GROUNDWATER SUSTAINABILITY AND ITS APPLICATION IN KANSAS

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SUSTAINABLE DEVELOPMENT

"…development that meets the needs of the present without comprising the ability of future generations to meet their own needs."

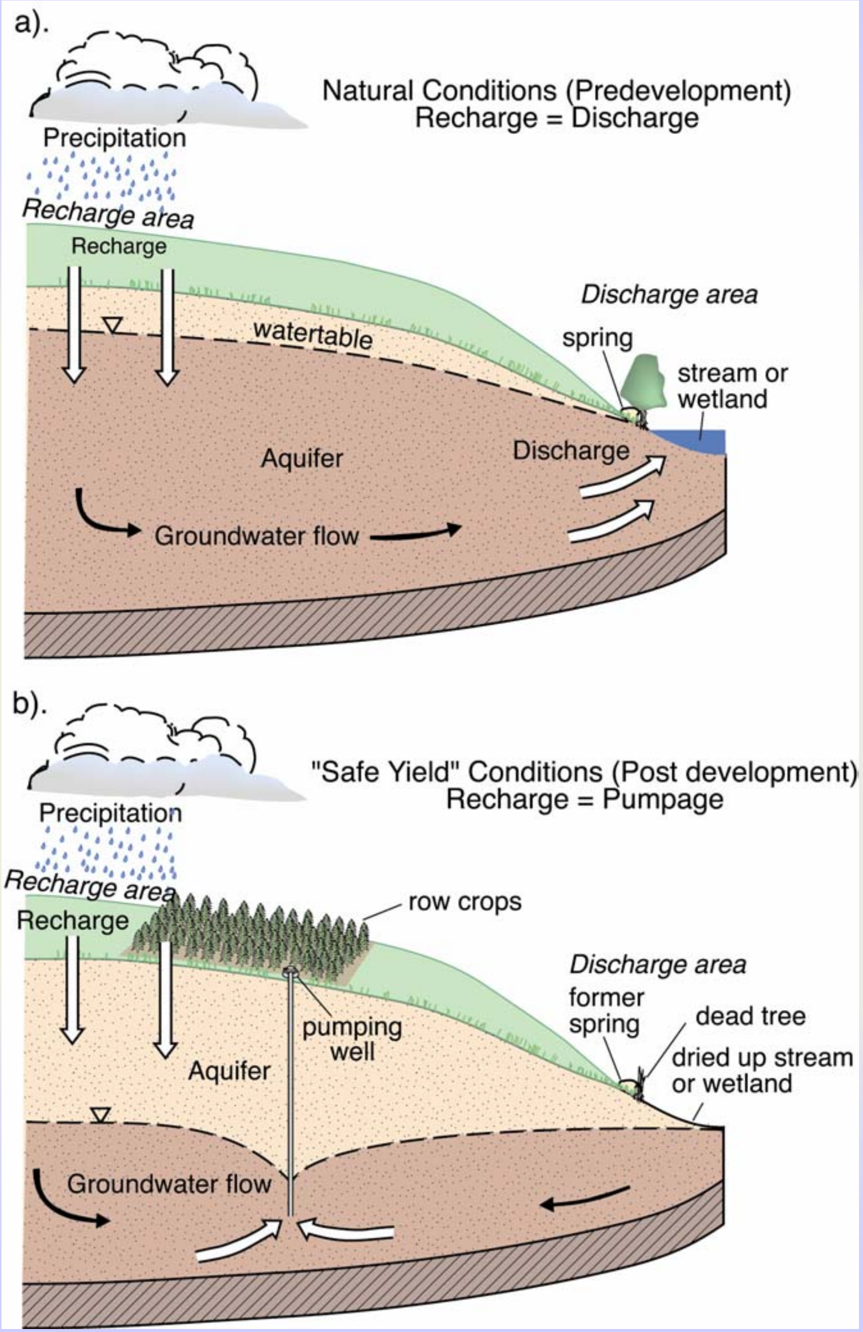
World Commission on Environment and Development (1987)
"Brundtland Commission"

WHAT IS THIS TALK ABOUT…

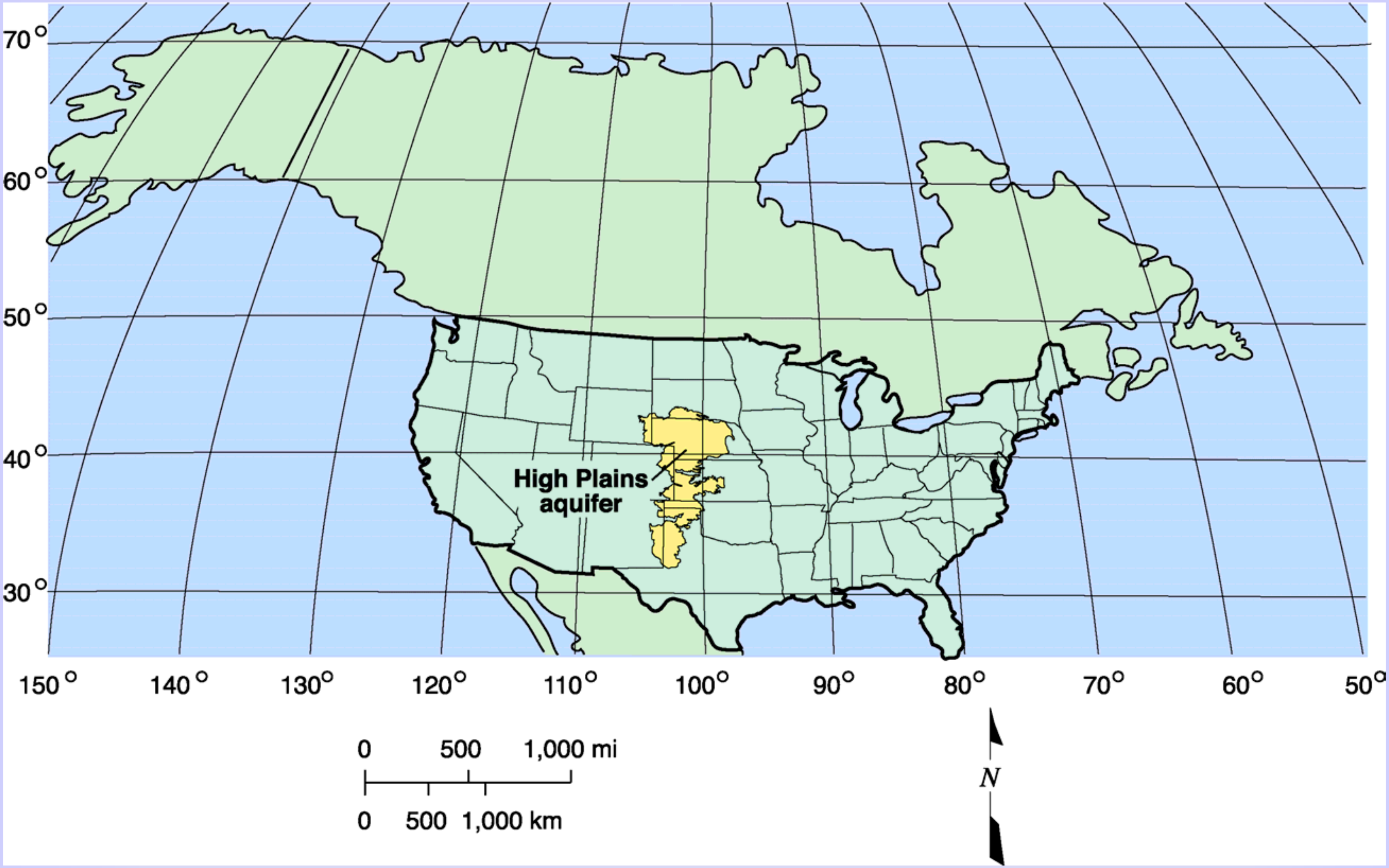
- General introduction
- Safe yield: hydro-ecologic fundamentals and shortcomings
- Hydrologic basis for a sound water-use planning policy
- Examples of groundwater systems and their response to development
- Expanding sustainability concepts
- Kansas water resources management experience
- Concluding comments: the way forward

