# KANSAS GEOLOGICAL SURVEY
# OPEN-FILE REPORT 97-43

UPPER ARKANSAS RIVER CORRIDOR STUDY:
PROGRESS ON LITHOLOGIC CHARACTERIZATION OF
UNCONSOLIDATED DEPOSITS IN THE STUDY AREA WITH
EMPHAIS ON KEARNY AND FINNEY COUNTIES

by

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# UPPER ARKANSAS RIVER CORRIDOR STUDY: PROGRESS ON LITHOLOGIC CHARACTERIZATION OF UNCONSOLIDATED DEPOSITS IN THE STUDY AREA WITH EMPHASIS ON KEARNY AND FINNEY COUNTIES

A Kansas Water Plan Project


by

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Conducted in cooperation with the
Kansas Water Office
Division of Water Resources, Kansas Department of Agriculture
Division of Plant Health, Kansas Department of Agriculture
Southwest Kansas Groundwater Management District No. 3
Kansas Department of Health and Environment
Southwest Kansas Local Environmental Planning Group
and other local, state, and federal agencies and units of government

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## ACKNOWLEDGMENTS

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SUMMARY

This is the fourth report for the Upper Arkansas River Corridor Study supported by the Kansas Water Plan. The first included problem identification, preliminary research, and FY 1996 and FY 1997 plans. The second report comprised an overview of the study, inventories and descriptions of available data and references, description of preliminary conceptual models, and FY 1997 and 1998 plans. The third report described the development of ground-water flow and salinity modeling for parts of Kearny and Finney counties, including integration of the modeling with a geographic information system. This report discusses progress made on characterizing the lithology of the unconsolidated Tertiary and Quaternary deposits that compose the aquifer system. It includes a review of literature concerning the geology and hydrology of the study area, and describes geologic cross sections developed for the Arkansas River corridor in Kearney and Finney counties. Additional reports in progress describe map products, the quality and fate of Arkansas River water in southwest Kansas, and ground-water quality investigations in Kearny and Finney counties.

For this report, geologic cross sections based on lithologic well logs were developed for the Arkansas River corridor in Kearny and Finney counties. Lithologic descriptions were converted into material identification codes ranging from 1 to 10, with 10 identifying the least permeable and 1 the most permeable materials. A new procedure was developed to electronically represent, manage, and display cross-section data using the lithology model in the log analysis software PfEFFER developed at the Kansas Geological Survey. Cross sections with accompanying color gradation of the 10 materials codes were produced using the PfEFFER add-on to Microsoft Excel. The cross sections help to characterize the shallow alluvial aquifer, the deeper High Plains aquifer, and a relatively impermeable layer between the two aquifers. The alluvial aquifer comprises a fairly continuous permeable unit of sands and gravels, especially south of the Arkansas River. The permeable material usually ranges in thickness from 10-50 feet. The deeper High Plains aquifer varies widely in type of material, thickness, and layer continuity. This aquifer has more clay, silt, and cemented units than the alluvial aquifer. The relatively impermeable layer between the aquifers is discontinuous and highly variable in thickness and materials composition. It is generally made up of clay, or clay interbedded with lenses of silt, caliche or sand.

# INTRODUCTION

## Problem

The Arkansas River in southeastern Colorado and westernmost Kansas is one of the most saline rivers in the United States. Consumption of water by evapotranspiration in Colorado has substantially decreased the flow and greatly increased the salinity of the river water entering Kansas. In addition to salinity, the concentration of many other dissolved constituents in the river water is high.

Ground-water levels have declined in the High Plains aquifer in southwest Kansas from decreased recharge from the river and consumptive pumping from the aquifer. As a result, Arkansas River flow entering Kansas from Colorado is lost in the river stretch from the state line to Dodge City. Some of this loss is due to infiltration and consumptive use of water diverted from the river for irrigation. Saline water from the river and fields irrigated with river water is infiltrating to and contaminating the ground water in the alluvial and High Plains aquifers in the upper Arkansas River corridor. Ground-water declines in the High Plains aquifer have also decreased the amount of fresh subsurface flow to the alluvium that can dilute salinity and other constituent concentrations. Another ground-water quality problem in the upper Arkansas River corridor is increasing nitrate concentrations in many well waters. The ground waters which have been and could become contaminated by salinity and nitrate include sole sources for several towns and cities, including Syracuse, Lakin, Garden City, Cimarron, and Dodge City.

The distribution of salinity and the mechanisms for entrance to and movement of the saline water within the aquifer system is not well known. An assessment of the source, migration, and present and possible future extent of the ground water contamination is critical for developing plans for minimizing or mitigating water-quality problems in the aquifers. The Upper Arkansas River Corridor Study was developed to provide information that will improve understanding of the river and ground-water salinity in the corridor to enable agencies, municipalities, farmers, and industries in the area to better manage water resources to minimize or mitigate water-quality problems.

Layers of low permeability clays and silty clays exist within and underlie the Arkansas River alluvium. This low-permeability material restricts the infiltration of the saline river water to the deeper ground water. As a result, perched saline water exists in some areas above the main body of the High Plains aquifer. Clay layers also occur within the main aquifer and further retard the downward movement of saline water. The sand and gravel units comprising the alluvial and High Plains aquifers vary substantially in hydraulic conductivity and thickness. The distribution and character of the low and high permeability layers in the aquifer system (both the alluvial and High Plains aquifers in most of the study area) are not well known. Understanding of the distribution of the different lithologic units is necessary for conceptual and quantitative models of the intrusion of the saline river water in the areas of the river valley and ditch irrigation, and the migration of the saline water within the High Plains aquifer. This report describes the progress on characterizing the lithology in the aquifer region most affected by the saline river water, Kearny and Finney counties.

### Objectives and Scope of Work

The basic objectives comprise major parts of the objectives listed under the water-quality and ground-water decline issues in the subsection on the Arkansas River Corridor Subbasin in the Upper Arkansas Basin section of the Kansas Water Plan:

A. Water-Quality Issue: Document the fate and effects of contaminated Arkansas River flows on the alluvial, Ogallala, and Dakota aquifers in the river valley.

B. Ground-Water Decline Issue: Clearly establish the links among decreased flow in the Arkansas River, increased levels of water contamination in the alluvial, Ogallala, and Dakota aquifers, and lowered ground-water tables.

The study was proposed as a 5-year plan in which the Kansas Geological Survey will design and conduct hydrogeological and geochemical investigations in cooperation with several local and state agencies. Information on the study is also being communicated to other entities in the area, including ditch companies, municipalities, and federal agencies. Description of components of the objectives and scope of work for the overall project are listed in the second report for the study (Whittemore et al., 1996).

This report addresses objectives related to the intrusion of the saline water into the alluvial and High Plains aquifers and migration of the intruded water. It includes a review of previous literature on the geology and hydrology of the study area, and presents and discusses geologic cross sections produced for the Arkansas River corridor in Kearny and Finney counties.

## GENERAL GEOLOGY AND HYDROLOGY OF THE STUDY AREA

### Previous Studies

Many studies have dealt with the geology and water resources of southwestern Kansas. Historical data for this report were obtained from the following reports: Lobmeyer and Sauer (1974) [Hamilton County]; McLaughlin (1943) [Hamilton and Kearny counties]; Gutentag et al. (1972a) [Kearny County]; Dunlap et al. (1985) [Kearny and Finney counties]; Meyer et al. (1969, 1970), and Gutentag et al. (1972b) [Finney County]; Latta (1944) [Finney and Gray counties]; McGovern and Long (1974) [Gray County]; Waite (1942), and Spinazola and Dealy [Ford County]; and Gutentag et al. (1981) [southwest Kansas]. Most of these publications include generalized geologic cross sections, and some contain maps showing surficial and bedrock geology. The cross sections generally do not contain information on the lithology of the unconsolidated Tertiary and Quaternary deposits.

## Location and Geohydrologic Setting

The study area covers approximately 3,560 mi$^2$ along the Arkansas River corridor from the Colorado state line to the Ford-Edwards county line in southwestern Kansas. It includes parts of Hamilton, Kearny, Finney, Gray, and Ford counties (Figure 1).

Southwestern Kansas lies in the High Plains region of the Great Plains physiographic province. The land surface in the study area generally varies from a flat upland covered with loess in the north to rolling sand dunes in the south. In most of the study area, the Arkansas River and its flood plain separate the uplands from the sand dunes (Figure 2).

Tertiary and Quaternary deposits underlie most of the study area and range in thickness up to 500 feet. The saturated part of the Ogallala Formation of Pliocene age, the undifferentiated Pleistocene deposits, and the Quaternary alluvium in the Arkansas River corridor form the aquifer system in the study area. The Pliocene and undifferentiated Pleistocene deposits are hydraulically connected and lithologically similar, and are considered as one aquifer, the High Plains aquifer. In this report the High Plains aquifer is differentiated from the shallower Arkansas River alluvial aquifer. Although both aquifers are hydraulically connected to some extent, the distinction is made on the basis of differences in water levels due to a relatively impermeable zone between them. Also, the permeability is greater in the Arkansas River alluvium. The Arkansas River meanders through the study area and interacts hydraulically with the aquifer system. The surface of the Cretaceous bedrock defines the lower limit of the aquifer system. In the western part of the study area, the Dakota aquifer may be considered as part of the aquifer system, but it will not be discussed in this report.

