerial drift that carries pesticide away from the field, and "overspray" by the spray plane beyond the field edge can damage or kill aquatic vegetation by landing directly on it. Large (macroscopic) aquatic plants are particularly sensitive. Microscopic phytoplankiton appear to be less sensitive, although the effects on plankton have not been extensively studied (ref. 6-3).

   Leaf burn and evidence of vegetative dieback on nontarget vegetation, whether aquatic or terrestrial, are indicators of herbicide damage. Care should be taken to look for this type of evidence in or along ponds, drainage ditches, and streams. Examine floating species, such as pond lilies and duckweed. Also examine emergent rooted aquatics, such as watercress, watershield, and spatterdock, and marginal weeds, such as alligator weed, smartweed, arrowhead, pickerelweed, and cattails (fig. B-7).

3. **Overall diversity of insects, presence of "fish bait types"** (Refer to Field Sheet 4A, rating item 3, figure 6-2).

   Insecticides kill nontarget, as well as target insects and other closely related species. It is not uncommon to observe reduced species diversity and reduced populations of aquatic bottom-dwelling organisms in waters that receive pesticide runoff. Diversity is reduced as sensitive species, such as some types of mayflies, dragonflies, water mites, or beetles, decline or die off. As sensitive species die, populations of insecticide-tolerant species, such as blackflies and chironomids, expand to fill the void vacated by the sensitive species. Ask the landowner if there have been any insect population upsurges or decreases in the local area. An excellent tool for determining the diversity of bottom-dwelling invertebrates is the Sequential Comparison Index (SCI) shown in appendix A.

4. **Overall diversity of fish** (Refer to Field Sheet 4A, rating item 4, figure 6–2).

   Chronic sublethal effects of pesticides in waters are difficult to observe. Chronic effects include:

   - Fish avoidance of contaminated watercourse areas. This may result in their absence in a localized area or prevent their swimming into these areas to spawn.
   - Altered reproduction due to toxicity or avoidance. Trout do not naturally reproduce in some agriculturally drained streams common to their range.
   - Lowered fish productivity.
   - Young fish mortality (decreased survival of newly hatched fish; adapted from Pimentel, Brown, Cross, ref. 6-4, 6-5, 6-6).

   These subtle effects, combined with the dieback of fish food (fish bait) organisms as described in number 3 above, manifest themselves in altered or degraded fisheries. In general, the greater the input of pesticides, the less diverse the fishery. Salmonids appear to be most sensitive and decline or are eliminated first. Next in sensitivity are the intolerant centrachids, such as longear sunfish, striped bass, smallmouth bass, crappie, redfin pickerel, and bluegill. These are followed by the more tolerant centrachids (blacknose dace, common shiner, sculpin, creek chub, madtom, golden shiner, largemouth bass, blueback herring and alewives). In the worst of the chronically polluted pesticide waters, there are only the very most tolerant species of cyprinid minnows and ictalurids. Typical species include brownhead carp, bullheads, white sucker, shad and catfish, or no fish at all. See appendix B for a brief summary of fish species (ref. 6–7, 6–8).

5. **Fish kills, animal teratology** (Refer to Field Sheet 4A, rating item 5, figure 6–2).

   Acute effects of lethal concentrations of pesticides result in insect kills (mayfly, dragonfly, etc.) or fish kills or both. These kills are usually of a limited nature and are easy to observe. They frequently occur after routine spraying of barns or feedlot areas that are in close proximity to a watercourse or pond, or from the improper washing of spray equipment and containers. Massive kills are rare.

   Chronic sublethal concentrations of pesticides are sometimes teratogenic; that is, they produce birth defects or tumors. One type of birth defect that might be observed is broken-back syndrome in fish (vertebral deformities and scoliosis). Other types are deformed bird beaks or the absence of ears or eyes, resulting from elevated levels of selenium or other trace elements or toxic ions.

Figure 6-2

Pesticides

FIELD SHEET 4A: PESTICIDES
INDICATORS FOR RECEIVING WATERCOURSES AND WATER BODIES

Evaluator ______________________ County/State ______________ Date ______________

Water Body Evaluated ______________ Water Body Location ______________ Total Score/Rank ______________