Safe yield: underlying hydro-ecological fundamentals

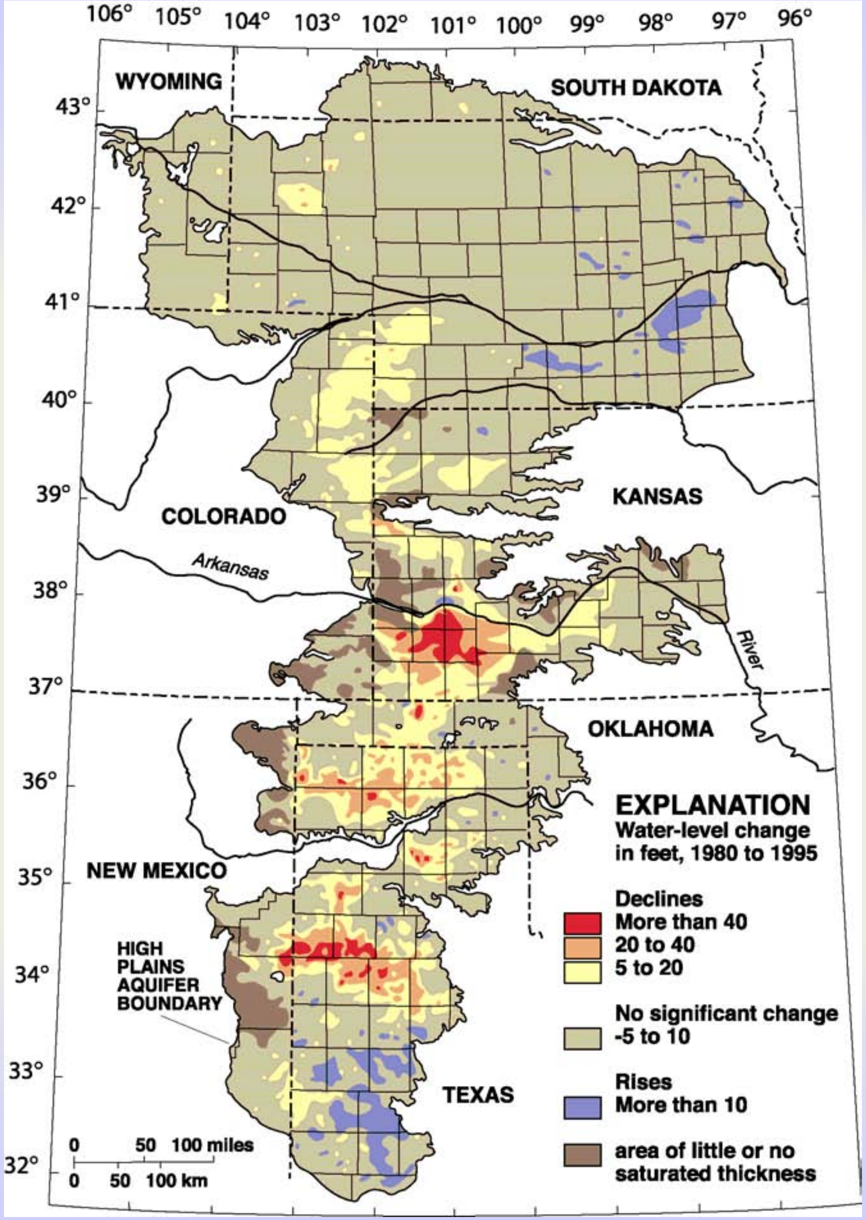
SAFE YIELD is commonly defined as the attainment and maintenance of a long-term balance between the amount of groundwater withdrawn annually and the annual amount of recharge

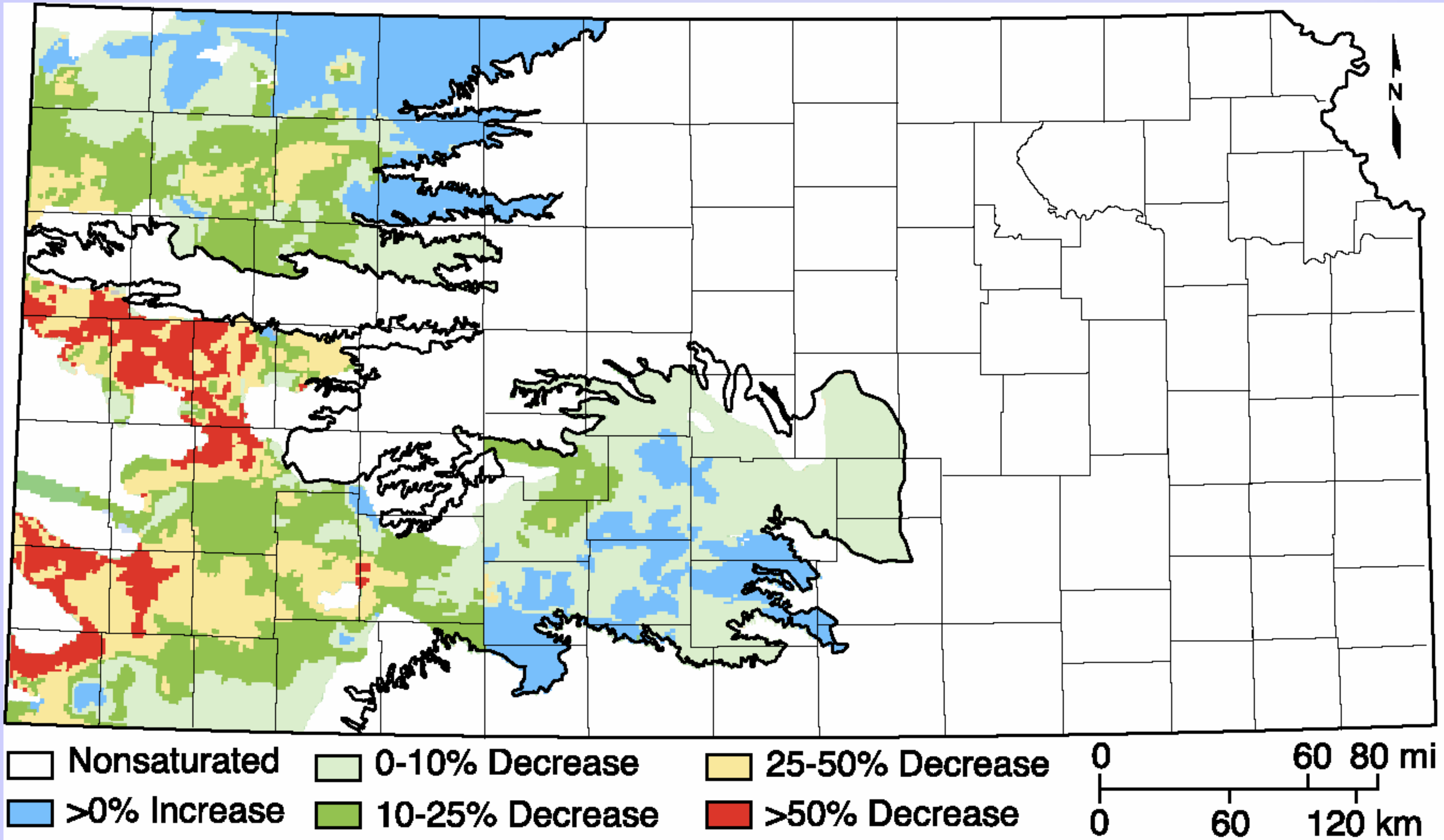


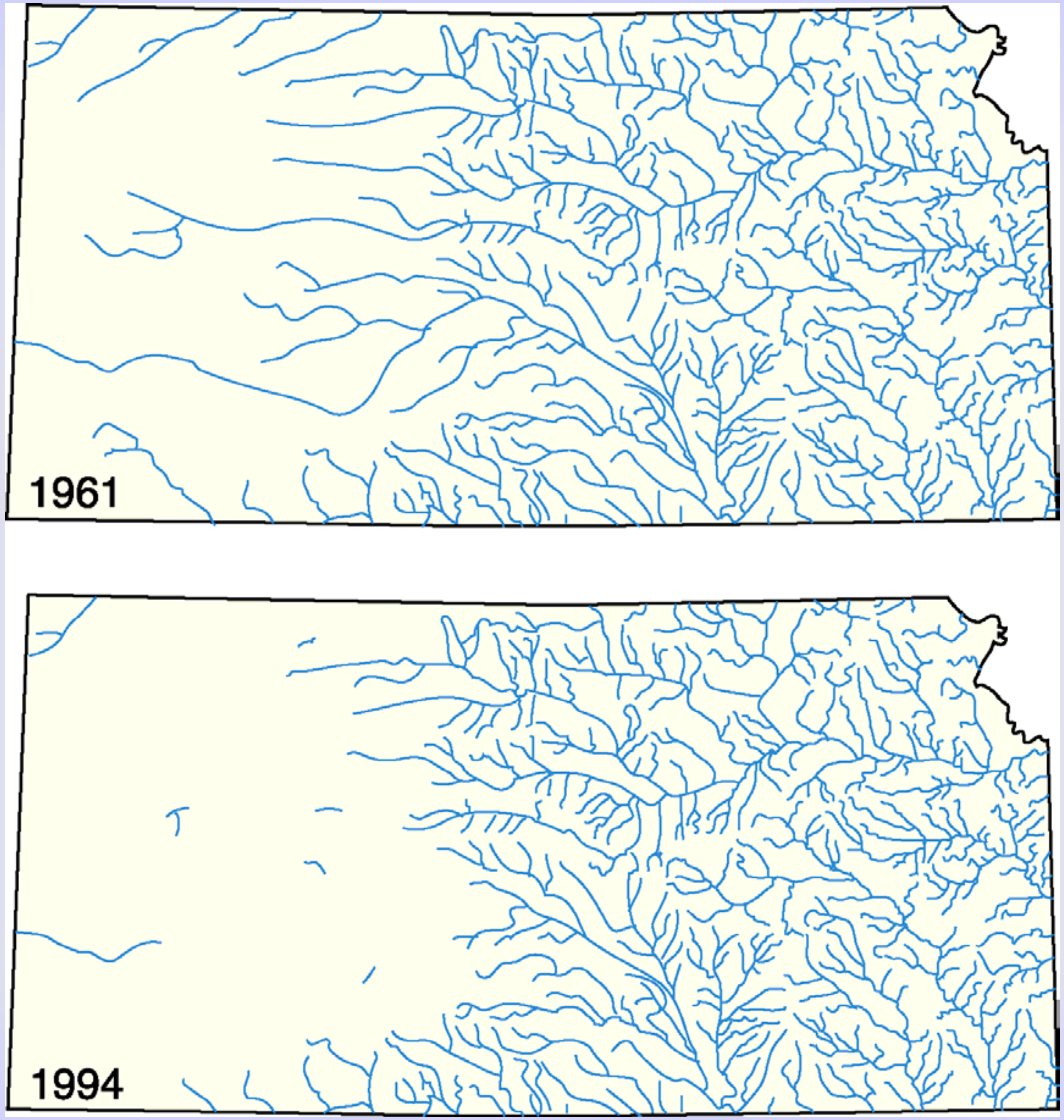
a).
Natural Conditions (Predevelopment)
Recharge = Discharge
Precipitation
Recharge area
Recharge
Discharge area
watertable
spring
stream or
wetland
Aquifer
Discharge
Groundwater flow
b).
"Safe Yield" Conditions (Post development)
Recharge = Pumpage
Precipitation
Recharge area
Recharge
row crops
Discharge area
former
spring
dead tree
pumping
well
dried up stream
or wetland
Aquifer
Groundwater flow



