

**HESA and GIS-Based  
Groundwater Resources Evaluation  
Delta County, Colorado  
PHASE II: NORTH FORK  
GUNNISON RIVER AREA**

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**and**

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Heath Hydrology, Inc**

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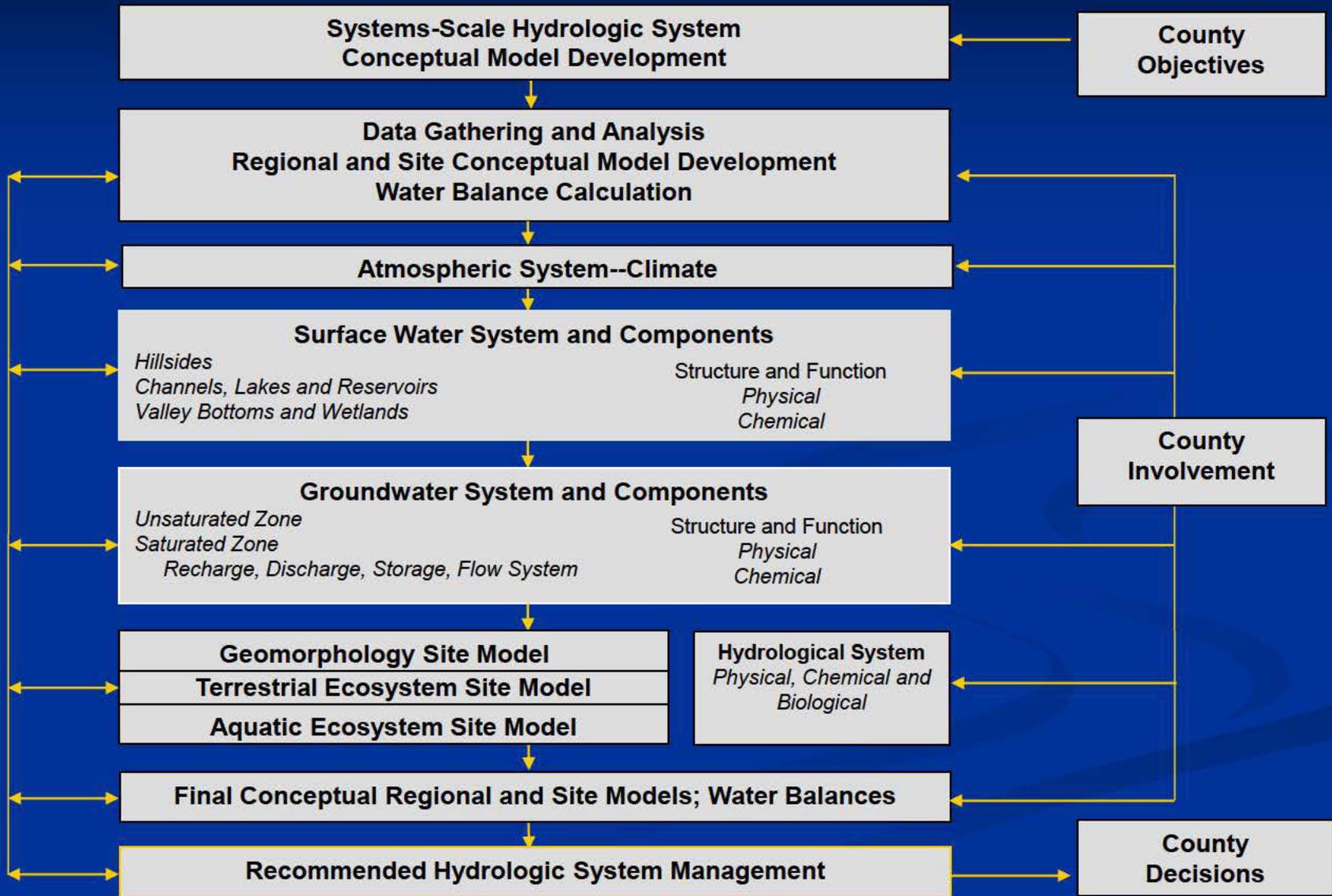
# Phase I: Oak Mesa

- Performed a **HESA** (Hydrologic and Environmental System Analysis) and formulated conceptual models of representative hydrogeologic subsystems of the **Oak Mesa** area
- Developed **GIS maps and data bases** of hydrological and hydrogeological characteristics from existing data for use in the HESA and as a cost-effective planning/management/educational tool

# Why did we do this?

- Source water assessment and protection (municipal and communal water supply systems)
- Sustainability of water supply sources
- Adequate water quantity and quality to sustain land development
- Effects of coal mining
- Effects of gas and oil exploitation
- ISDS and well setbacks
- Protection of groundwater-fed wetlands.
- Groundwater contribution to in-stream flows and water quality
- Effects of land use changes (agriculture to mining and subdivisions)

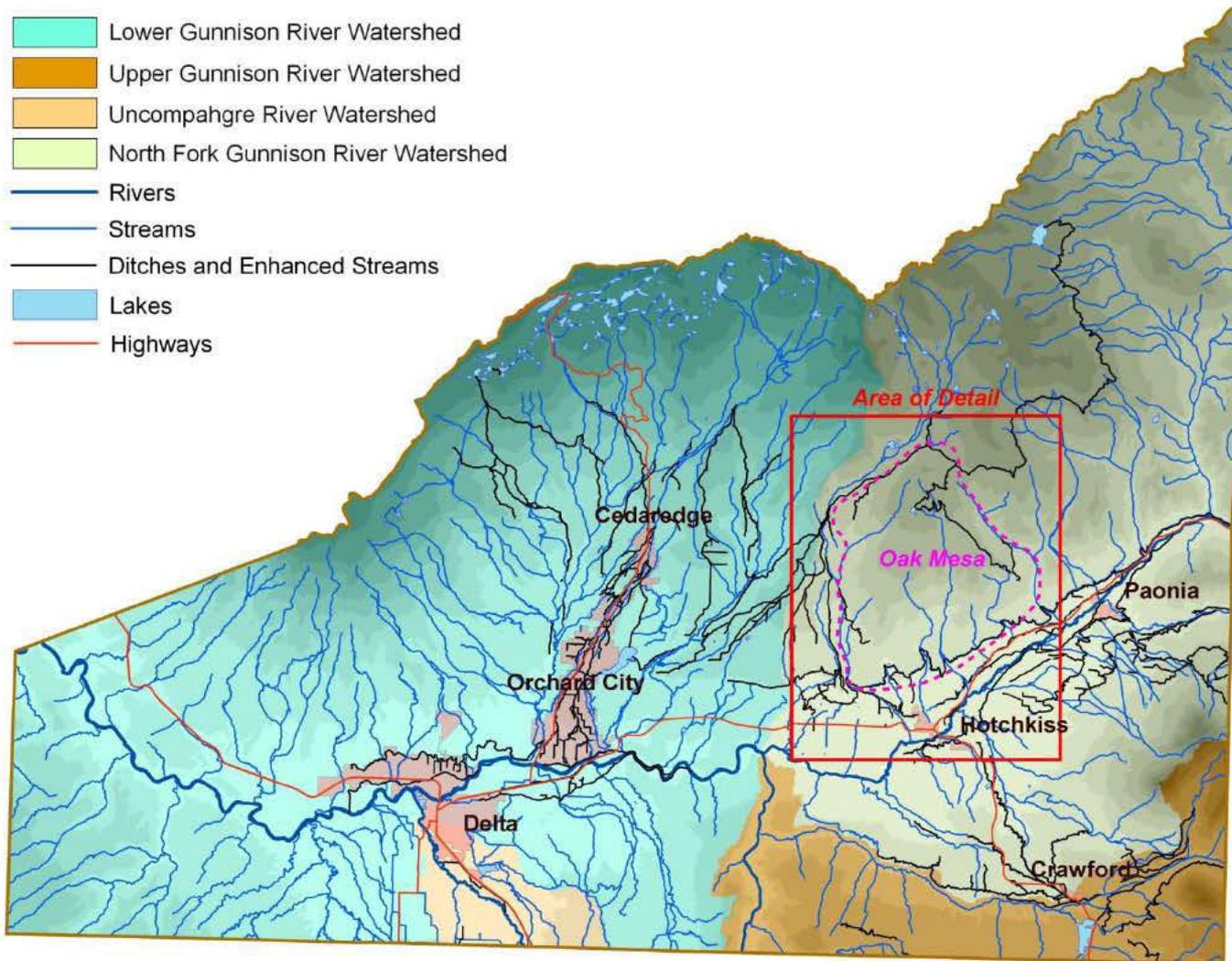
# HESA Flowchart



# HESA Elements in Oak Mesa Study

- **Surface characterization**
  - Climate, vegetation, soils, geomorphology, topography, surface water, and land use and other anthropogenic elements
- **Subsurface characterization**
  - Geologic framework, hydrogeologic framework, hydrogeologic properties
- **Groundwater flow system characterization**
  - Flow paths, velocities, recharge, discharge, water budget
- [Ground water quality/chemistry characterization]
- [Ground water modeling]

# Phase I Study Area Location



# Correlation of Geological and Hydrogeological Units in Delta County - 1

<i>Geological Unit</i>	<i>Geological Subunit</i>	<i>Hydrogeological Unit</i>	<i>Hydrogeological Unit Symbol</i>	<i>Composition</i>	<i>Hydrogeological Characteristics</i>	<i>Permeability/Storativity</i>	<i>Depth to Water (small/moderate/large/highly fluctuating)</i>	<i>Extent (local/sub-regional/regional)</i>	<i>Recharge Type (natural/anthropogenic)</i>
Alluvium (Qa); alluvium and eolian deposits (Qae)		Alluvium	Qa1	Poorly sorted riverine gravel, sand and silt deposited mainly in stream channels and floodplains in major stream valley bottoms; moderately to well bedded deposits	Generally good local phreatic aquifer with matrix based permeability; limited variations in groundwater levels; often sustained by local and sub-regional discharge to adjacent stream or directly by stream.	high matrix-permeability; high storativity	small	local	natural
Younger gravel (Qg, Qgy)		Younger valley gravels	Qgy	Poorly sorted sands and gravels; pebbles and cobbles in sand to silt matrix	Potentially good, spatially continuous phreatic aquifer with high matrix based permeability; may be supported by underlying bedrock.	high matrix-permeability; high storativity	highly fluctuating	local	natural and anthropogenic
Glacial drift, till, moraine (Qd, Qm, Qpt)		Quaternary glacial deposits	Qd	Heterogeneous, poorly sorted deposits of boulders, gravel, sand, silt and clay	Potentially good local phreatic aquifer with variable matrix based permeability and high water table gradients.	high matrix-permeability; high storativity	highly fluctuating	local	natural and anthropogenic
Landslide deposits, colluvium, mudflow deposits, talus (Ql, Qcl, Qs, Qls, Qta); unconsolidated deposits derived from the Wasatch Formation and Basalt cap on Grand Mesa (Quw)		Hillside (slope) deposits	Qs	Loose gravels and rock debris with mixed matrix composition (sand-clay) on valley sides, valley floors and hillslopes; deposited by gravitational processes	Potentially good, highly localized phreatic aquifer with high matrix based permeability and high water table gradients.	high matrix-permeability; high storativity	highly fluctuating	local	natural and anthropogenic
Old/older gravels (Qgo, Qgd)		Older mesa top gravels	Qgo	Poorly sorted sands and gravels; pebbles and cobbles in sand to silt matrix	Potentially good, spatially continuous phreatic aquifer with high matrix based permeability; may be prone to significant (seasonal) water table fluctuations; tends to recharge bedrock systems	high matrix-permeability; high storativity	moderate	local	natural and anthropogenic
Middle gravel (Qgm) and fans (Qf)		Fans and lower mesa gravels	Qgf	Poorly sorted sands and gravels; pebbles and cobbles in sand to silt matrix	Although having high matrix based permeability, location in topography precludes any significant groundwater presence.	high matrix-permeability; high storativity	highly fluctuating	local	natural and anthropogenic
High level alluvium (Qat); younger terraces (Qad); alluvial gravels (Qga)		Younger river terraces	Qat	Poorly sorted sands and gravels; pebbles and cobbles in sand to silt matrix; forms terraces above current North Fork level	Potentially good, spatially continuous phreatic aquifer with high matrix based permeability.	high matrix-permeability; high storativity	highly fluctuating	local	natural and anthropogenic