Rating Item	Excellent	Good	Fair	Poor
	(Circle one number among the four choices in each row which BEST describes the conditions of the watercourse or water body being evaluated. If a condition has characteristics of two categories, you can "split" a score.)			
1. Presence of pesticide containers	:-- No containers in or near water. :-- OTHER 9	:-- No containers in or near water. :-- OTHER 9	:-- Containers located near the water. :-- OTHER 5	:-- Containers in the water. :-- OTHER 3
2. Appearance of non-target vegetation	:-- No leaf burn. :-- No vegetation dieback. :-- OTHER 9	:-- Some leaf burn. :-- No vegetation dieback. :-- OTHER 6	:-- Significant leaf burn. :-- Some vegetation dieback. :-- OTHER 4	:-- Severe dieback of vegetation. :-- OTHER 1
3. Overall diversity of insects ("fish bait")	:-- High diversity including dragonflies, stoneflies, mayflies, caddisflies, water mites or beetles. :-- OTHER 10	:-- Average diversity of insects—some of those listed under excellent. :-- OTHER 8	:-- Occasional insect kills. Reduced numbers and kinds. Upsurges of blackflies & chironomids. :-- OTHER 3	:-- Insect kills common. Not many fish-bait types such as hellgrammites (the larvae of dobsonflies), alderflies, or fishflies. :-- OTHER 1
4. Overall diversity of fish	:-- Excellent fish diversity—what's expected in the area. :-- Presence of intolerants such as brook, brown or rainbow trout, salmon or stickleback. :-- OTHER 9	:-- Good fish diversity. :-- Native salmonids (trout & salmon) begin to die out first. The least tolerant centrarchids (longear sunfish, rock bass, smallmouth bass, crappie, redfinned pickerel and bluegill) begin to decline. :-- OTHER 7	:-- Reduced fish diversity. :-- The more tolerant centrarchids die off—blacknose dace, common shiner, sculpin, creekchub, madtom, golden shiner, large mouth bass, blueback herring, and alewives. :-- Larger proportion of green sunfish. :-- Occasional (once every 1-2 years) pond fish kills. :-- OTHER 4	:-- Extremely reduced fish diversity. :-- Only very tolerant species of cyprinids & ictalurids (such as brownhead carp, bullheads, white sucker, shad, and catfish. :-- Some highly polluted waters (usually ponds) may lack fish entirely. :-- OTHER 1
5. Fish kills; animal teratology (birth defects & tumors in fish & other animals)	:-- No fish kills in last 2 years. :-- No birth defects of tumors. :-- OTHER 9	:-- Fish kills rare in last 2 years. :-- Minimal birth defects & tumors occurring in the population randomly. :-- OTHER 5	:-- Occasional fish kills. :-- Some birth defects & tumors. :-- OTHER 3	:-- Fish kills common in last couple of years. :-- Frequent fish kills during spring thaws. :-- Yearly pond fish kills following aquatic vegetation dieback not uncommon. :-- Considerable numbers of birth defects & tumors. :-- OTHER 0
OPTIONAL 6. Fish behavior in hot weather; fish kills, especially before dawn	:-- Normal behavior, e.g. fish seen breaking the surface for insects. :-- No evidence of disease, tumors, fin damage, or other anomalies. :-- No fish piping or aberrant behavior. :-- No fish kills. :-- OTHER 9	:-- Behavior as expected, e.g. evidence of fish, such as water rings or bubbles. :-- Little if any evidence of disease, tumors, fin damage, or other anomalies. :-- In hot climates, occasional fish piping or gulping for air in ponds just before dawn. :-- No fish kills in last 2 years. :-- OTHER 7	:-- Behavioral changes in fish—swimming near surface, uncoordinated movements, convulsive darting movements, erratic swimming up & down or in small circles, hyperexcitability (jumping out), difficulty in respiration. More likely seen in ponds. :-- Fish piping common. :-- Occasional fish kills. :-- OTHER 4	:-- Fish avoidance or behaviors, such as erratic swimming near surface & gulping for or piping for air. More likely seen in ponds. :-- Pond fish kills common. :-- Frequent stream fish kills during Spring thaw. :-- Very tolerant species (e.g. bullhead, catfish). :-- OTHER 0

1. Add the circled Rating Item scores to get a total for the field sheet. TOTAL [ ]
2. Check the ranking for this site based on the total field score. Check "excellent" if the score totals at least 40. Check "good" if the score falls between 27 and 39, etc. Record your total score and rank (excellent, good, etc.) in the upper right-hand corner of the field sheet. If a Rating Item is "fair" or "poor," complete Field Sheet 4B.

RANKING	Excellent (40-46) [ ]	Good (27-39) [ ]	Fair (12-26) [ ]	Poor (11 or less) [ ]
OPTIONAL RANKING	Excellent (48-55) [ ]	Good (32-47) [ ]	Fair (14-31) [ ]	Poor (13 or less) [ ]

6. **Fish behavior and condition** (Refer to Field Sheet 4A, rating item 6, figure 6-2).

In addition to a degraded (less diverse) and less productive fishery, chronic sublethal doses of pesticides can lead to the following conditions, which are more likely to be observed in standing waters than in flowing waters:

- Increased susceptibility to attack by parasites and disease, such as infection by the aquatic fungus, *Saprolegnia;*
- Increased incidences of tumors;
- Behavioral changes in fish:
  - uncoordinated movements;
  - convulsive darting movements;
  - erratic swimming up and down or in a small circle;
  - sluggishness (nonresponsiveness) alternating with hyper-excitability (jumping out);
  - difficulty in respiration (adapted from Pimentel, Brown, Cross, ref. 6-4, 6-5, 6-6).

Frog tadpoles display some of the same aberrant types of behavior as fish; that is, hyper-irritability, spastic activity, and rhythmic muscular contractions that produce a whirling motion (ref. 6-9).

Chapter 7

Animal Wastes

Animal Waste Pollutants: Micro-organisms, Organic Matter, and Nutrients

Surface runoff of animal wastes contaminates a receiving body of water with four types of pollutants: (1) pathogenic and nonpathogenic micro-organisms; (2) biodegradable organic matter; (3) nutrients; and (4) salts. Ground water can be adversely affected by animal-waste nutrients and salts. Only organic matter can be seen with the naked eye, but it, too, may be degraded into fine particles that dissolve or remain suspended in the water. These particles color the water, increase its turbidity, and increase the biochemical oxygen demand (BOD). Refer to figure 7-1 for a comparison of typical BOD concentrations in municipal and agricultural wastes. Effects of the bacteria, nutrients, and salts may be observed indirectly, such as human-health effects from shellfish contamination or as eutrophication.