70°
60°
50°
40°
30°
High Plains aquifer
150°
140°
130°
120°
110°
100°
90°
80°
70°
60°
50°
0
500
1,000 mi
0
500
1,000 km
N


106° 105° 104° 103° 102° 101° 100° 99° 98° 97° 96°
43°
42°
41°
40°
39°
38°
37°
36°
35°
34°
33°
32°
WYOMING
SOUTH DAKOTA
COLORADO
KANSAS
Arkansas
River
OKLAHOMA
NEW MEXICO
TEXAS
HIGH PLAINS AQUIFER BOUNDARY
0 50 100 miles
0 50 100 km
EXPLANATION
Water-level change in feet, 1980 to 1995
Declines
More than 40
20 to 40
5 to 20
No significant change -5 to 10
Rises
More than 10
area of little or no saturated thickness


N
Nonsaturated
>0% Increase
0-10% Decrease
10-25% Decrease
25-50% Decrease
>50% Decrease
0 60 80 mi
0 60 120 km


1961
1994

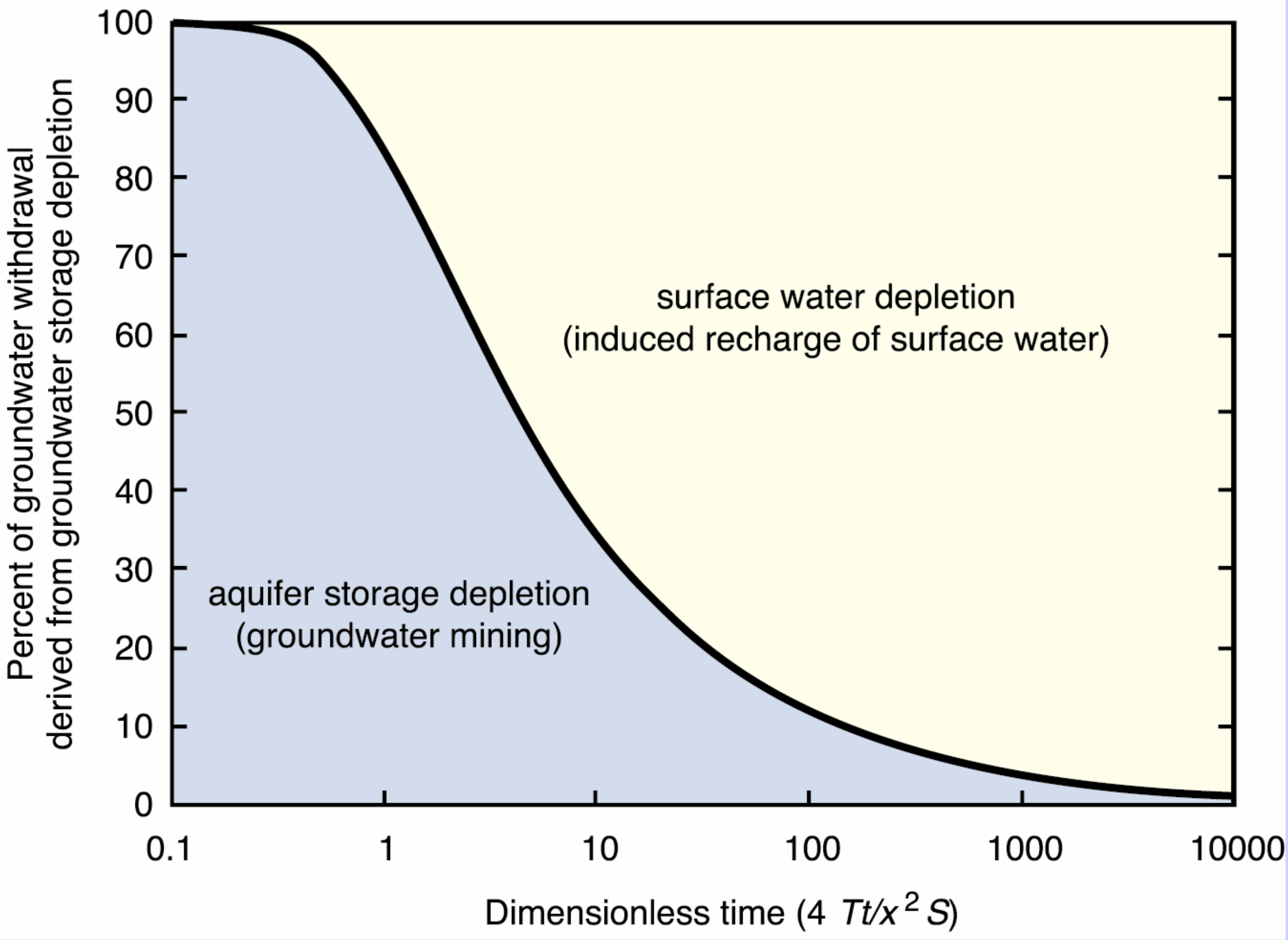
DYNAMIC EQUILIBRIUM AFTER DEVELOPMENT can only be achieved by

1. an increase in recharge (natural or artificial)
2. an decrease in natural discharge

or 3. a combination of the two

GROUNDWATER SOURCES

- Groundwater storage
- Induced recharge of surface water

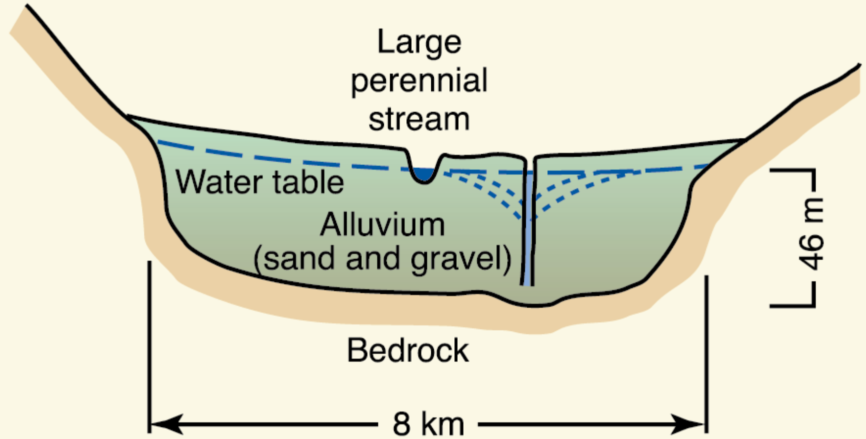


100
90
80
70
60
50
40
30
20
10
0
Percent of groundwater withdrawal derived from groundwater storage depletion
surface water depletion
(induced recharge of surface water)
aquifer storage depletion
(groundwater mining)
0.1
1
10
100
1000
10000
Dimensionless time (4 Tt/x 2 S)