## Bedrock

Consolidated rocks of Cretaceous age, which underlie the unconsolidated Tertiary and Quaternary deposits, are referred to as bedrock in this report. As a rule, undifferentiated Lower Cretaceous rocks form the bedrock surface in the southern part of the study area, and Upper Cretaceous rocks in the north. Upper Cretaceous rocks, which may include Graneros Shale, Greenhorn Limestone, Carlile Shale, and Niobrara Chalk, subcrop in normal stratigraphic sequence as the elevation of the bedrock surface rises to the north. The dip of the Cretaceous formations is northeastward. Upper Cretaceous rocks crop out in areas where streams have eroded the Tertiary and Quaternary deposits, particularly north of the Arkansas River (Figure 2).

The configuration of the bedrock surface, shown in Figure 3, indicates a southeast-trending drainage system that has been altered by faulting. The major structural features on the bedrock surface are the Bear Creek Fault in Hamilton and Kearny counties

# Upper Arkansas River Corridor Study Area

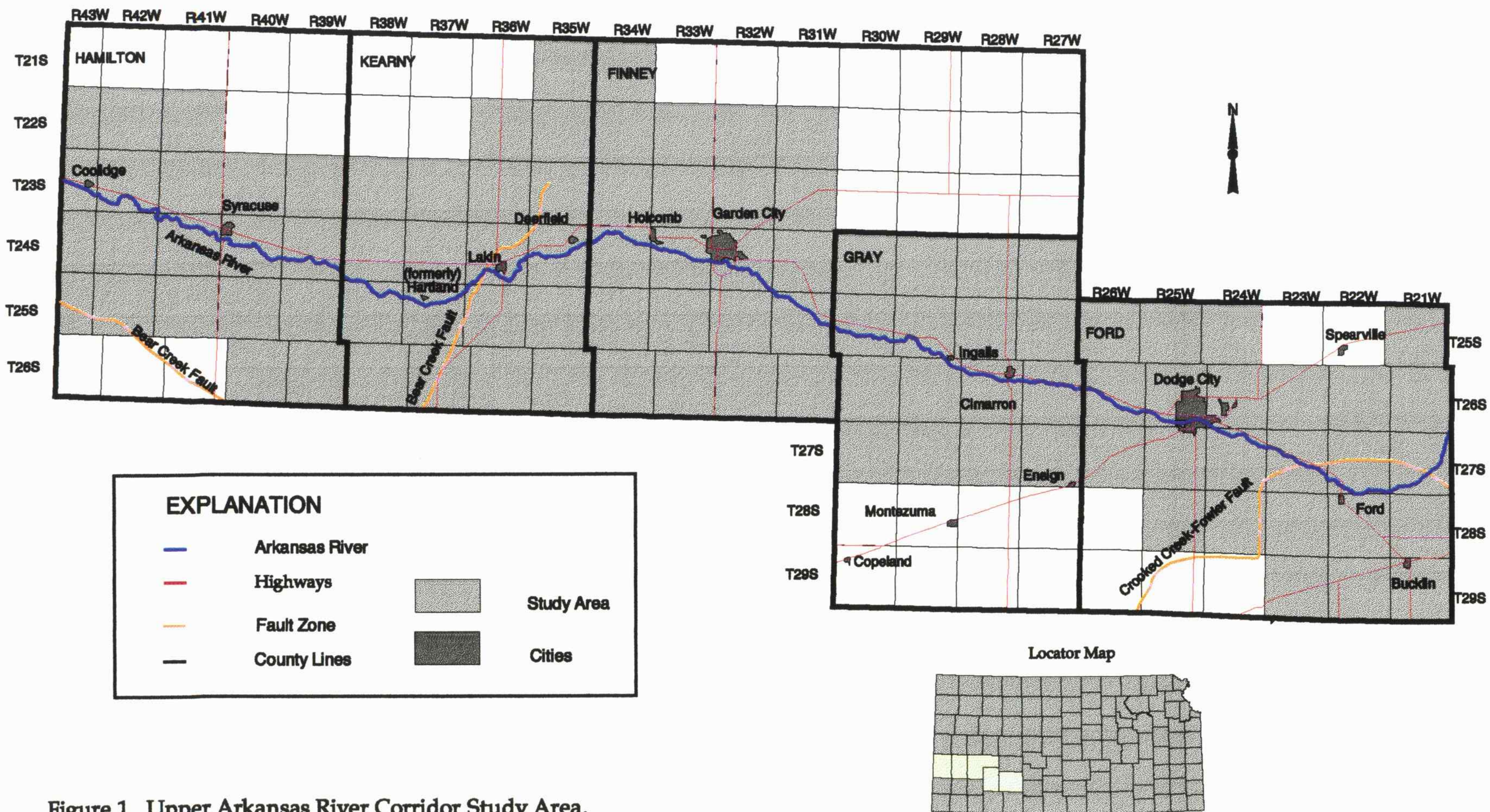


Figure 1. Upper Arkansas River Corridor Study Area.

## General Surface Geology in the Upper Arkansas River Corridor Study Area

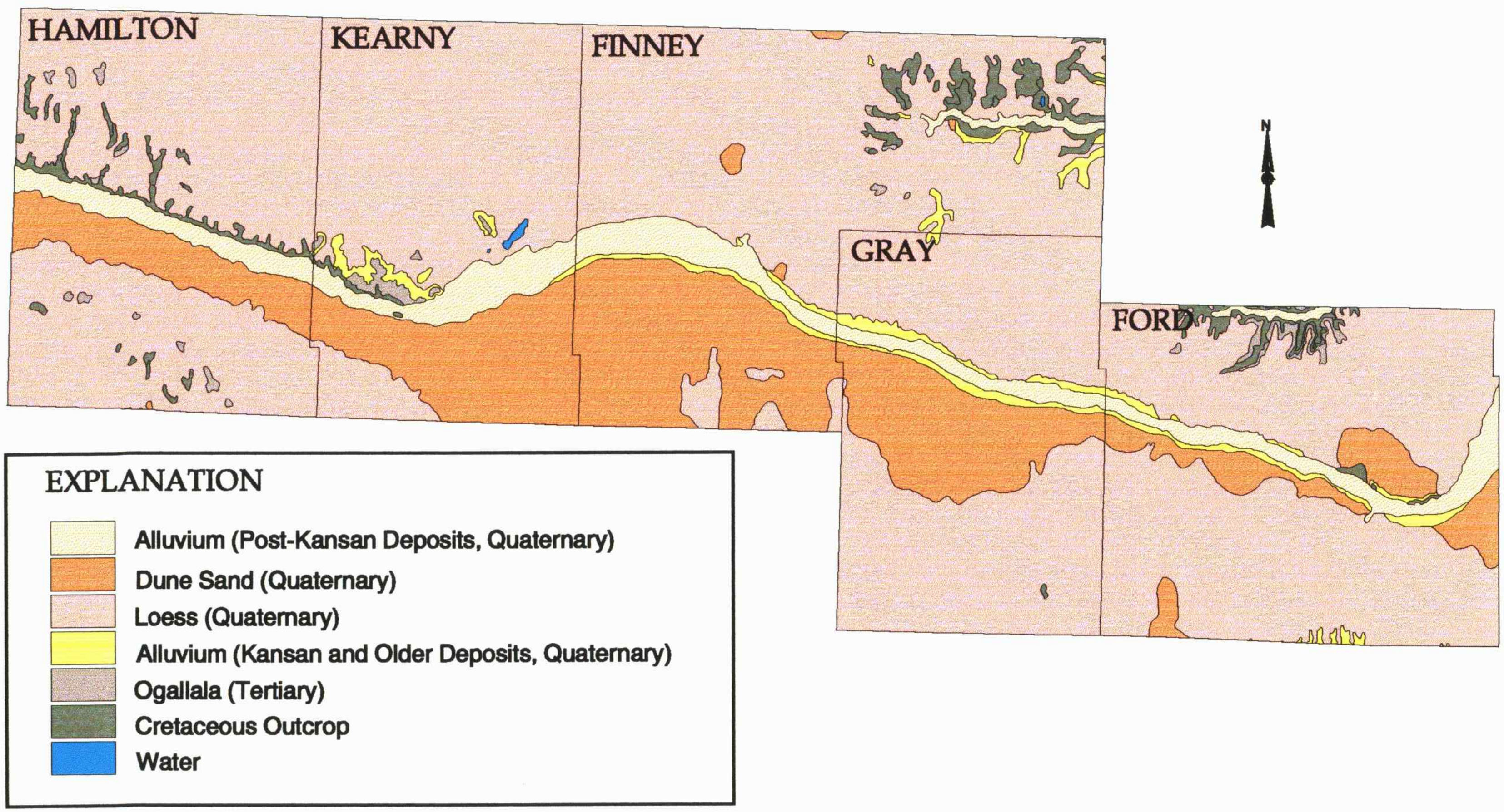


Figure 2. Surface geology of UARC study area.