Micro-organisms. Animal wastes are potential sources of approximately 150 diseases. Illnesses that may be transmitted by animal manure include bacterial diseases, such as typhoid fever, gastro-intestinal disorders, cholera, tuberculosis, anthrax, and mastitis. Transmittable viral diseases are hog cholera, foot and mouth disease, polio, respiratory diseases, and eye infections (ref. 7-3).

Figure 7-1.—BOD concentrations in municipal and agricultural wastes (ref. 7-1, 7-2).

All values are BOD_5* in milligrams per liter (mg/l).

Raw domestic (municipal) sewage	200
Treated sewage with secondary treatment	20
Milking center wastes	1,500

	Influent source to a lagoon	Effluent source from a lagoon
Dairy cattle	6,000	2,100
Beef cattle	6,700	2,345
Swine	12,800	4,480
Poultry	9,800	3,430

*The determination of Biochemical Oxygen Demand as an empirical testing procedure to determine relative oxygen requirements of wastewater, effluents, and polluted waters using a 5-day incubation period.

Numerous factors influence the nature and amount of disease-producing organisms that reach waterways. Some of these factors are climate, soil types and infiltration rates, topography, animal species, animal health, and the presence of "carrier" organisms. These latter organisms carry disease-causing micro-organisms in significant numbers, but do not contract the disease themselves. Manure, applied to the land in solid or slurry form or stored in lagoons, poses varying public health hazards, depending on the distance to watercourses, nature of the soil overlying aquifers, etc. When manure is applied on hot, sunny days, harmful bacteria die quite rapidly, virtually eliminating any potential health threat. However, rain falling on freshly applied manure may yield 10,000 to 10 million bacteria per milliliter in runoff waters. The public health hazard increases if manure is applied onto frozen ground or in the rain, or if a lagoon overflows. Direct disposal into water represents a significant threat to animals, or to humans swimming in or drinking the water (ref. 7-4).

Public health departments test for the presence of *Escherichia coli (E. coli)* to determine if waters classified for swimming are contaminated by organic pollution. The most commonly used indicator species of organic pollution is *E. coli.* It is generally nonpathogenic and is a member of a group of fecal coliforms, bacteria that reside in the intestine of warm blooded animals, including humans. The presence of *E. coli* does not by itself confirm the presence of pathogens. Rather, it indicates contamination by sewage or animal manure and the potential for health risks. Unfortunately, there is still no easy method for distinguishing between human and animal coliform bacteria (ref. 7-5).

For this reason and because bacterial identification requires the use of sterile technique and incubation, field offices generally have not used bacteria as pollution indicators. However, those individuals interested in using bacteria as pollution indicators should refer to the last page in appendix B and to *Standard Methods for the Examination of Water and Waste Water* (ref. B-5) for details.

Organic Matter. Animal waste contaminates receiving waters with oxygen-demanding organic matter, including organic nitrogen and phosphorus compounds. When manure enters a standing water body, such as a pond, it is subject to natural decay. As decomposition occurs, BOD increases, dissolved oxygen (DO) decreases, and ammonia is released. Low DO levels and increased ammonia cause stress to stream inhabitants. Fish, in particular, are sensitive to ammonia. Nonionic (un-ionized) ammonia (NH_3) concentrations as low as 0.2 ppm may prove toxic to fish (ref. 7-6).

Animal manure is commonly spread on frozen ground in cold regions. When snowmelt runoff occurs in early spring, some of the manure washes away in the runoff from the frozen ground, contaminating nearby watercourses and bodies. Fish kills are common under these circumstances. Frequently, the receiving waters are the farm's own pond or stream.

It is only later in the spring after a complete thaw that manure nutrients are able to seep into the soil. Even then, since the crop has not been planted, or if planted, is immature and lacks extensive root systems, more than half of the nutrients can wash through the soil or run off it. Since surfaces coated with very dry or very wet manure repel water, there is greater runoff in range areas or feedlots under these conditions compared to less runoff from water-absorbing, moderately moist manured areas. In general, from 0.22 to 0.5 in of rain is necessary to produce runoff. Monitoring has shown that manure solids in late-February and early-March runoffs can be ten times more concentrated than summer rain-storm runoffs (ref. 7-3, 7-4, 7-7).

Fast-moving (lotic) waters usually can effectively degrade moderate amounts of manure and organic matter without severe declines in water quality. However, since lakes and ponds (lentic waters) are characterized by lesser flows, they often have less dissolved oxygen. They usually degrade less manure and organic matter and can be easily overloaded.

Nutrients. The effects of nutrient enrichment on receiving waters, whether nutrients come from fertilizers or manure, are the same. Since this is the case, the effects of nutrients on receiving waters discussed in Chapter 5 are applicable here.

Salts. Salts are added to animal feeds to maintain the animal's chemical balance and increase weight. Excess salts pass through the animals and are eliminated in the wastes. When manure accumulates, salt leaching becomes a potential pollution problem. With sufficient rainfall and runoff, salts can contribute to surface and ground water pollution (ref. 7-8).

Animal Waste Indicators for Receiving Waters

1. **Evidence of animal waste: visual and olfactory** (Refer to Field Sheet 2A, rating item 1, figure 7-2).

   The most obvious indication of fresh manure, even at a distance, is the unpleasant odor and the smell of ammonia. Closer visual inspection of the water and the water's edge is necessary to locate dried sludge, which may be fairly odorless.

2. **Turbidity and color** (Refer to Field Sheet 2A, rating item 2, figure 7-2).

   When manure enters water, it disintegrates fairly rapidly into small particulate matter. When the manure input is heavy and the rate of water flow is low, a noticeable increase in turbidity might occur (i.e., water may appear more opaque or cloudy).