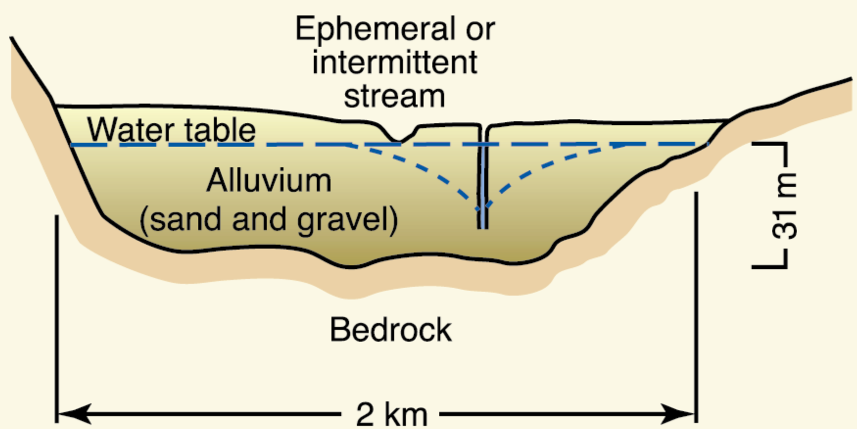
STREAM-AQUIFER MODELS

- A predictive tool explaining the connection between well field withdrawal and surface-water depletion at particular sites

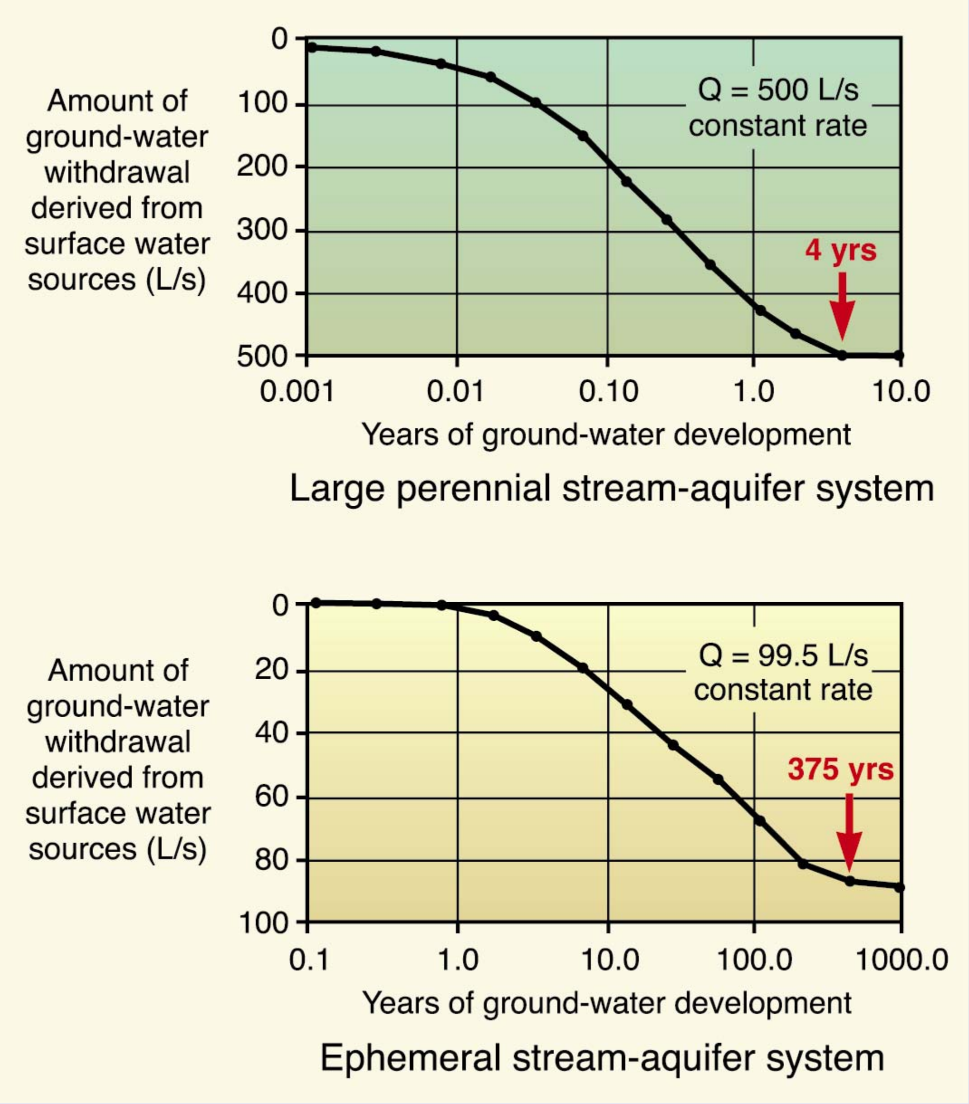
- Can generate the system transition curve from reliance on aquifer storage to surface-water depletion



Valley of large perennial stream in humid region.



Valley of ephemeral stream in semiarid region.


Amount of ground-water withdrawal derived from surface water sources (L/s)
0
100
200
300
400
500
Q = 500 L/s constant rate
4 yrs
0.001
0.01
0.10
1.0
10.0
Years of ground-water development
Large perennial stream-aquifer system
Amount of ground-water withdrawal derived from surface water sources (L/s)
0
20
40
60
80
100
Q = 99.5 L/s constant rate
375 yrs
0.1
1.0
10.0
100.0
1000.0
Years of ground-water development
Ephemeral stream-aquifer system

EXPANDING SUSTAINABILITY CONCEPTS

…management for change and for complexity

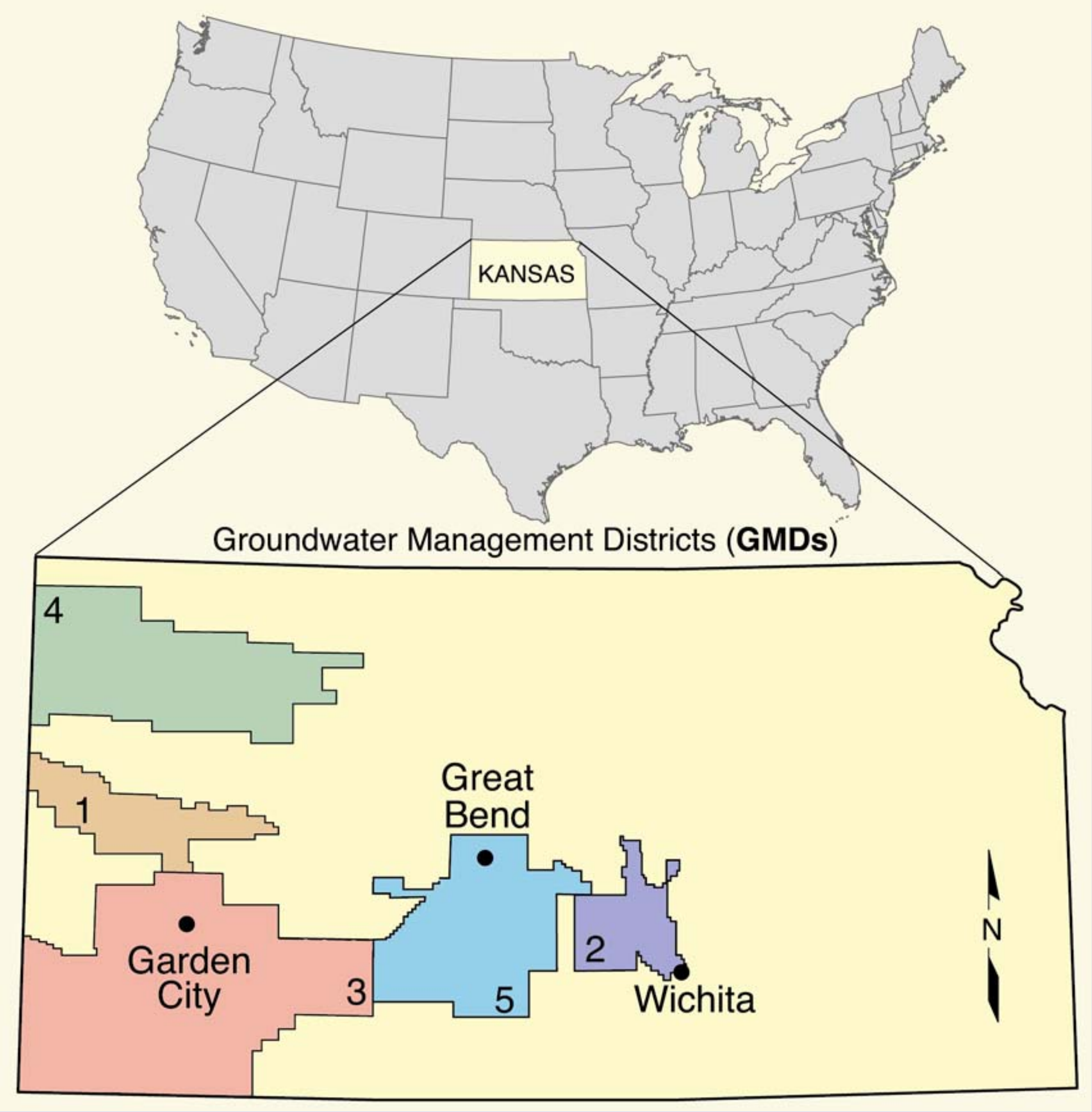
- ecosystem approach
- adaptive management approach

