

CHAPTER 3

Evolving Sustainability Concepts: Modern Developments and the Kansas Experience

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Introduction

The purpose of this chapter is to put the concept of sustainable water yield, expanded on in chapter 2, into the broader concept of environmental/ecological sustainability, and briefly outline our still-evolving ideas on environmental sustainability. Our view of nature and the role of human intervention in it has changed during the last two decades. The role of water-resource-management institutions is changing from development to management. From the turn of the century through the 1960's, large-scale multipurpose water-resources projects were considered essential to the economic well-being of nations; water management meant planning and operating these projects to maximize four primary uses—irrigation, hydropower generation, municipal and industrial supply, and flood control. Recreation was a late and secondary add-on. This assumption eroded as environmental awareness grew and environmental concerns mounted (Feldman, 1991), in addition to the realization that the old ways of piece-meal management demonstrably failed (see Boxed section 3.1). The most fundamental change is the idea that human uses of water resources and environmental protection and management should be given equal weight. The result is that we now rely less on permanent structural solutions and more on adaptive management of existing physical and semi-natural systems. The ultimate challenge for present and future resource managers is to integrate science, technology, and institutions into the new ethic of sustainability.

The World Commission on Environment and Development, known as the Brundtland Commission, defined sustainable development as a “process of change in which the use of resources, the direction of investments, the orientation of technological developments, and institutional change all enhance the potential to meet human needs both today and tomorrow” (WCED, 1987). Sustainable development is inherently intergenerational because it implies that we must use the environment in ways that are compatible with maintaining it for future generations. This intergenerational perspective constrains our management of the environment and its resources, including water.

Despite progress in defining the goals of sustainable development, the mechanisms to bring about these changes are still a matter of debate. The move from

principle to practice is far from easy and poses a series of dilemmas for which there are no clear solutions. Although sustainable development is still an abstract concept, it is as powerful as many other abstract concepts such as liberty, equality, and justice. The concept is a dynamic one and will be continually refined. The ability to adapt to new knowledge (and resulting new ways of thinking about resources) is the hallmark of successful management, and it is a necessary condition for water management as we move from an era of rapid exploitation to one of sustainable use.

Environmental Sustainability: The Broader View

The paramount importance of sustainability arose partly because of the realization that present levels of per capita resource consumption of developed countries may not be possible for all currently living people, much less to future generations, without liquidating the natural capital on which future economic activity depends (Goodland et al., 1993). According to Postel (1996), as of 1995, the world as a whole was consuming directly or indirectly (through animal products) an average of just over 300 kilograms of grain per person a year (based on U.S. Department of Agriculture, Economic Research Service, 1991 figures). At this level of consumption, growing enough grain for the 90 million people now added to the planet each year (based on U.S. Bureau of Census projections, 1993) requires an additional 27 billion cubic meters of water annually—roughly 1.3 times the average annual flow of the Colorado River. Grain consumption per person varies widely by country, but assuming the global average remains the same as today, it will take an additional 780 billion cubic meters of water to meet the grain requirement of the projected world population in 2025—more than nine times the annual flow of the Nile River. Where this water is to come from on a sustainable basis is not obvious. Much of the crop production required to meet future food needs would seem to depend on an expansion of irrigation. However, serious constraints exist here as well. Falling water tables, depleted river flows, the lack of economical and environmentally sound sites for new supply projects,

Boxed section 3.1: Water-resource Sustainability — How Far, How Long?

The failures and unintended consequences of conventional water management and development strategies provide some of the strongest incentives for sustainable-resource management. Examples range from local to regional to global:

- Ground-water pumping has dried up or threatened numerous reaches of baseflow-dependent streams, wetlands, and subirrigated land—with many examples to be found in Kansas along the fringes of the High Plains aquifer (see also chapters 2 and 7).
- Increases in consumptive water use leave behind the salts dissolved in the water—irrigation has contaminated the land in many areas (for example, irrigation drainage water had contaminated the ponds at Kesterson National Wildlife Refuge in California with toxic levels of selenium), and the flow of

saline water from irrigation return flow into the Upper Arkansas River basin now threatens the ground-water resources of the alluvial and Ogallala aquifers.

- Part of water's role in the natural cycle is the transport of sediment, which it does best during floods. As streamflows are reduced and controlled, the sediment loads gradually fill reservoirs, seal off stream channels from the alluvial aquifers—and starve the downstream deltas (see also chapter 6).
- Whole regional ecosystems change and disappear with large-scale water development—the Gulf of California has changed from an estuary to a marine lagoon as the Colorado River has been dried up, and nutrient runoff from the central United States has changed the ecology of the area surrounding the mouth of the Mississippi River.

and rapidly growing urban demands are all placing limits on the availability of water for agriculture.