# Correlation of Geological and Hydrogeological Units in Delta County - 2

<i>Geological Unit</i>	<i>Geological Subunit</i>	<i>Hydrogeological Unit</i>	<i>Hydrogeological Unit Symbol</i>	<i>Composition</i>
Alluvium (Qa); alluvium and eolian deposits (Qae)		Alluvium	Qal	Poorly sorted riverine gravel, sand and silt deposited mainly in stream channels and floodplains in major stream valley bottoms; moderately to well bedded deposits
Younger gravel (Qg, Qgy)		Younger valley gravels	Qgy	Poorly sorted sands and gravels; pebbles and cobbles in sand to silt matrix
Glacial drift, till, moraine (Qd, Qm, Qpt)		Quaternary glacial deposits	Qd	Heterogeneous, poorly sorted deposits of boulders, gravel, sand, silt and clay

# Correlation of Geological and Hydrogeological Units in Delta County - 3

<i>Hydrogeological Unit Symbol</i>	<i>Hydrogeological Characteristics</i>	<i>Permeability/Storativity</i>	<i>Depth to Water</i> (small/ moderate/ large/ highly fluctuating)	<i>Extent</i> (local/ sub-regional/ regional)	<i>Recharge Type</i> (natural/ anthropogenic)
Qal	Generally good local phreatic aquifer with matrix based permeability; limited variations in groundwater levels; often sustained by local and sub-regional discharge to adjacent stream or directly by stream.	high matrix-permeability; high storativity	small	local	natural
Qgy	Potentially good, spatially continuous phreatic aquifer with high matrix based permeability; may be supported by underlying bedrock.	high matrix-permeability; high storativity	highly fluctuating	local	natural and anthropogenic
Qd	Potentially good local phreatic aquifer with variable matrix based permeability and high water table gradients; sustainability depends on local natural and/or anthropogenic recharge mechanisms.	high matrix-permeability; high storativity	highly fluctuating	local	natural and anthropogenic

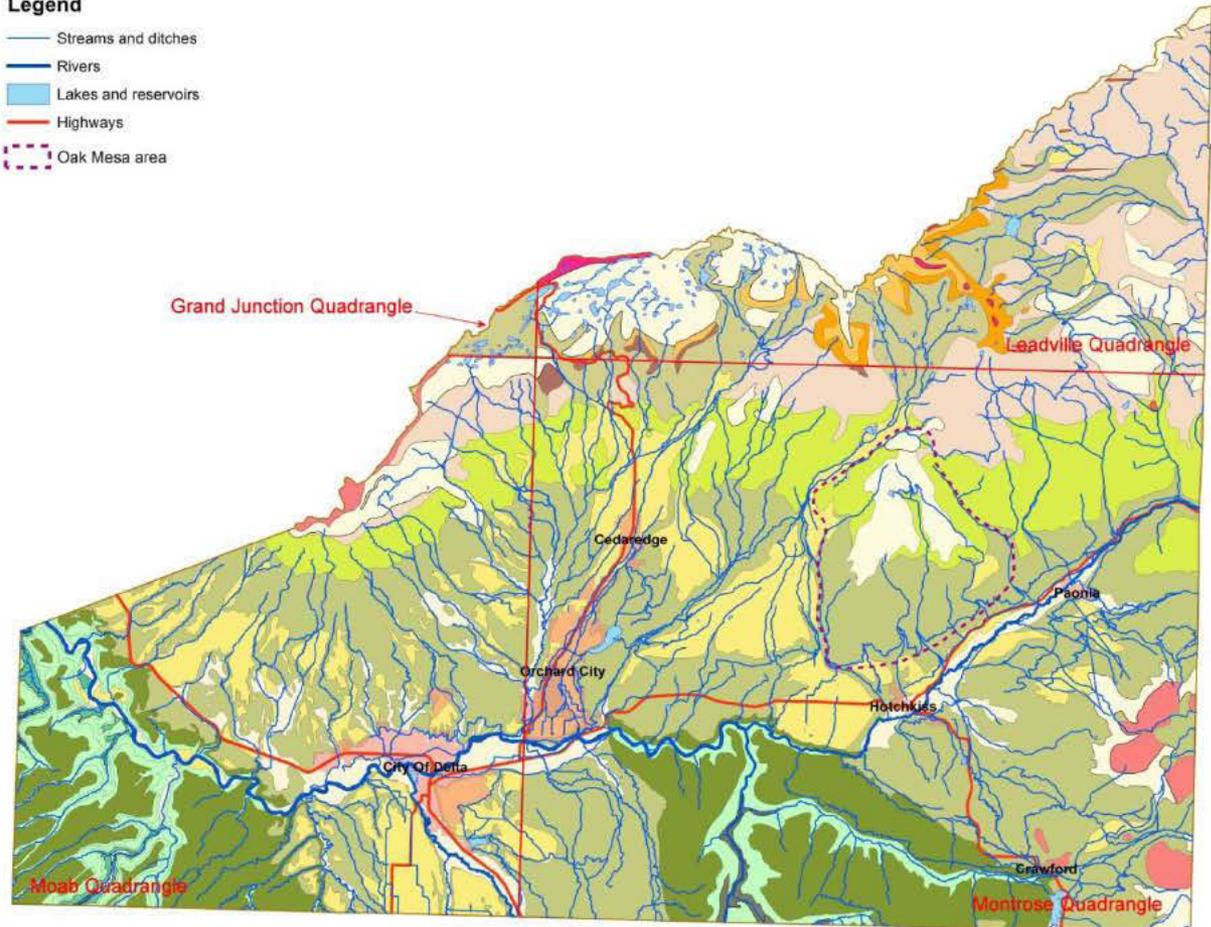
# Geological Map of Delta County

## Geological Units

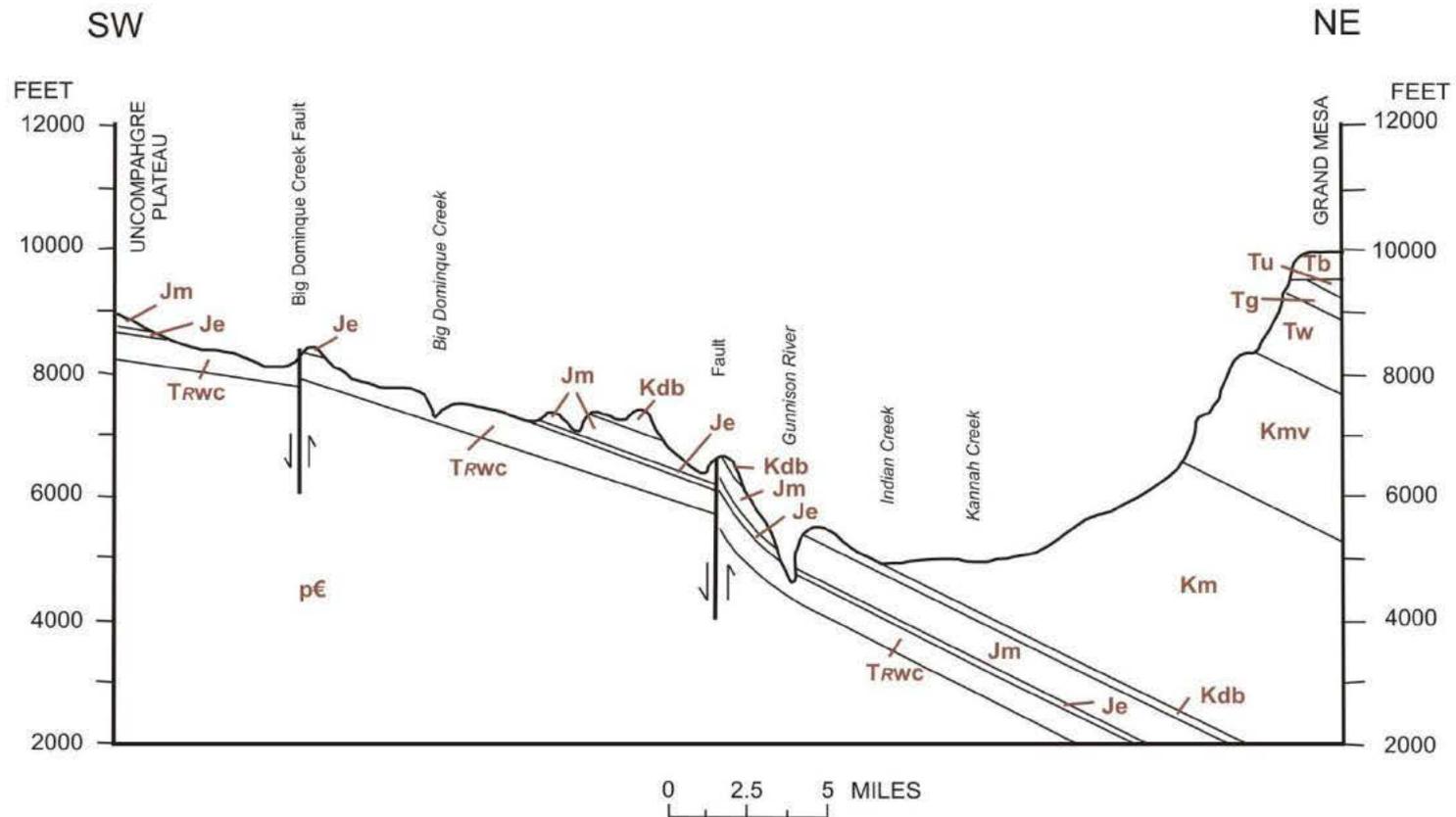
- Qa - Alluvium
- Qb - Basalt [Lava flows]
- Qd - Glacial Drift [Till]
- Qe - Eolian Deposits
- Qg - Young Gravels [Terraces, fans, outwash deposits]
- Qgo - Old Gravels [On ridge and mesa tops]
- Qls - Landslide Deposits [Colluvium, talus]
- Tb - Basalt [Lava flows]
- Tbi - Basalt Dikes and Plugs [Intrusions]
- Tg - Green River Formation
- Tgp - Green River Formation - Parachute Creek Member
- Tmi - Mid-Tertiary Intrusions [Stocks, dikes, sills, laccoliths]
- Tu - Uinta Formation
- Tw - Wasatch Formation
- Two - Wasatch and Ohio Creek Formations
- Kdb - Dakota Sandstone and Burro Canyon Formation
- Km - Mancos Shale
- Kmv - Mesa Verde Group or Formation
- Jmb - Morrison Formation - Brushy Basin Member
- Jms - Morrison Formation - Salt Wash Sandstone Member
- Jmwe - Morrison and Wanakah Formations and Entrada Sandstone
- Jse - Summerville Formation and Entrada Sandstone
- TRc - Chinle Formation
- TRw - Wingate Sandstone
- pC - Precambrium Crystalline Rock