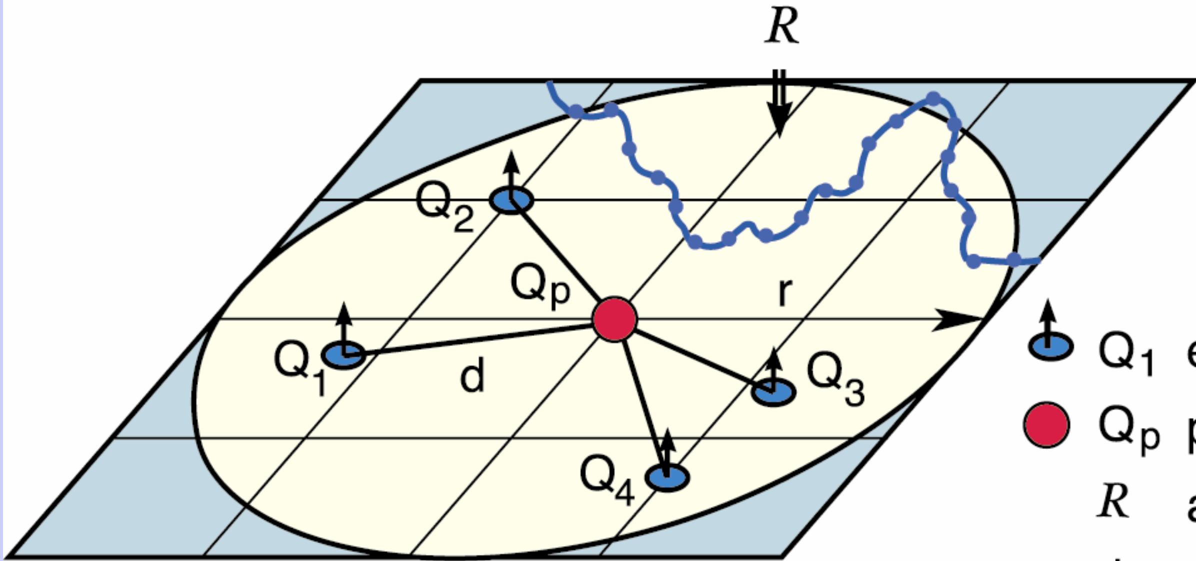
Sustainability of the “system”

INTEGRATED RESOURCE PLANNING

"assured that water resources are managed
for the greatest good of people and the environment
and that all segments of society have a voice
in the process" (AWWA, 1994)

The Kansas water resources management experience


KANSAS
Groundwater Management Districts (**GMDs**)
4
1
Great Bend
Garden City
3
5
2
Wichita
N



Q_1 existing irrigation well

Q_p proposed irrigation well

R aquifer recharge

d well spacing

r search radius (3.2 km)

• stream nodes

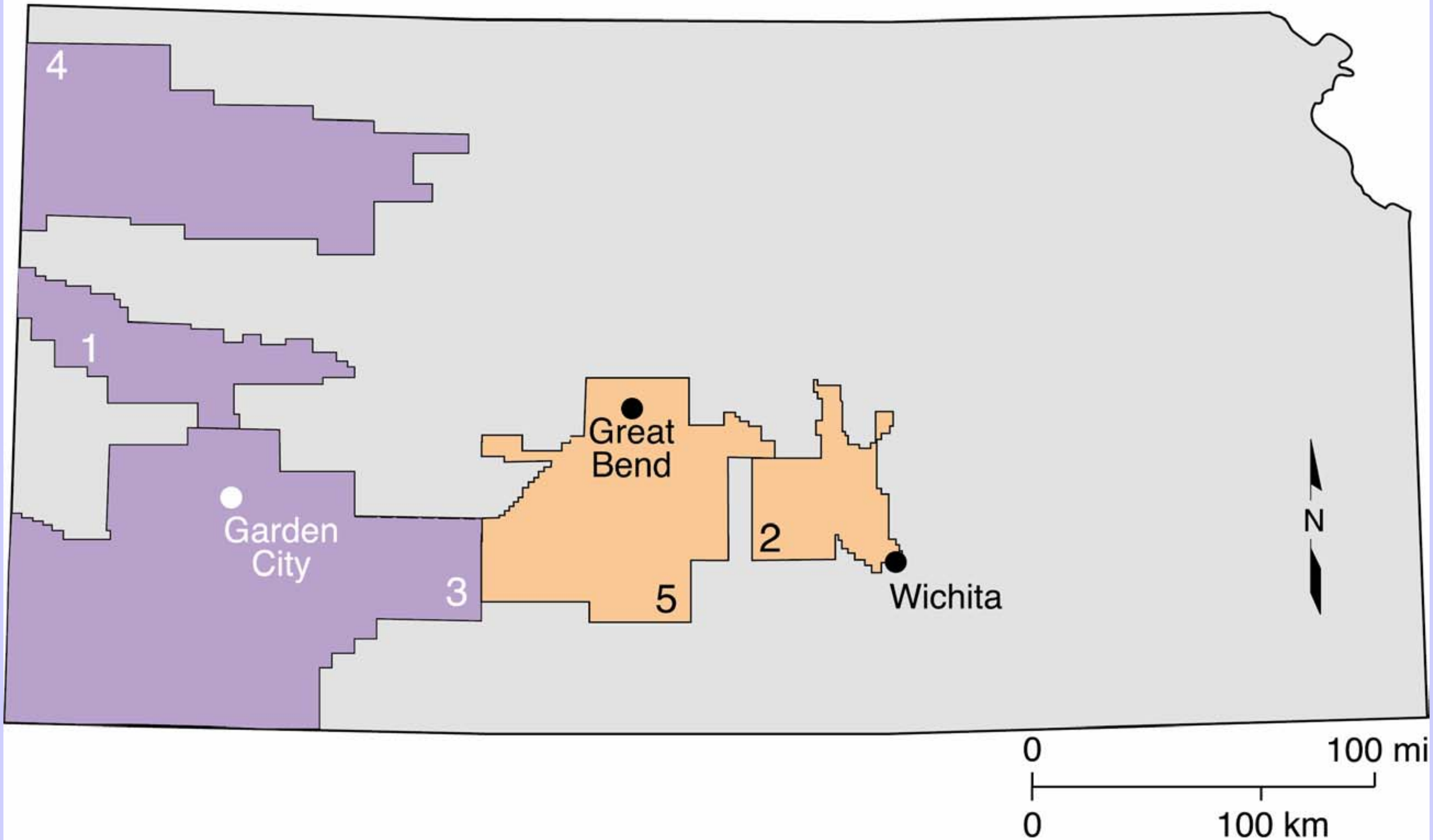
Draw 3.2-km (2-mile) radius circle

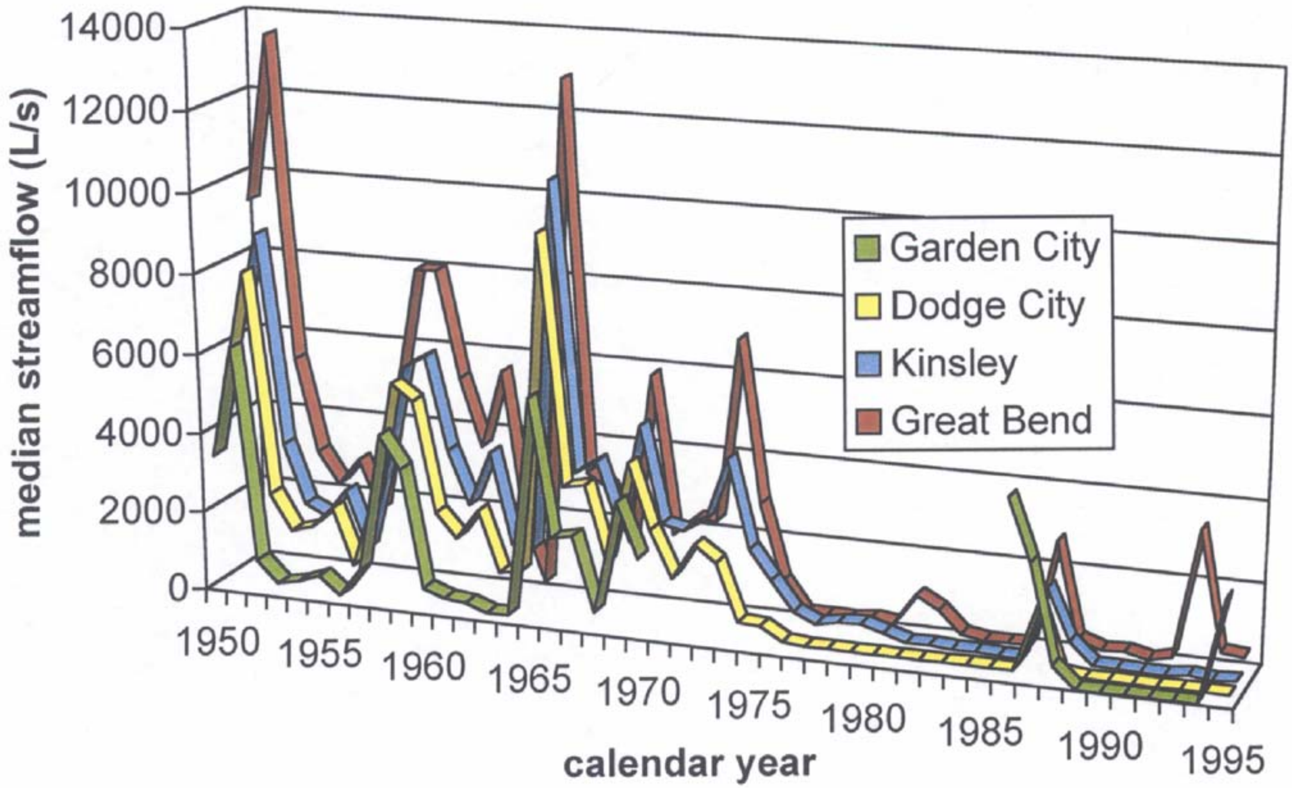
Is $\Sigma Q_i \leq R$?