Natural capital is basically our natural environment and is defined as the stock of environmentally provided assets (such as soil, atmosphere, forests, water, wetlands), which provide a flow of useful goods or services. *Environmental sustainability* refers to natural capital. It means maintaining environmental assets, or at least not depleting them. Operationally, this translates into encouraging the growth of natural capital by reducing our level of current exploitation; investing in projects to relieve pressure on natural capital stocks by expanding “cultivated natural capital,” such as tree plantations, fish ponds, artificial recharge schemes for aquifers to relieve pressure on natural forests, fish populations, or ground-water resources, respectively; and increasing the end-use efficiency of products (improved light bulbs, appliances, cars, irrigation equipment, manure rather than chemical fertilizer, etc.).

An organism, an economy, or a project, all relate to their environment in basically the same way: they depend on the environment to supply useful inputs of raw materials and energy and to absorb less-useful outputs of waste materials and heat. Either the environmental “source” or the “sink” capacity can be diminished through overuse. Both must be limited for sustainability to succeed. The basic operational principles of sustainability can thus be summarized in the form of practical rules-of-thumb (table 3.1) to guide the design of economic development (Goodland et al., 1993). As a first approximation, the design of new projects should be compared with the input/output rules shown in table 3.1 in order to assess the extent to which a project is sustainable.

The global ecosystem is the source of all material inputs feeding the economic subsystem and is the sink for all its wastes. Population times per-capita resource consumption is the total flow—*throughput*—of resources from the global ecosystem to the economic subsystem,

then back to the global ecosystem as waste, as depicted in fig. 3.1.

In general, sustainability can be achieved not through increasing the throughput growth (i.e. materials and energy) but by ‘developing’ toward that goal. When something “grows” it gets quantitatively bigger; when it “develops,” it gets qualitatively better or at least different (Goodland et al., 1993). Quantitative growth and qualitative improvement follow different laws. Our planet changes over time without growing. According to Goodland et al. (1993), to achieve sustainability, the economy, a subsystem of the finite and nongrowing earth, must eventually adapt to a similar pattern of development without throughput growth. Some scholars, notably the ecologists Paul and Anne Ehrlich and the economist Herman Daly, believe that the scale of human pressure on natural systems already is well past a sustainable level. They point out that the world’s human population likely will at least double before stabilizing, and that to achieve any semblance of a decent living standard for the majority of people, the current level of world economic activity must grow, perhaps fivefold to tenfold. They cannot conceive of already stressed ecological systems tolerating the intense flows of materials use and waste discharge that presumably would be required to accomplish this growth. However, others perceive that through science and technology, mankind can achieve high-quality living standards with growth.

Ascertaining more clearly where the facts lie in this debate and determining appropriate response strategies are difficult problems—perhaps among the most difficult faced by all who are concerned with human advance and sound natural-resource management (Toman, 1992). Progress on these fronts is hampered by continued disagreements about basic concepts and terms of reference. To narrow the gaps, it may be helpful first to identify salient elements of the sustainability concept about which there are contrasts in view between econo-

TABLE 3.1—RULES-OF-THUMB FOR ENVIRONMENTAL SUSTAINABILITY (modified from Goodland et al., 1993).

1. Output rule
 Waste emissions from a project should be within the assimilative capacity of the local environment without unacceptable degradation of its future waste-absorptive capacity or other important services or health problems to communities. For example, sewage-discharge permits should be conditioned on both adequate (properly defined) streamflow for dilution, and on adequate spacing of discharge points for such dilution.

2. Input rule
 - a. *Renewables*: harvest rates of renewable-resource inputs should be within the regenerative capacity of the natural system that generates them but within a sufficiently short timespan to be of relevance to human beings. The sustainable yield policies of the local Groundwater Management Districts of central Kansas, where the Equus Beds and Great Bend Prairie aquifers are generally adequately replenished, constitute an example of such a rule (see details under the Kansas water-resources-management experience).
 - b. *Nonrenewables*: depletion rates of nonrenewable-resource inputs should be equal to the rate at which renewable substitutes are developed by human invention and investment. It is suggested (El Serafy, 1991) that part of the proceeds from liquidating nonrenewables should be allocated to research in pursuit of sustainable substitutes. The ground-water mining policies of the western Kansas Groundwater Management Districts, where the Ogallala aquifer replenishment rates are too miniscule to counterbalance the ground-water irrigation-based agricultural economy of the region, coupled with the western Kansas weather modification program and additional proposed water conservation measures, constitute an example of such a rule. The idea here is to extend the life of the aquifer, not sustain it.

mists and resource planners on the one hand, and ecologists and environmental ethicists on the other. Box 3.2 outlines key conceptual issues related to the definitions of sustainability (refer also to the glossary for additional definitions).