# Base of High Plains Aquifer

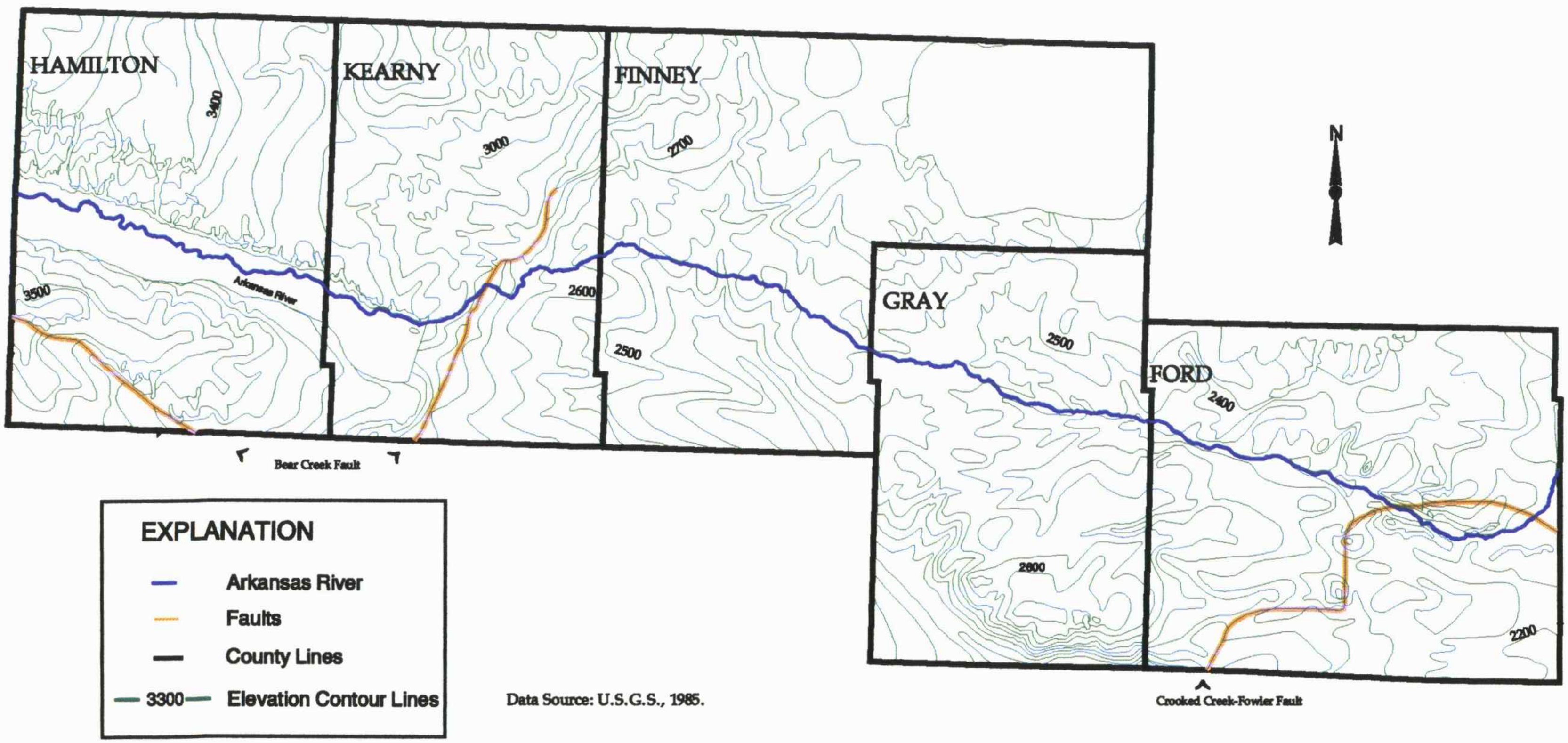


Figure 3. Configuration of base of High Plains aquifer in the UARC study area

and the Crooked Creek-Fowler Fault in Ford County. These faults, which are result of dissolution of salt evaporites and subsidence, have a vertical displacement of as much as 250 feet. The area of subsidence in the study area is bounded on the west by Bear Creek Fault and on the east by the Crooked Creek-Fowler Fault.

The sandstones of the Dakota aquifer (Lower Cretaceous) may be a source of water in some locations (see Macfarlane et al., 1989). Upper Cretaceous rocks yield little or no water to wells. Some solution channels are present in the Niobrara Chalk, but they are not believed to constitute a continuous aquifer. Table 1 provides a generalized description of the geologic formations in the study area and their water-bearing properties.

**Undifferentiated Pliocene and Pleistocene Deposits**

Thick, layered unconsolidated sediments of Tertiary and Quaternary age underlie the study area. The principal sources of water are sand and gravel layers in Pliocene (Ogallala Formation) and undifferentiated Pleistocene deposits. The unconsolidated Pliocene and Pleistocene deposits are hydraulically connected and lithologically similar, and are considered as one aquifer, the High Plains aquifer. The Quaternary alluvium in the Arkansas River valley is also a source of water and will be discussed in the next section. The Arkansas River, the Quaternary alluvial aquifer, and the underlying High Plains aquifer are hydraulically connected.

The High Plains aquifer consists of a heterogeneous assortment of alluvial sediments. Individual beds of silt, clay, sand, gravel, and caliche generally are not continuous and within very short distances may grade laterally or vertically into material of different composition. Where the aquifer has been divided at aquifer test sites into the Pliocene Ogallala Formation and the undifferentiated Pleistocene deposits, the sand and gravel beds of the Ogallala contain a greater amount of interbedded and mixed silt, clay, and caliche than do those of Pleistocene age (Meyer et al., 1970).

The Ogallala Formation was deposited by east to southeast flowing streams. The source material was erosional debris from the Rocky Mountains, and exposed sedimentary rocks of southeastern Colorado and western Kansas. The pre-Ogallala surface was a Cretaceous southeastward-sloping erosional base, which was gradually filled in by Ogallala sediments, forming an alluvial plain. The sediment deposition by meandering streams created a discontinuous, heterogeneous assortment of alluvial sediments. The Ogallala Formation consists primarily of silt, sand, gravel, and clay. It may be loosely consolidated or tightly cemented by calcium carbonate to form a very compact "mortar bed" that resembles concrete. Caliche is common and occurs as cementing material, pipy concretions, nodules, or irregular beds. In some places, the Ogallala is capped by a hard limestone bed (Meyer et al., 1970).

Table 1.--Generalized section of geologic formations and their water-bearing properties* (from Gutentag et al., 1981).

| System | Series | Stratigraphic unit | Thickness, feet | Physical character | Water supply |
|---|---|---|---|---|---|
| Quaternary | Pleistocene | Alluvium | 0-80 | Stream-laid deposits ranging from silt and clay to sand and gravel that occur along principal stream valleys. | Yields to wells range from 500 to more than 1,000 gal/min in the Arkansas River valley; 50 to 500 gal/min in the Pawnee River valley; and 50 to 1,000 gal/min in the Cimarron River valley. |
| | | Dune sand | 0-75 | Fine to medium quartzose sand with small amounts of clay, silt, and coarse sand formed into mounds and ridges by the wind. | Lies above the water table and does not yield water to wells. The sand has a high infiltration rate and is important as area of ground-water recharge. |
| | | Loess | 0-45 | Silt with subordinate amounts of very fine sand and clay deposited as windblown dust. | Lies above the water table and does not yield water to wells. Serves as minor area of ground-water recharge. |
| | | Undifferentiated deposits | 0-550 | Sand, gravel, silt, clay, and caliche overlie Ogallala Formation when both formations are present; composite of stream-lain and windblown deposits. | The sand and gravel of the undifferentiated Pleistocene deposits and the Ogallala Formation are the principal water-bearing deposits in the area. Yields range from 100 to 3,100 gal/min. |
| Tertiary | Pliocene | Ogallala Formation | 0-500 | Poorly sorted clay, silt, sand, and gravel generally calcareous; when cemented by calcium carbonate, forms caliche layers or mortar beds. | |
| Cretaceous | Upper Cretaceous | Niobrara Chalk | 0-250 | Upper unit (Smoky Hill Chalk Member)--yellow to orange-yellow chalk and light- to dark-gray beds of chalky shale. Lower unit (Fort Hays Limestone Member)--consists of a white to yellow massive chalky limestone: contains thin beds of dark-gray chalky shale. | Initially (1968-72), yielded 500 to 2,500 gal/min to wells in northern Finney and eastern Kearny Counties where the Fort Hays Limestone Member has been honeycombed by fractures and solution openings. Because of increased irrigation development, yields have been reduced by 100 to as much as 2,000 gal/min. |
| | | Carlile Shale | 0-330 | Upper unit consists of a dark-gray to blue-black noncalcareous to slightly calcareous shale that locally is interbedded with calcareous silty very fine-grained sandstone. Lower part consists of very calcareous dark-gray shale and thin gray interbedded limestone layers. | Sandstone in upper part may yield 5 to 10 gal/min to wells. |
| | | Greenhorn Limestone | 0-200 | Chalky light yellow-brown shale with thin-bedded limestone. Dark-gray calcareous shale and light-gray thin-bedded limestone; contains layers of bentonite. | Not known to yield water to wells in southwestern Kansas. |