Are spacing requirements (d) satisfied?

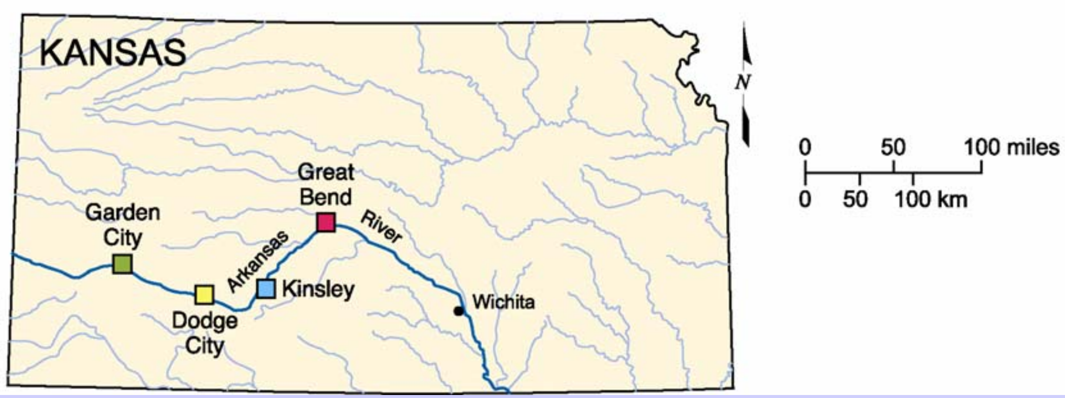
Are other local and state regulations satisfied?

Groundwater Management Districts of Kansas





14000
12000
10000
8000
6000
4000
2000
0
median streamflow (L/s)
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
calendar year
Garden City
Dodge City
Kinsley
Great Bend

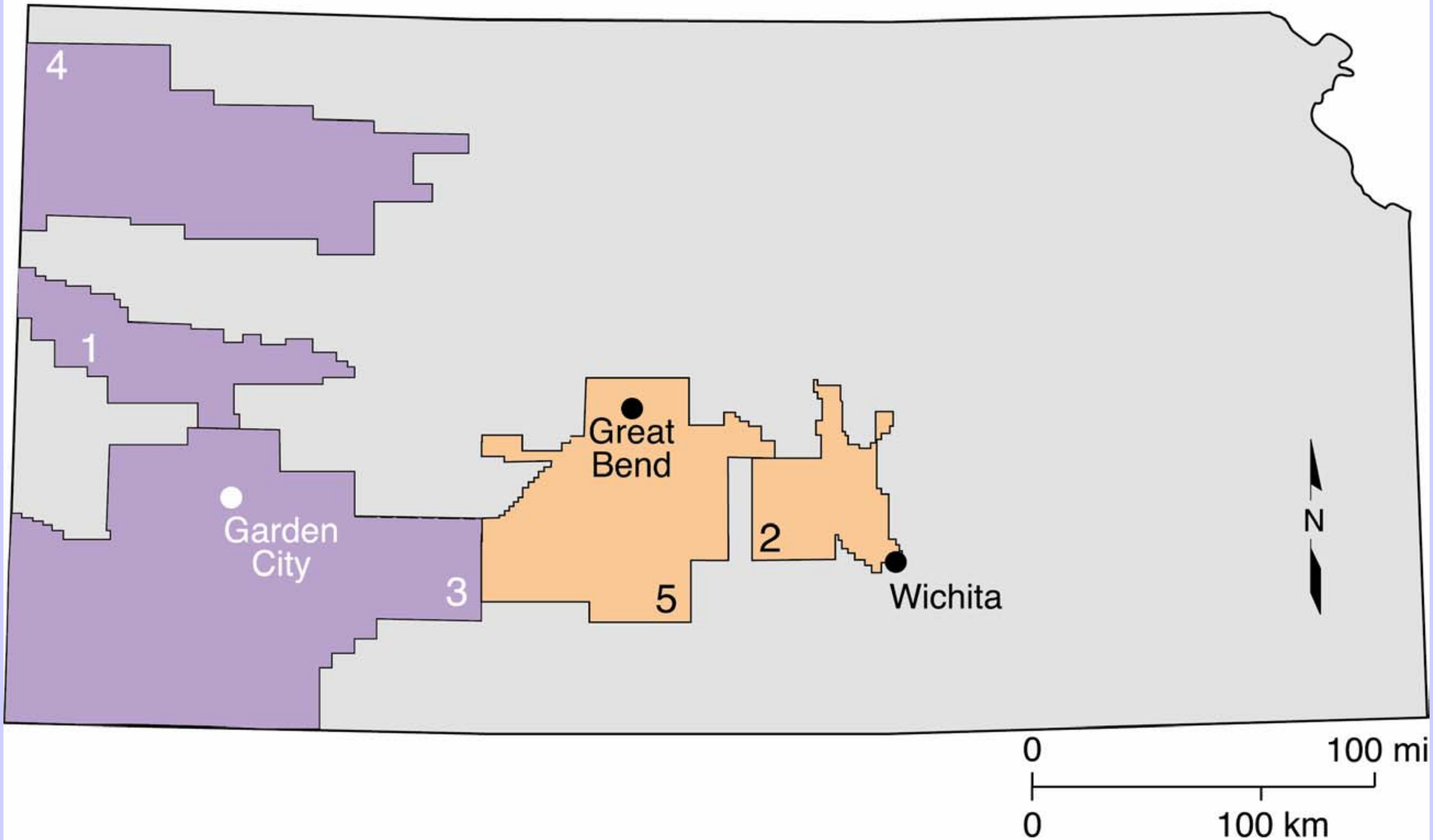


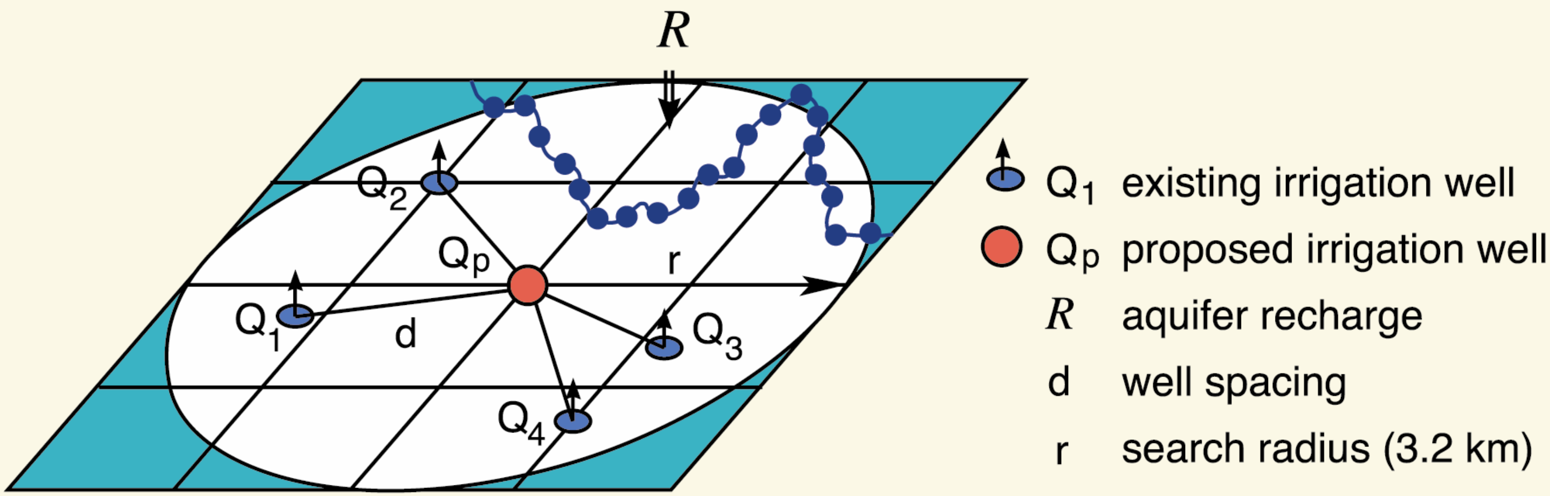
KANSAS
N
Garden City
Dodge City
Arkansas
Kinsley
Great Bend
River
Wichita
0
50
100 miles
0
50
100 km

Total Maximum Daily Load (TMDL) limits

TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards, and an allocation of that amount to the pollutant’s sources.