Ehrlich and Holdren (1974) encapsulate the sustainability concept as follows: The impact (*I*) of any population or nation upon environmental sources and sinks is a product of its population (*P*), its level of affluence (*A*), and the damage done by the particular technologies (*T*) that support that affluence,

$$I = P \cdot A \cdot T$$

$$[I = P \cdot Y/P \cdot I/Y]$$

where population (*P*) refers to human numbers; affluence (*Y/P*) is output (*Y*) per capita; and technology (*I/Y*) refers to environmental impact (or throughput intensity) per unit of output, i.e. a dollar's worth of solar heating stresses the environment less than a dollar's worth of heat from a coal-fired thermal-power plant. Environmental sustainability occurs when impact (*I*) or throughput, i.e. the maintenance flow of matter-energy, beginning with depletion and ending with pollution, is held below carrying capacity (*CC*). *Carrying capacity* is a measure of the amount of renewable resources in the environment in units of the number of organisms these resources can support. Carrying capacity is a function of the area and the organism, and it is indeed difficult to estimate, especially for humans, because of major differences in affluence and technology. The only three ways of addressing the need to keep $I < CC$ are: 1) limit population, 2) limit affluence, or 3) improve technology by reducing throughput intensity of production (Goodland et al., 1993). However, the $I = P \cdot A \cdot T$ identity is not sufficiently detailed to explain the feedbacks between population growth and environmental transforma-

tions. Moreover, $I = P \cdot A \cdot T$ limits the policy debate to only changing population, consumption levels, and technology, and leaves out the role of economic and political forces that determine who has access to and control over natural resources (Loh, 1995).

Meeting human needs while facing up to water's limits—economic, ecological, and political—entails developing a wholly new relationship to water (Postel, 1993). Historically, we have managed water with a frontier philosophy, manipulating natural systems to whatever degree engineering know-how would permit. Modern society has come to view water only as a resource

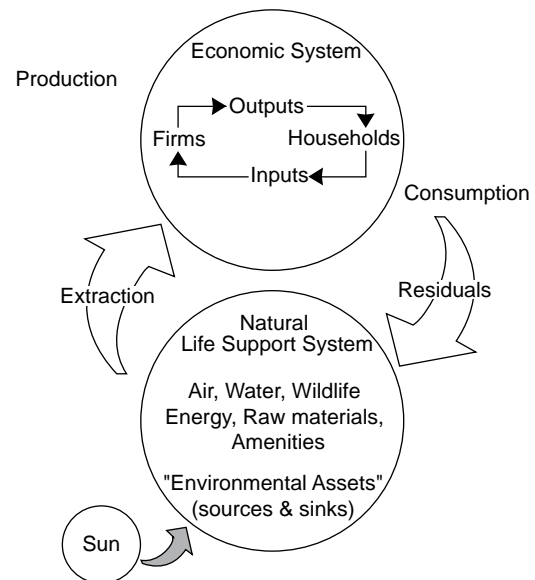


FIGURE 3.1—RELATIONSHIP BETWEEN THE ECONOMIC AND THE ENVIRONMENTAL SYSTEMS. Adapted from Goodland and Daly, 1995.

that is there for the taking, rather than a life-support system that underpins the natural world upon which we depend. The challenge now is to put as much human ingenuity into learning to live in balance with water as we have put into controlling and manipulating it. Conservation, efficiency, recycling, and reuse can generate a new supply large enough to get us through many of the shortages on the horizon, buying time to bring consumption down to sustainable levels.

Environmental Sustainability versus Sustained Yield

Whether environmental sustainability (ES) is ‘sustained yield’ (S–Y) in the form of water extraction from an aquifer, for example, is debatable. Clearly ES includes, but certainly is far from limited to, sustained yield. ES is more akin to the simultaneous S–Y of many interrelated entities in an ecosystem. ES counts all the natural services of the sustained resource. S–Y counts only the service of the product extracted and ignores all other natural services.

Water S–Y counts only the quantity (and quality) of water extracted; ES of water resources counts all services. These include protecting both water quality and quantity, ground and surface waters, biological concerns, the land-water interface ecosystems, and the objectives of the user community. The relation between the two is that if S–Y is actually achieved, then the stock resource (e.g., the water) will be nearer sustainability than if S–Y is not achieved. The optimal solution for a single variable, such as S–Y, usually results in declining utility or declining natural capital sometime in the future, and therefore may not be sustainable. (See also Boxed section 3.2).

Expanding Sustainability Concepts: The Ecosystem Management Approach

Over the past 50 years, the concepts underlying management of water resources have gradually shifted from a deterministic world view based on *the balance of nature* to a recognition that *nature is characterized by chance and randomness*, that natural systems are inher-

Boxed section 3.2: On the Definitions of Sustainability.