## Legend

- Streams and ditches
- Rivers
- Lakes and reservoirs
- Highways
- ⋯ Oak Mesa area



# NE-SW Geological Cross Section



Tb - Tertiary Basalt  
 Tu - Uinta Formation  
 Tg - Green River Formation  
 Tw - Wasatch Formation  
 Kmv - Mesaverde Formation  
 Km - Mancos Shale

Kdb - Dakota Sandstone and  
 Burro Canyon Formation  
 Jm - Morrison Formation  
 Je - Entrada Sandstone  
 Trwc - Wingate Sandstone and  
 Chinle Formation  
 p€ - Precambrian

# Hydrogeology of Oak Mesa Area

## Shallow Unconsolidated Units

### Unconsolidated Hydrogeological Units

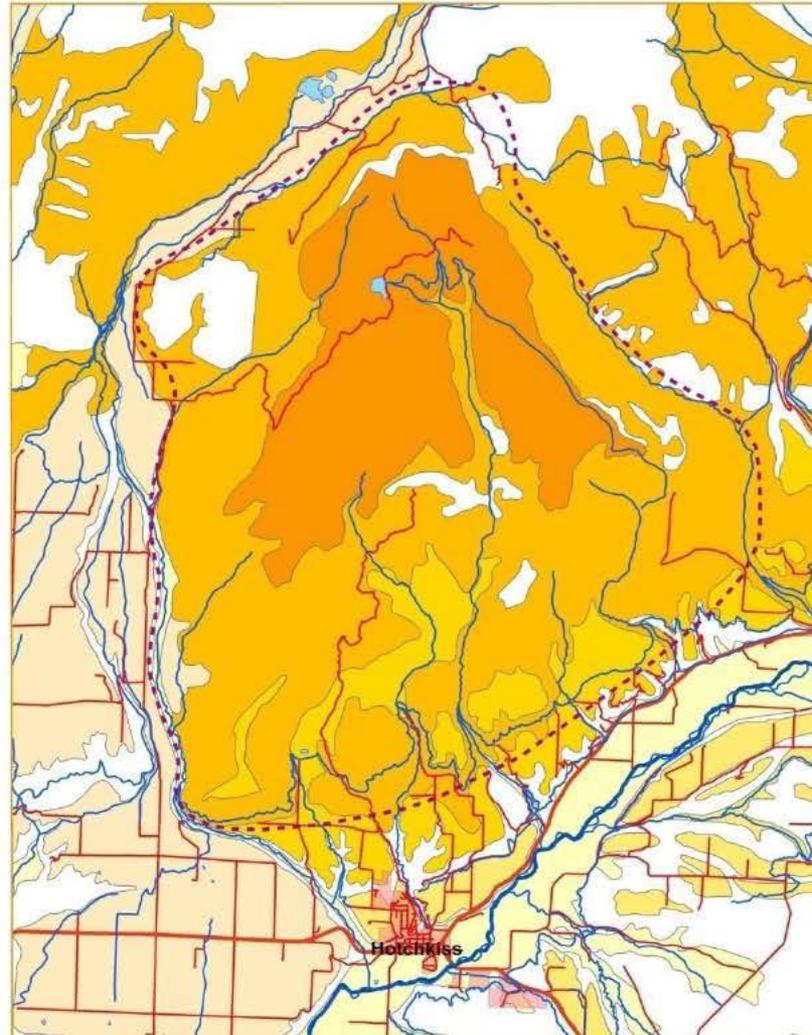
-  Alluvium (Qal)
-  Younger Valley Gravels (Qgy)
-  Younger River Terraces (Qat)
-  Fans and Lower Mesa Gravels (Qgf)
-  Hillside (Slope) Deposits (Qs)
-  Older Mesa Top Gravels (Qgo)
-  Bedrock

### Legend

-  Streams and ditches
-  Rivers
-  Lakes and reservoirs
-  Highways
-  Roads
-  Oak Mesa area



0 0.5 1 2 Miles  

# Hydrogeology of Oak Mesa Area

## Bedrock Units

### Bedrock Hydrogeological Units

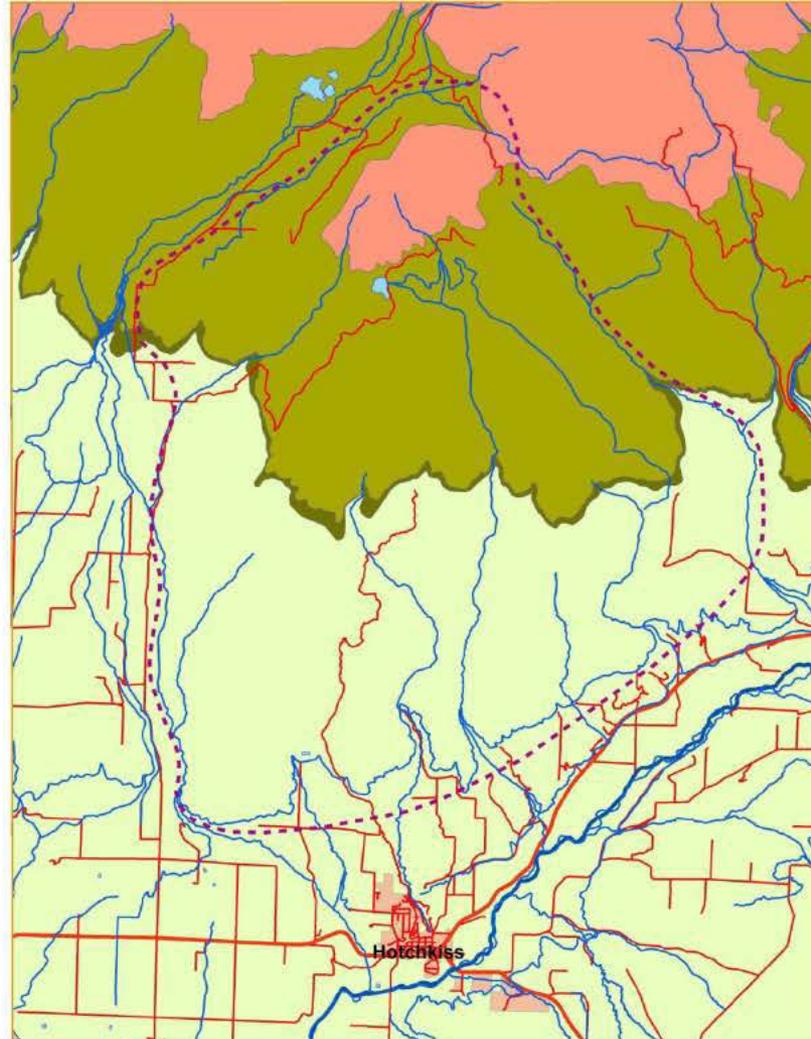
- Wasatch Formation (Tw)
- Mesa Verde Formation incl. Ohio Creek Member (Kmv)
- Rollins Sandstone (Kmr)
- Mancos Shale (Km)
- Dakota-Burro Canyon (Kdb)

### Legend

- Streams and ditches
- Rivers
- Lakes and reservoirs
- Highways
- Roads
- Oak Mesa area



0 0.5 1 2 Miles

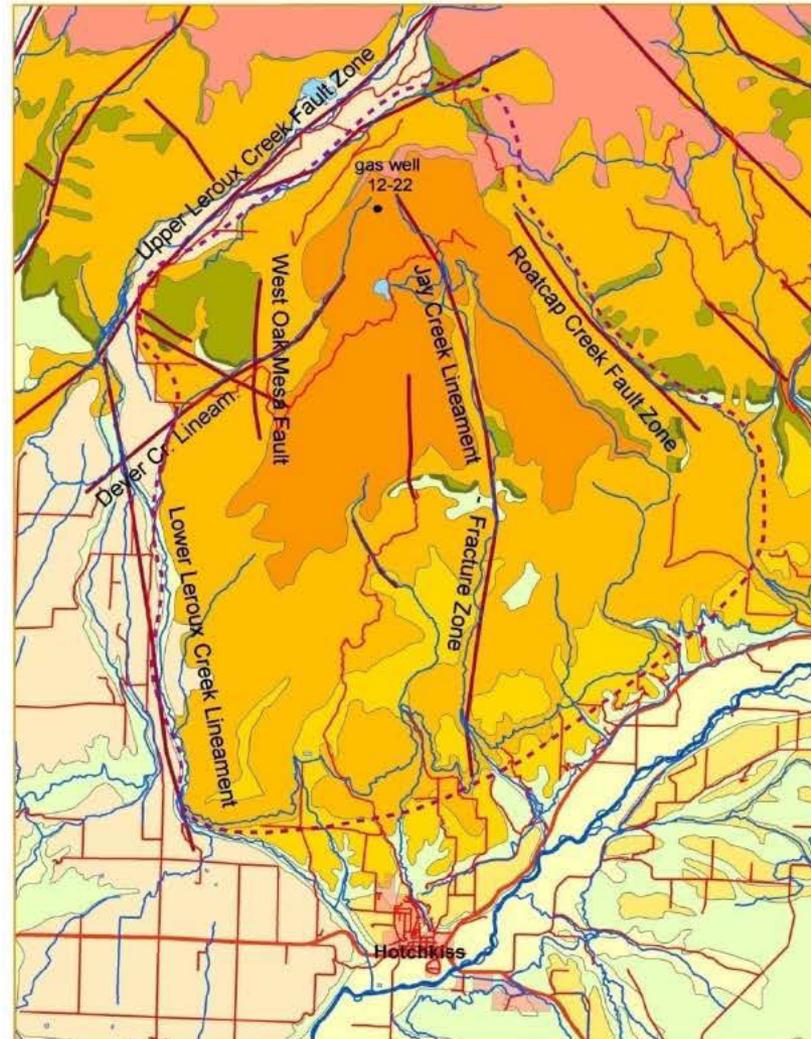


# Hydrogeology of Oak Mesa Area

## Hydrostructures

### Legend

- Streams and ditches
- Rivers
- Lakes and reservoirs
- Highways
- Roads
- Oak Mesa area
- Hydro-structures

