

**HESA and GIS-Based  
Groundwater Resources Evaluation  
Delta County, Colorado  
PHASE II: NORTH FORK VALLEY  
AND TERRACES AREA**

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Hydrologic Systems Analysis, LLC**

**and**

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Heath Hydrology, Inc**

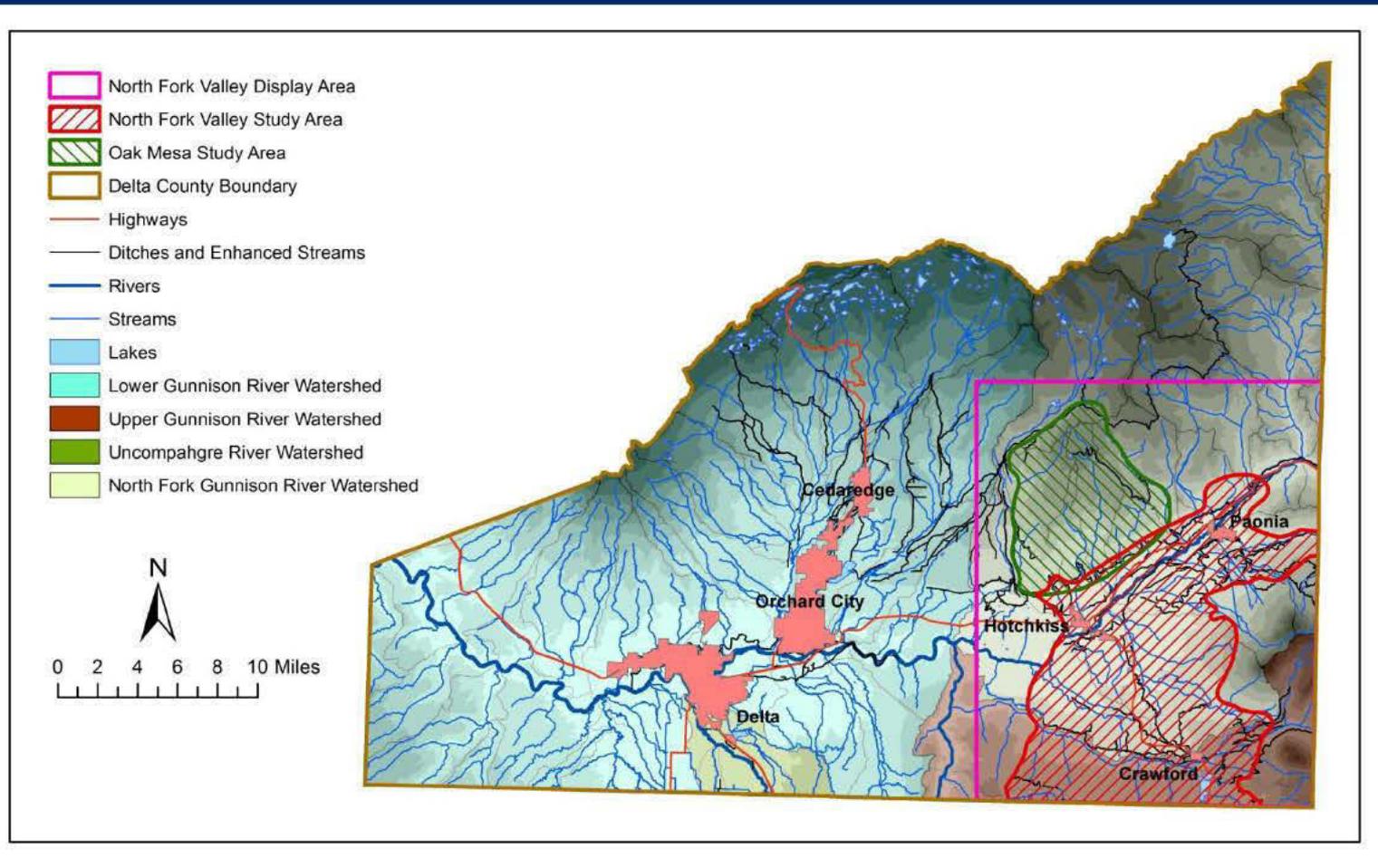
**November 2013**

**HESA and GIS-Based  
Groundwater Resources Evaluation  
Delta County, Colorado**

**Phase 1: Oak Mesa Area**

**Phase 2: North Fork Valley and  
Terraces (NFVT) Area**

# Study Area Location



# 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?

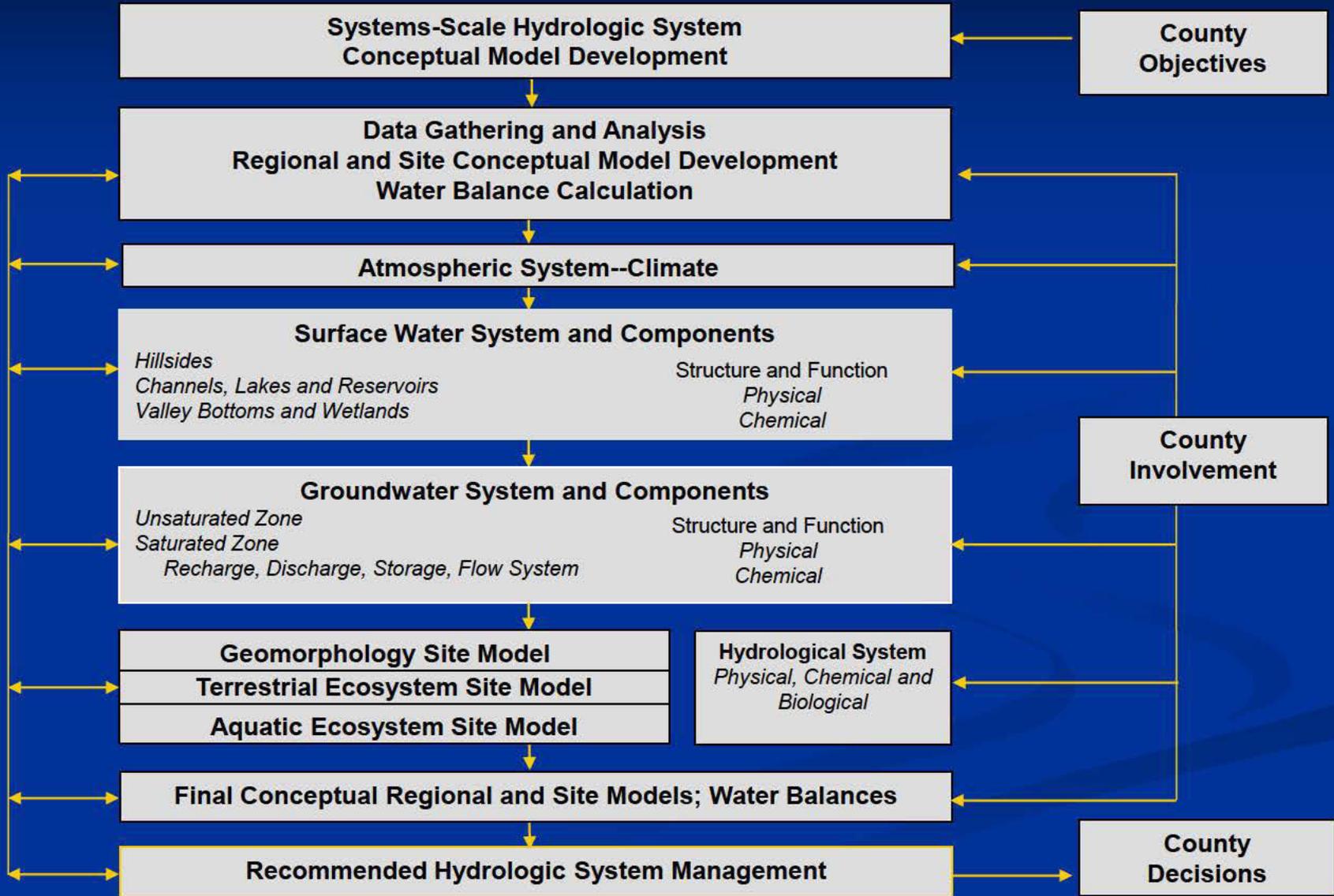
- Source water assessment and protection (municipal and communal water supply systems)
- Sustainability of water supply sources
- Maintaining integrity of agricultural water resources
- Adequate water quantity and quality to sustain land development
- Effects of coal mining
- Effects of gas and oil exploitation
- 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)

# What is HESA?

## Hydrologic and Environmental Systems Analysis

- HESA is an approach used to conceptualize and characterize relevant features of hydrologic and environmental systems, integrating relevant considerations of climate, topography, geomorphology, groundwater and surface water hydrology, geology, ecosystem structure and function, and the human activities associated with these systems into a **holistic, three-dimensional dynamic conceptual site model** (CSM).
- Using HESA, all relevant controlling factors of a particular environment can be identified at the planning/characterization stage, leading to more **focused, cost effective strategies and better decision-making** throughout water resources related management