   Nutrients contained in the manure eventually dissolve and are taken up by plants. The indirect effects of increased nutrients manifest themselves in both the vigor and amount of aquatic vegetation. For a detailed discussion of these effects, refer to chapter 5.

3. **Aquatic vegetation; fish behavior; bottom-dwelling organisms** (For rating items 3, 4, and 5 on Field Sheet 2A, see items 1, 3, and 5 in Chapter 5).

   Some of the same water-use impacts noted for nutrients in item 4, chapter 5 are also true for manure. For example, waters having excessive inputs of manure are often characterized by reduction in fishery quality. These waters also have reduced recreational use because of odors, muddy conditions, decay of massive amounts of vegetation, etc. Property near or adjacent to these waters is often devalued.

   Health effects, such as blue baby syndrome or waterborne bacterial and viral diseases sometimes occur. The closing of bacterially contaminated areas to fishing or recreation by public health agencies is sometimes due to animal waste pollution from agricultural sources. Drinking water may also be impaired by taste, color, odor, or turbidity problems.

Figure 7-2

Animal Waste

FIELD SHEET 2A: ANIMAL WASTE
INDICATORS FOR RECEIVING WATERCOURSES AND WATER BODIES

Evaluator ____________ County/State ____________ Date ____________
Water Body Evaluated ____________ Water Body Location ____________ Total Score/Rank ____________

(Circle one number among the four choices in each row which BEST describes the conditions of the watercourse or water body being evaluated. If a condition has characteristics of two categories, you can "split" a score.)

Rating Item	Excellent	Good	Fair	Poor
1. Evidence of animal waste: visual and olfactory	:-- No manure in or near water body. :-- No odor. :-- OTHER 9	:-- Occasional manure droppings where cattle cross or in water. :-- Slight musk odor. :-- OTHER 6	:-- Manure droppings in concentrated localized areas. :-- Strong manure or ammonia odor. :-- OTHER 2	:-- Dry and wet manure all over banks or in water. :-- Strong manure & ammonia odor. :-- OTHER 0
2. Turbidity & color (observe in slow water)	:-- Clear or slightly greenish water in pond or along the whole reach of stream. :-- No noticeable colored film on submerged objects or rocks. :-- OTHER 9	:-- Occasionally turbid or cloudy. Water stirred up & muddy & brownish at animal crossings. :-- Pond water greenish. :-- Rocks or submerged objects covered with thin coating of green, olive, or brown build-up less than 5 mm thick. :-- OTHER 6	:-- Stream & pond water bubbly, brownish and cloudy where muddied by animal use. :-- Pea green color in ponds when not stirred up by animals. :-- Bottom covered w/green or olive film. Rocks or submerged objects coated with heavy or filamentous build-up 5-75 mm thick or long. :-- OTHER 3	:-- Stream & pond water brown to black, occasionally with a manure crust along banks. :-- Sluggish & standing water—murky and bubbly (foaming). :-- Ponds often bright green or with brown/black decaying algal mats. :-- OTHER 0
3. Amount of aquatic vegetation	:-- Little vegetation—uncluttered look to stream or pond. :-- What you would expect for a pristine water body in area. :-- Usually fairly low amounts of many different kinds of plants. :-- OTHER 8	:-- Moderate amounts of vegetation; *or* :-- What you would expect for the naturally occurring site-specific conditions. :-- OTHER 6	:-- Cluttered weedy conditions. Vegetation sometimes luxurious and green. :-- Seasonal algal blooms. :-- OTHER 3	:-- Choked weedy conditions or heavy algal blooms or no vegetation at all. :-- Dense masses of slimy white, greyish green, rusty brown or black water molds common on bottom. :-- OTHER 0
4. Fish behavior in hot weather; fish kills, especially before dawn	:-- No fish piping or aberrant behavior. :-- No fish kills. :-- OTHER 8	:-- In hot climates, occasional fish piping or gulping for air in ponds just before dawn. :-- No fish kills in last two years. :-- OTHER 5	:-- Fish piping common just before dawn. :-- Occasional fish kills. :-- OTHER 3	:-- Pronounced fish piping. :-- Pond fish kills common. :-- Frequent stream fish kills during spring thaw. :-- Very tolerant species (e.g., bullhead, catfish). :-- OTHER 0
5. Bottom dwelling aquatic organisms	:-- Intolerant species occur: mayflies, stoneflies, caddisflies, water penny, riffle beetle and a mix of tolerants. :-- High diversity. :-- OTHER 9	:-- A mix of tolerants: shrimp, damselflies, dragonflies, black flies. :-- Intolerants rare. :-- Moderate diversity. :-- OTHER 5	:-- Many tolerants (snails, shrimp, damselflies, dragonflies, black flies). :-- Mainly tolerants and some very tolerants. :-- Intolerants rare. :-- Reduced diversity with occasional upsurges of tolerants, e.g. tube worms, and chironomids. :-- OTHER 3	:-- Only tolerants or very tolerants: midges, craneflies, horseflies, rat-tailed maggots, or none at all. :-- Very reduced diversity. upsurges of very tolerants common. :-- OTHER 0

1. Add the circled Rating Item scores to get a total for the field sheet. TOTAL [ ]
2. Check the ranking for this site based on the total field score. Check "excellent" if the score totals at least 35. Check "good" if the score falls between 21 and 34, etc. Record your total score and rank (excellent, good, etc.) in the upper right-hand corner of the field sheet. If a Rating Item is "fair" or "poor," complete Field Sheet $2B_1$ or $2B_2$.