Groundwater Management Districts of Kansas





Draw 3.2-km (2-mile) radius circle

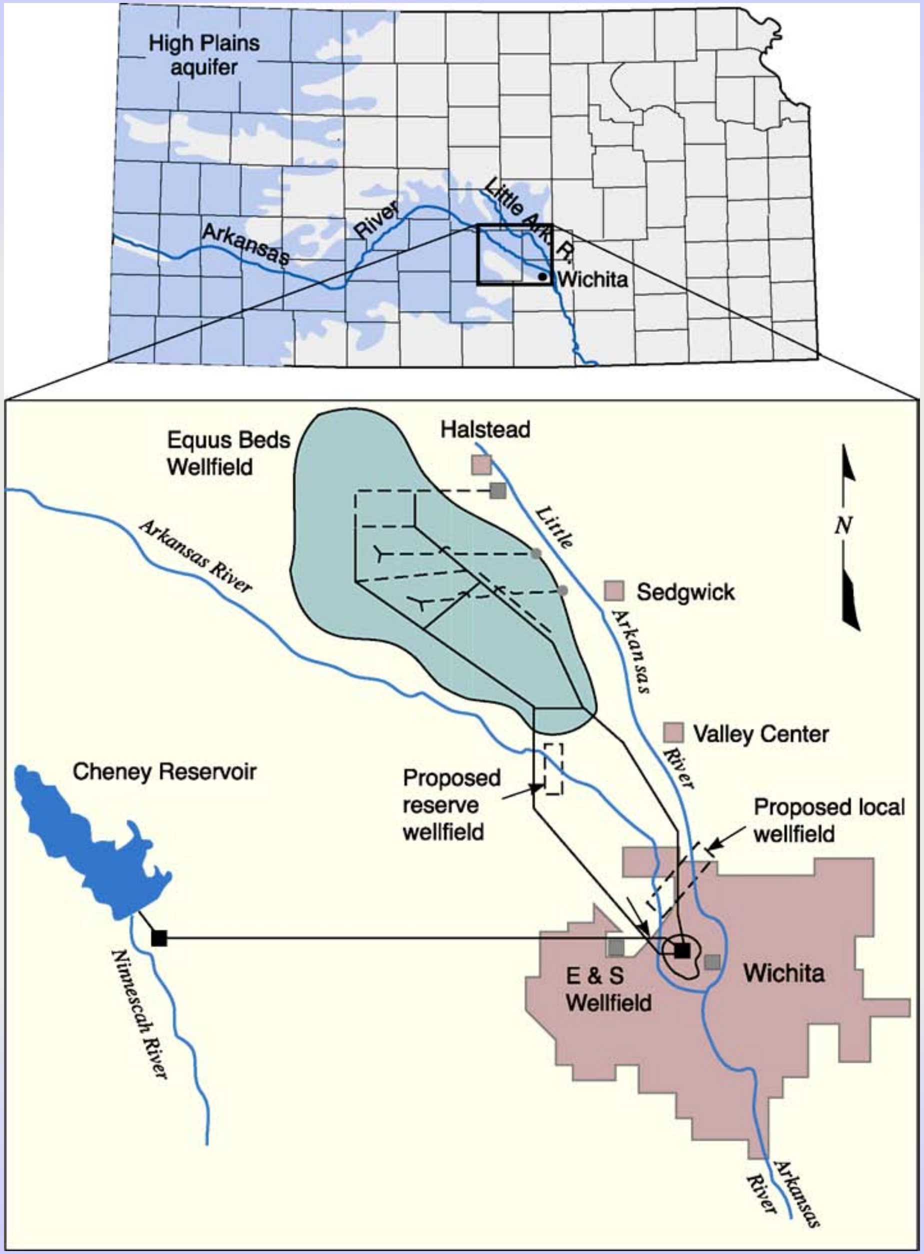
Is $\Sigma Q_i \leq R$?

Are spacing requirements (d) satisfied?

Are other local and state regulations satisfied?

Adopted Management Programs in Kansas

- controls on new development
- regulation of existing development
- well-spacing requirements
- annual water use reporting
- water metering
- water-supply augmentation
- public education and involvement


High Plains
aquifer
Arkansas
River
Little Ark. R.
Wichita
Equus Beds
Wellfield
Halstead
Arkansas River
Little
Arkansas
River
Sedgwick
N
Valley Center
Cheney Reservoir
Proposed
reserve
wellfield
Proposed local
wellfield
E & S
Wellfield
Wichita
Ninnescah River
Arkansas
River

PROGRESSIVE EVOLUTION OF KANSAS WATER MANAGEMENT

- Local GMDs and their management policies
- Minimum desireable streamflow and TMDL standards
- Water use reporting and water metering
- Modified safe yield policies
- Subbasin water resources management programs
- Integrated resource planning (City of Wichita)

The way forward (1)

Consider sustainable yield of an aquifer considerably less than recharge to allow adequate amounts of water to sustain streams, springs, wetlands, and GDEs.

Bring over-extraction areas back to sustainable use or at least community-acceptable levels while exploring more sustainable options.

The way forward (2)

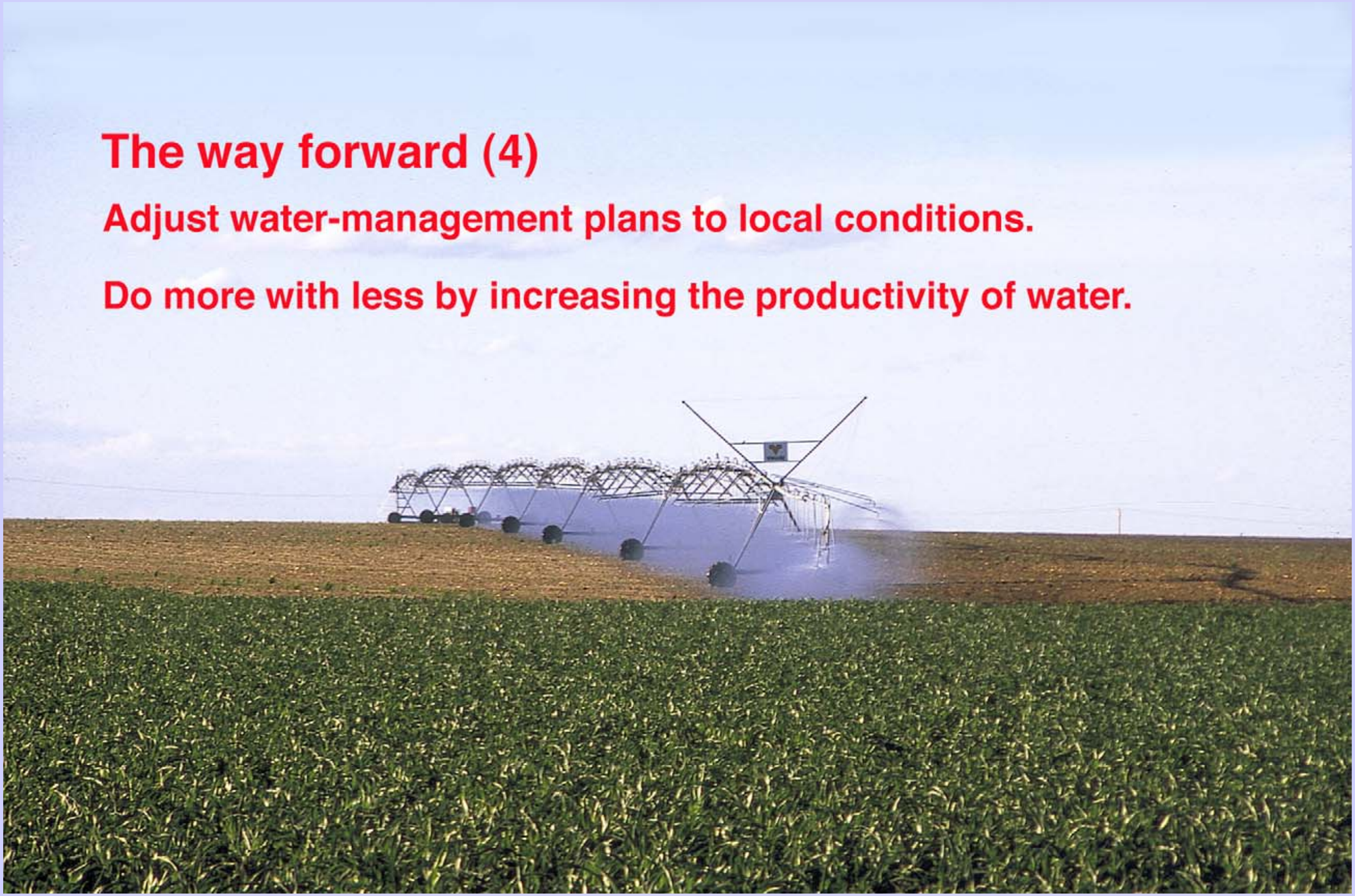
Focus not only on the volume of water available but also on the impact of groundwater exploitation on the natural environment.