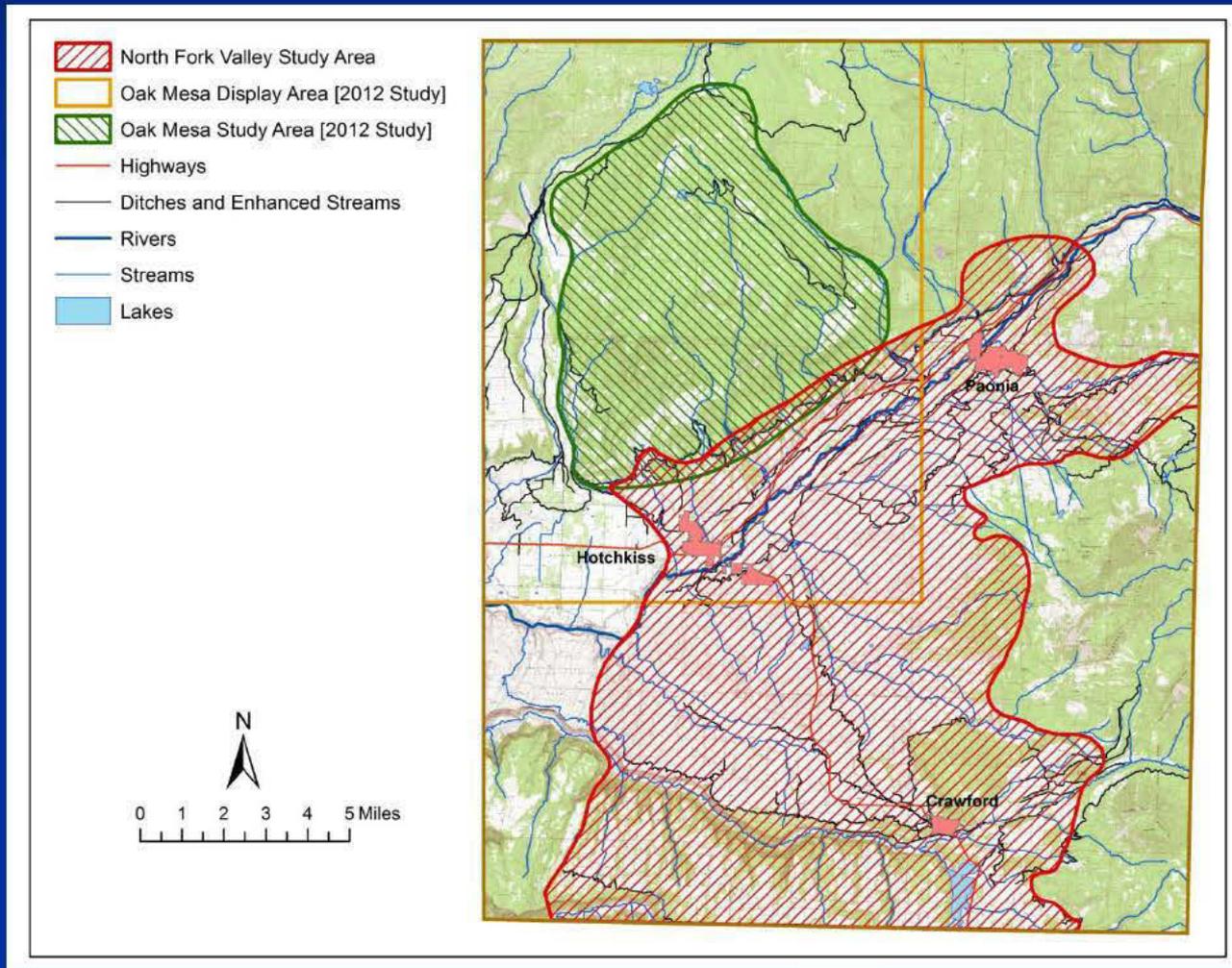
# HESA Flowchart



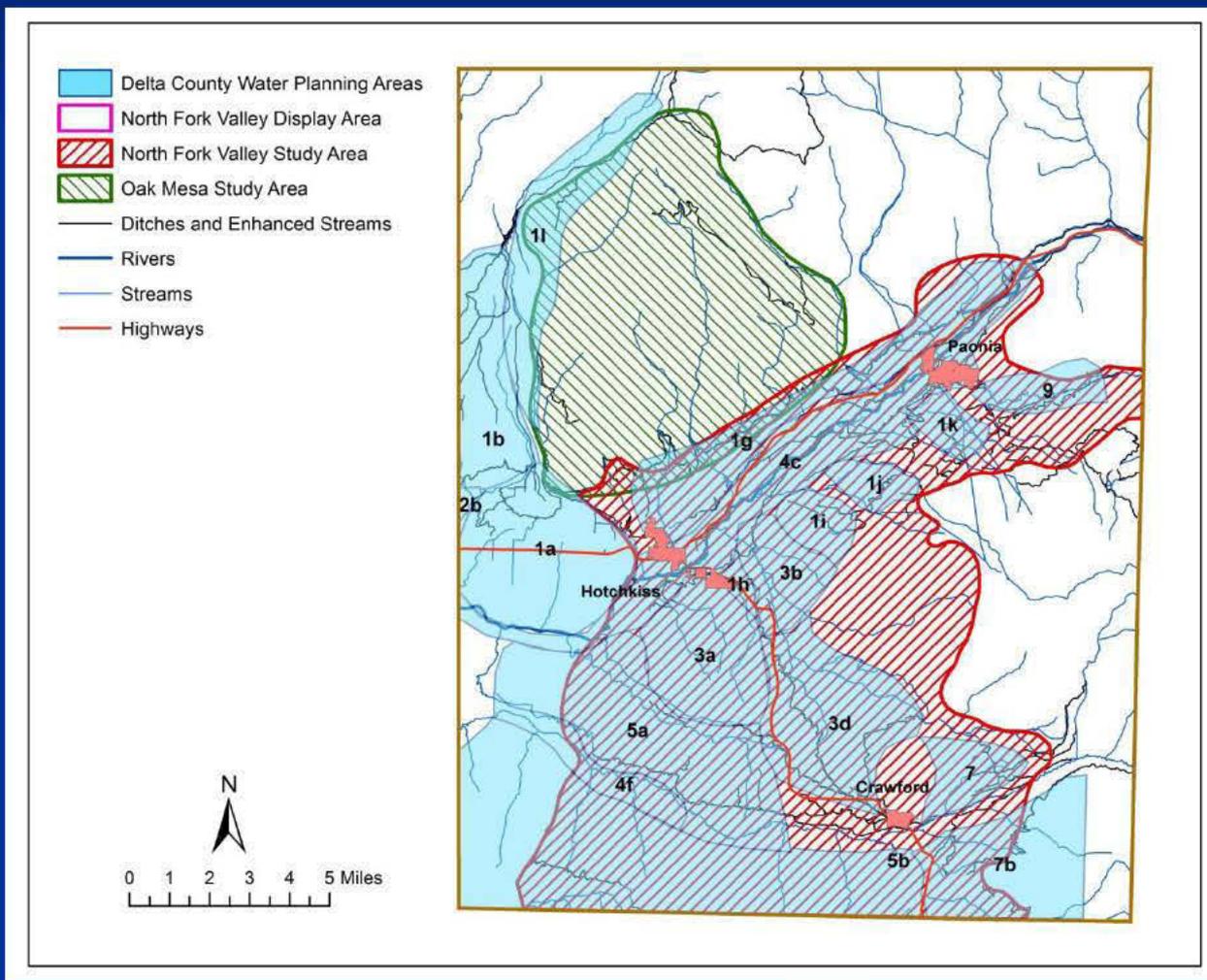
# HESA Elements in NFVT Study

- **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]

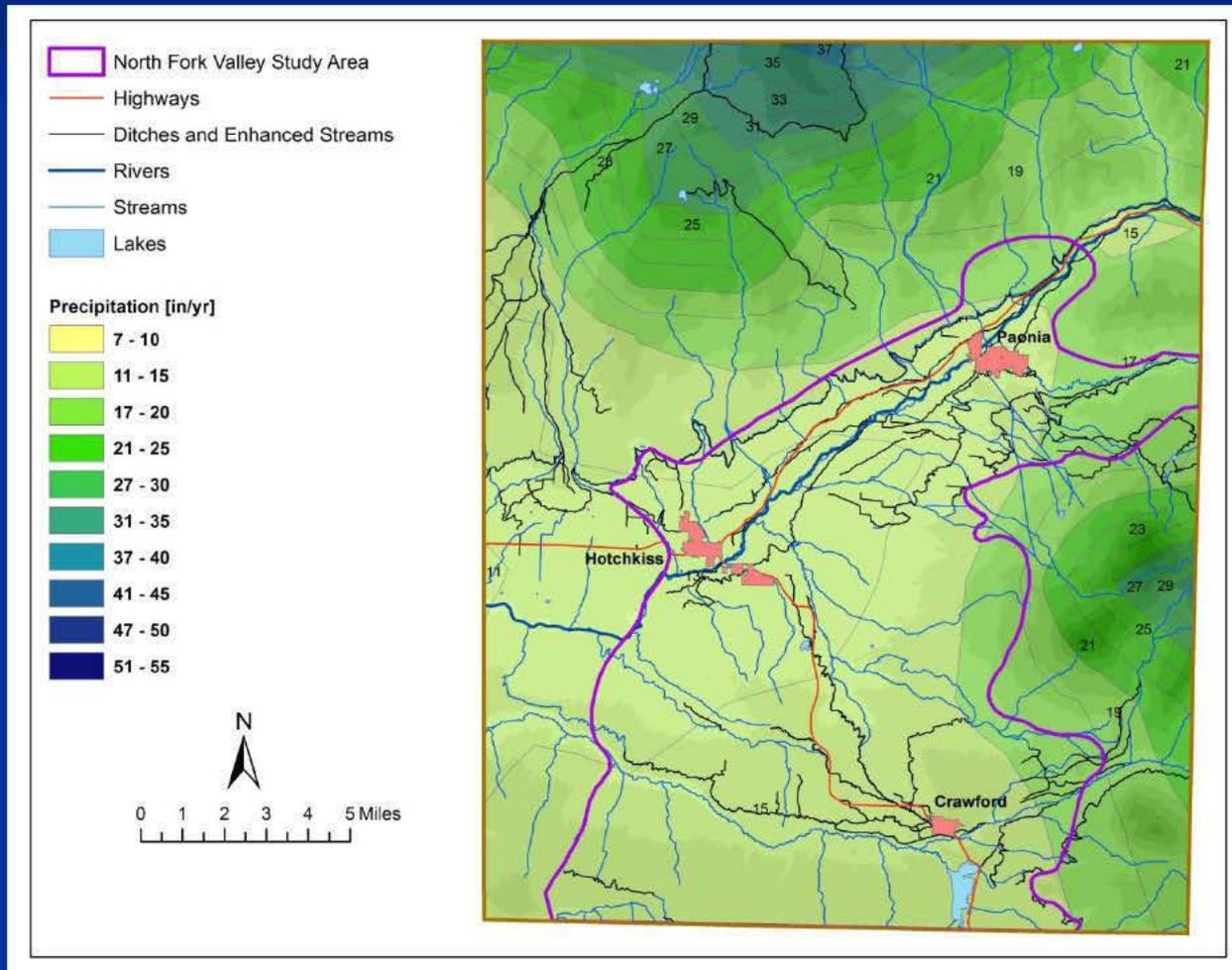
# NFVT and Oak Mesa Study and Display Areas