Sustain (vt) 1. to give support or relief to 2. to supply with sustenance : NOURISH 3. KEEP UP, PROLONG (Webster’s Ninth New Collegiate Dictionary)

Straightforward definitions? Let’s see how far they get us as we explore sustainability of resources—and resource uses.

Sustainability has come to be the watchword of those concerned with “intergenerational equity,” the idea that succeeding generations should have access to a resource base comparable to our own. Sounds fair—but what is it that we want to be sustainable?

The problem of defining and maintaining sustainability is not just intergenerational, it is interstate and international as well. We may have an obligation to the future, but we know that the present climate and its hydrologic characteristics is not permanent (see chapter 8), so how faithfully and for how long do we try to preserve present conditions? A decade, a human lifetime, a thousand years? It seems utopian to expect sustainable to mean “forever” (Worster, 1993). Then what degree of sustainability should we settle on? And what are the rights and obligations involved in water use that affects people a thousand miles away and in a different country? They are certainly not defined or protected under the doctrines of western water law—and yet as the global interconnectedness of both economies and ecosystems becomes ever more obvious, they cannot be ignored.

“Sustainable yield” is often used as a single-product exploitation goal—the number of trees cut, the number of fish caught, the volume of water pumped from ground or river, year after year without destroying the resource base. But experience has shown, over and over, that a single-product goal is too narrow a definition of the resource, because other resources

inevitably depend on or interact with or flow from the exploited product. We can maximize our sustainable yield of water by drying up our streams—but when we do, we find that the streams were much more than just containers of usable water.

The next level of sustainable yield addresses the sustainability of the “system,” not just the fish, but the marine food chain; not just the trees, but the whole forest; not just the ground water, but the running streams, wetlands, and all of the plants and animals that depend on them. A worthwhile approach, perhaps even a noble one—but fraught with difficulty. We cannot use a natural system without altering it, and the more intensive and efficient the use, the greater the alteration. How much is too much? What are the central characteristics that must be preserved or sustained? Is there any way to answer these questions before it is too late? Here is the forefront of the definition problem—even if we assume that we care about the next generation, do we permit anything that cannot be proven dangerous or forbid what cannot be proven safe?

At the most abstract level we talk about sustainable development—not the resource, not the ecosystem, but the economic benefit derived from it. Can we have development without growth, or growth without degradation? Many scientists are suspicious of the idea, but it comes naturally to many economists, who have been steeped in the doctrine of substitutability—let a resource become scarce or expensive, and *Homo sapiens* will devise a replacement. It is a comforting concept—if nothing is limiting, then there are no limits!

Substitutability is an attractive theory, but what do we drink when the well runs dry? Sustainability is an attractive goal, but how many people can drink from the stream if they have to leave enough water for the salamanders?

ently variable, patchy, and often require disturbance to persist. (Stream ecosystems in particular depend on natural disturbances such as flooding.) We also recognized the interdependency of system components and the importance of indirect effects (instead of temperature affecting biology, biology is affecting temperature!) The management implication of these realizations is that we must manage for change and for complexity. This approach dictates (Meyer, 1993) 1) management in the context of the *ecosystem* rather than managing parts as though they were in isolation, and 2) use of an *adaptive management* scheme that is responsive to changing environmental conditions.

The term *watershed ecosystem* refers to all of the elements and processes that interact within the catchment basin or watershed. The concept of the watershed includes four-dimensional processes (Doppelt et al., 1993) that connect the longitudinal (upstream—downstream), lateral (floodplain—upland), and vertical (hyporheic or ground-water zone—stream channel) dimensions, each differing temporally. Watersheds are ecosystems composed of a mosaic of different land or terrestrial “patches” that are connected by (drained by) a network of streams. In turn, the flowing water environment is composed of a mosaic of habitats in which organisms, materials, and energy move in complex, yet highly integrated, systems. Physical and chemical processes and complex food webs depend on those movements. Given the dynamic connectedness of a watershed, management activities can fragment and disconnect the habitat patches if they are not planned and implemented from an ecosystem and watershed perspective. In-stream conditions are largely determined by processes occurring within the watershed and underlying aquifers, and they cannot be isolated from or manipulated independently of this context.

Meyer (1993) summarizes the changing concepts of ecological-system management resulting from recent advances in our scientific understanding. Many aquatic ecosystems depend on disturbance. A change in the natural disturbance regime is a major cause of alterations in riverine ecosystems after dam construction. For example, when disturbances caused by variable water discharge, high summer temperatures, and massive sediment transport are removed, the system changes. This has happened below Glen Canyon Dam, and it is one of the issues addressed by the Water Science and Technology Board Glen Canyon Environmental Studies (NRC, 1987) committee. Since dam construction, flood flows and sediment transport have been reduced, resulting in depletion of sand stored in the active channel (Andrews, 1991). Because of stabilized flows, a larger riparian area remains moist, and the riparian zone has expanded and has been invaded by several exotic species, including salt cedar or tamarisk (*Tamarisk chinensis*), camelthorn (*Alhagi camelorum*), and Russian olive (*Elaeagnus angustifolia*) (Johnson, 1991; Bowers et al., 1995). Release of cool, sediment-poor but nutrient-rich water