Consider surface water-groundwater interactons; groundwater cannot be managed separately from surface water.

The way forward (3)

Sustainability should be understood as a dynamic and iterative process requiring continued monitoring, analysis, prioritization and revision.

Given ubiquitous uncertainties, select policies that are precautionary.

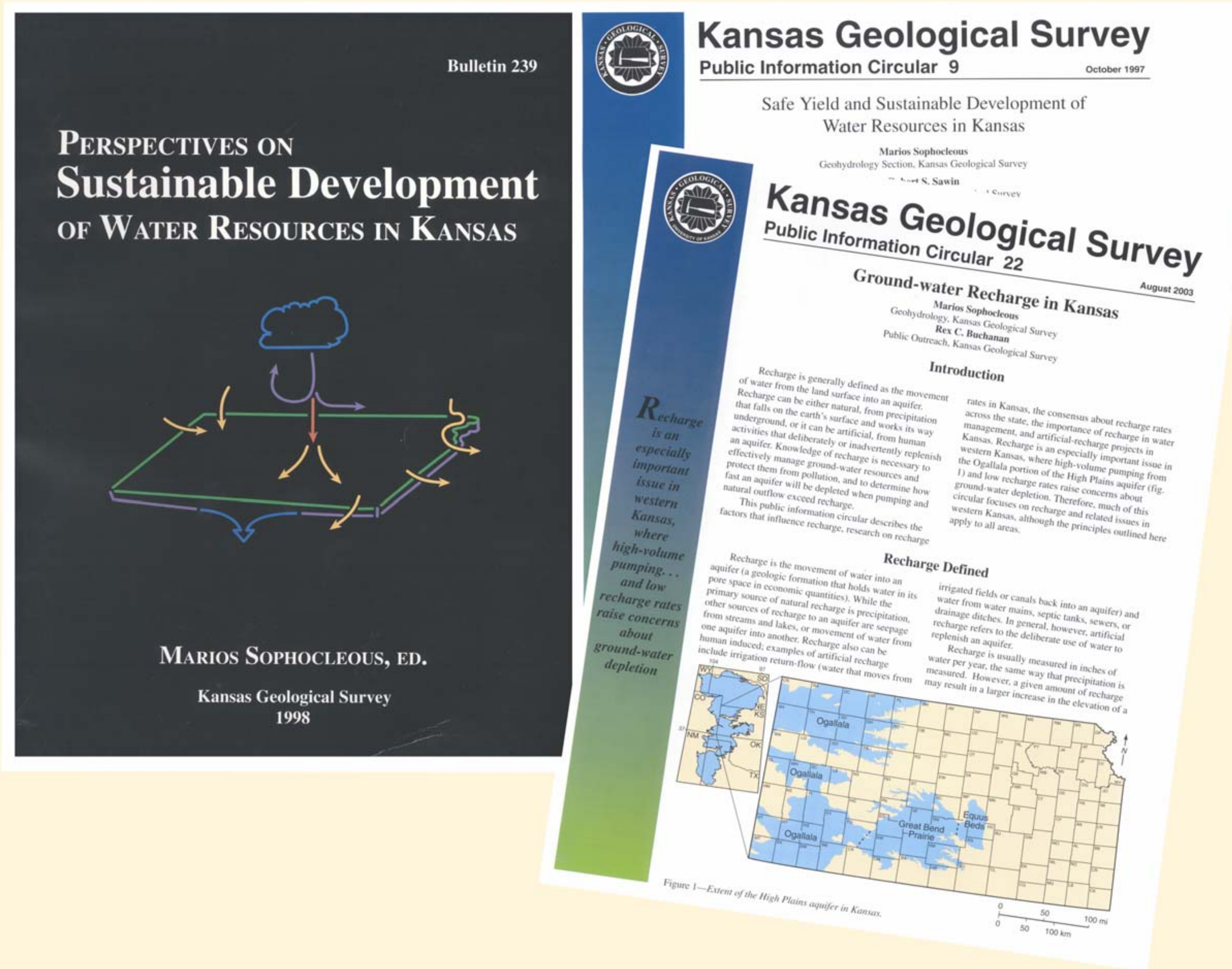

The way forward (4)
Adjust water-management plans to local conditions.
Do more with less by increasing the productivity of water.

The way forward (5)

Communicate with the multitude of diverse groundwater users to encourage sustainable use of the resource base.

Promote education, technical assistance, and supporting research.

Promote public participation in policy formulations



Bulletin 239

PERSPECTIVES ON
Sustainable Development
OF WATER RESOURCES IN KANSAS

MARIOS SOPHOCLEOUS, ED.

Kansas Geological Survey
1998

Kansas Geological Survey
Public Information Circular 9 October 1997

Safe Yield and Sustainable Development of
Water Resources in Kansas

Marios Sophocleous
Geohydrology Section, Kansas Geological Survey

Kansas Geological Survey
Public Information Circular 22 August 2003

Ground-water Recharge in Kansas

Marios Sophocleous
Geohydrology, Kansas Geological Survey
Rex C. Buchanan
Public Outreach, Kansas Geological Survey

Recharge is an especially important issue in western Kansas, where high-volume pumping. . . and low recharge rates raise concerns about ground-water depletion

Introduction

Recharge is generally defined as the movement of water from the land surface into an aquifer. Recharge can be either natural, from precipitation that falls on the earth's surface and works its way underground, or it can be artificial, from human activities that deliberately or inadvertently replenish an aquifer. Knowledge of recharge is necessary to effectively manage ground-water resources and protect them from pollution, and to determine how fast an aquifer will be depleted when pumping and natural outflow exceed recharge.

This public information circular describes the factors that influence recharge, research on recharge rates in Kansas, the consensus about recharge rates across the state, the importance of recharge in water management, and artificial-recharge projects in Kansas. Recharge is an especially important issue in western Kansas, where high-volume pumping from the Ogallala portion of the High Plains aquifer (fig. 1) and low recharge rates raise concerns about ground-water depletion. Therefore, much of this circular focuses on recharge and related issues in western Kansas, although the principles outlined here apply to all areas.

Recharge Defined

Recharge is the movement of water into an aquifer (a geologic formation that holds water in its pore space in economic quantities). While the primary source of natural recharge is precipitation, other sources of recharge to an aquifer are seepage from streams and lakes, or movement of water from one aquifer into another. Recharge also can be human induced; examples of artificial recharge include irrigation return-flow (water that moves from irrigated fields or canals back into an aquifer) and water from water mains, septic tanks, sewers, or drainage ditches. In general, however, artificial recharge refers to the deliberate use of water to replenish an aquifer.

Recharge is usually measured in inches of water per year, the same way that precipitation is measured. However, a given amount of recharge may result in a larger increase in the elevation of a

Figure 1—*Extent of the High Plains aquifer in Kansas.*

A few words on the "**sustainability challenge**"

Kansas Geological Survey

Bulletin 249

Ground-water Recharge and Water Budgets of the Kansas High Plains and Related Aquifers

Marios Sophocleous

Kansas Water Plan goals

- Reduce water level decline rates within the Ogallala aquifer by 2010 and implement enhanced water management in targeted areas.
- Achieve sustainable water management outside of the Ogallala aquifer by 2015.
- Meet minimum desirable streamflow standards at a frequency no less than the historical achievement by 2015.

Important note

In the long term, it is impossible to extract more water from an aquifer than is recharged to it by seepage from precipitation and surface water bodies.

Sooner or later, the pumping rate will automatically have to adjust to the availability of water.

Clearly, it is wiser to strike this balance at high GW levels than at low levels.

Key steps to move towards sustainable water use

- Improve the knowledge base
- Improve reporting and access to information
- Improve public education, and better understand the public's attitudinal motivations
- Further improve water efficiency and crop productivity

- Use the ecosystem approach to manage groundwater
- Embrace **adaptive management**
- Exploit the full potential of rainfed and biosaline agriculture
- Adopt a goal of sustainable use