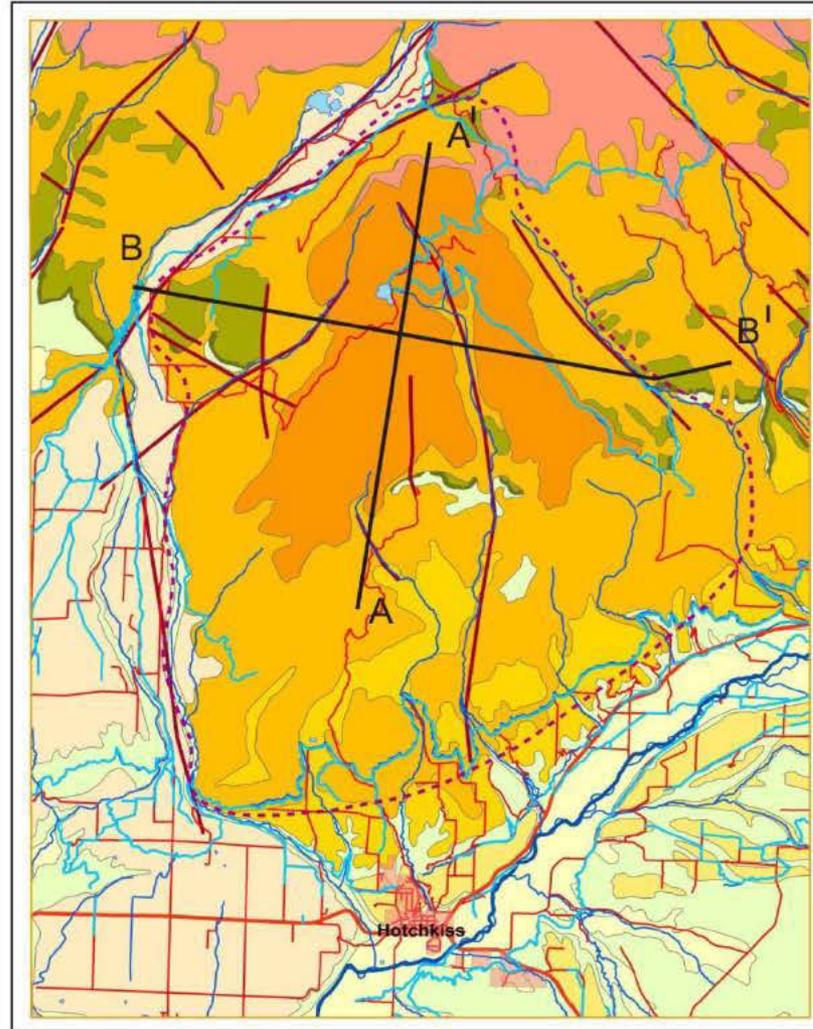


# Hydrogeology of Oak Mesa Area

## Location of CSM Cross Sections

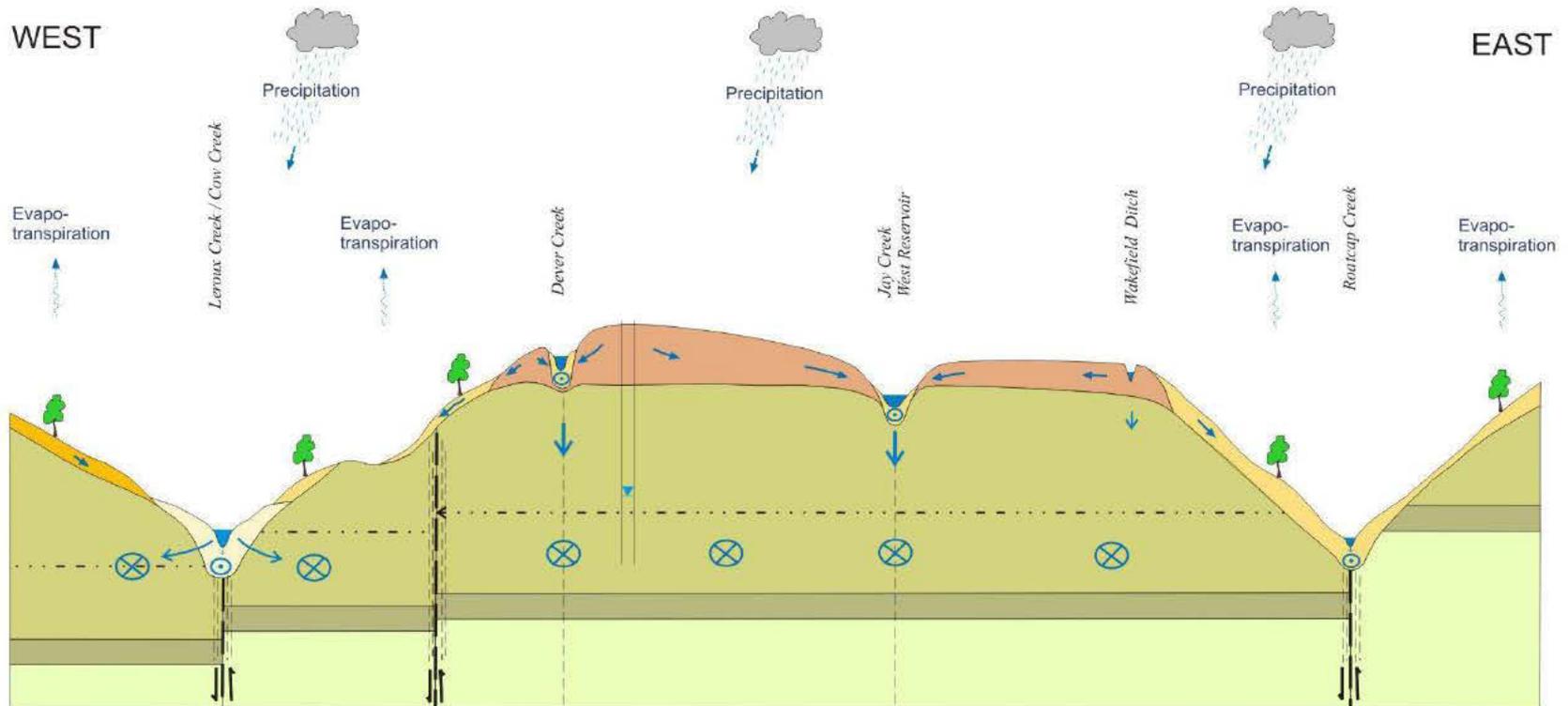
### Legend

- Oak Mesa area
- Ditches and enhanced streams
- Rivers
- Streams and ditches
- Lakes and reservoirs
- Towns
- Highways
- Roads
- Oak Mesa hydro-structures
- Alluvium [Qal]
- Younger Valley Gravels [Qgy]
- Younger River Terraces [Qat]
- Fans and Lower Mesa Gravels [Qgf]
- Hillside (Slope) Deposits [Qs]
- Older Mesa Top Gravels [Qgo]
- Wasatch Formation [Tw]
- Mesaverde Formation [Kmv]
- Rollins Sandstone [Kmv]
- Mancos Shale [Km]
- Dakota-Burro Canyon [Kdb]



# Hydrogeology of Oak Mesa Area

## Shallow Aquifer Subsystem – X-section



B

- Qgy - Younger Valley Gravels
- Qs - Hillside Deposits
- Qgo - Older Mesa Top Gravels
- Kmv - Mesaverde Formation
- Kmvr - Rollins Member of Mesaverde F.
- Km - Mancos Shale
- Top Coal-bearing Members

- Groundwater Flow
- X Groundwater Flow into Plane of Cross-section
- Groundwater Flow out of Plane of Cross-section
- Fault (arrows indicate direction of movement)
- Fracture Zone
- Lineament
- ▽ Static Groundwater Level in Well

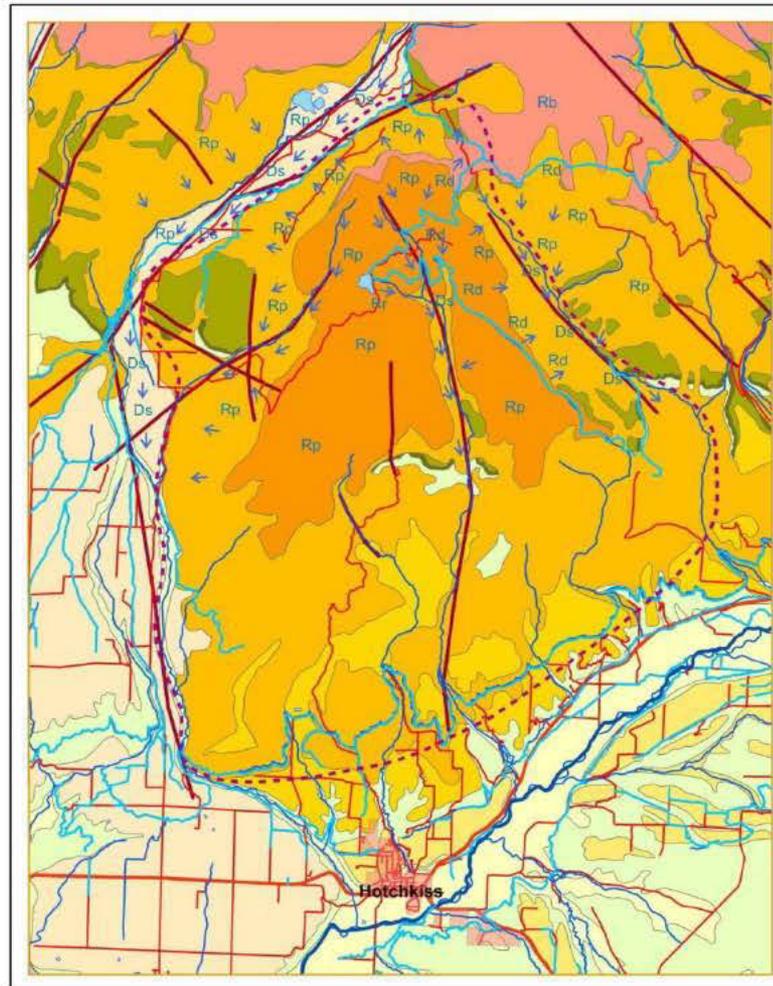
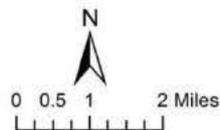
B'

# Hydrogeology of Oak Mesa Area

## Shallow Aquifer Subsystem – Plan View

### Legend

-  Oak Mesa area
  -  Ditches and enhanced streams
  -  Rivers
  -  Streams and ditches
  -  Lakes and reservoirs
  -  Towns
  -  Highways
  -  Roads
  -  Oak Mesa hydro-structures
  -  Alluvium [Qal]
  -  Younger Valley Gravels [Qgy]
  -  Younger River Terraces [Qat]
  -  Fans and Lower Mesa Gravels [Qgf]
  -  Hillside (Slope) Deposits [Qs]
  -  Older Mesa Top Gravels [Qgo]
  -  Wasatch Formation [Tw]
  -  Mesaverde Formation [Kmv]
  -  Rollins Sandstone [Kmv]
  -  Mancos Shale [Km]
  -  Dakota-Burro Canyon [Kdb]
- 
-  Rp - Recharge from precipitation into gravel and through gravel into bedrock
  -  Rd - Recharge from leaky ditch
  -  Rb - Recharge from precipitation directly into bedrock
  -  Rr - Recharge from reservoir/lake
  -  Ds - Discharge to stream
  -  → - Direction of groundwater flow