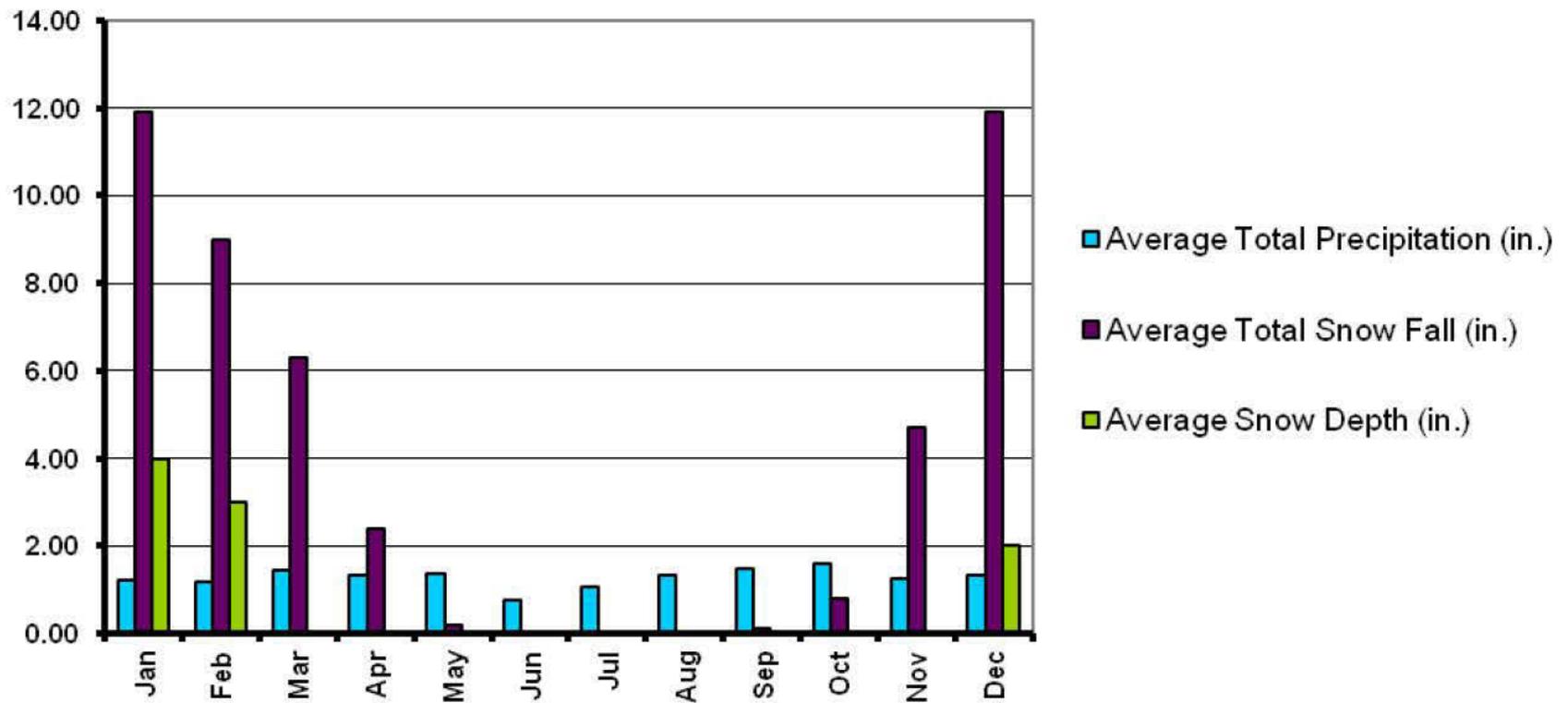
# NFVT Area and Water Planning Areas



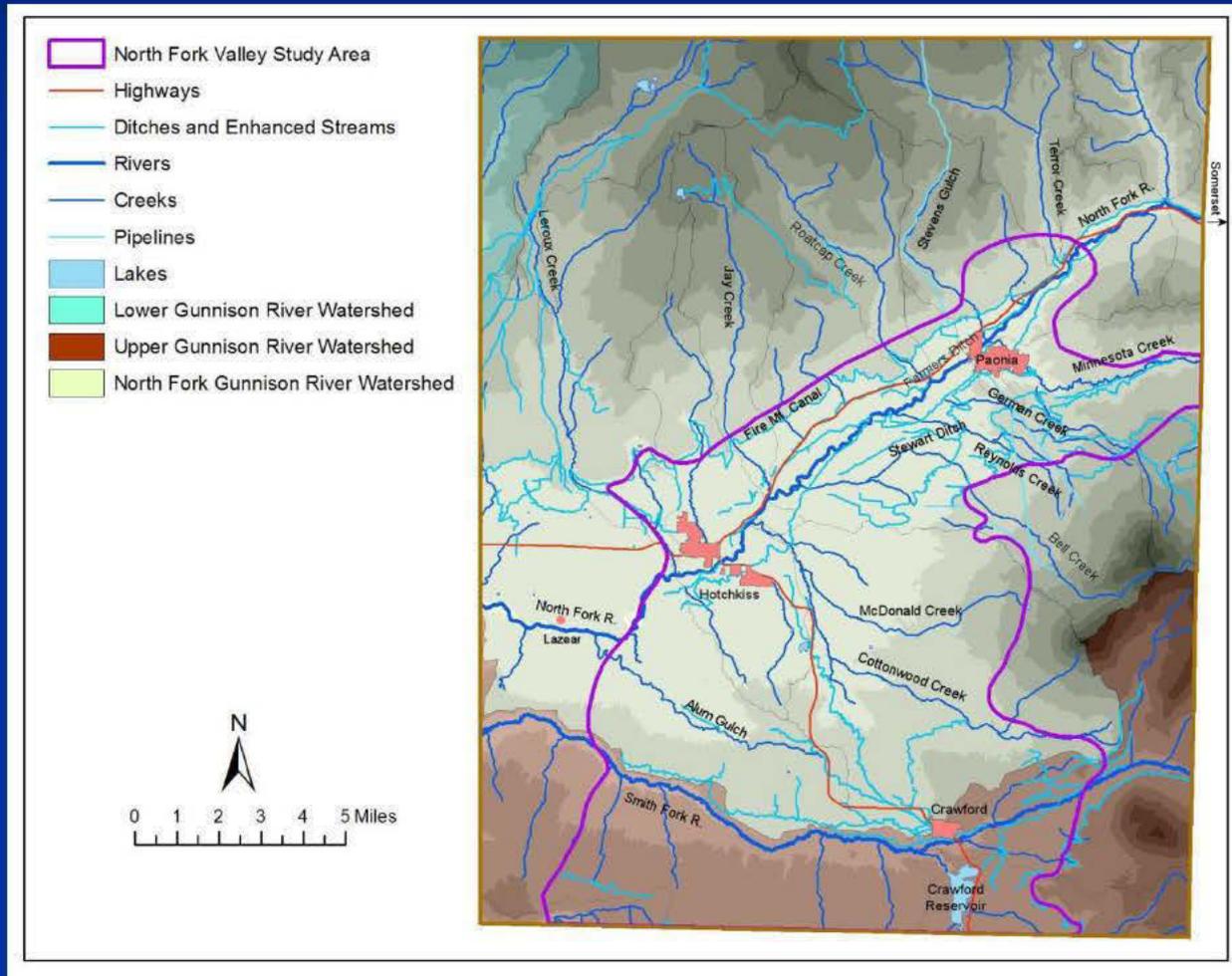
# NFVT Area Precipitation



# Precipitation, Snow Fall and Snow Depth for Paonia Station

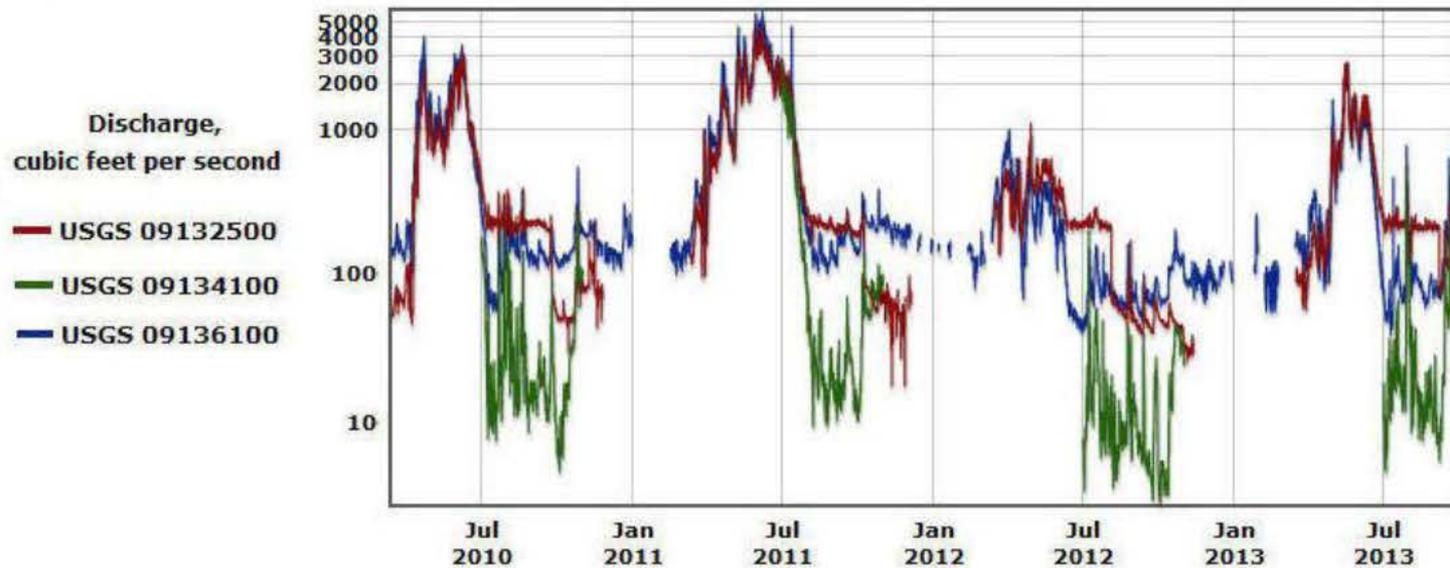


# NFVT Area Surface Water



# North Fork Hydrograph

**USGS 09132500 NORTH FORK GUNNISON RIVER NEAR SOMERSET, CO.**  
**USGS 09134100 NORTH FORK GUNNISON RIVER BELOW PAONIA, CO**  
**USGS 09136100 NORTH FK GUNNISON RIVER ABOVE MOUTH NR LAZEAR, CO**



# 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

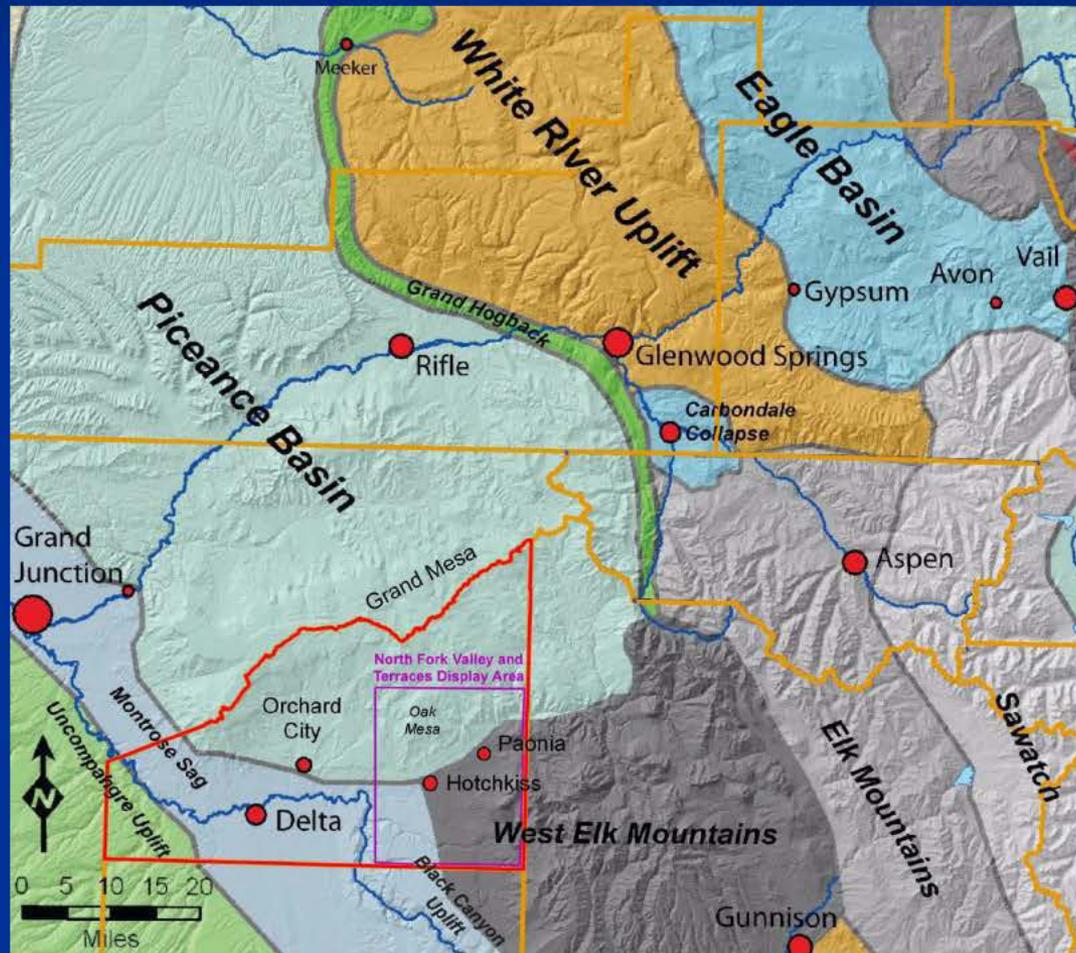
# Correlation of Geological and Hydrogeological Units in Delta County - 2