from Lake Powell leads to high biomass of algae (*Cladophora*) and invertebrates in the river (Stanford and Ward, 1991). The continued existence of the native fishes is threatened by the altered thermal environment but more critically by the introduction of nonnative species that are able to thrive in the new environment created by the dam (Minckley, 1991). Native fishes also are failing to reproduce because of the absence of large seasonal changes in water level, which synchronized their breeding cycles (Minckley and Deacon, 1991). Clearly, reservoir operations that have altered the natural-disturbance regime have had an effect on many components of the downstream ecosystem (Carothers and Brown, 1991).

How might one manage for change in this situation? The NRC committee has advocated adaptive management (NRC, 1991). The combination of 1) introducing environmental dimensions into decisions on dam operation at the beginning of the process, 2) using experiments to assess ecological consequences on downstream ecosystems of management activities (i.e. of different release schedules), and 3) continued dialogue between scientists and managers to evaluate policies in the face of a variable environment are at the core of adaptive management (Holling, 1976). The idea of adaptive management grew from a recognition of basic properties of ecological systems, which include *the unexpected can be expected* (see Boxed section 3.3 later on) and *environmental quality is not achieved by eliminating change* (Holling, 1976). Clearly, this is managing for change (Meyer, 1993).

Science will never know all there is to know. Science is a process, not an end point. Rather than allowing the unknown or uncertain to paralyze us, we must apply the best of what we know today—while, at the same time, providing sufficient management flexibility to allow for change and for what we don’t yet know. This means we must not plan for riverine systems, for example, to operate near the limits of their capacity.

An additional component of management for change is managing in a probabilistic and risk-assessment framework in which one recognizes the inherent unpredictability of nature (Meyer, 1993). This is particularly appropriate for managing populations of rare species (e.g., desert pupfishes) but also applies to managing a fisheries resource (Meyer, 1993), or a water-resource system. Rather than determining a fixed sustainable yield, managers recognize that yield should vary over time as environmental conditions vary. In the long term this produces a more sustainable yield. This type of management requires greater input of scientific understanding and continued monitoring than is currently practiced (Meyer, 1993).

How do we manage for complexity? The obvious answer, given by numerous Water Science and Technology Board committees (e.g., NRC, 1991), is to manage in an ecosystem context (Meyer, 1993). Rather than managing for a single resource (board feet of lumber or acre-feet of water), managers work to sustain the diversity of services provided by the ecosystem with a recognition of the

Boxed section 3.3: A Failure to Recognize Stream-aquifer Interconnections: Unexpected Things Can Happen!

Sometimes a decision about one aspect of a water system in Kansas has an impact on a variety of systems, impacts not necessarily intended or even recognized when the original decision was made. In 1951, the Bureau of Reclamation constructed Cedar Bluff Dam on the upper reaches of the Smoky Hill River in Trego County in west-central Kansas. Cedar Bluff captures drainage from the Smoky Hill and two of its major tributaries, Ladder Creek and Hackberry Creek. The dam was intended to provide flood control, water for irrigation and municipal use, and water for a fish hatchery below the dam, operated by the U.S. Fish and Wildlife Service. Shortly after the dam was completed, heavy spring and summer rains in 1951 and 1957 filled the reservoir. In about 1965, however, inflow into the reservoir slowed substantially. In other parts of northwestern Kansas, decreased inflow to reservoirs was attributed to a lessening of streamflow caused by lower water tables and the increased use of conservation practices in agriculture, such as terracing and building of farm ponds that dramatically decrease runoff (Bureau of Reclamation, 1984). These causes may apply to the reduced flow into Cedar Bluff. Because of this lack of inflow, the contents of Cedar Bluff Reservoir averaged about 13% of the designed level since 1980 (Ratzlaff, 1987). Releases of water from Cedar Bluff to entities with water rights stopped by 1979.