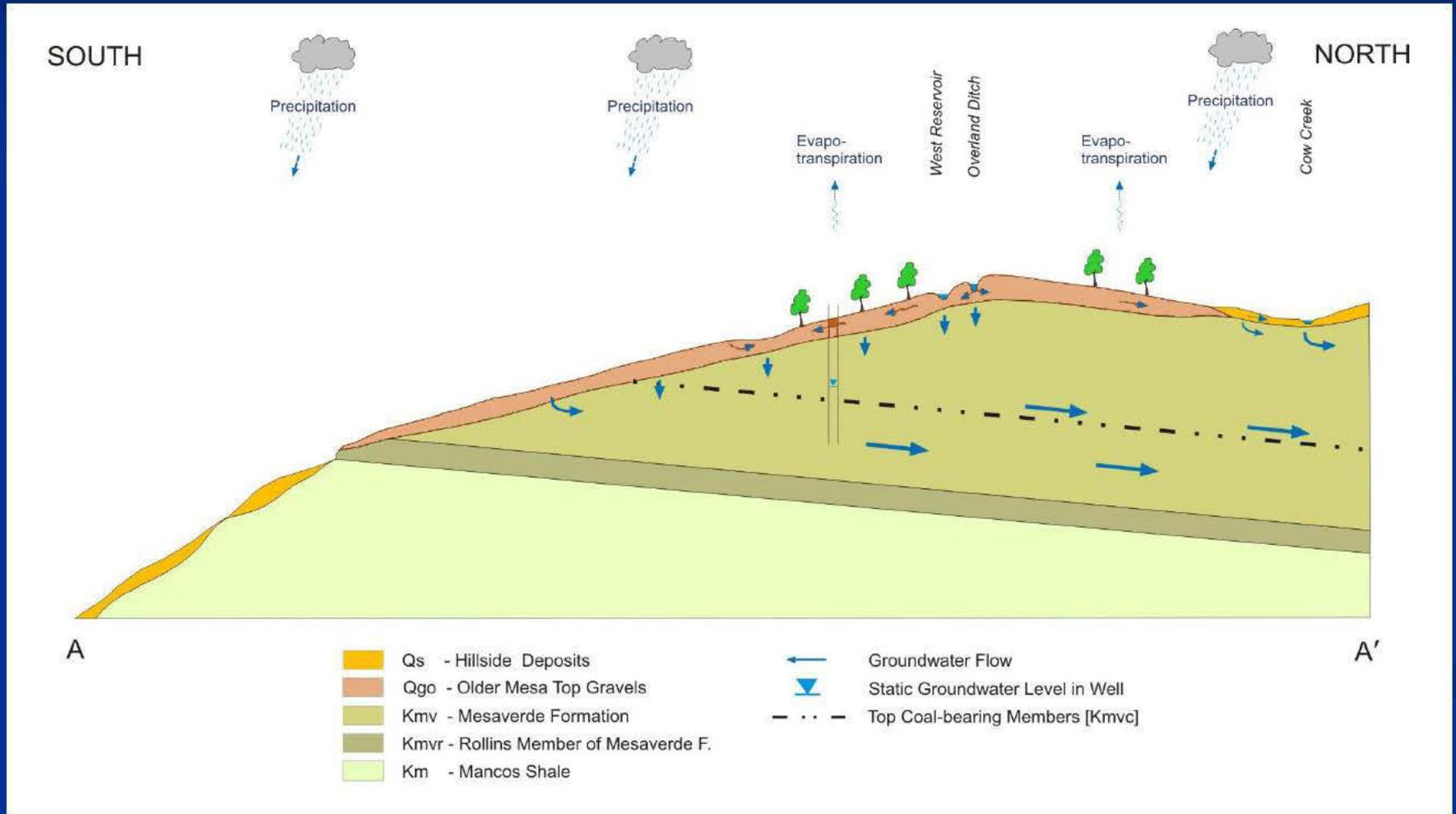
# Hydrogeology of Oak Mesa Area

## Shallow Aquifer Subsystem – Google Earth View



# Hydrogeology of Oak Mesa Area

## Regional Bedrock Subsystem – X-section



# Hydrogeology of Oak Mesa Area

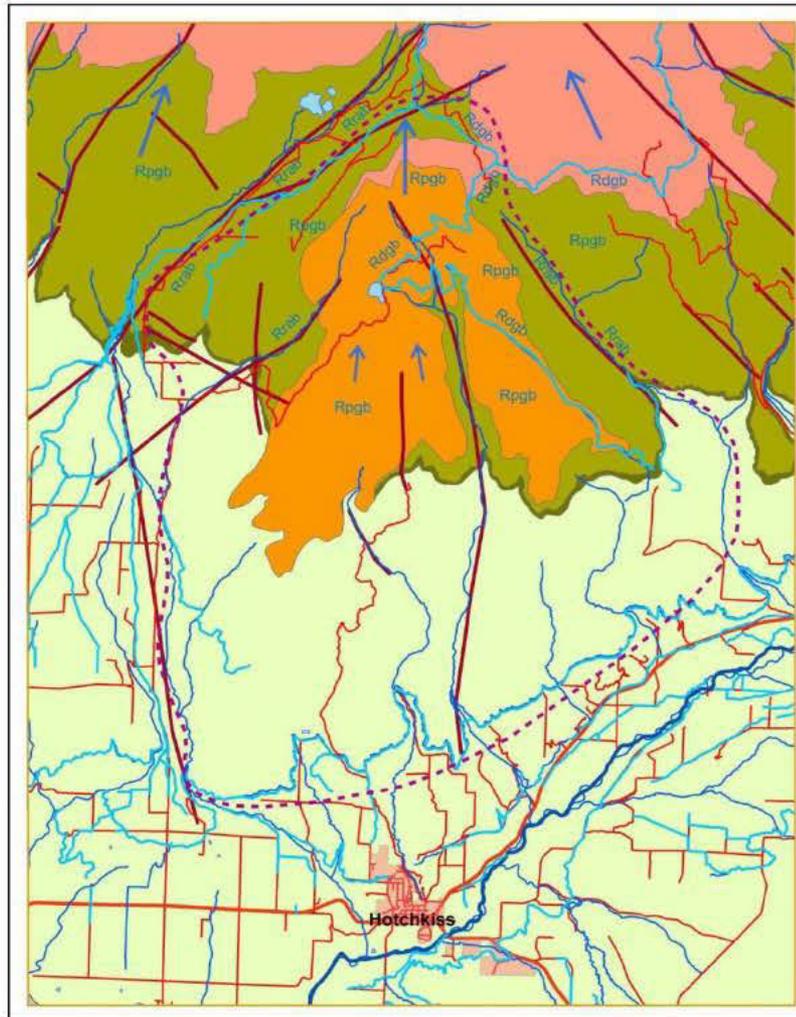
## Regional Bedrock Subsystem – Plan View

### Legend

-  Oak Mesa area
  -  Ditches and enhanced streams
  -  Rivers
  -  Streams
  -  Lakes and reservoirs
  -  Towns
  -  Highways
  -  Roads
  -  Oak Mesa hydro-structures
  -  Older Mesa Top Gravels [Qgo]
  -  Wasatch Formation [Tw]
  -  Mesaverde Formation [Kmv]
  -  Rollins Sandstone [Kmv]
  -  Mancos Shale [Km]
  -  Dakota-Burro Canyon [Kdb]
- 
-  Rpgb - Recharge from precipitation through gravels to bedrock
  -  Rrab - Recharge from leaky river through alluvium into bedrock
  -  Rdgb - Recharge from leaky ditch through gravels into bedrock
  -  → - Direction of groundwater flow