RANKING Excellent (35-43) [ ] Good (21-34) [ ] Fair (7-20) [ ] Poor (6 or less) [ ]

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Chapter 8

Salts

More than 90 percent of the total irrigated land in the United States is distributed in 8 major river basins of the West, encompassing parts of 17 States (fig. 8–1). California and Texas lead the Nation in the number of irrigated acres. The major water quality problem identified in seven out of the eight basins is salinity or salt pollution (ref. 8–1). Half of the 90 to 100 million tons of salt delivered annually to watercourses comes from agriculturally related activities (ref. 8–2). Salinity is commonly measured and expressed as milligrams per liter (mg/l) or parts per million (ppm).

Approximately one-fourth of all irrigated land (about 10 million acres) suffers from salt-caused crop yield reductions (ref. 8–3). Although the most severe salt problems occur in the arid and semiarid West (fig. 8–2), increasing salinity is symptomatic of water use and reuse.

Salinity Indicators for Receiving Waters

1. Geology of area and geochemistry of water (Refer to Field Sheet 5A, rating item 1, figure 8–3).

Salts come from natural sources and result from human activities. Natural sources include geologic formations of marine origin, soils with poor drainage, salty ground water, and salty springs. The salinity of the soil is increased primarily by overapplying irrigation water to areas where drainage is inadequate. The salinity of receiving waters is increased primarily by over-irrigating lands underlain with salt-bearing layers.

Saline waters contain a number of salts whose relative proportions reflect the geology of the region as well as seasonal changes in hydrology. Consequently, salt proportions tend to be site-specific. The primary components of the dissolved solids that constitute saline water are chlorides, sulfates, and bicarbonates of the following elements: sodium, calcium, magnesium, and potassium (ref. 8–3).

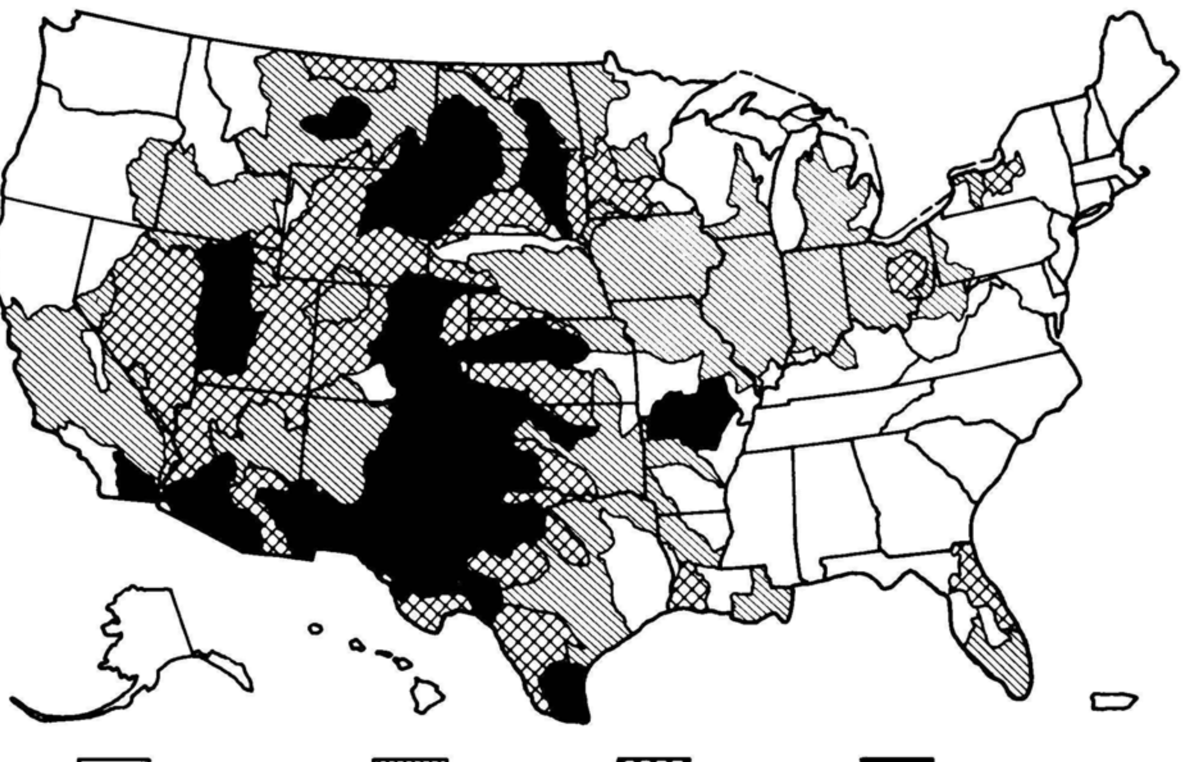
Figure 8-1

Hydrologic Divisions.[1]

[1]Source: EPA - Pollution Control Manual for Irrigated Agriculture (Ref. 8-1).

Figure 8-2

Levels of Dissolved Solids (Mg/1) in U.S. Streams.[2]



[2]Source: EPA - Council on Environmental Quality. Analysis of U.S. Geological Survey data of the National Stream Quality Accounting Network (Ref. 8-4).