<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

# Regional Geographic and Geological Features



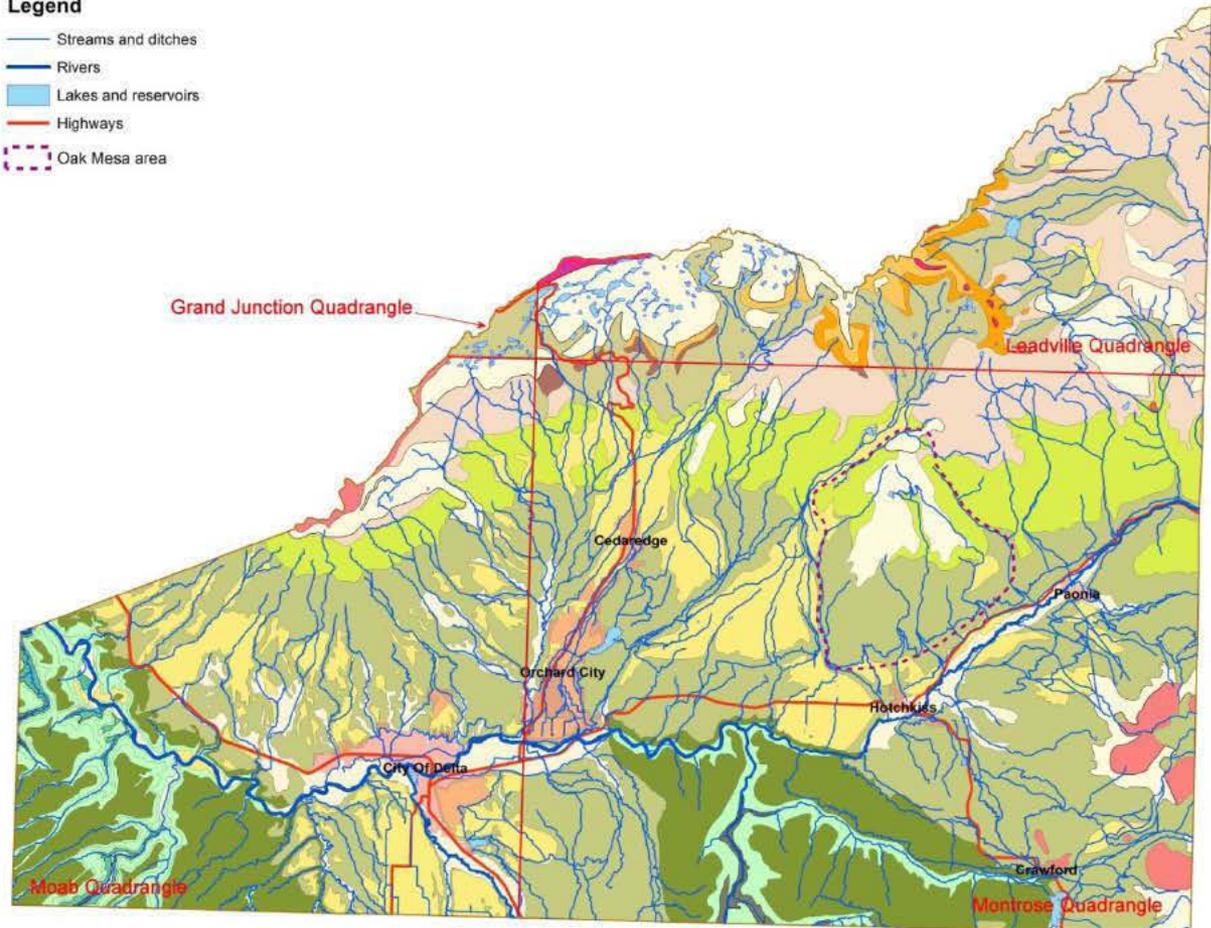
# Geological Map of Delta County

## Geological Units

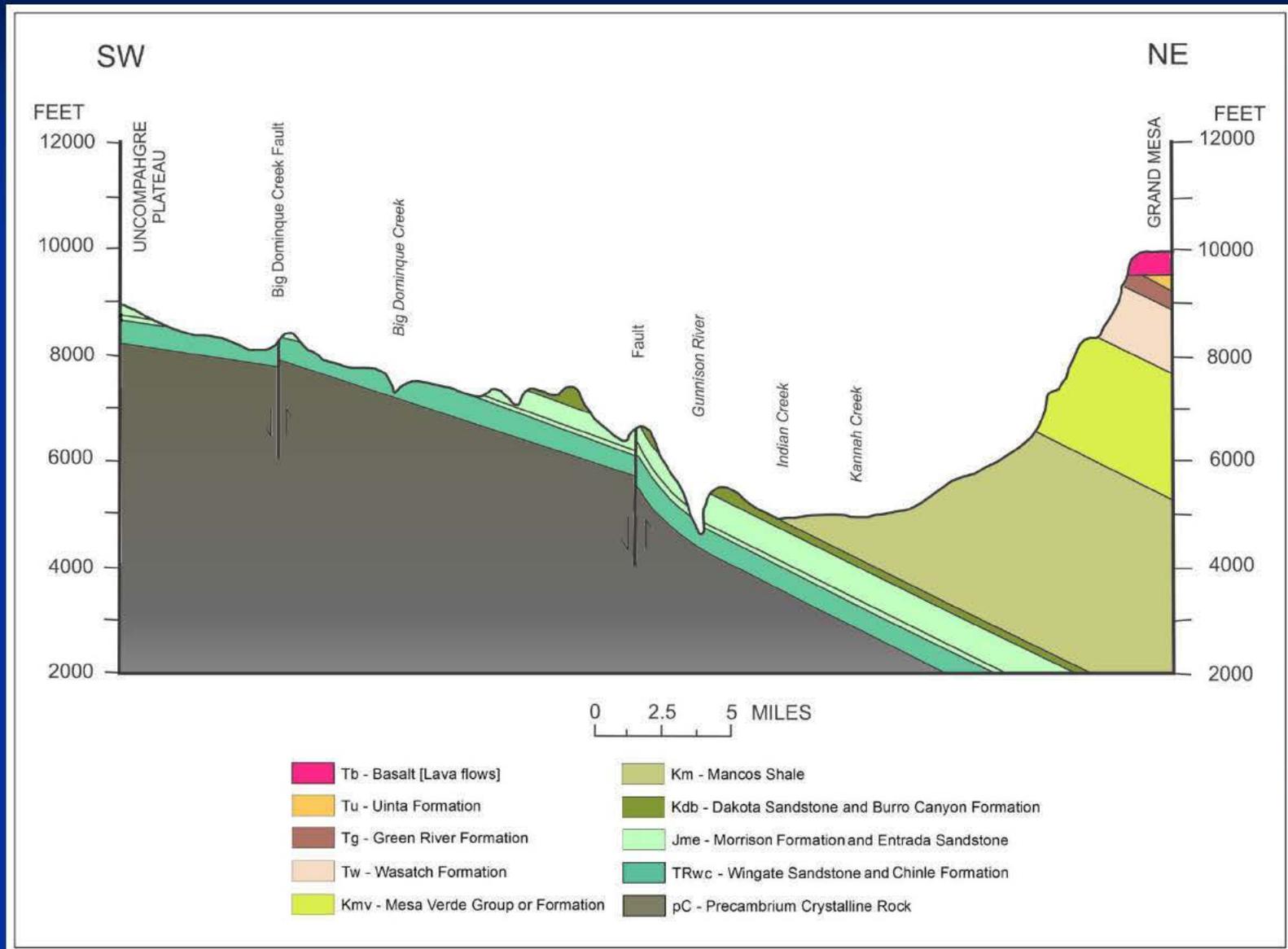
Qa - Alluvium
Qb - Basalt [Lava flows]
Qd - Glacial Drift [Till]
Qe - Eolian Deposits
Qg - Young Gravels [Terraces, fans, outwash deposits]
Qgo - Old Gravels [On ridge and mesa tops]
Qls - Landslide Deposits [Colluvium, talus]
Tb - Basalt [Lava flows]
Tbi - Basalt Dikes and Plugs [Intrusions]
Tg - Green 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



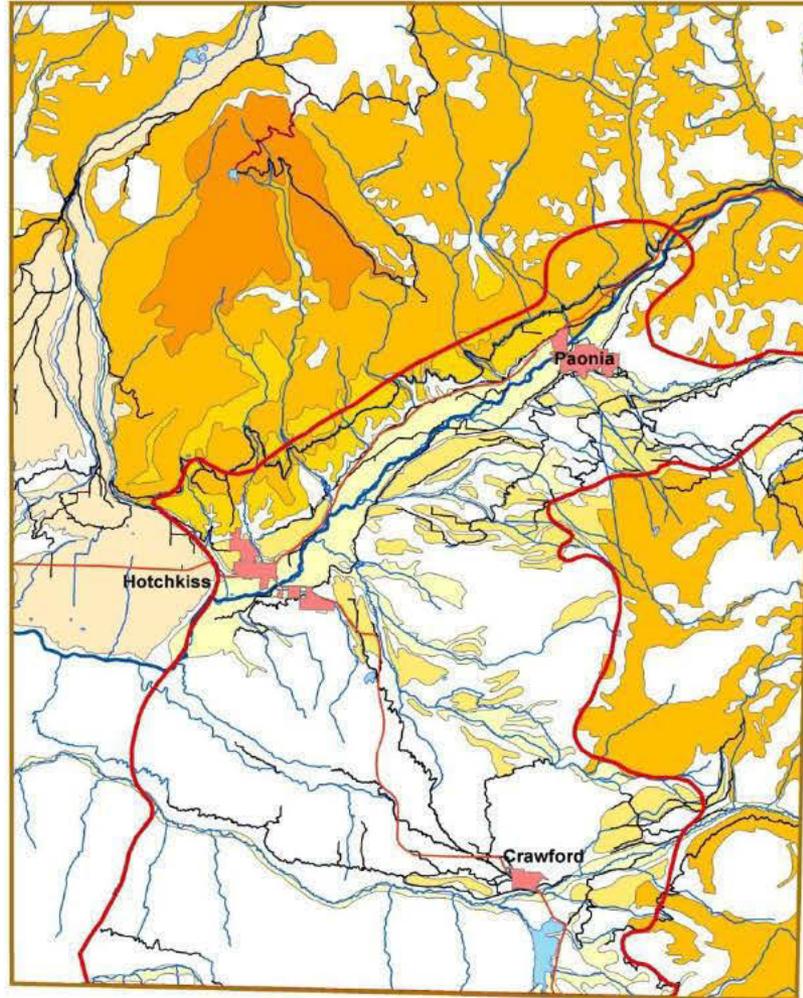
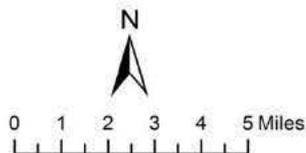
# Hydrogeology of NFVT Area

## Shallow Unconsolidated Units

### Unconsolidated Hydrogeological Units

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

-  North Fork Valley Study Area
-  Highways
-  Ditches and Enhanced Streams
-  Rivers
-  Streams
-  Lakes