Hays, Kansas, a city of about 18,000 people, is about 22 miles (35 km) downstream from Cedar Bluff, about 10 miles (16 km) north of the Smoky Hill River. One of the city's primary water sources was a well field in the alluvial aquifer of

the Smoky Hill River, which produced about 2,500 acre-feet ($3.1 \times 10^6 \text{ m}^3$) of water annually. Lessened streamflows in the Smoky Hill—caused by lower water tables, decreased runoff, and the lack of discharge from the reservoir—meant that considerably less water was available in the Smoky Hill to recharge the alluvial aquifer. Yields in the Hays well field dropped to about 1,000 acre feet ($1.2 \times 10^6 \text{ m}^3$) annually (Henson and Zacharias, 1993). In addition, the Smoky Hill River valley below the lake (from Cedar Bluff to the confluence of the Smoky Hill and Big Creek in western Russell County) was declared an Intensive Ground-water Use Control Area (or IGUCA) by the State engineer in 1984 (Macfarlane, 1985). Because of dwindling water supplies, Hays began a number of conservation efforts, resulting in a substantial reduction in per capita water use. The city also began aggressively seeking additional water sources, and eventually purchased land and water rights to a ranch in Edwards County, Kansas, about 85 miles (136 km) away, with plans of transferring water for municipal use in Hays, in spite of considerable opposition to the plan in Edwards County. In short, then, lessened streamflow in the Smoky Hill River in the Kansas River drainage basin, combined with changing agricultural practices and lower water tables, had the domino effect of lessening supplies in Hays, leading to the possible transfer of water from the Arkansas River drainage basin, more than 100 miles (160 km) away from Cedar Bluffs. The reservoir's construction, along with other factors, clearly had a variety of consequences—related to agricultural, municipal, and irrigation water supply, as well as streamflow—that reverberated far beyond the simple building of a dam in Trego County.

complex interactions and numerous indirect effects that characterize ecological systems. Ecosystem management recognizes that if it is the entire system and its continued productivity for a wide array of uses and values that we desire, then production goals for individual resources might not point a path toward sustainability. We need instead objectives that relate to ecological conditions in the basin and that sustain land uses and resource yields compatible with those conditions (Kessler et al., 1992).

The evidence shows that we have altered the hydrologic cycle as well as cycles of most elements, that we seem to be affecting climate, and that biodiversity may be declining rapidly. These events call for a more holistic concept of system management that has the goal of maintaining and restoring the ecological integrity of the resource rather than simply preserving water quantity or quality (Meyer, 1993).

Kansas Water-resources-management Experience

In view of persistent ground-water-level declines especially in western Kansas, the Kansas Legislature in 1972 passed the Kansas Groundwater Act authorizing the formation of local groundwater management districts (GMDs) to help control and direct the development and use of ground-water resources. Since passage of the enabling

act, five districts have been formed of which the three western districts overlie all or parts of the Ogallala aquifer. The three western districts (1, 3, and 4) have the greatest number of large-capacity wells and the highest rate of water-level declines in addition to having the least precipitation and least ground-water recharge. Each of these districts has adopted a plan that will allow a portion of the aquifer to be depleted (no more than 40%) over a period of 20–25 years (*planned depletion policy*; this implies that the Ogallala is not a renewable resource at least within a human generation, although the Northwest Kansas GMD4 implemented a “*zero depletion*” policy in 1990 for new wells, as mentioned in Chapter 1.) The districts to the east (2 and 5), which have more precipitation, and thus more ground-water recharge, have initially adopted a “*safe yield*” management plan (during the late 1970's) to balance ground-water pumping with the average annual recharge. According to this policy, the total amount that may be appropriated in a 2-mile (3.2-km) circle around the proposed diversion is limited to the long-term average annual recharge calculated for the circle. Thus, the quantity already appropriated within that 2-mile (3.2-km) circle plus the quantity proposed under the new application must be less than the long-term average annual recharge (implying a renewable ground-water resource). Ground-water pumping between predevelopment (circa 1940's) and 1990's has depleted significant portions of the High Plains aquifer and caused water-level declines of as

much as 200 ft (60 m) at places in southwestern Kansas. Figure 3.2 shows the declines in saturated thickness since predevelopment across western and central Kansas. As a result of these declines, the Division of Water Resources has officially closed many areas of western and central Kansas to new ground-water development (fig. 1.37B of Chapter 1).

In addition, as a result of the above mentioned ground-water-level declines, streamflows of western and central streams have been decreasing, especially since the mid-1970's. In response to these streamflow declines, the Kansas Legislature passed the minimum instream flow law in 1982, which requires that minimum desirable streamflows (MDS) be maintained in different streams in Kansas. Although the establishment of MDS is a major step toward conservation of riverine habitat within the state, the trend in reduction of discharge since the mid-seventies appears to be continuing (Ferrington, 1993). Figure 3.3 is a graph of mean daily discharge in the Arkansas River averaged by month for Coolidge, Syracuse, Garden City, and Dodge City for the period of October 1987 to September 1993, where the longitudinal pattern in reduction of surface discharge is clearly visible. Maps comparing the perennial streams in Kansas in the 1960's to those of the 1990's show a marked decrease in miles of streamflow in the western third of the state (fig. 2.15 in Chapter 2).