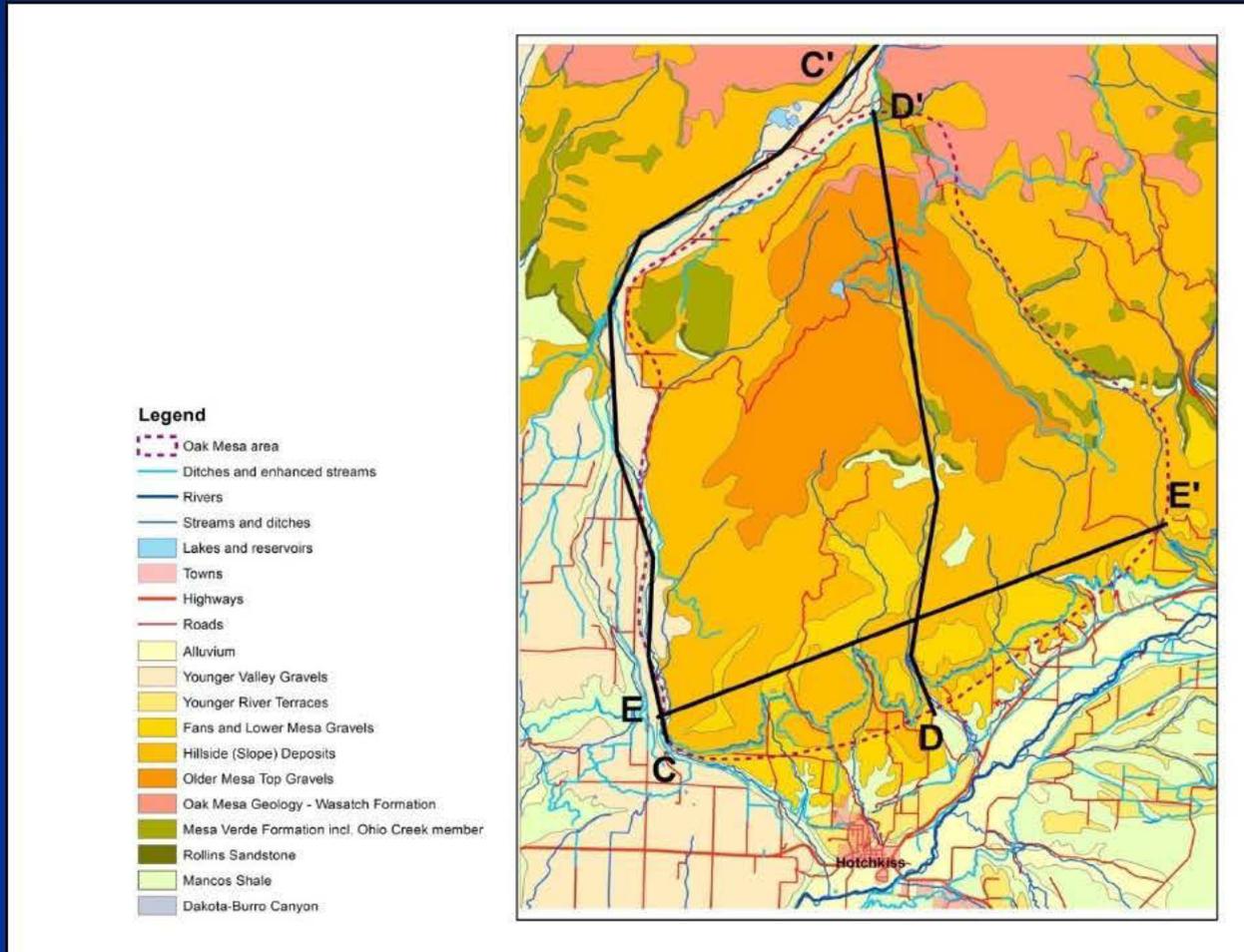


0 0.5 1 2 Miles



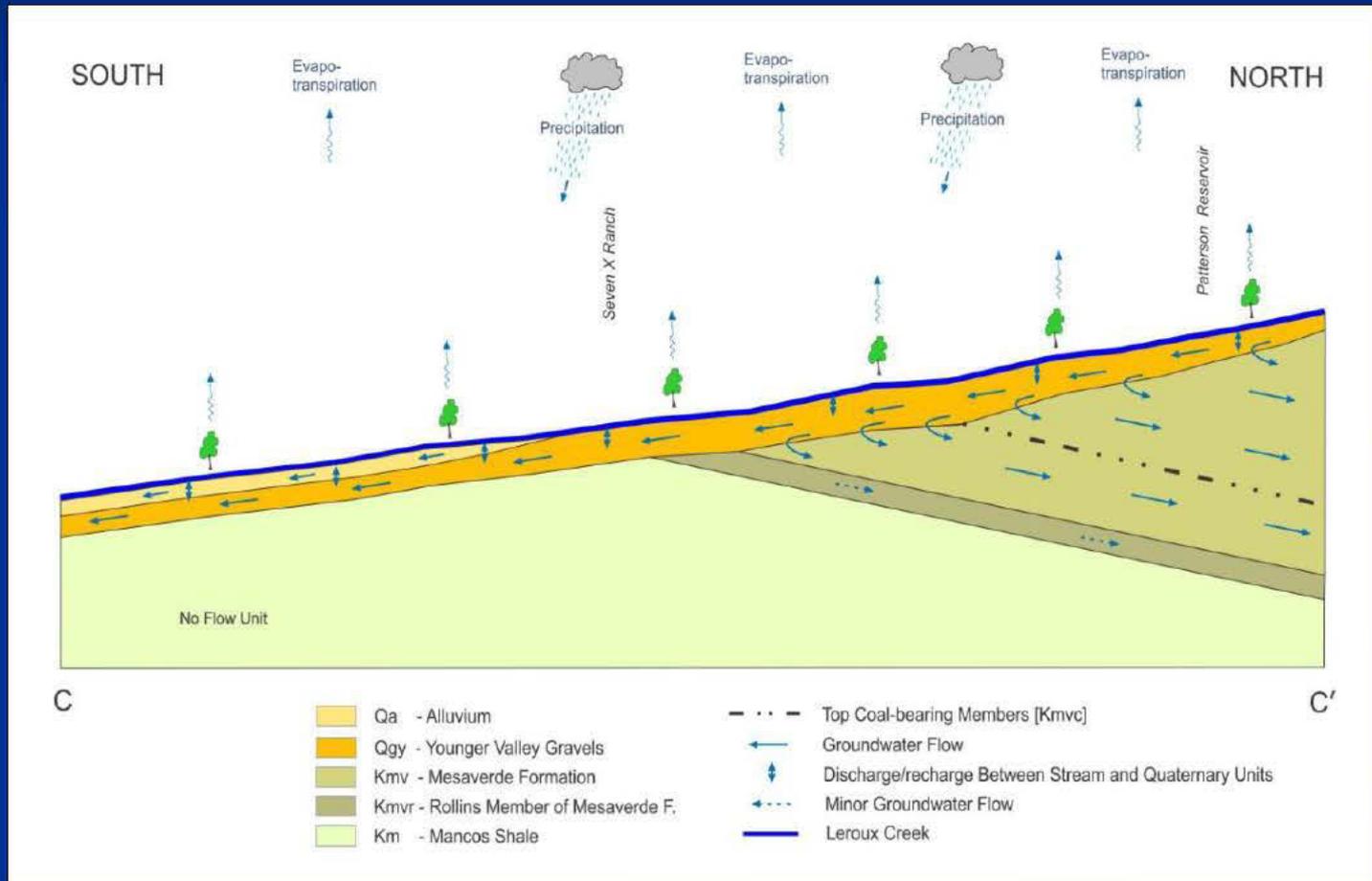
# Hydrogeology of Oak Mesa Area

## Location of Addendum CSM Cross Sections



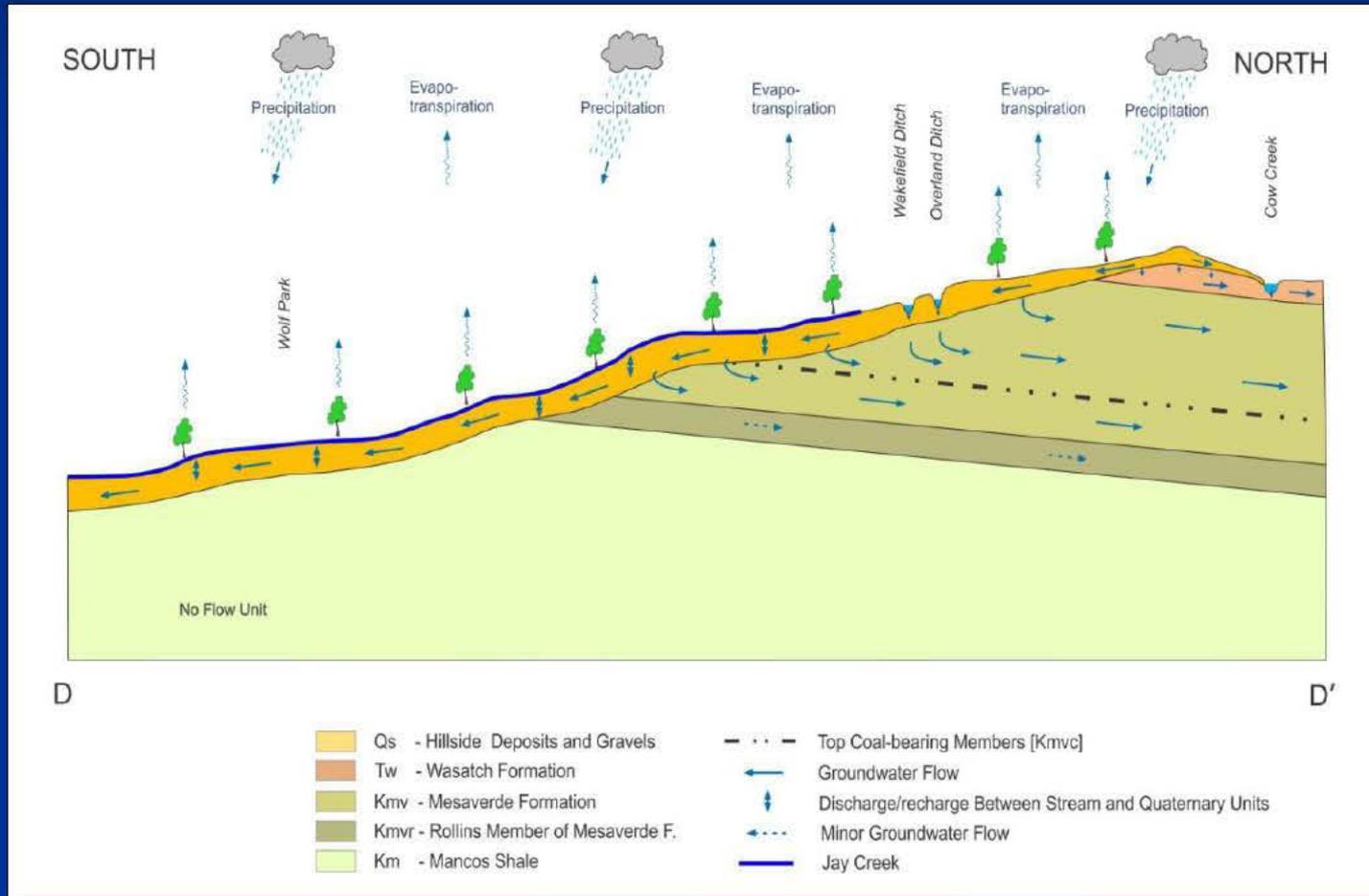
# Groundwater of Leroux Creek Area

## Leroux Creek Aquifer Subsystem – X-section



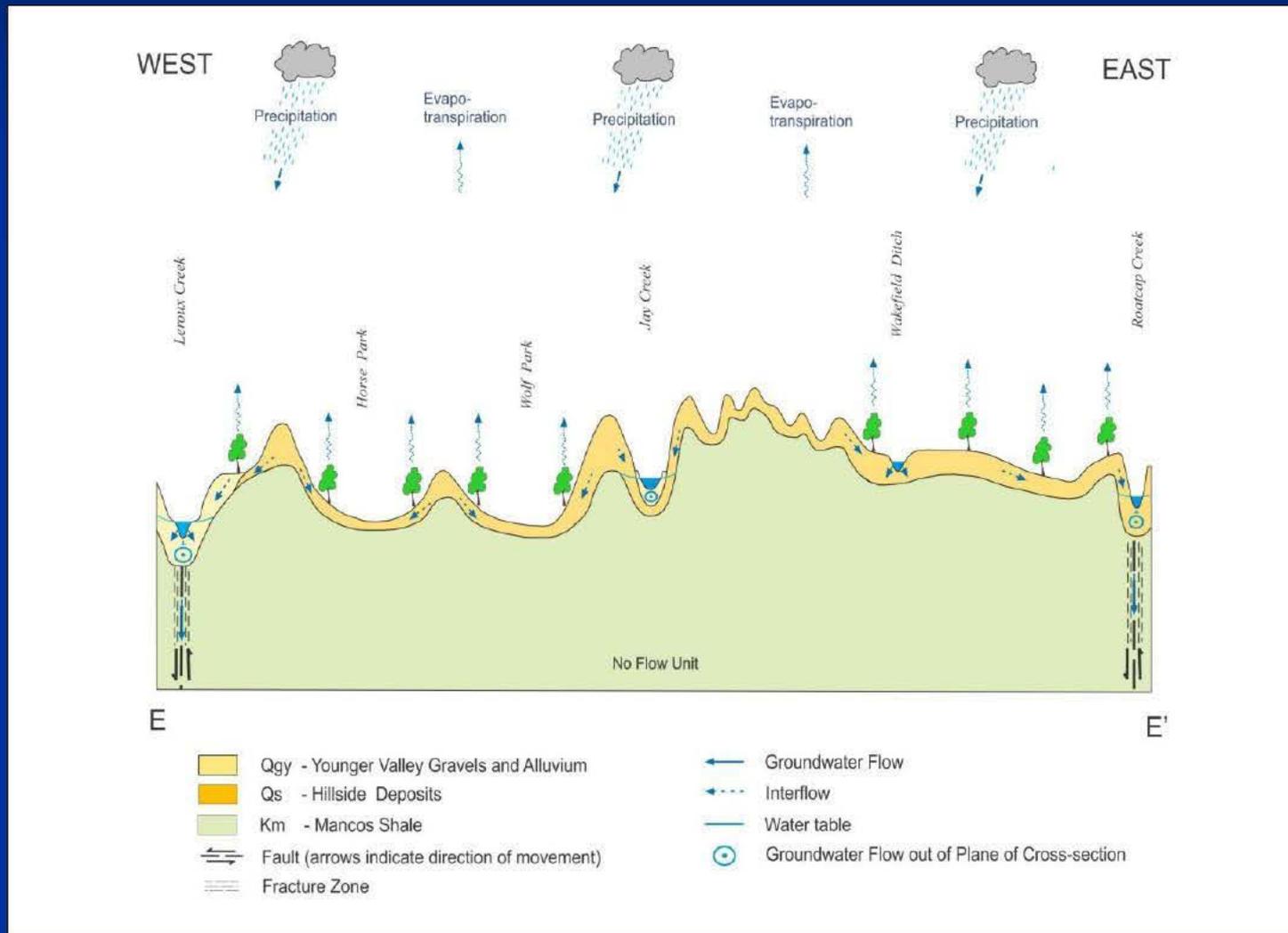
# Groundwater of Jay Creek Area

## Jay Creek Aquifer Subsystem – X-section

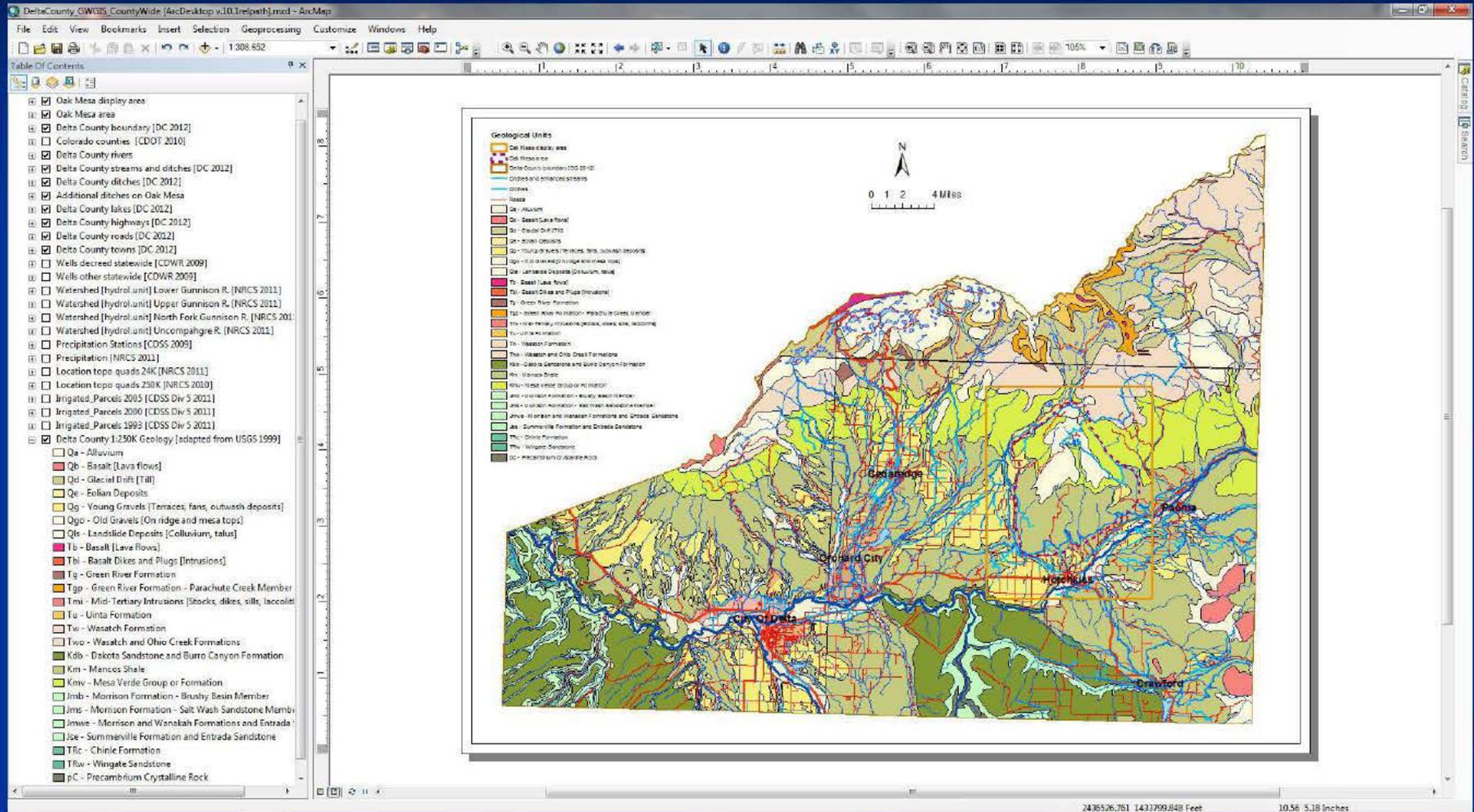


# Groundwater of Southern Oak Mesa

## S. Oak Mesa Aquifer Subsystem – X-section



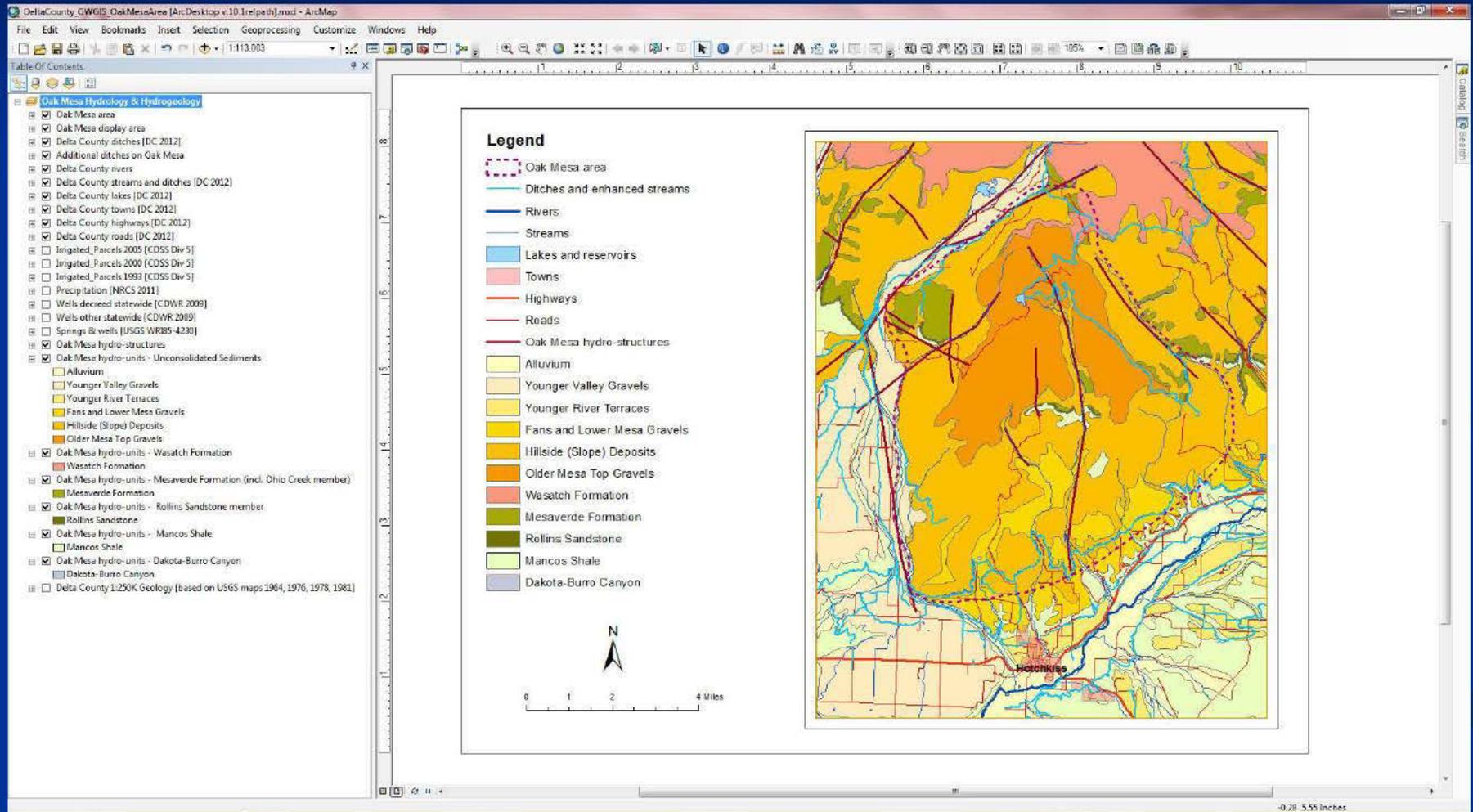
# GIS MAPS: Delta County



2436526.761 1431799.848 Feet

10.58 5.38 Inches

# GIS MAPS: Oak Mesa Area



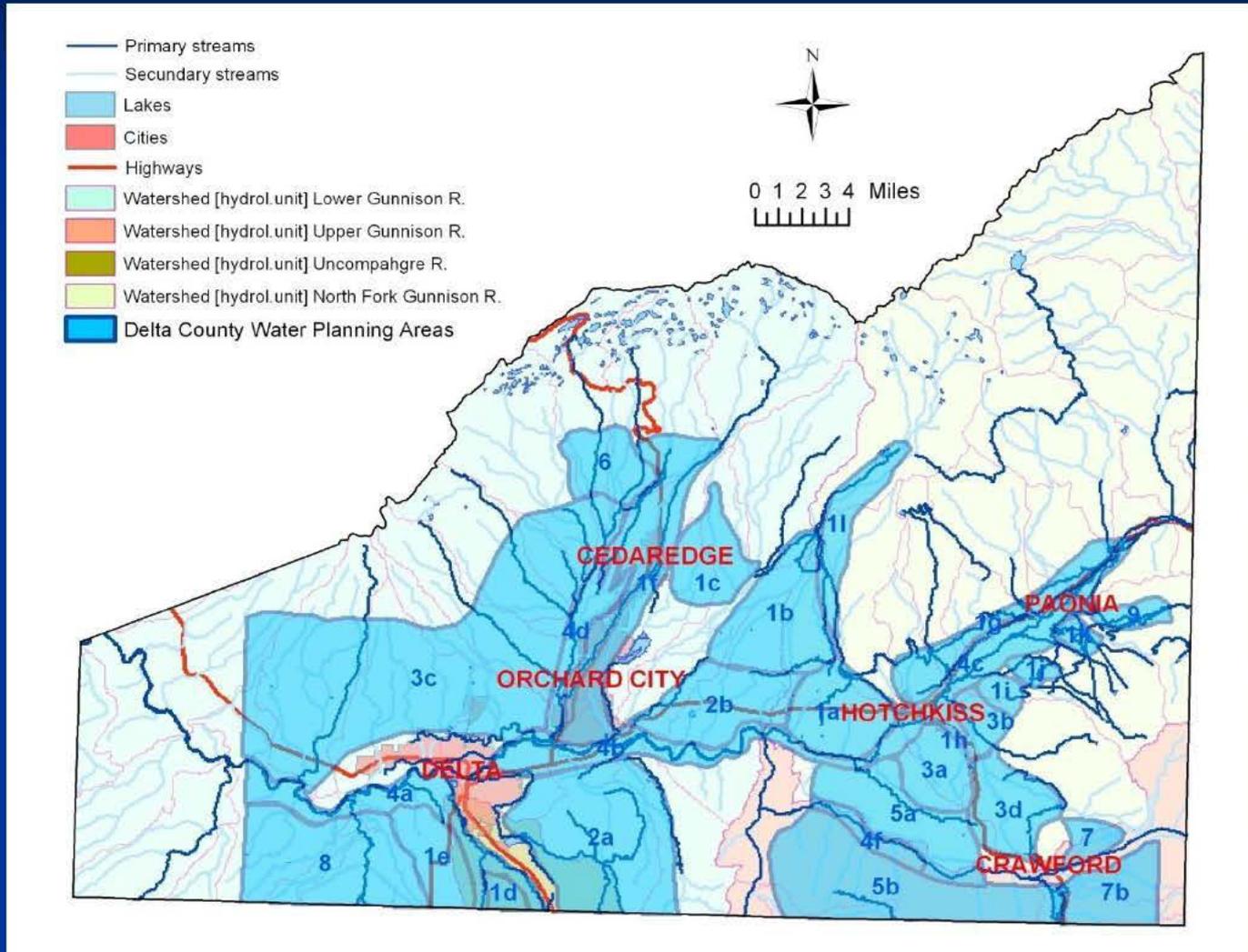
# Phase II Project

- Perform a **HESA** (Hydrologic and Environmental System Analysis) and formulate conceptual models of representative hydrogeologic subsystems of the **North Fork Gunnison River** area
- Develop **GIS maps and data bases** of hydrological and hydrogeological characteristics from existing data for use in the HESA and as a cost-effective planning/management/educational tool

# Why do this?

- Source water assessment and protection (municipal and communal water supply systems)
- Sustainability of water supply sources
- Adequate water quantity and quality to sustain land development
- Effects of coal mining
- Effects of gas and oil exploitation
- ISDS and well setbacks
- Protection of groundwater-fed wetlands.
- Groundwater contribution to in-stream flows and water quality
- Effects of land use changes (agriculture to mining and subdivisions)