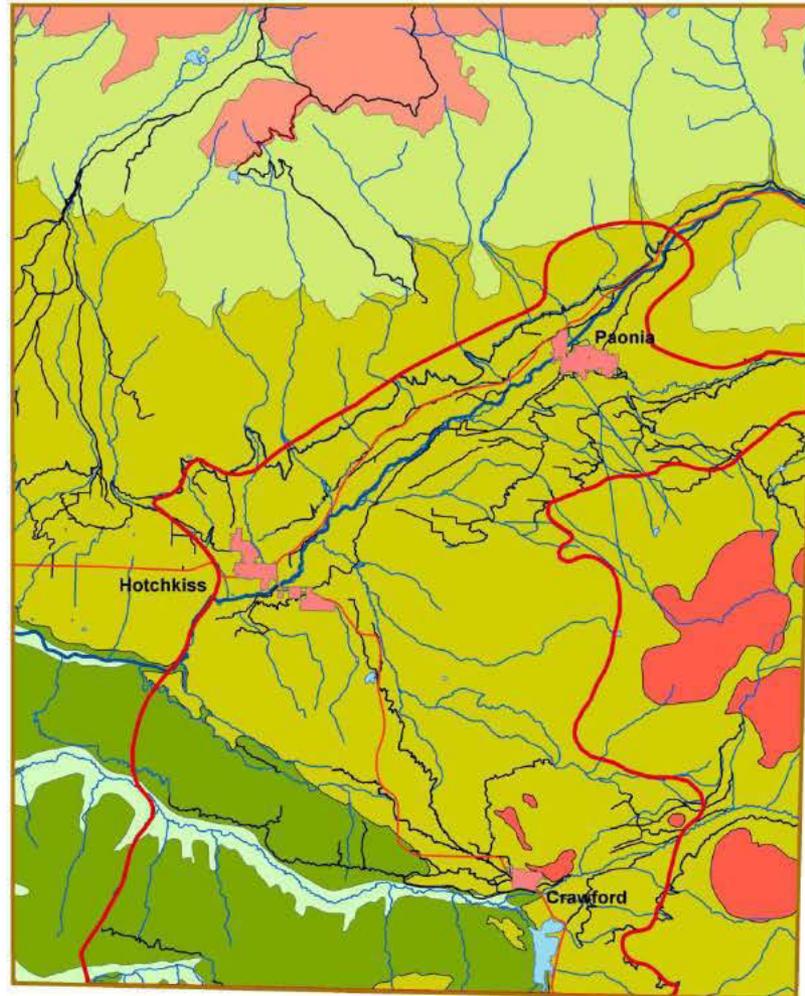


# Hydrogeology of NFVT Area

## Bedrock Units

### Bedrock Hydrogeological Units

-  Tmi - Tertiary Intrusions
  -  Two - Wasatch [incl. Ohio Creek Formation]
  -  Kmv - Mesaverde Formation [incl. Rollins Sandstone]
  -  Km - Mancos Shale
  -  Kdb - Dakota-Burro Canyon Formation
  -  Jmwe - Morrison & Wanakah Formations, Entrada Sandstone
- 
-  North Fork Valley Study
  -  Highways
  -  Ditches and Enhanced Streams
  -  Rivers
  -  Streams
  -  Lakes



# Hydrogeology of NFVT Area

## Hydrostructures

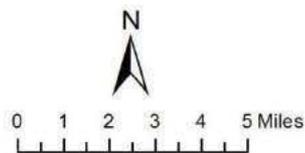
-  North Fork Valley Study Area
-  Highways
-  Ditches and Enhanced Streams
-  Rivers
-  Streams
-  Lakes
-  Hydro-structures

### Unconsolidated Hydrogeological Units

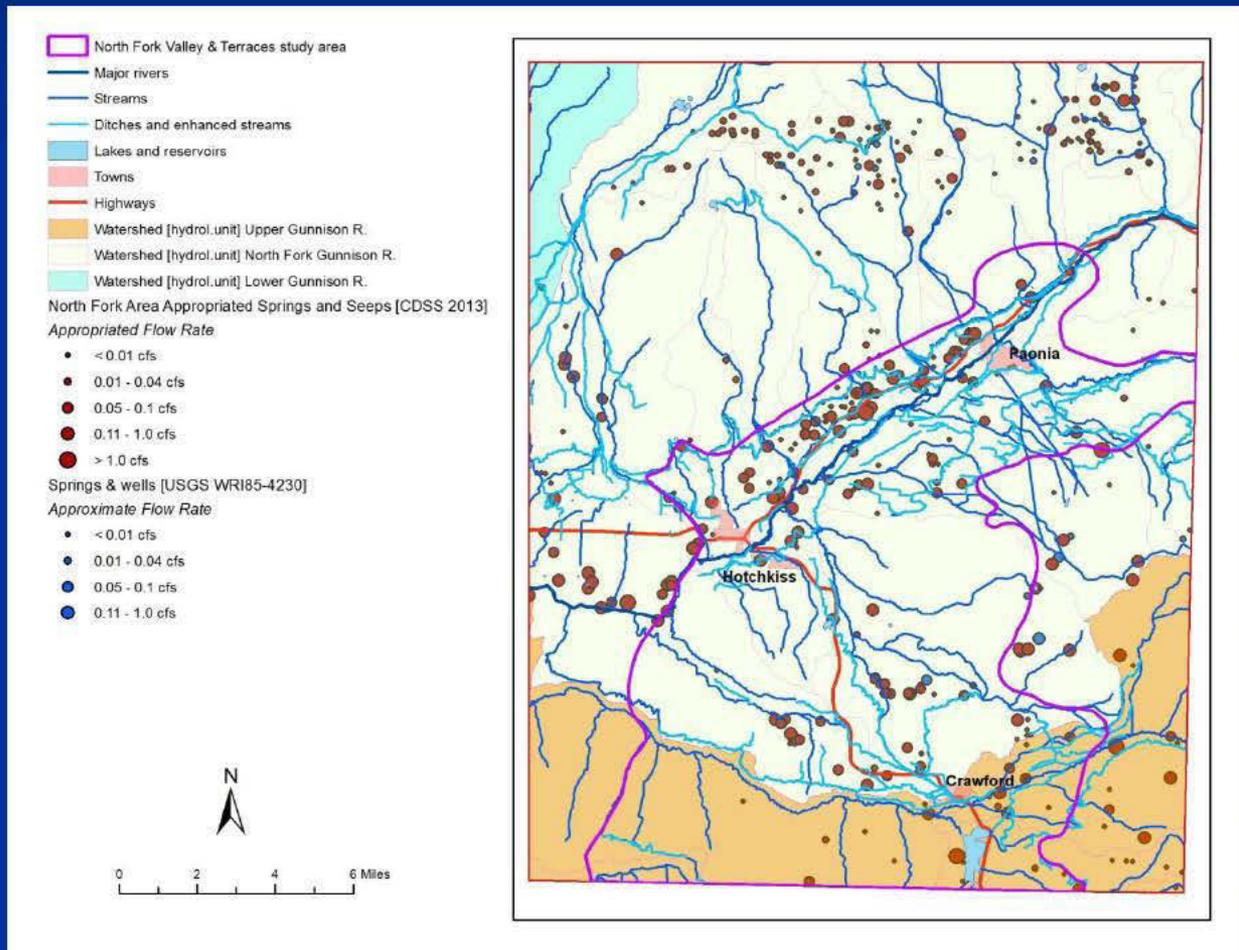
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### Bedrock Hydrogeological Units

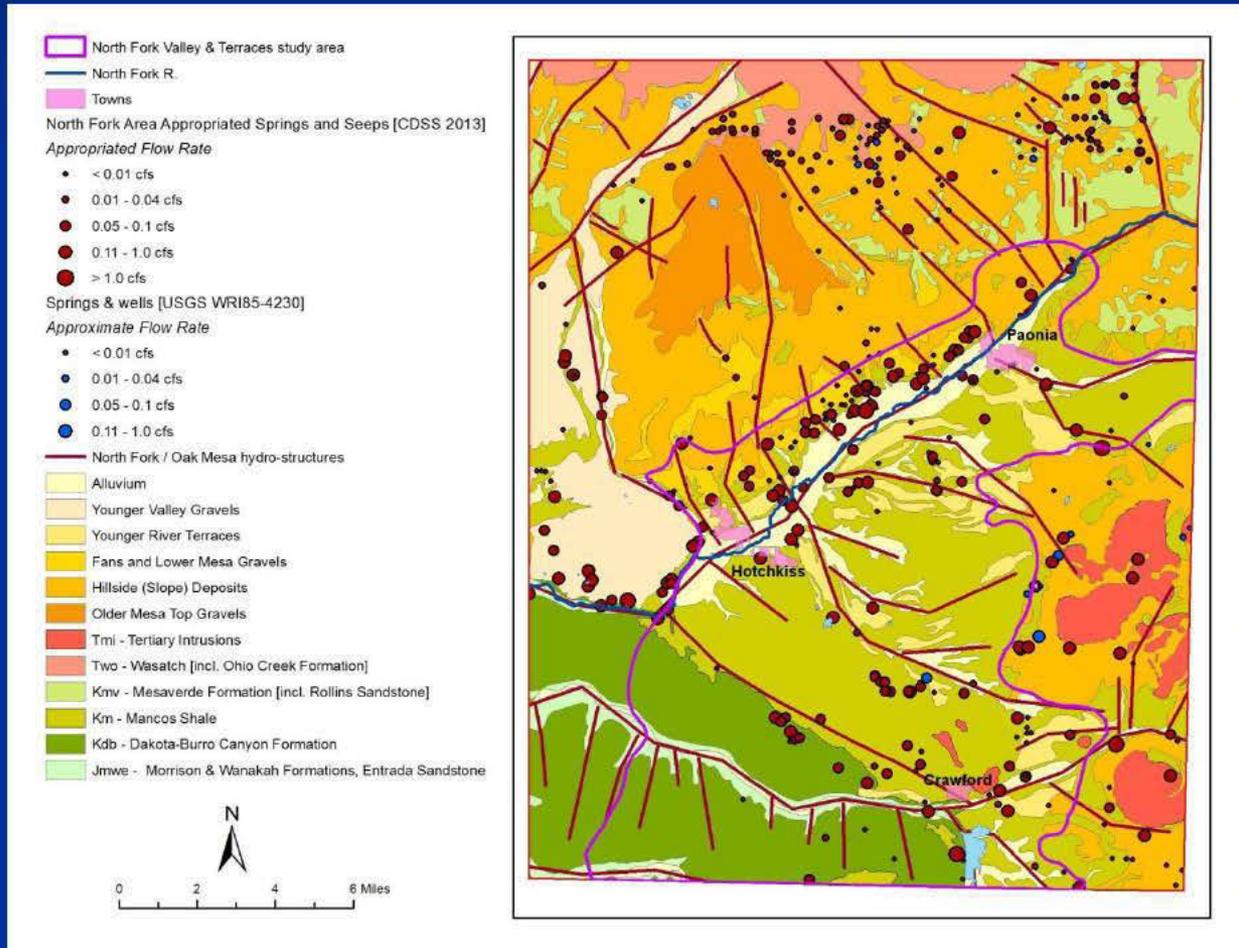
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# NFVT Springs and Seeps 1