Kansans have come to realize that ground water and surface water are closely interrelated systems. Ground water feeds springs and surface streams, and surface water recharges aquifers. The decline of ground-water levels

around pumping wells located near streams creates gradients that capture some of the ambient ground-water flow that would have, without pumping, discharged as baseflow to the streams. At sufficiently large pumping rates, these declines induce flow out of the body of surface water into the aquifer, a process known as *induced infiltration or recharge*. The sum of these two effects leads to *streamflow depletion*. In addition to quantity issues, stream-aquifer interactions are also important in situations of ground-water contamination by polluted surface water, and of degradation of surface water by discharge of low-quality ground water as we saw in Boxed section 2.4 of Chapter 2. Ground-water discharge of saline water (mineral intrusion) or other low-quality ground water to streams results in surface-water quality degradation, as it happens for example in the Rattlesnake Creek east of US-281, and in the Arkansas River from Coolidge to Arkansas City (Whittemore, 1995). In turn, such polluted surface water presents a threat of ground-water contamination to the freshwater Equus Beds aquifer along the Arkansas River valley between Hutchinson and Wichita. In fact, streams and their alluvial aquifers are so closely linked in terms of water supply and water quality that neither can be properly understood or managed by itself, and therefore the combined stream-aquifer system must be considered (see also Boxed section 3.3).

As a result of the above-mentioned declines in ground-water levels and streamflow, both GMDs 2 and 5 have recently (early 1990's) reevaluated their "safe-yield" policies and moved toward conjunctive stream-aquifer management by amending their "safe yield" regulations to

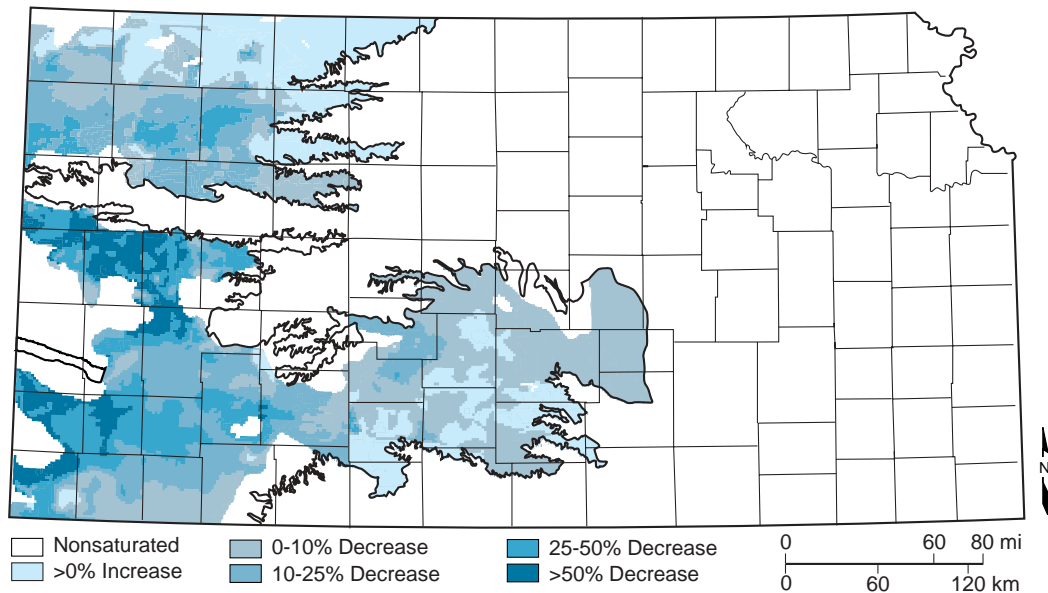


FIGURE 3.2—PERCENT CHANGE IN SATURATED THICKNESS (pre-development through 1996).

include baseflow (the natural ground-water discharge to a stream) as ground-water withdrawals along with regular water-permit appropriations when evaluating a ground-water-permit application. (Baseflow is usually estimated as the streamflow that is exceeded 90% of the time on a monthly basis.) The concept is to prorate the baseflow to a series of phantom wells, known as “baseflow nodes” located on the stream centerline at 1/4-mile (0.4-km) intervals (the GMDs well-spacing requirement), each having an annual quantity of water assigned to it equal to its prorata share of the estimated baseflow, which is considered its appropriation for “2-mile circle” computations. If there are such nodes in a 2-mile (3.2-km) circle, they are each treated as water rights for purposes of determining whether or not a new application should be approved. For regulatory and name-recognition purposes, GMD 2 continues to refer to these regulations as “safe-yield” ones, whereas GMD 5 renamed theirs as “sustainable yield.” Hopefully, this new measure together with the establishment of minimum-desirable-streamflow standards will provide additional needed protection to the riverine-riparian ecosystem. (See also the section on statewide water appropriations outside the GMDs in Part IV of Chapter 1.) In addition, the integrated resource planning (IRP) program of the City of Wichita, outlined in Boxed section 2.4 of Chapter 2, will further improve the GMD2 water-related picture.