| | | | | | |
|---|---|---|---|---|---|
| | | Graneros Shale | 0-130 | Dark-gray calcareous shale interbedded with black calcareous shale; contains thin beds of bentonite. Also contains thin-bedded gray limestone and fine-grained silty sandstone layers. | Not known to yield water to wells in southwestern Kansas. |
| | Lower Cretaceous | Undifferentiated rocks | 0-450 | Upper unit (Dakota Formation)--brown to gray fine- to medium-grained sandstone; interbedded with gray sandy shale and varicolored shale; contains lignite lenses (0-160 feet). Middle unit (Kiowa Formation) --dark-gray to black shale; interbedded with light yellow-brown and gray sandstone (0-150 feet). Lower unit (Cheyenne Sandstone)--gray and brown very fine- to medium-grained sandstone; interbedded with dark-gray shale (0-125 feet). | The sandstone units commonly yield from 50 to 500 gal/min to wells. Yields of more than 1,000 gal/min are reported in a few areas. Water may be more mineralized in the lower unit than in the upper unit. |
| Jurassic | Upper Jurassic | Undifferentiated rocks | 0-350 | Dark-gray shale; interbedded with grayish-green and bluish-green calcareous shale. Contains very fine- to medium-grained silty sandstone and some thin limestone beds at the base. | In Morton and Stanton Counties, sandstone beds are yielding in combination with the overlying Lower Cretaceous units. In the northernmost counties where the aquifer is deepest, the water may be mineralized. |
| Permian | Upper Permian | Big Basin Formation | 0-160 | Brick-red to maroon siltstone and shale; contains very fine-grained sandstone. | Where not highly mineralized, may yield small quantities of usable water for domestic and stock purposes. |
| | | Day Creek Dolomite | 0-80 | White to pink anhydrite and gypsum; contains interbedded dark-red shale. | Solution cavities have yielded large quantities (300 to 1,000 gal/min) of high sulfate water to wells in Morton County. |
| | | Whitehorse Formation | 100-350 | Red to maroon fine-grained silty sandstone, siltstone, and shale. | Fresh to highly mineralized water. Not known to yield significant amounts of water to wells in southwestern Kansas. |
| | Lower Permian | Dog Creek Formation | 15-60 | Maroon silty shale, siltstone, very fine sandstone, and thin layers of dolomite and gypsum. | Not known to yield significant amounts of water to wells in southwestern Kansas. Water probably highly mineralized. |
| | | Blaine Formation | 20-150 | Generally consists of four gypsum and anhydrite beds separated by red shale; contains bedded halite at some sites. | |

*The classification and nomenclature of the stratigraphic units used in this report are those of the Kansas Geological Survey and differ somewhat from those of the U.S. Geological Survey.

The undifferentiated Pleistocene deposits are the result of filling in of valley cuts in the Ogallala Formation. A heterogeneous mixture of coarse-grained channel sediment and fine-grained stream or lake sediment was deposited by meandering streams. These deposits consist primarily of unconsolidated sand and gravel, interbedded with clay, silt, and local deposits of volcanic ash. The coarse-grained deposits commonly are not cemented with caliche, as they are in the Ogallala. Sand is generally the most abundant material. Similar to the Ogallala, the Pleistocene deposits generally are poorly sorted, and individual layers are discontinuous (McLaughlin, 1943).

Because the aquifer consists of alternating lenses of fine- and coarse-grained sediments, ground-water movement may be retarded vertically and laterally. Further, the water-yielding capacity varies widely and water may be unconfined or semiconfined. Ground-water flow is mainly eastward in the study area. The aquifer system is recharged by infiltration of precipitation and irrigation water, by seepage of water from the Arkansas River and irrigation canals, and by underflow from adjacent areas. Discharge from the aquifer is by underflow eastward, by transpiration and evaporation in areas of shallow water table, and by wells. Since the 1970's, baseflow to the river and ground-water evapotranspiration have been practically nonexistent (Dunlap et al., 1985). Today the discharge is primarily by wells.

The thickness of the unconsolidated deposits varies substantially. The greatest saturated thicknesses are found between the Bear Creek and Crooked Creek-Fowler Faults, on the downthrown sides (Figure 3). Thicknesses may increase by as much as 250 feet across the fault zones. The thickness of the Pliocene and Pleistocene sediments increases from north to south, with the greatest thicknesses, more than 500 feet, located in southwestern Finney and southeastern Kearny counties.

Below the Arkansas River valley in Hamilton County, the alluvium rests on Cretaceous bedrock, and the High Plains aquifer is absent. Water may be obtained from the Arkansas River alluvium or underlying sandstones in the Dakota aquifer. The thickness of Pliocene and Pleistocene deposits elsewhere in Hamilton County is extremely variable. The greatest thicknesses of over 200 feet are found in the northeast part of the county and in the extreme southwest region south of Bear Creek Fault. In other parts of Hamilton County, little water is available from the unconsolidated sediments.

The thickness of Tertiary and Quaternary deposits in Kearny County ranges from a few feet to about 500 feet. From west to east across the Bear Creek fault zone there is a saturated thickness increase of more than 200 feet. The southeast part of the county has the greatest saturated thickness. Although the lithology of the deposits differs from one area to another, Gutentag et al. (1972a) found a general relationship between saturated thickness and well yield.

In Finney County there is a general increase in saturated thickness from north to south. The unconsolidated Tertiary and Quaternary sediments range in thickness from a few feet in the northeast to more than 500 feet in the southwest. Areas of greatest thickness coincide with ancient stream-channel courses (Gutentag et al., 1972b).

Dunlap et al. (1985) separated an upper and lower aquifer in Kearny and Finney counties with a confining layer for modeling purposes. The lower aquifer consisted of undifferentiated Pliocene or Miocene and Pleistocene deposits. The confining zone consisted of fine-grained Lower Pleistocene deposits. The upper layer was composed of coarse materials of Pleistocene age. The model also included the Arkansas River valley aquifer of Pleistocene and Holocene age. The confining zone ranged from near zero to about 200 feet thick. The authors noted that individual clay and silt lenses were difficult to correlate from one area to the next.

The thickness of Tertiary and Quaternary deposits in Gray County ranges from a few feet to about 550 feet, with greater thicknesses in the south. In Ford County, the unconsolidated deposits reach thicknesses of as much as 530 feet west of the Crooked Creek Fault. The deposits are much thinner east of the fault.

It is important to recognize the heterogeneity of the sediments and the difficulty in characterizing the aquifer system. Nearly all previous reports emphasize that individual beds and lenses are not continuous over wide areas. As Meyer et al. (1970) reported, "...the individual beds pinch out or grade, almost imperceptibly, both laterally and vertically, into finer or coarser material of another bed or lense." Because of the heterogeneity, most of the reports recommend test drilling for locating a large-capacity well.

**Arkansas River Alluvial Valley**

The Arkansas River alluvial sediments are the most permeable water-bearing deposits in the study area. The alluvial material underlying the Arkansas River valley consists of coarse-grained deposits of Pleistocene age overlain by fine-grained deposits of Holocene age. The alluvium is composed of sand and gravel and lesser amounts of silt and clay. The material is poorly sorted and grades into material of different composition within short distances both laterally and vertically. Clay is generally found at or near the base of the alluvium.

West of the former town of Hartland in Kearny County, the alluvium overlies Cretaceous bedrock. East of Hartland the alluvium is underlain by undifferentiated Pliocene and Pleistocene deposits. The former town of Hartland is located where the course of the Arkansas River changes from a southeast to a northeast direction (see Figures 1 and 2). The Arkansas River valley ranges in width from 2 to 3 miles in Hamilton County, and is less than 1 mile at its narrowest point near Hartland. East of Hartland the valley broadens and attains a maximum width of about 5 miles near Lakin (Figures 1 and 2).