# NFVT Springs and Seeps 2



# Hydrogeology of NFVT Area

## Location of CSM Cross Sections

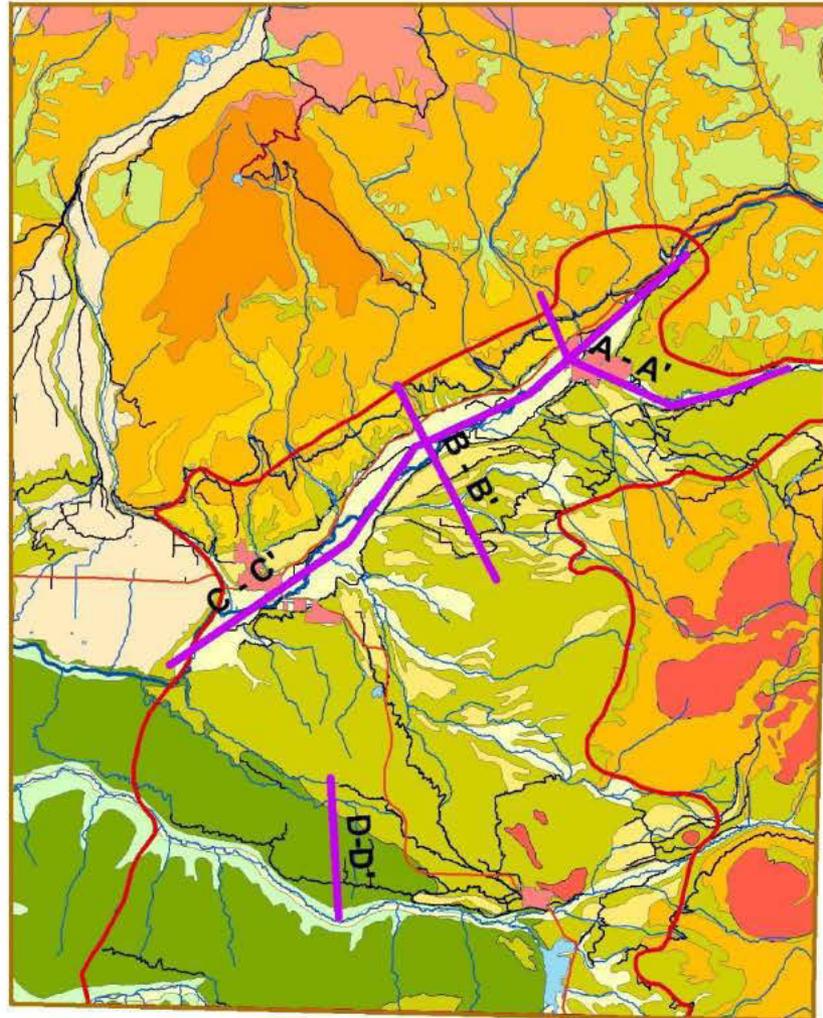
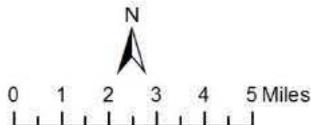
- North Fork Valley Study Area
- Highways
- Ditches and Enhanced Streams
- Rivers
- Streams
- Lakes
- North Fork Terraces and Valley Profiles

### Unconsolidated Hydrogeological Units

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- Qgo - Older Mesa Top Gravels

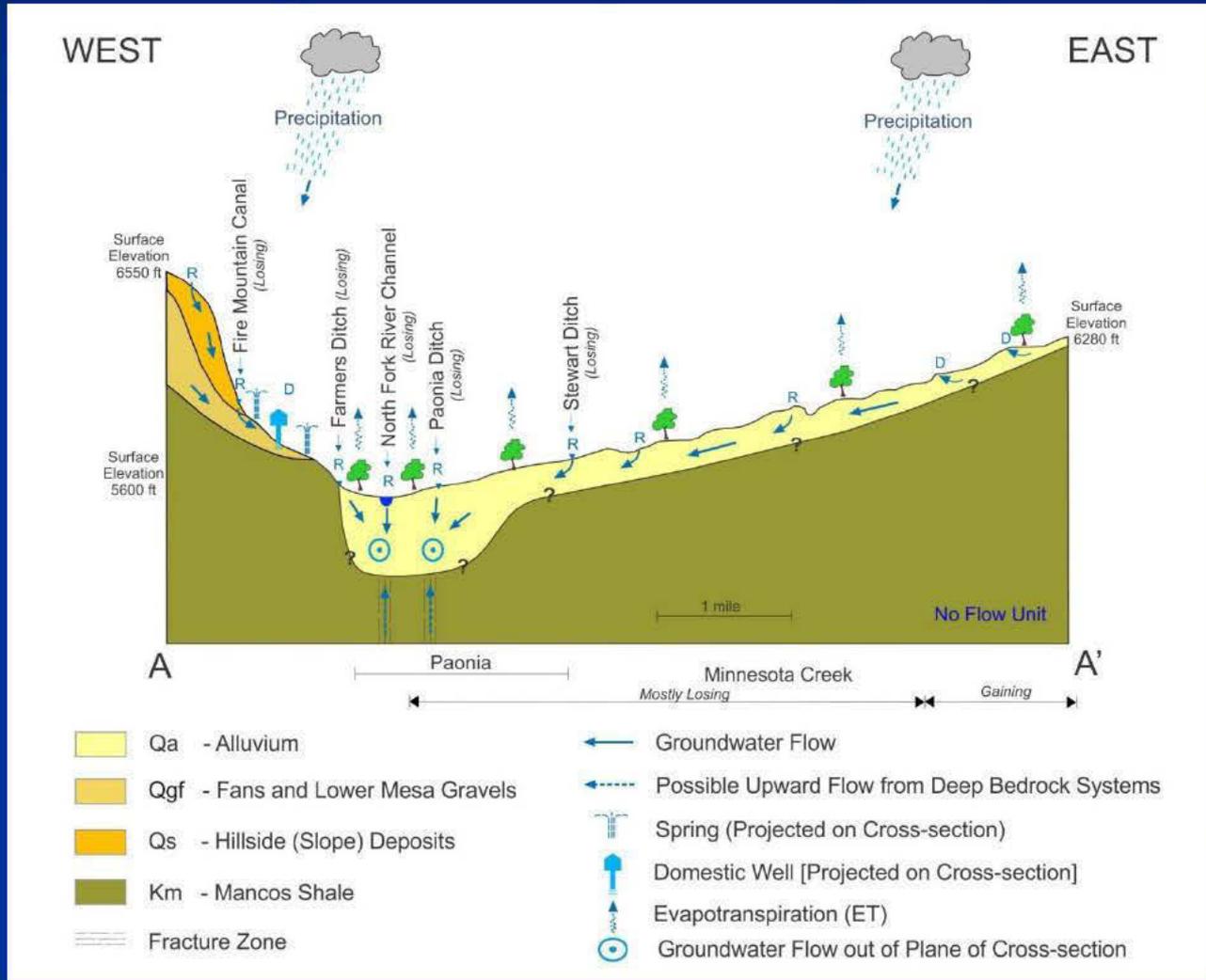
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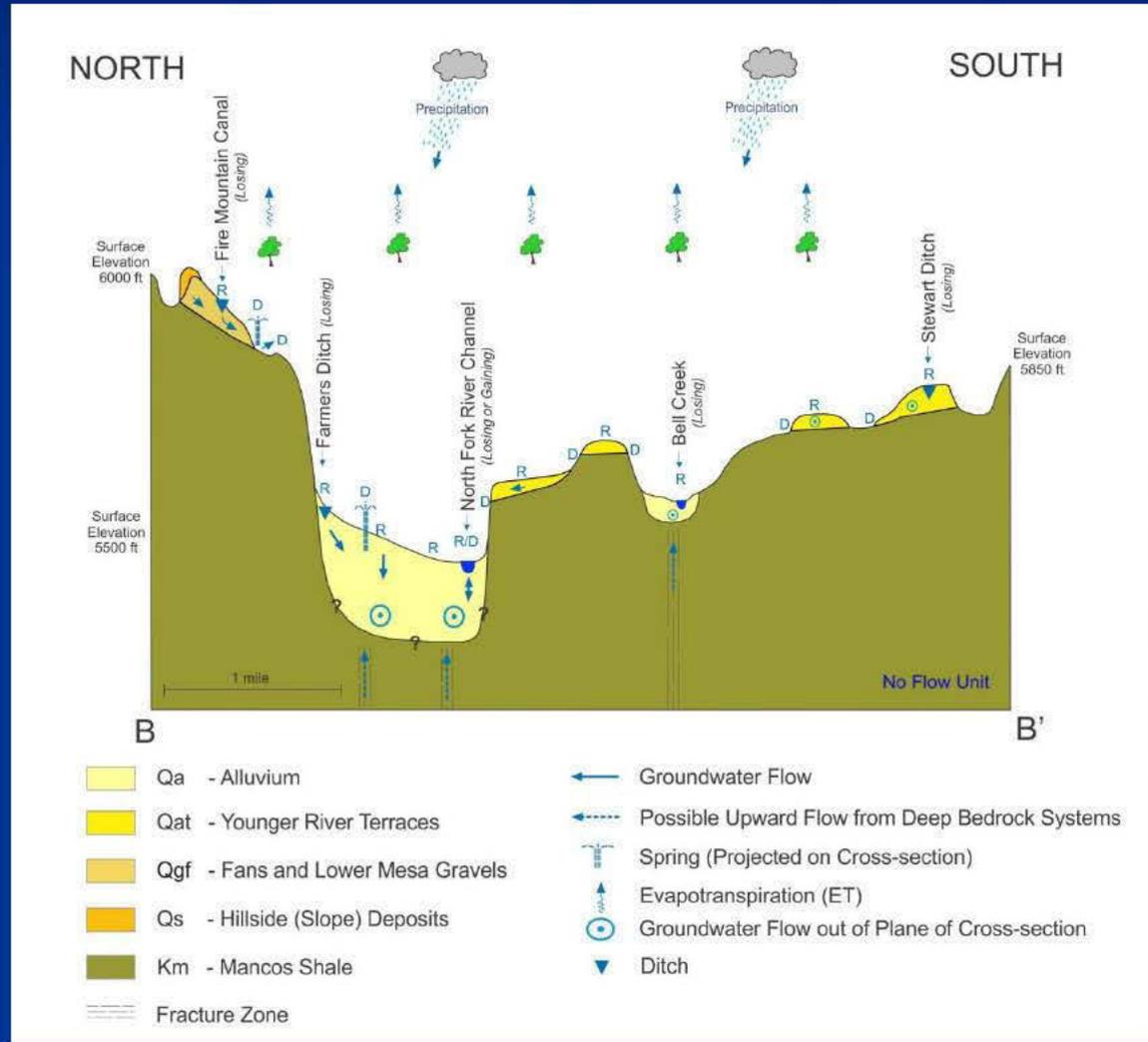
# Hydrogeology of NFVT Area