The Division of Water Resources also is attempting to develop a comprehensive basinwide-management program in areas of Kansas with significant water problems. The

purpose of this subbasin water-resources management program is to develop comprehensive, long-term water-management strategies to implement solutions to water problems within the framework of existing State water laws on a proactive basis. This program is intended to be holistic, addressing concerns related to surface-water depletions, ground-water declines, and deterioration of the water quality. The approach taken is that of the *watershed ecosystem*, recognizing that streams are not simply water flowing through a channel, but are the products of their drainage basins or watersheds and their associated aquifers (ground-water basins), and that to understand and model such stream-aquifer interactions, it is necessary to understand the flow paths within the surface- and ground-water watersheds associated with the stream. Close consultation and cooperation with the local district, irrigators’ associations, and other interested parties are integral parts of this program.

Thus the concept of integrated management of ground water and surface water on a watershed or basin-scale basis embracing the ecosystem concept is now taking hold in Kansas. Such integrated watershed-management efforts include interrelating the management of water quality and quantity, ground and surface waters, the land-water interface, biologic concerns, and the objectives of the user community. Watersheds are considered generally equivalent to ecosystems. Thus, the ecosystem concept provides a basis for a holistic framework to unite environment and society. The progressive evolution of Kansas water management incorporating local groundwater management

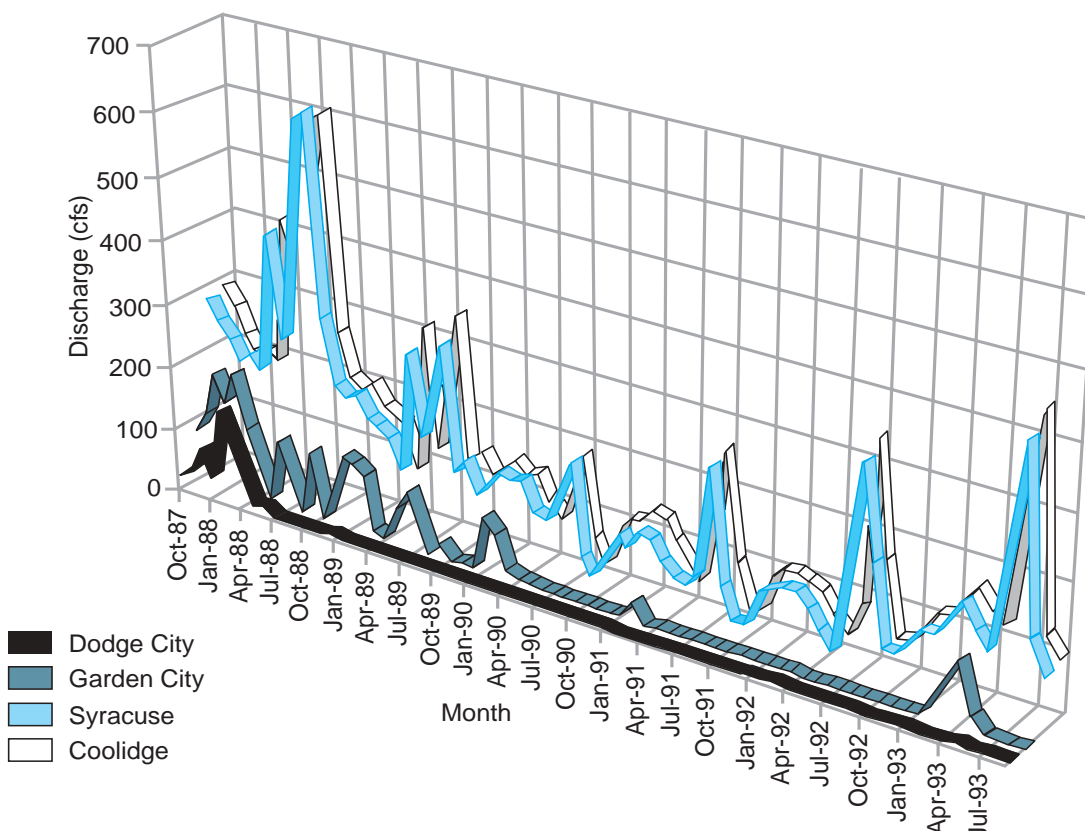


FIGURE 3.3—AVERAGE MONTHLY DISCHARGE OF THE ARKANSAS RIVER AT COOLIDGE, SYRACUSE, GARDEN CITY, AND DODGE CITY STREAM-GAGING STATIONS. Modified from Ferrington (1993).

districts, minimum-streamflow standards, the conjunctive stream-aquifer management embodied in the sustainable-yield policies, integrated resource planning, and the DWR subbasin water-resources-management program are all appropriate steps toward the ethic of sustainable development.

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