# Delta County Water Planning Areas



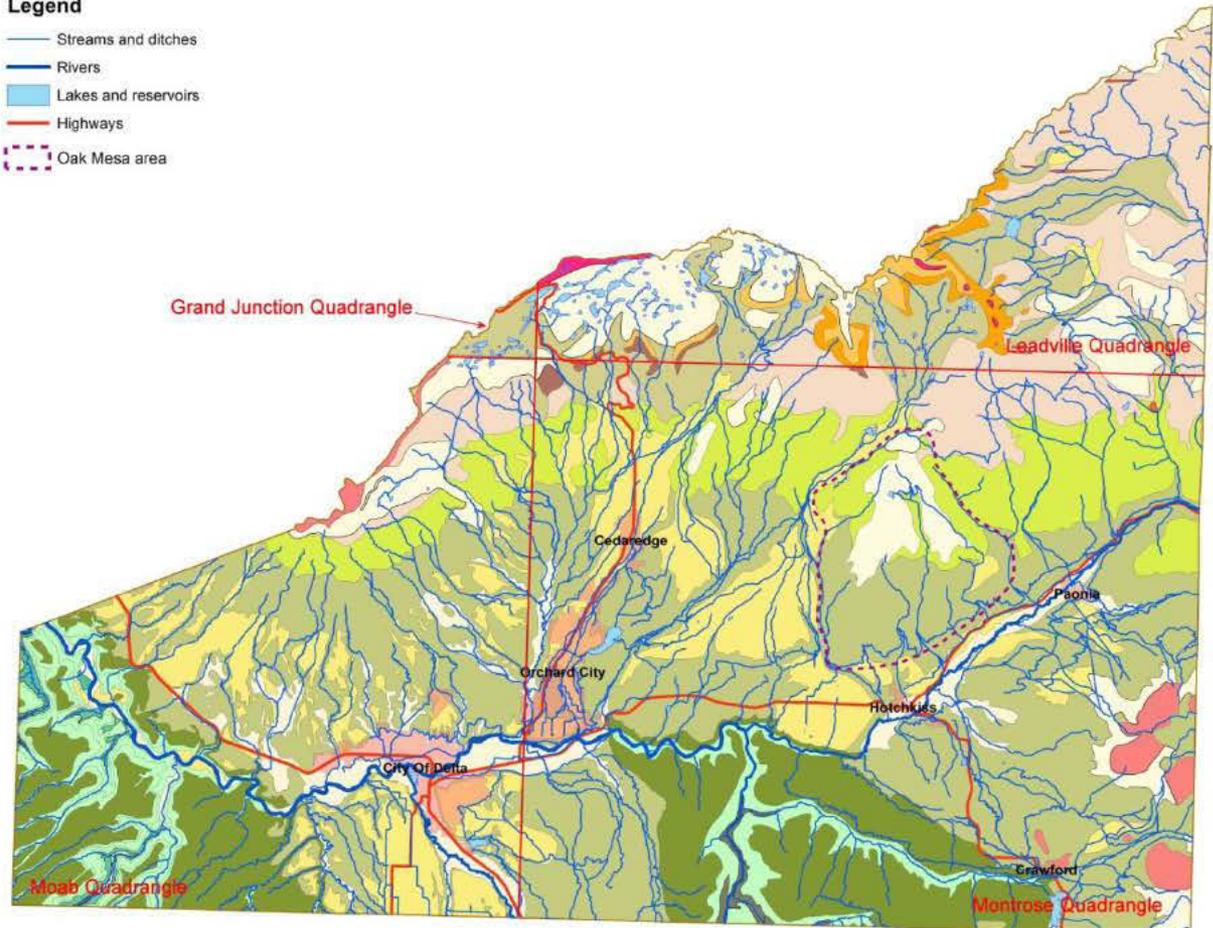
# Geological Map of Delta County

## Geological Units

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- Qb - Basalt [Lava flows]
- Qd - Glacial Drift [Till]
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- pC - Precambrium Crystalline Rock

## Legend

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- Highways
- ⋯ Oak Mesa area

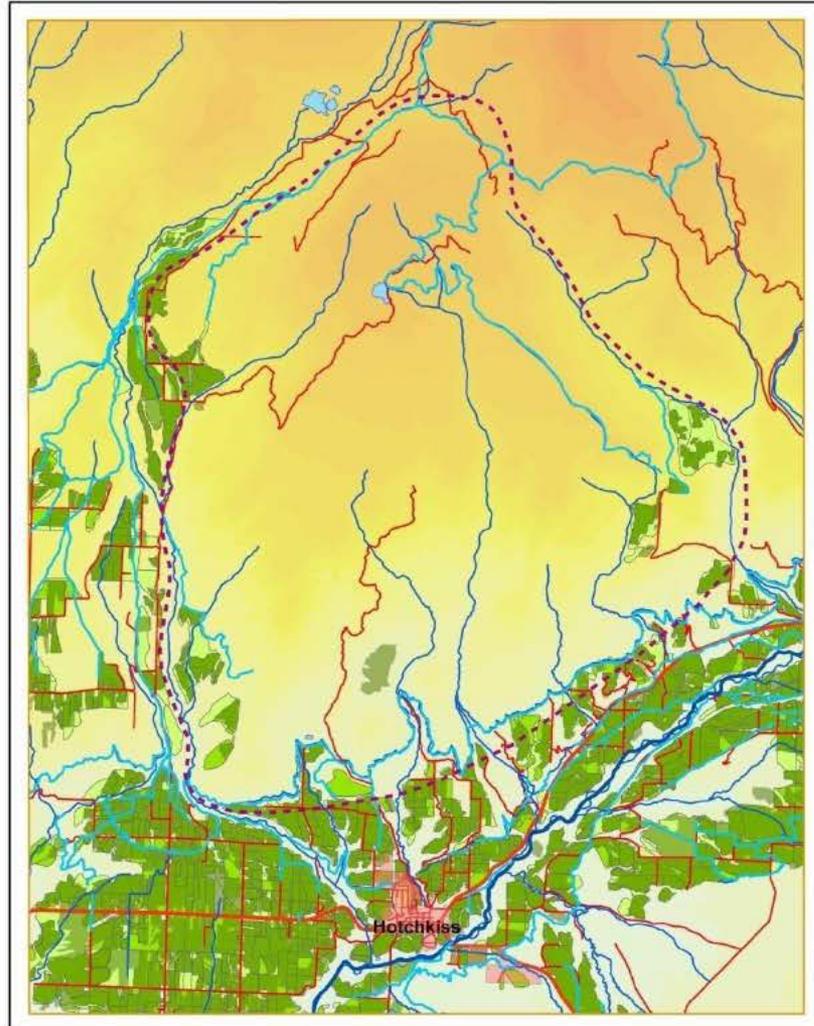
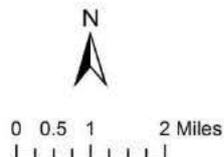


# North Fork Gunnison Area

## Anthropogenic Elements – Irrigation

### Legend

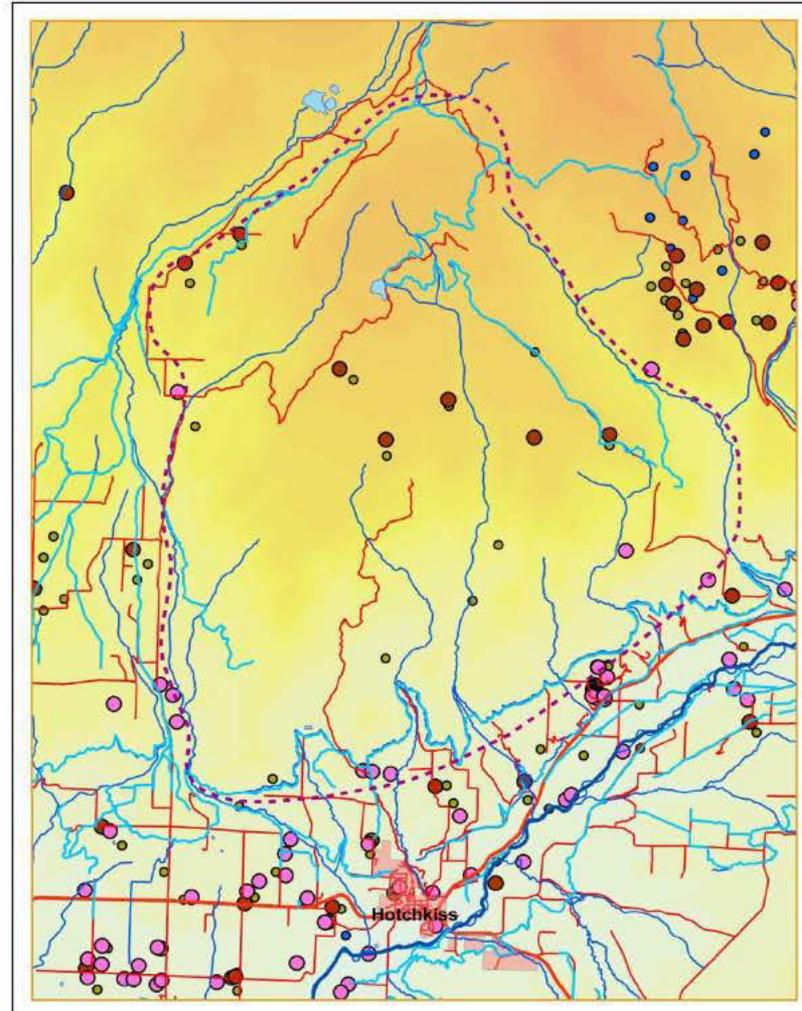
- Oak Mesa area
- Ditches and enhanced streams
- Rivers
- Streams and ditches
- Lakes and reservoirs
- Towns
- Highways
- Roads
- Irrigated\_Parcel 1993 [CDSS Div 5]
- Irrigated\_Parcel 2000 [CDSS Div 5]
- Irrigated\_Parcel 2005 [CDSS Div 5]



# North Fork Gunnison Area Anthropogenic Elements – Wells

## Legend

-  Oak Mesa area
-  Ditches and enhanced streams
-  Rivers
-  Streams and ditches
-  Lakes and reservoirs
-  Towns
-  Highways
-  Roads
-  Wells - decreed [CDWR database 2009]
-  Wells - other [CDWR database 2009]
-  Selected wells [from USGS WRI85-4230]
-  Selected springs [from USGS WRI85-4230]



# North Fork Gunnison Area

## Anthropogenic Elements – Land Use



# Phase II Study Area Location

- Plot current and future areas of the North Fork of the Gunnison River that contain Oil and Gas leases or have other activities of concern.
- Compare the lease areas with surface areas that have unconsolidated hydrogeologic units (Quaternary hydrogeologic units).
- Compare areas having both lease areas and unconsolidated hydrogeologic units in close proximity with sensitive current land use (for example, urban, agriculture, well locations) where conflict may occur.
- Determine planning areas that are critical for Phase II and meet budget constraints.

# Summary

- Combining Hydrologic and Environmental Systems Analysis (HESA) with GIS provides an efficient, low cost approach to study and describe the North Fork Gunnison River study area's hydrogeology and groundwater resources using existing data sources.
- Systematic, step-wise evaluation of groundwater resources, facilitated by the HESA/GIS approach, provides a quick assessment of presence, sustainability, and vulnerability of the North Fork Gunnison River study area's groundwater resources.
- The HESA/GIS methodology provides a solid basis for planning and decision-making regarding local groundwater resources for the North Fork Gunnison River study area.

# QUESTIONS?



# THANK YOU