2. Precipitation and irrigation requirements (Refer to Field Sheet 5A, rating item 2, figure 8–3).

The salinity of both water and soil is increased by salt concentration and salt loading. High salt concentrations are more likely to occur in semiarid and arid regions where evaporation exceeds precipitation. In these regions of salt-bearing layers, the usual salty water becomes even saltier as water is lost by evaporation from soil and plants (evapotranspiration). Salt pollution is even more likely to occur in these regions when drainage is inadequate or if water tables are "perched" close to the surface (5 feet or less).

Salt "loading" occurs when irrigation water percolates through a salt-laden soil profile or geologic layer on its way back to a river or stream, or when irrigation return flows accumulate salt as they run over the soil surface. The greater the irrigation requirements, the greater the opportunity for salt loading of soils.

For example, of the 10 million metric tons of salt annually reaching the Lower Colorado River Basin, 600,000 to 700,000 metric tons are annually contributed by the Grand Valley. The salt-load contribution from the Grand Valley is the result of saline subsurface irrigation return flows reaching the Colorado River. The alluvial soils of Grand Valley are high in natural salts. However, the most significant salt source is the Mancos Shale geologic formation, which underlies these alluvial soils and which contains crystalline lenses of salt that are readily dissolved by subsurface return flows (ref. 8-3, 8-5).

In this area, the irrigation water applied is at least three times greater than the crop water requirements. Although much of this excess water returns to open drains as surface runoff, having negligible effect on the Colorado River salinity, significant water quantities still reach the underlying Mancos Shale formation and pass to a near-surface cobble aquifer, where the water is returned into the Colorado River (ref. 8-5).

Figure 8-3

Salinity

FIELD SHEET 5A: SALINITY
INDICATORS FOR RECEIVING WATERCOURSES AND WATER BODIES

Evaluator ______ County/State ______ Date ______
Water Body Evaluated ______ Water Body Location ______ Total Score/Rank ______

(Circle one number among the four choices in each row which BEST describes the conditions of the watercourse or water body being evaluated. If a condition has characteristics of two categories, you can "split" a score.)

Rating Item	Excellent	Good	Fair	Poor
1. Geology of area and geochemistry of water	Agricultural area overlies formations of igneous or metamorphic origin. Few fractures or faults in the area. Very low to low mineral content—soft waters of the East and Southeast. OTHER 10	Agricultural area primarily overlies formations of igneous or metamorphic origin with occasional areas above marine deposits. Few fractures or faults. Low to moderate mineral content—soft waters. OTHER 7	Agricultural area overlies marine deposits. Faulting common. Moderate to high mineral content—hard waters of mountain states, deserts, and Great Plains. OTHER 3	Agricultural area overlies marine deposits of recent origin. Fractures and faulting very common in the area. High to very high mineral content. Soils of marine origin. Salty ground water and springs. Mineral springs. Saltwater intrusion. OTHER 0
2. Precipitation and irrigation requirements	Average crop water consumption is equal to or less than average precipitation. Minimal irrigation required. OTHER 8	Average crop water consumption is between 5 & 10% more than average precipitation. Moderate irrigation req'd. OTHER 6	Average crop water consumption is between 10 & 25% more than precipitation. Considerable irrigation required. OTHER 4	Average crop water consumption exceeds average precipitation by more than 25%. Maximal irrigation required. OTHER 0
3. Location of watercourse in watershed	Near headwaters. OTHER 9	Not far from headwaters. OTHER 7	Moderate distance from headwaters. OTHER 5	Far from headwaters. OTHER 3
4. Appearance of water's edge (shoreline or banks)	No evidence of salt crusts. OTHER 9	Some evidence of white, crusty deposits on banks. OTHER 6	Numerous localized patches of white, crusty deposits on banks. OTHER 4	Most of the pond or stream bank covered with a thick, white, crusty deposit. Salt "feathering" on posts abundant. OTHER 1
5. Appearance of aquatic vegetation	No evidence of wilting, toxicity, or stunting. OTHER 10	Minimal wilting and toxicity, bleaching, leaf burn. Little if any stunting. OTHER 7	Stream or pond vegetation may show wilted and toxic symptoms—bleaching, leaf burn. Presence of some salt-tolerant species. OTHER 3	Evidence of severe wilting, toxicity, or stunting. Presence of only the most salt-tolerant species or complete absence of vegetation. OTHER 0
6. Streamside vegetation	Very few species. OTHER 8	Few salt tolerant species. Refer to list below*. OTHER 7	Increasing dominance of salt-tolerant species. OTHER 5	Vegetation almost totally salt-tolerant species or absence of vegetation. OTHER 3
OPTIONAL 7. Animal teratology (birth defects & tumors in fish and other animals)	No birth defects or tumors. OTHER 10	Minimal birth defects & tumors occuring in the population randomly. OTHER 6	Some birth defects & tumors. OTHER 1	Considerable numbers of birth defects & tumors. OTHER 0

*Salt-tolerant species include greasewood, alkali sacaton, fourwing saltbush, shadscales, saltgrass, tamarisk (salt cedar), galleta, western wheatgrass, crested wheat, mat saltbush, reed canarygrass, and rabbitbrush.

1. Add the circled Rating Item scores to get a total for the field sheet. TOTAL [ ]
2. Check the ranking for this site based on the total field score. Check "excellent" if the score totals at least 47. Check "good" if the score falls between 32 and 46, etc. Record your total score and rank (excellent, good, etc.) in the upper right-hand corner of the field sheet. If a Rating Item is "fair" or "poor," complete Field Sheet $5B_1$ or $5B_2$.