In the western part of the study area the thickness of the alluvium ranges from about 10 feet southwest of Hartland to about 100 feet south of the river near Coolidge. Generally, the thickness in Hamilton County is between 50 and 60 feet and in Kearny County is between 40 and 50 feet. Thicknesses may be as great as 70 feet in Kearny County (Dunlap et al., 1985). Between Hartland and Deerfield, the bed of clay that is encountered at depths of 35 to 45 feet represents the base of the alluvium (McLaughlin, 1943).

In Finney County the width of the Arkansas River alluvium ranges from 1 mile in the east to 3.5 miles west of Garden City, and averages about 2 miles. The average thickness of the alluvium in Finney County is about 40 feet (Meyer et al., 1970). This average thickness of alluvium of 40 feet is evident in well logs and in the cross sections presented in the Appendix, especially south of the river.

In Gray County the alluvial valley is relatively narrow, and has a consistent width of about 2.5 miles. The alluvium is thickest, up to 60 feet, in the central and eastern parts of the county. The thickness varies considerably both along and across the valley in Finney and Gray counties (Latta, 1944).

The width of the alluvial valley in Ford County ranges from about 2 miles along the western border to about 4 miles across the eastern border. Thickness of the alluvium ranges from about 15 feet in the eastern part of the county to about 40 feet in the central and western parts, and may be 50 feet or more in places (Waite, 1942). Cretaceous bedrock also underlies the alluvium in parts of Ford County.

## GEOLOGIC CROSS SECTIONS

### Procedure

Geologic data used in producing cross sections were obtained from lithologic logs from water well records (WWC-5 forms filed by well drillers since 1975) available at the Kansas Geological Survey, and from lithologic logs of wells and test holes published in previous reports of the U.S. Geological Survey and Kansas Geological Survey.

The first lithologic cross sections made for this study were drawn and color shaded by hand on large graph sheets. The predominant materials described in the logs were written in the depth intervals of the columns representing each borehole. The wide variety of descriptive materials were grouped according to relative permeability for the color shading. Although these initial logs were valuable for the research process and for display at meetings with state agency staff and the Technical Advisory Committee, they could not be easily reproduced for multiple copies in reports. Rather than pursue the traditional approach of conversion by a graphic artist into figures, other procedures were considered that would allow electronic storage, processing, and display of the lithologic data. This method could allow easier printing of copies as needed and updating based on new lithologic data.

The first step taken for electronic handling of data and production of displays was the simplification of the wide variety of lithologic descriptions into general categories. Each described material from the lithologic logs was assigned a numerical geologic code from 1 to 10, based on relative permeability (Figure 4). The lithologic logs were then transformed into numerical logs based on the geologic codes.

The first electronic method tried for handling the numerical logs involved using the subsurface characterization module of the software GMS (Groundwater Modeling System) of the U.S. Department of Defense developed by Brigham Young University. The transformed numerical logs were entered into the software module for display. Although the program contained some advantages in allowing generation of 3D representation of cross sections in the form of fence diagrams, limitations of user interaction and printing of the colored images caused search for another procedure.

The second program investigated for adaptation to the cross-section processing and display is the software PfEFFER. The Kansas Geological Survey (Doveton et al., 1996) has been developing the computer program PfEFFER for real-time interactive analysis of geophysical logs primarily used in the petroleum industry. The beta version of the lithology solution module in this software includes the capability of displaying columns with colored intervals representing log data. The software operates as an add-on to the spreadsheet program Microsoft Excel. The numerical logs for a cross section were entered into the spreadsheet. Each column in the spreadsheet represents either a borehole or space between the boreholes as appropriate for hardcopy production. Each spreadsheet row represents a uniform depth interval in the borehole. An interval of one foot was used for this study. Thus, geologic intervals of more than one foot occupy multiple adjoining rows in the column for that borehole.

The PfEFFER program uses the numerical geologic codes in each column-row cell of the Excel spreadsheet as a color index, with lighter shades indicating more permeable materials and darker shades indicating less permeable materials. Initially, each of the 10 numerical codes listed in Figure 4 was assigned a different color for preparing cross sections. However, the present limitation on the colors that can be used in the software, coupled with the fact that 10 colors is a relatively large number for the viewer to comprehend, made the cross sections too complex to easily interpret visually. The use of 5 colors, each representing two geologic codes appears at present to be a satisfactory compromise between lithologic information and visual comprehension. This does not significantly reduce lithologic information, especially considering the subjective nature and variation in geologic materials identification by different individuals for the boreholes. The range of colors corresponding to the different (permeability) materials is shown in Figure 4.

**MATERIAL IDENTIFICATION CODES** — **PFEFFER COLOR CODES**

**1** = GRAVEL, FINE GRAVEL, MEDIUM GRAVEL, COARSE GRAVEL =
**2** = VERY FINE GRAVEL, VERY COARSE SAND, SAND & GRAVEL =

**3** = COARSE SAND =
**4** = SAND, MEDIUM SAND, SAND & GRAVEL & CLAY =

**5** = FINE SAND, SAND & CALICHE =
**6** = VERY FINE SAND, SILTY SAND =

**7** = SANDY CLAY, SAND & CLAY, CLAY & SAND, TOP SOIL =
**8** = SILT, FINE SAND & CLAY =

**9** = SILTY CLAY, CLAY & CALICHE =
**10** = CLAY =

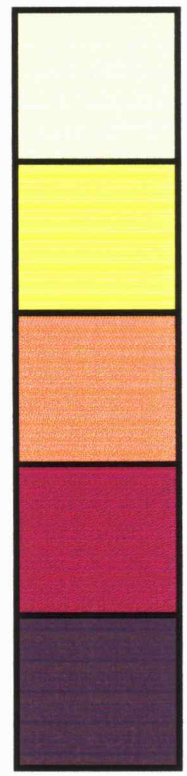

Figure 4. Material identification codes.

The adaptation of the lithology module in PfEFFER has some limitations in labeling cross sections and in page setup for hard copies, but appears to be a valuable method for producing colored cross sections. Files produced in PfEFFER were imported as post script files into the geographic infomation system ArcView for final editing and labeling. Hard copies were printed on an HP-750 color printer.

**Discussion**

The cross sections presented in the Appendix were produced with the programs PfEFFER, Excel, and ArcView. It should be noted that they are based on lithologic well logs that are subjective, and differ in quality depending on the individual driller or site geologist. The cross sections are intended to show general characteristics. They are presented here as work in progress. Actual elevations and lithology may vary from those portrayed in the sections depending on the accuracy of the data reporting and materials identification. Locations of the wells used for the cross sections are shown in Figure 5 and listed in Table 2.

Figure A1 displays a west-east cross section based on 56 well logs from Lakin to east of Garden City. All of the wells are located in the Arkansas River alluvial valley. Surface elevation decreases from west to east, as shown by the position of the tops of the columns representing the wells in Figure A1. The bottom of the columns suggests an eastward slope of the bedrock surface west of about Deerfield, and a more level surface east of Deerfield, however not all wells were drilled to bedrock. Future work will include additional characterization of the bedrock surface.

The permeable sands and gravels of the Arkansas River alluvial aquifer are seen in the upper fifty feet of the majority of the wells. They are capped by an average of 5 feet of surface materials or soil. The alluvial aquifer is primarily composed of sand and gravel, with thin lenses of silt or clay. Below the shallow alluvial aquifer is a relatively impermeable layer of varying thickness. This layer is most often made up of clay, or clay with lenses of silt, caliche or (cemented) sand. Other permeable units are seen deeper in the profiles. These permeable units are generally the producing (screened) intervals in the High Plains aquifer. They are made up of varied sizes and combinations of sand and gravel, and are commonly cemented with calcium carbonate or caliche. The continuity of layers in the deeper High Plains aquifer may be difficult to correlate from one well to the next. There are commonly multiple small lenses, 5-10 feet thick, of less permeable material such as fine sands, silt and caliche within the High Plains aquifer material. Frequently, high-capacity water wells are screened across more than one permeable unit.

Figure A1 includes wells both north and south of the Arkansas River. The same group of wells was used to produce Figures A2 and A3, with Figure A2 displaying the wells north of the river, and Figure A3 displaying the wells south of the river. Comparison of Figures A2 and A3 clearly shows differing lithological characteristics on the north versus the south side of the river. In general, wells located south of the river penetrate a more defined and more continuous alluvial aquifer comprising mostly gravels.