## Mesa Top and Hillslope, and Valley Bottom Shallow Aquifer Subsystems (A-A')



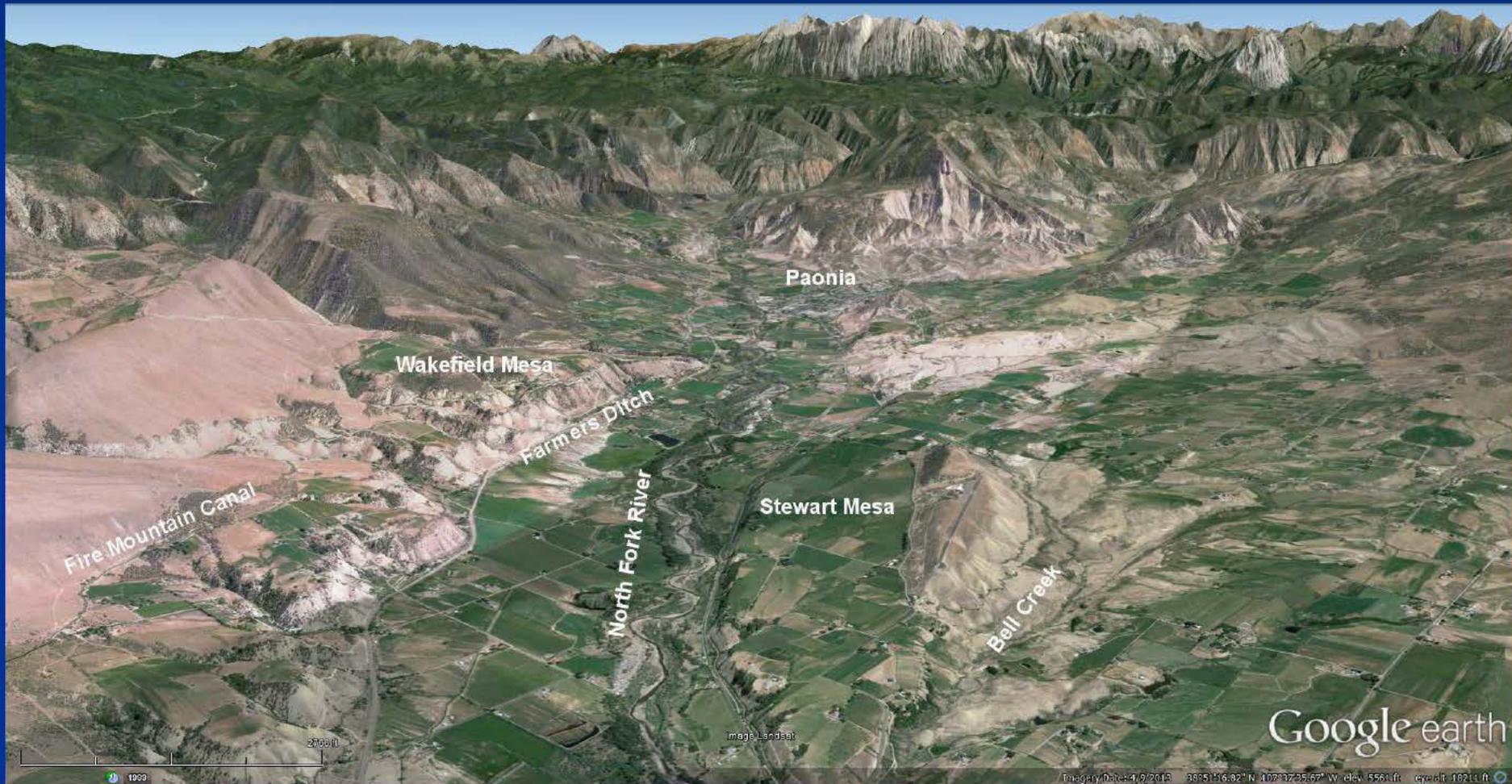
# Hydrogeology of NFVT Area

## Mesa Top and Hillslope, and Valley Bottom Shallow Aquifer Subsystems (B-B')



# Hydrogeology of NFVT Area

## Mesa Top and Hillslope, and Valley Bottom Shallow Aquifer Subsystems



# Hydrogeology of NFVT Area

## Mesa Top and Hillslope, and Valley Bottom Shallow Aquifer Subsystems



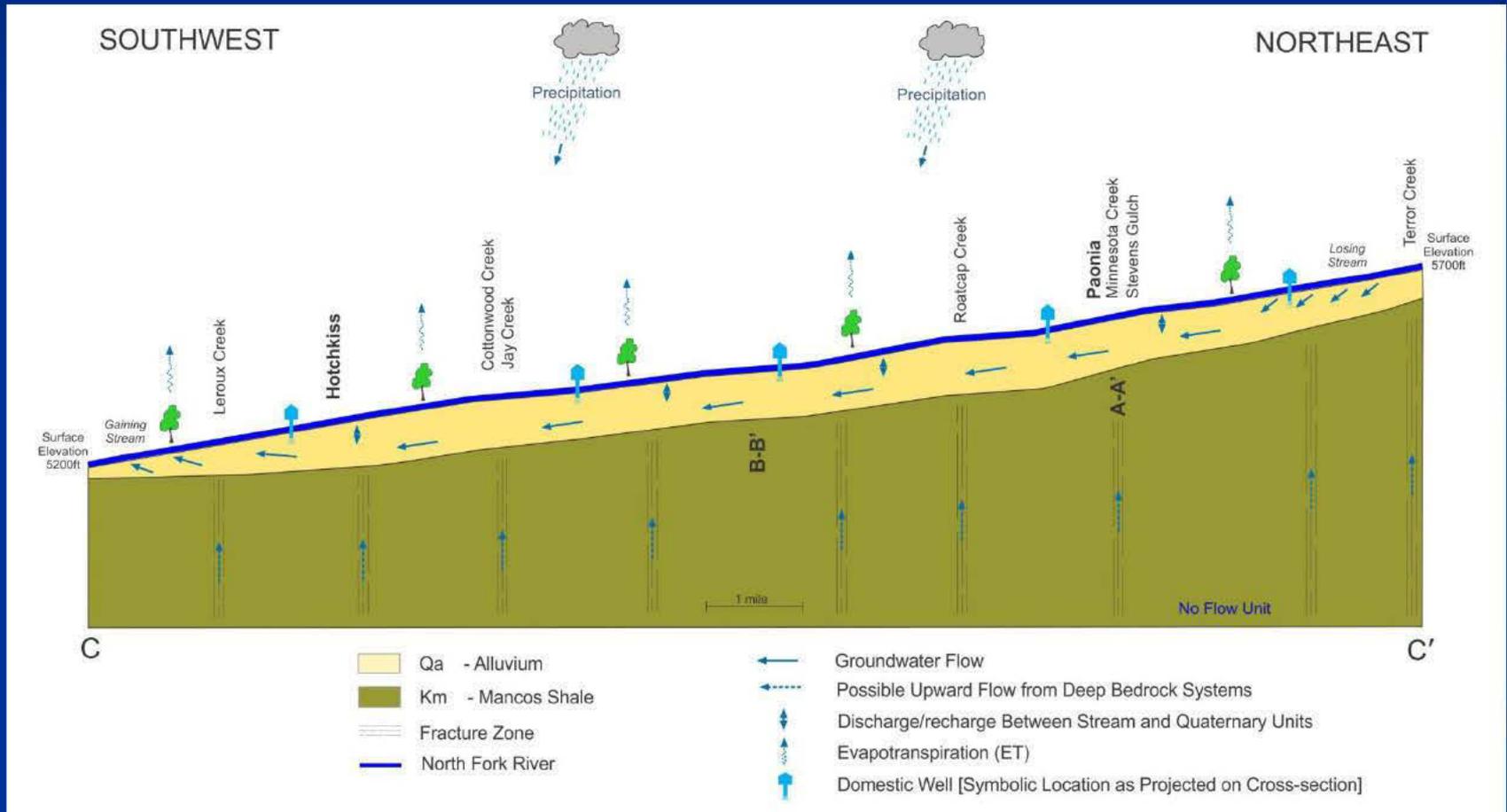
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## Mesa Top and Hillslope, and Valley Bottom Shallow Aquifer Subsystems



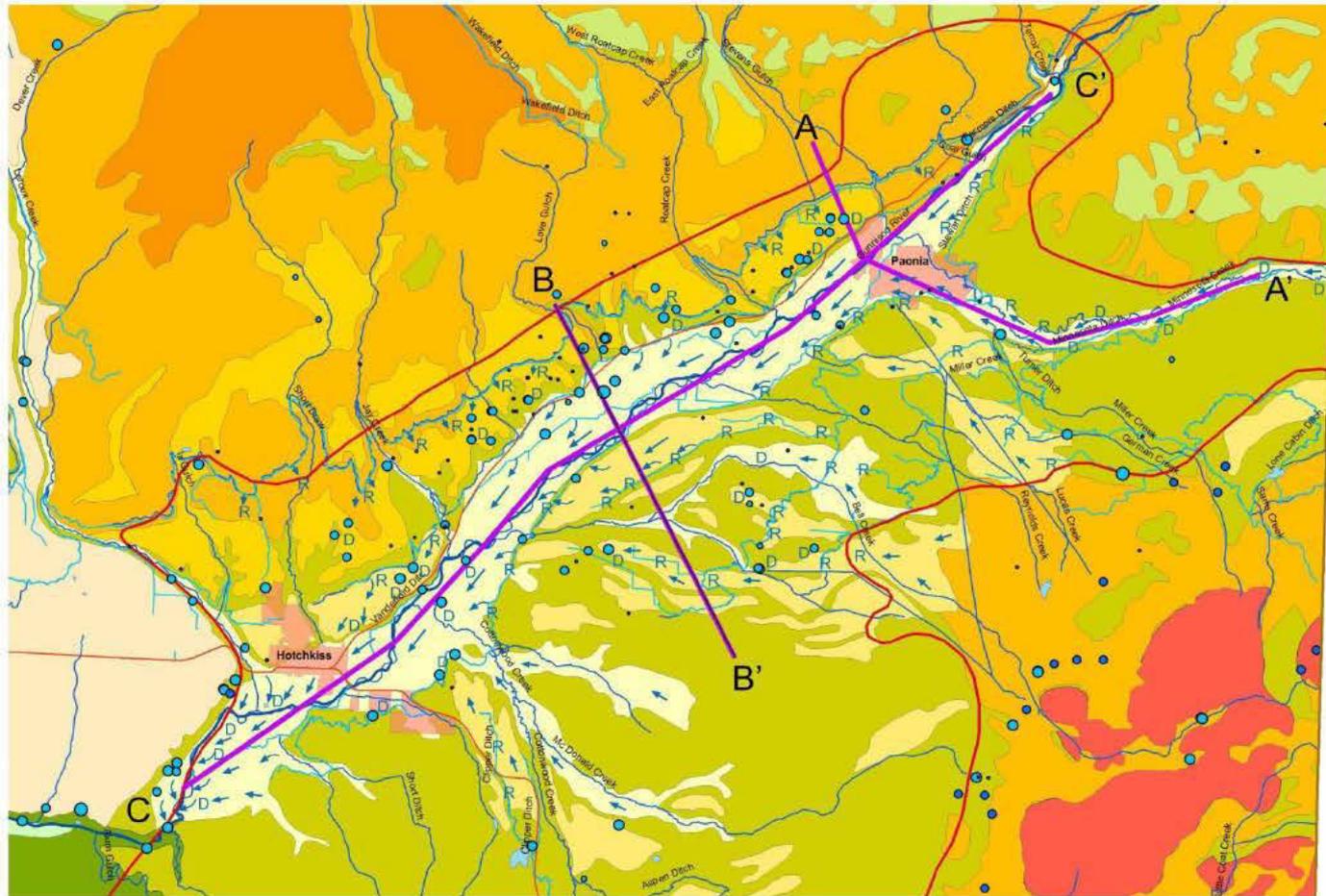
# Hydrogeology of NFVT Area

## Valley Bottom Shallow Aquifer Subsystem (C-C')



# Hydrogeology of NFVT Area

## GW Flow Direction, Recharge/Discharge in Northern Section Study Area



- R Recharge to Unconsolidated Sediments (Qal, Qat, Qgf, Qs) from Streams or Ditches
- D Discharge from Unconsolidated Sediments (Qal, Qat, Qgf) to Streams or Springs
- ← Direction Shallow Groundwater Flow (Qal, Qat, Qgf, Qs)