RANKING	Excellent (47-54) [ ]	Good (32-46) [ ]	Fair (15-31) [ ]	Poor (14 or less) [ ]
RANKING (optional)	Excellent (55-64) [ ]	Good (35-54) [ ]	Fair (16-34) [ ]	Poor (15 or less) [ ]

Figure 8-4

Salinity

FIELD SHEET $5B_2$: SALINITY
INDICATORS FOR SALINE SEEPS

Evaluator ______ County/State ______ Date ______

Saline Seep Evaluated ______ Seep Location ______ Total Score/Rank ______

(Circle one number among the four choices in each row which BEST describes the conditions of the field or area being evaluated. If a condition has characteristics of two categories, you can "split" a score.)

Rating Item	Excellent	Good	Fair	Poor	Practices from Appendix E
1. Geology	-- Agricultural area overlies formations of igneous or metamorphic origin. -- Few fractures or faults in the area. -- OTHER 10	-- Agricultural areas primarily overlies formations of igneous or metamorphic origin with occasional areas above marine deposits. -- Few fractures or faults. -- OTHER 7	-- Agricultural area overlies marine deposits. -- Faulting common. -- OTHER 3	-- Agricultural area overlies marine deposits of recent origin. -- Fractures and faulting very common in the area. -- OTHER 0	
2. Precipitation and irrigation requirements	-- Average crop water consumption is equal to or less than average precipitation. -- OTHER 8	-- Average crop water consumption is between 5 and 10% more than average precipitation. -- OTHER 6	-- Average crop water consumption is between 10 and 25% more than precipitation. -- OTHER 4	-- Average crop water consumption exceeds average precipitation by more than 25%. -- OTHER 0	
3. Cropping system	-- Crop rotation consists of annual crops with maximum consumptive water use. -- OTHER 8	-- Crop rotation consists of annual crops. -- OTHER 6	-- Crop rotation contains a biannual fallow period. -- Crops with maximum water consumptive use grown. -- OTHER 4	-- Crop rotation contains a biannual fallow period. -- OTHER 2	17,37,68, 72
4. Field appearance, including salt crusts	-- Downslope fields exhibit even-appearing crop growth. High yields are common for the area. -- OTHER 9	-- Downslope areas of field or downslope fields exhibit even crop growth, but of reduced yield for the area. -- OTHER 7	-- Downslope areas of field or downslope fields have uneven growth of crops with patches of crops significantly stunted. -- Occasionally white crust occurs in these patches. -- OTHER 3	-- Downslope areas of fields have bare spots not accounted for by soil variations. Bare spots occur in highly saline soils. White crust common. -- OTHER 1	

1. Add the circled Rating Item scores to get a total for the field sheet. TOTAL [ ]
2. Check the ranking for this site based on the total field score. Check "excellent" if the score totals at least 30. Check "good" if the score falls between 20 and 29, etc. Record your total score and rank (excellent, good, etc.) in the upper right-hand corner of the field sheet. If a Rating Item is "fair" or "poor," find the practices in the right-hand column to help remedy the conditions.

RANKING Excellent (30-35) [ ] Good (20-29) [ ] Fair (8-19) [ ] Poor (7 or less) [ ]

3. Location of watercourses in watershed (Refer to Field Sheet 5A, rating item 3, figure 8–3).

In geologic regions where the soils are underlain by salt-bearing layers, the salinity of receiving watercourses increases with the distance from the headwaters. The salinity is least near the headwaters, where there has been little opportunity for salt loading or salt concentration, and greatest downstream, where effects of these two processes are maximized. Generally, salt loading is the major cause of salinity increases in the arid and semiarid regions of the United States. Salinity in the Colorado River ranges from an average of less than 50 milligrams per liter (mg/l) in the headwaters to 825 mg/l at Imperial Dam and 950 mg/l in Mexico (ref. 8–3, 8–6, 8–7).