# Well Locations For Geologic Cross Sections

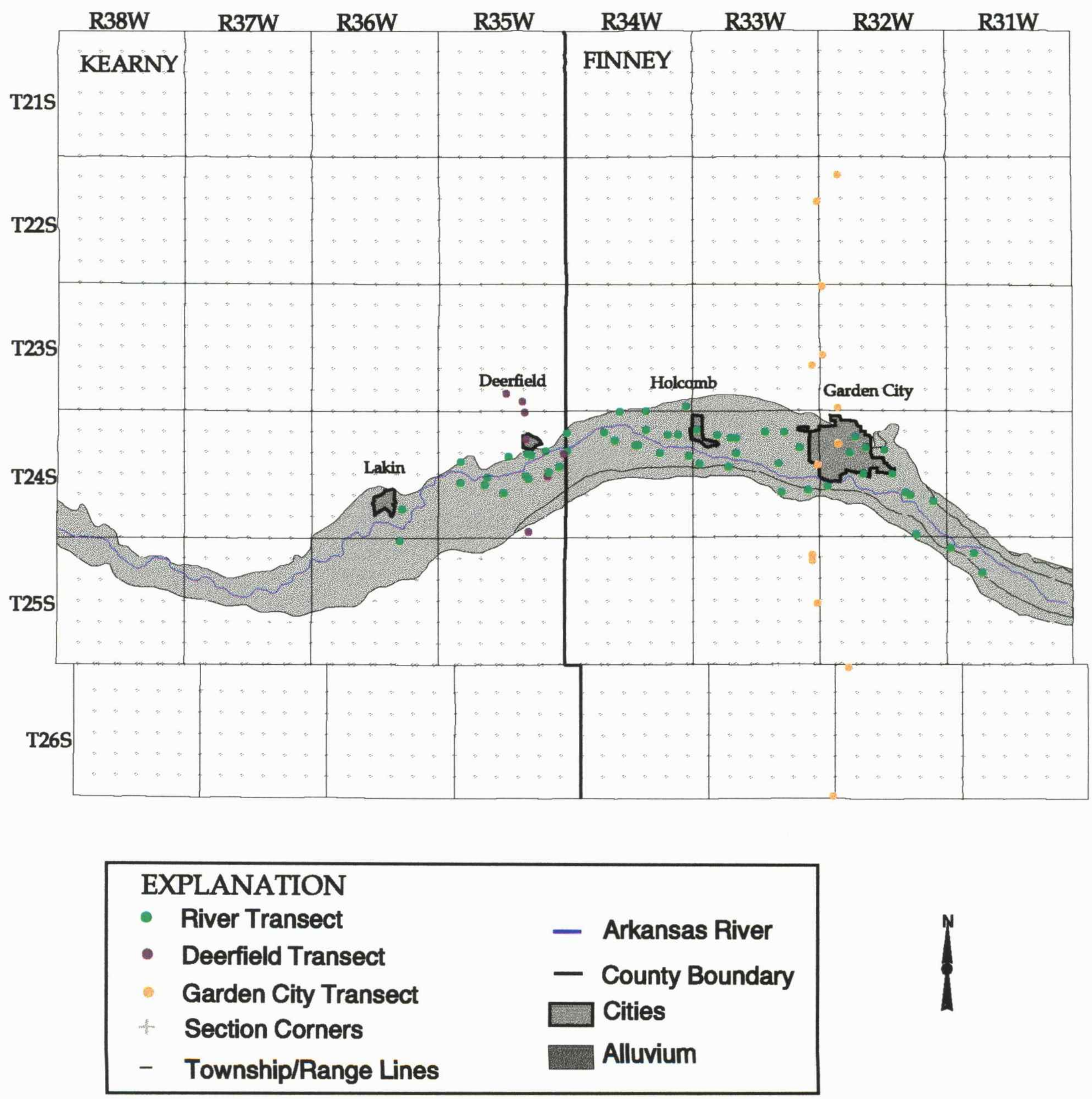


Figure 5. Well locations for geologic cross sections.

Table 2. Locations of wells and test holes used in geologic cross sections.

Arkansas River Transect

| ID | LEGAL LOCATION |
|---|---|
| 1 | 25S 36W 02 BBD |
| 2 | 24S 36W 26 CAC |
| 3 | 24S 35W 17 BCC |
| 4 | 24S 35W 20 BCC |
| 5 | 24S 35W 21 CBA |
| 6 | 24S 35W 21 BAC |
| 7 | 24S 35W 22 CCC |
| 8 | 24S 35W 15 BAC |
| 9 | 24S 35W 23 B |
| 10 | 24S 35W 23 BB |
| 11 | 24S 35W 14 BBA |
| 12 | 24S 35W 14 BA |
| 13 | 24S 35W 13 CCD |
| 14 | 24S 35W 12 CCC |
| 15 | 24S 35W 13 DBD |
| 16 | 24S 34W 07 CCC |
| 17 | 24S 34W 07 BBB |
| 18 | 24S 34W 08 AAB |
| 19 | 24S 34W 09 BDC |
| 20 | 24S 34W 04 ABB |
| 21 | 24S 34W 10 CAC |
| 22 | 24S 34W 10 CAD |
| 23 | 24S 34W 03 DDC |
| 24 | 24S 34W 03 AAB |
| 25 | 24S 34W 14 BAA |
| 26 | 24S 34W 11 AAC |
| 27 | 24S 34W 12 BAC |
| 28 | 23S 34W 36 DCA |
| 29 | 24S 34W 13 AAC |
| 30 | 24S 33W 06 CCD |
| 31 | 24S 33W 18 CAB |
| 32 | 24S 33W 08 BBD |
| 33 | 24S 33W 17 DBD |
| 34 | 24S 33W 08 ADB |
| 35 | 24S 33W 16 BBB |
| 36 | 24S 33W 09 BCB |
| 37 | 24S 33W 10 BAA |
| 38 | 24S 33W 14 CBB |
| 39 | 24S 33W 23 CCD |
| 40 | 24S 33W 11 BAB |
| 41 | 24S 33W 12 CCB |
| 42 | 24S 33W 24 CDA |
| 43 | 24S 32W 19 CA |
| 44 | 24S 32W 17 BAA |
| 45 | 24S 32W 08 ACA |
| 46 | 24S 32W 21 BBB |
| 47 | 24S 32W 09 CCA |
| 48 | 24S 32W 10 CCC |
| 49 | 24S 32W 22 BAA |
| 50 | 24S 32W 23 CCC |
| 51 | 24S 32W 26 BAB |
| 52 | 24S 32W 35 DCC |
| 53 | 24S 32W 25 BD |
| 54 | 25S 31W 06 CBA |
| 55 | 25S 31W 05 CDB |
| 56 | 25S 31W 08 DBD |

Note: ID is from left to right on sections.

North of River Transect

| ID | LEGAL LOCATION |
|---|---|
| 1 | 24S 36W 26 CAC |
| 2 | 24S 35W 17 BCC |
| 3 | 24S 35W 15 BAC |
| 4 | 24S 35W 14 BBA |
| 5 | 24S 35W 14 BA |
| 6 | 24S 35W 12 CCC |
| 7 | 24S 34W 07 BBB |
| 8 | 24S 34W 04 ABB |
| 9 | 24S 34W 03 DDC |
| 10 | 24S 34W 03 AAB |
| 11 | 24S 34W 11 AAC |
| 12 | 24S 34W 12 BAC |
| 13 | 23S 34W 36 DCA |
| 14 | 24S 33W 06 CCD |
| 15 | 24S 33W 08 BBD |
| 16 | 24S 33W 08 ADB |
| 17 | 24S 33W 16 BBB |
| 18 | 24S 33W 09 BCB |
| 19 | 24S 33W 10 BAA |
| 20 | 24S 33W 14 CBB |
| 21 | 24S 33W 11 BAB |
| 22 | 24S 33W 12 CCB |
| 23 | 24S 32W 17 BAA |
| 24 | 24S 32W 21 BBB |
| 25 | 24S 32W 23 CCC |
| 26 | 24S 32W 26 BAB |
| 27 | 24S 32W 25 BD |

South of River Transect

| ID | LEGAL LOCATION |
|---|---|
| 1 | 25S 36W 02 BBD |
| 2 | 24S 35W 20 BCC |
| 3 | 24S 35W 21 CBA |
| 4 | 24S 35W 21 BAC |
| 5 | 24S 35W 22 CCC |
| 6 | 24S 35W 23 B |
| 7 | 24S 35W 23 BB |
| 8 | 24S 35W 13 CCD |
| 9 | 24S 35W 13 DBD |
| 10 | 24S 34W 07 CCC |
| 11 | 24S 34W 08 AAB |
| 12 | 24S 34W 09 BDC |
| 13 | 24S 34W 10 CAC |
| 14 | 24S 34W 10 CAD |
| 15 | 24S 34W 14 BAA |
| 16 | 24S 34W 13 AAC |
| 17 | 24S 33W 18 CAB |
| 18 | 24S 33W 17 DBD |
| 19 | 24S 33W 23 CCD |
| 20 | 24S 33W 24 CDA |
| 21 | 24S 32W 19 CA |
| 22 | 24S 32W 08 ACA |
| 23 | 24S 32W 09 CCA |
| 24 | 24S 32W 10 CCC |
| 25 | 24S 32W 22 BAA |
| 26 | 24S 32W 35 DCC |
| 27 | 25S 31W 06 CBA |
| 28 | 25S 31W 05 CDB |
| 29 | 25S 31W 08 DBD |

Table 2. Locations of wells and test holes used in geologic cross sections (continued).

Deerfield Transect

| ID | LEGAL LOCATION |
|---|---|
| 1 | 23S 35W 34 BBD |
| 2 | 23S 35W 34 DAA |
| 3 | 24S 35W 02 BBB |
| 4 | 24S 35W 11 BC |
| 5 | 24S 35W 13 AAA |
| 6 | 24S 35W 13 CCD |
| 7 | 24S 35W 24 BB |
| 8 | 24S 35W 35 C |

Garden City Transect

| ID | LEGAL LOCATION |
|---|---|
| 1 | 22S 32W 06 DD |
| 2 | 22S 33W 13 AA |
| 3 | 23S 32W 06 BB |
| 4 | 23S 32W 19 BC |
| 5 | 23S 33W 24 DC |
| 6 | 23S 32W 31 DD |
| 7 | 24S 32W 07 DA |
| 8 | 24S 33W 13 DA |
| 9 | 24S 32W 19 CA |
| 10 | 25S 33W 01 DC |
| 11 | 25S 33W 12 AB |
| 12 | 25S 33W 24 AA |
| 13 | 26S 32W 06 AB |
| 14 | 26S 33W 36 DD |

Note: ID is from left to right on sections.

Wells located north of the river indicate a somewhat less continuous alluvial aquifer composed of more sand than gravel. The relatively impermeable layer between the aquifers tends to be thicker with more clay in the cross section for north of the river than for south of the river. The High Plains aquifer south of the river generally has thicker, more continuous gravely layers compared to the aquifer north of the river, which has fairly thin discontinuous layers of sand and gravel often interbedded with lenses of caliche and silt.

Figures A4 and A5 are north-south sections through Deerfield and Garden City, respectively. These reflect the same sort of differences observed for north versus south of the Arkansas River as those discussed in the preceeding paragraph. The shallow alluvial aquifer is well defined south of the Arkansas river in both north-south sections, while more fine-grained materials occur north of the river. The deeper High Plains aquifer also contains more permeable materials and appears more continuous south of the river compared with north of the river. Both sections show a general southward slope of the bedrock surface; the Deerfield section (Figure A4) suggests a bedrock ridge south of the river.

## PROPOSED ACTIVITIES FOR FY 1998

Proposed activities for FY 1998 include additional work in characterizing the aquifer system in Finney and Kearny counties. This will consist of more detailed work, particularly in the Deerfield and Garden City areas, including producing more cross sections and producing fence diagrams. Efforts will include additional characterization of the bedrock surface, which may incorporate additional sources of data such as gamma logs from oil and gas well logs. Efforts in Finney and Kearny counties will be based in part on new monitoring sites that are being installed by the project. Also, work will begin on lithologic characterization of the other counties comprising the study area. Because of some limitations of the PfEFFER program, experimentation with other methods of cross-section display of lithologic data will be conducted.

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# APPENDIX. GEOLOGIC CROSS SECTIONS

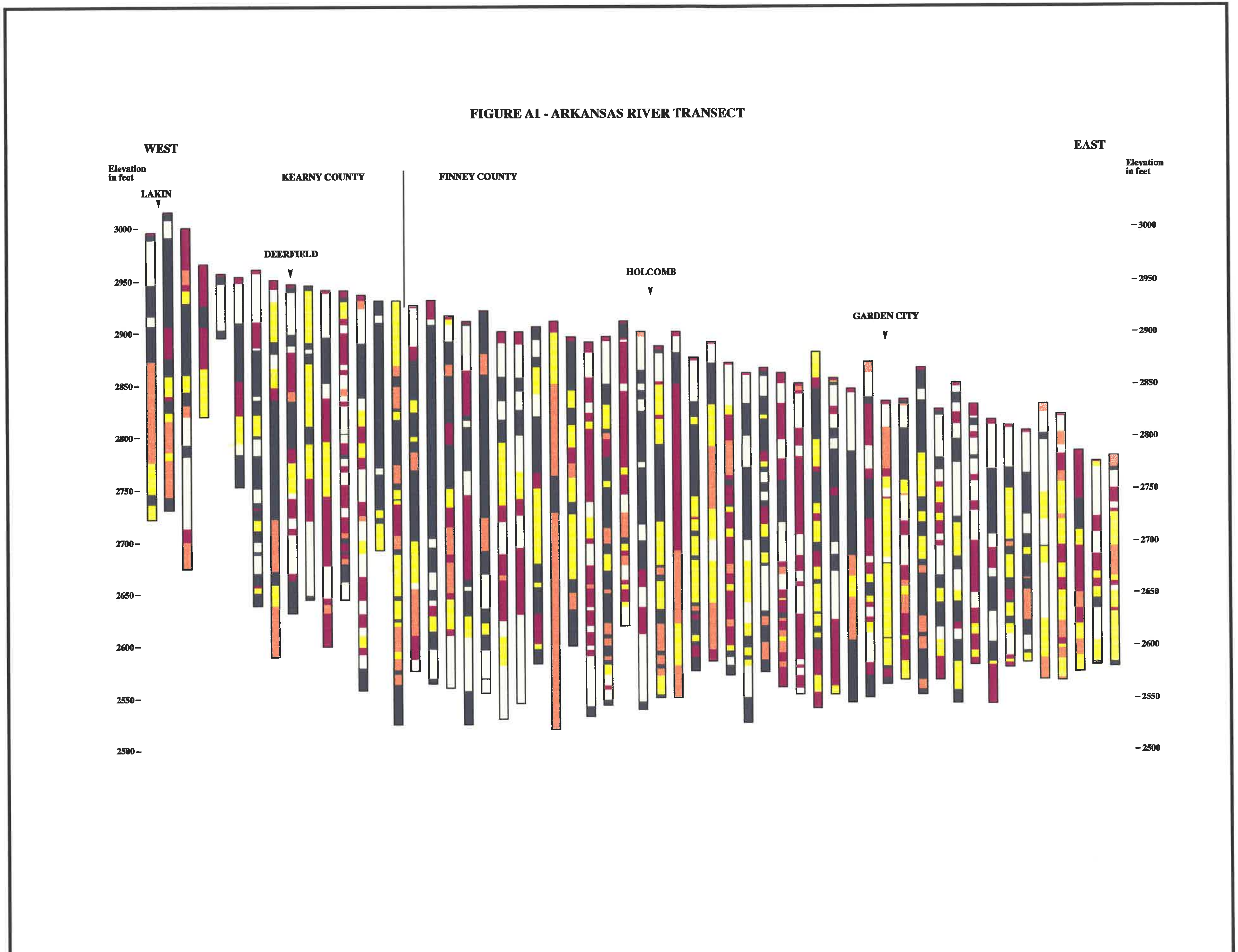
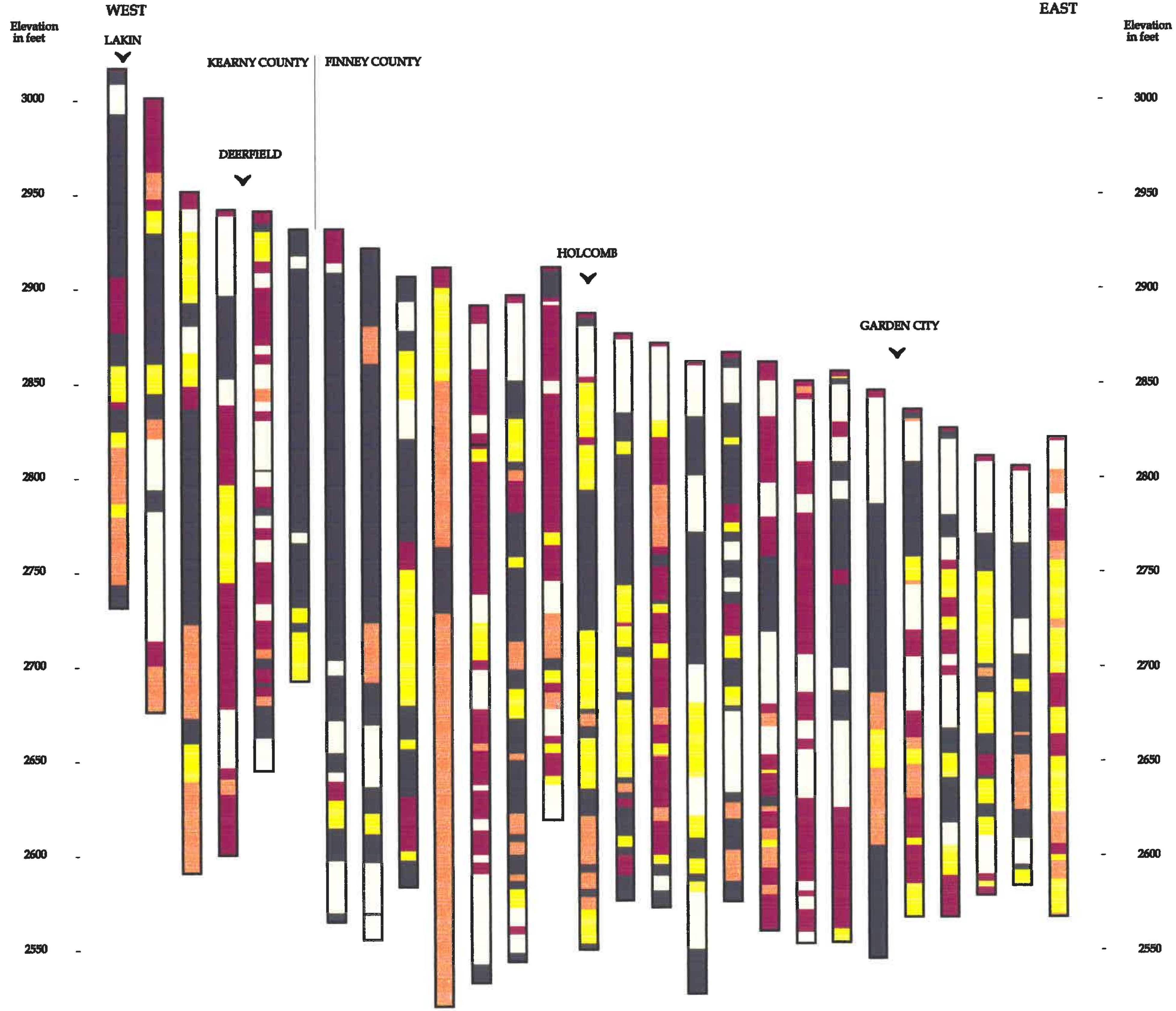
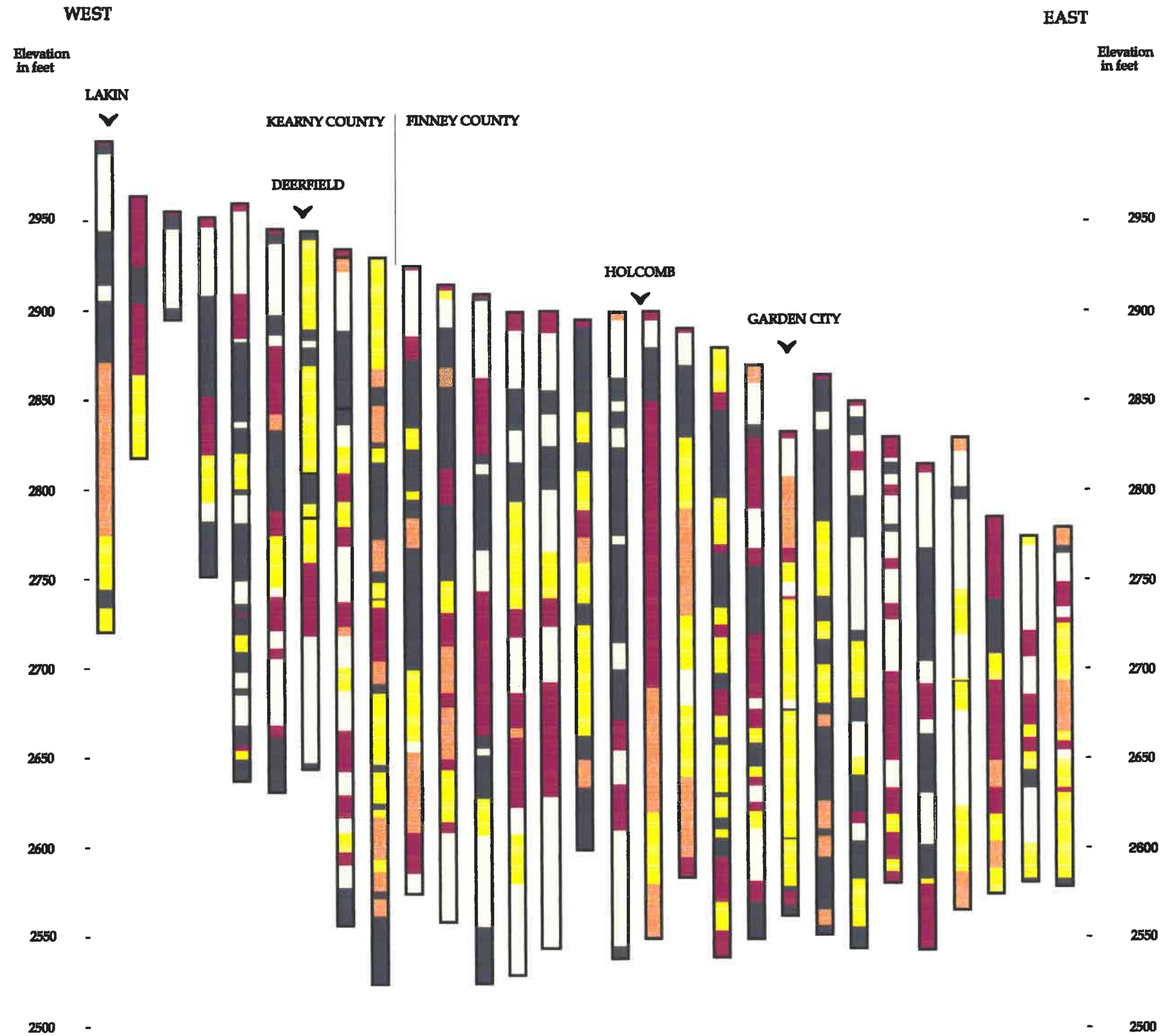