4. Appearance of water's edge (shoreline or banks) (Refer to Field Sheet 5A, rating item 4, figure 8–3).

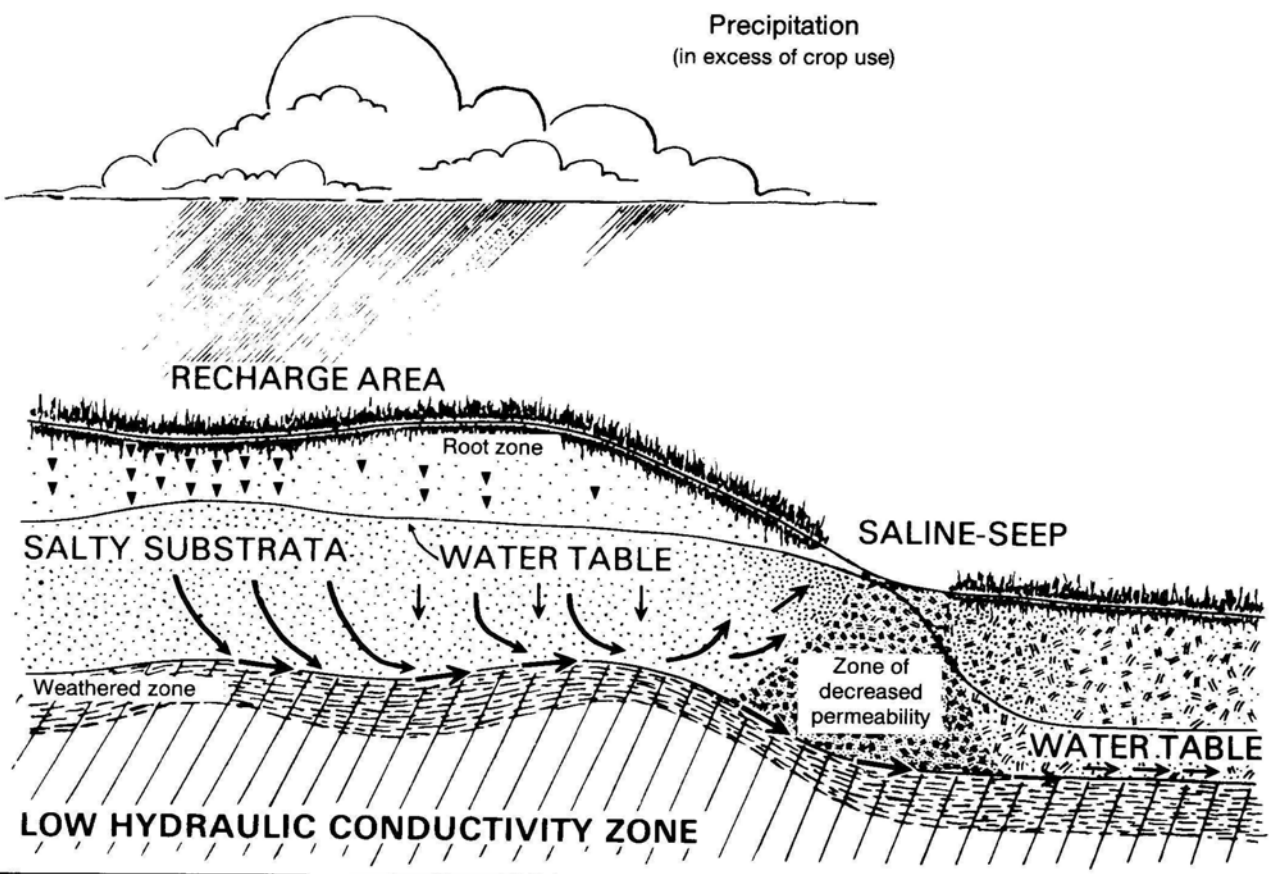
The most obvious indicator of excessive salinity is the presence of white, crusty deposits of salts. These deposits may occur at the high water mark along the banks of a stream or river, or at seepage points along a high bank or cliff. "Salt feathering," the crystallizing of salt in feathery-like patches on posts and tree stumps, is another indicator of highly saline conditions.

5. Appearance of aquatic vegetation (Refer to Field Sheet 5A, rating item 5, figure 8–3).

Salt pollution becomes a problem when the concentration of salts in the soil/water solution interferes with the growth of plants. Table salt (sodium chloride) is often the dominant salt present. It affects plants in two ways: (1) By increasing

Figure 8-5

Generalized Diagram of Saline Seep, Recharge Area, and the Substrata Formation That Contributes to a Saline Seep (Ref. 8-10).



the osmotic pressure, it reduces the amount of water that plants can take up, leading to stunted growth and reduced yields; (2) At high concentrations it causes toxic effects, such as leaf tip and marginal leaf burn, chlorosis (bleaching), or defoliation (ref. 8–8).

6. **Streamside vegetation** (Refer to Field Sheet 5A, rating item 6, figure 8–3).

   As the salinity of water increases, salt-intolerant species die and are replaced by more salt-tolerant types. Examples of the latter are greasewood, alkali sacaton, fourwing saltbush, shadscales, saltgrass, tamarisk (salt cedar), galleta, western wheatgrass, mat saltbush, reed canarygrass, and rabbitbrush. Some emergent rooted aquatics, such as cattails, appear to be tolerant of even the highest concentration of salts.

7. **Animal teratology (birth defects)** (Refer to Field Sheet 5A, rating item 7, figure 8–3).

   Severe toxic effects and birth defects or tumors in animals have been observed in isolated areas (e.g., Kesterson Reservoir in California) because of high concentrations of toxic compounds, selenium, or flouride. Some newly hatched ducks and other birds in the Kesterson Reservoir, which had elevated levels of selenium, lacked ears, eyes, beaks, wings, or legs (ref. 8–9).

8. **Salinity indicators** (Refer to Field Sheet $5B_2$, figure 8–4. Field Sheet $5B_2$ should only be used in areas where the geology makes saline seeps possible.)

A white salty crust can be an indicator of a saline seep. Saline seeps are in those localities where saline water surfaces downslope of its recharge area. The seeping water results from excess root zone moisture that percolates through salt-bearing layers. Water, leaching below the root zone, carries dissolved salt to the surface downslope of the area of infiltration. These areas are common in the Northern Great Plains Region (Montana, North Dakota, and South Dakota), where precipitation percolates through salt-laden glacial till into ground water, emerging later in a discharge area at another location (fig. 8–5).

Indicators for saline seeps are land-based, not water-based. Rating items 1 and 2 approximate those discussed above in field sheet 5A, "Salinity Indicators for Receiving Waters." Other indicators include the type of cropping system (rating item 3) and the appearance of field crops downslope of the recharge area (rating item 4). Saline seep areas will have uneven growth of crops with some significantly stunted patches or bare spots. White salt crusts occur in occasional patches in areas considered to be "fair," and are common under "poor" conditions.

Since saline seeps result from excess moisture in the soil profile, it is important to consider the cropping system thoroughly. There will be less "seeping" when crops with the maximum consumptive water use are planted. This is especially true when crops are grown on an annual basis; i.e., when the fields are not allowed to lie fallow.