FIGURE A1 - ARKANSAS RIVER TRANSECT
WEST
EAST
Elevation in feet
Elevation in feet
KEARNY COUNTY
FINNEY COUNTY
LAKIN
DEERFIELD
HOLCOMB
GARDEN CITY
3000
2950
2900
2850
2800
2750
2700
2650
2600
2550
2500

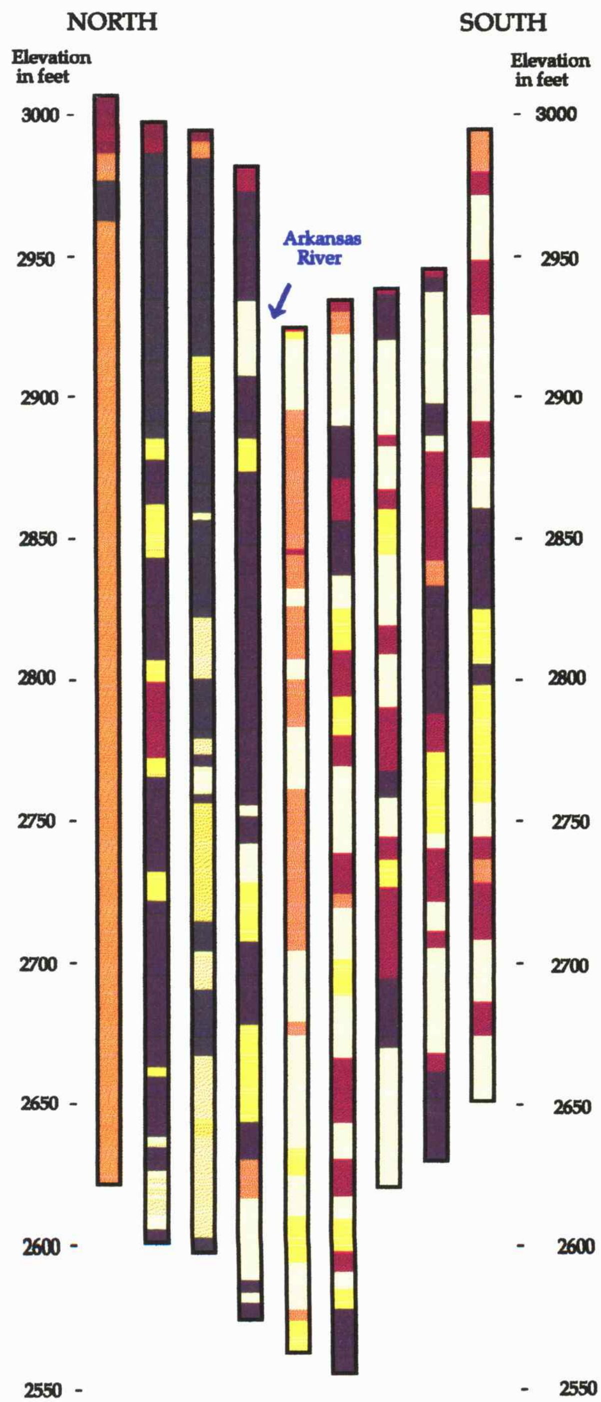
FIGURE A2 - NORTH OF RIVER TRANSECT



# FIGURE A3 - SOUTH OF RIVER TRANSECT



## FIGURE A4 - DEERFIELD TRANSECT



# FIGURE A5 - GARDEN CITY TRANSECT