- Spring
- Stream
- Ditch or Enhanced Stream

# Hydrogeology of NFVT Area

## Location of CSM Cross Sections

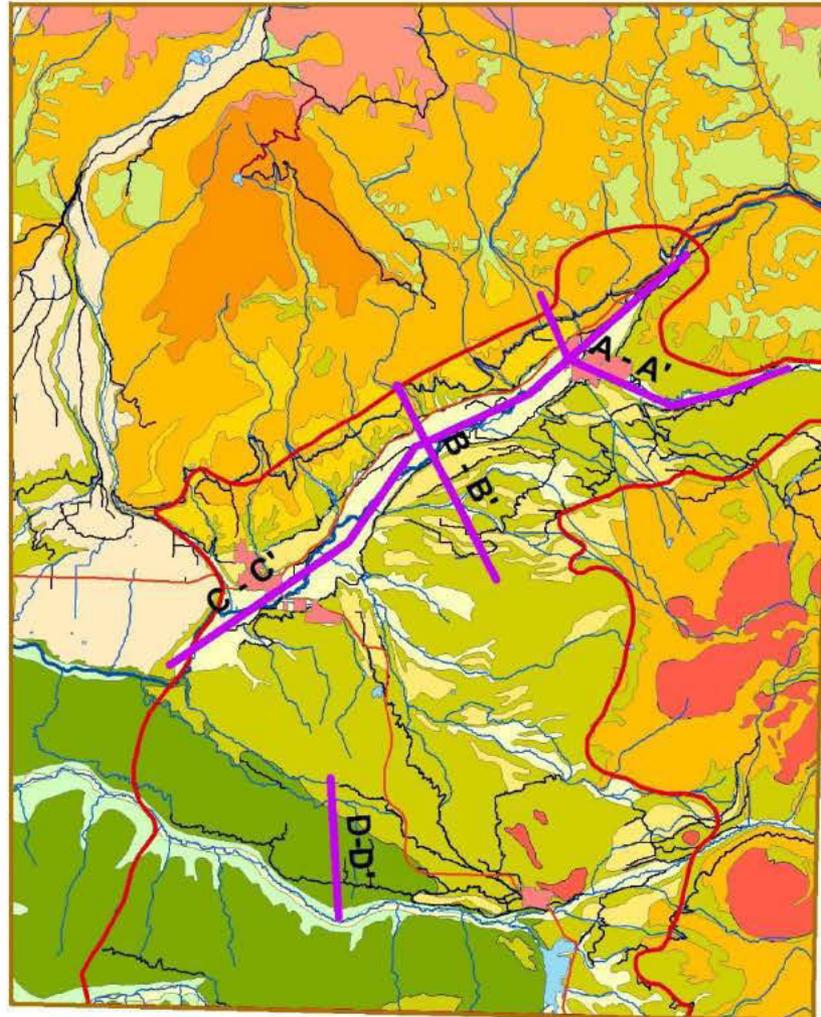
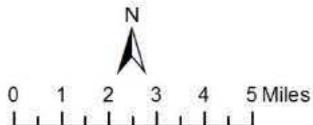
- North Fork Valley Study Area
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- Rivers
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- Lakes
- North Fork Terraces and Valley Profiles

### Unconsolidated Hydrogeological Units

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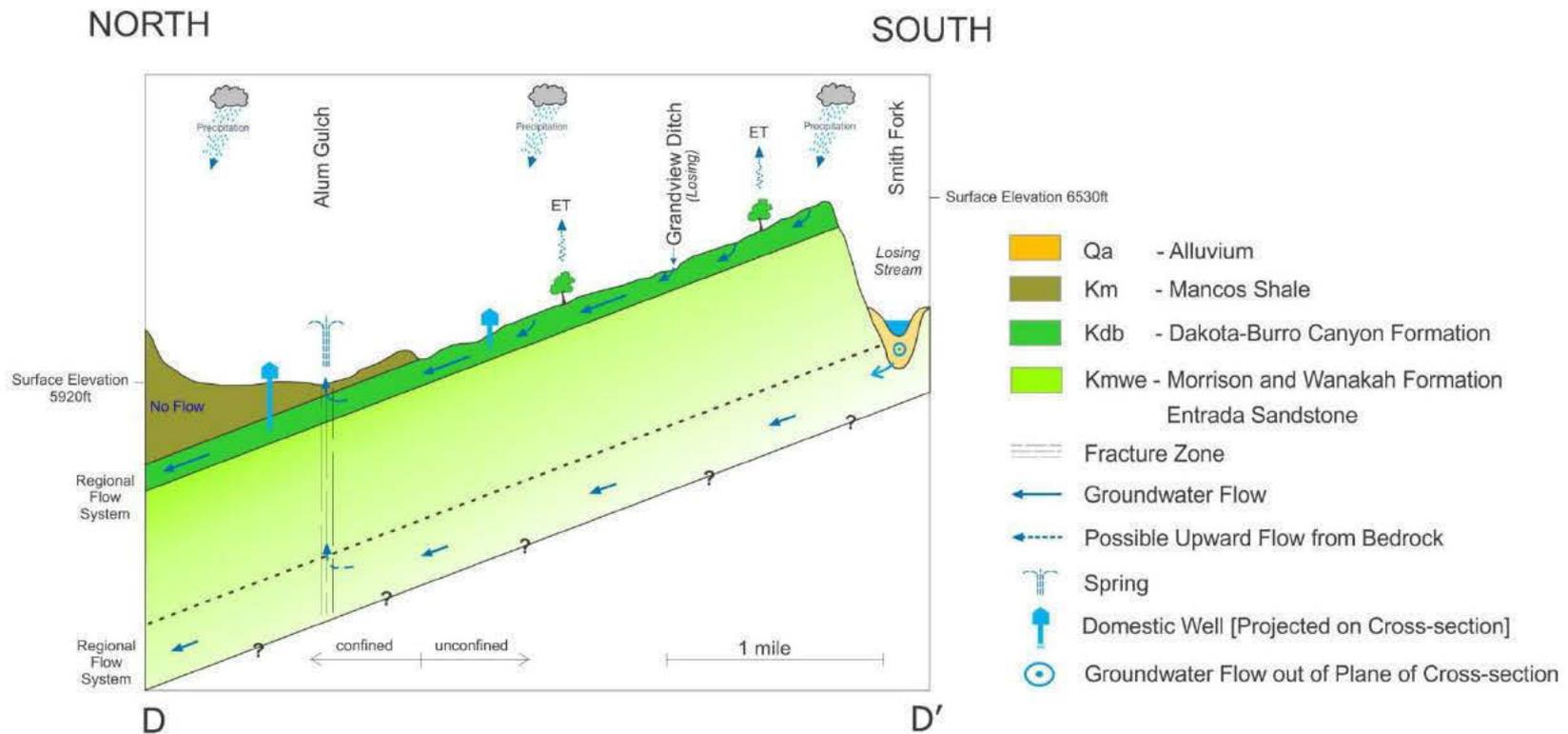
### Bedrock Hydrogeological Units

- Tmi - Tertiary Intrusions
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- Kmv - Mesaverde Formation [incl. Rollins Sandstone]
- Km - Mancos Shale
- Kdb - Dakota-Burro Canyon Formation
- Jmwe - Morrison & Wanakah Formations, Entrada Sandstone



# Hydrogeology of NFVT Area

## Regional Bedrock Subsystem (D-D')



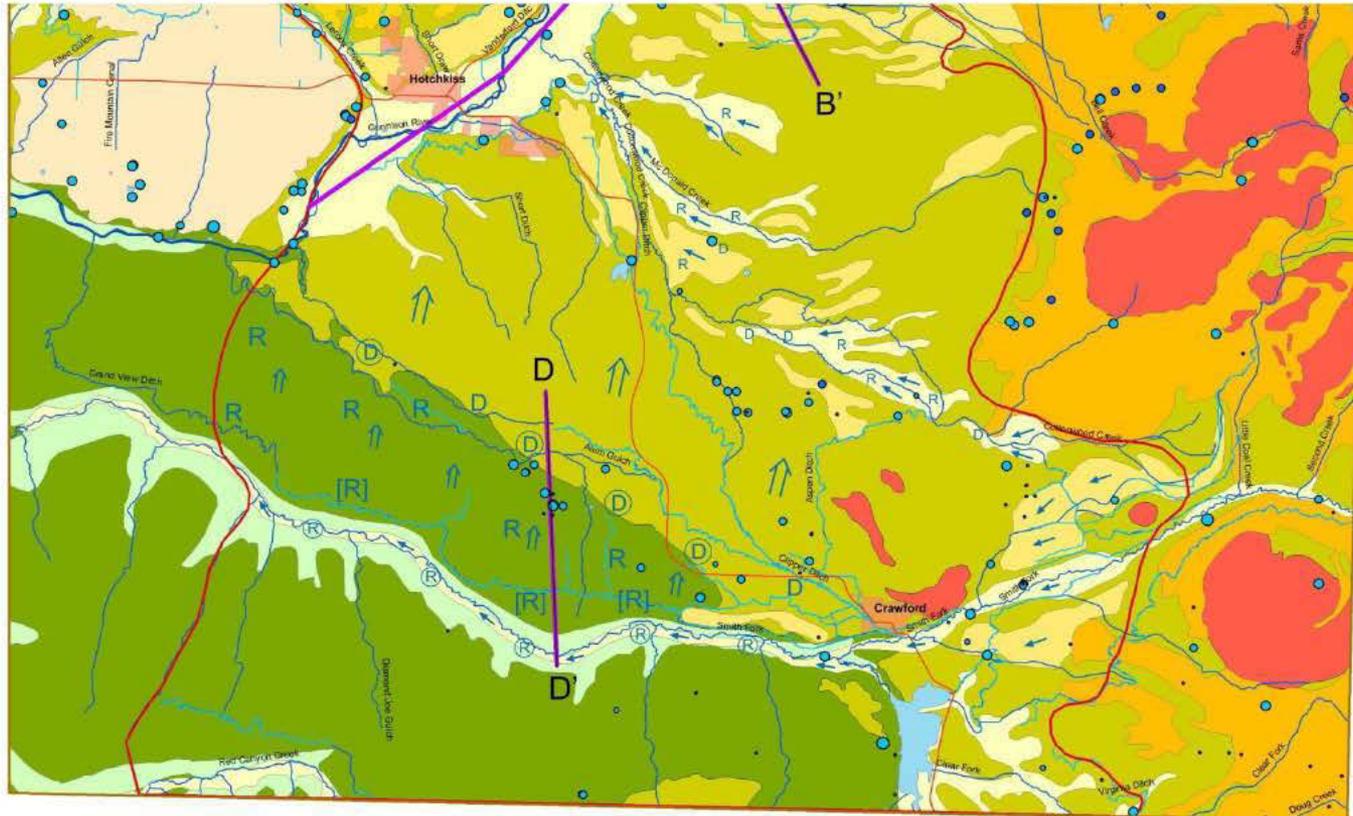
# Hydrogeology of NFVT Area

## Regional Bedrock Subsystem



# Hydrogeology of NFVT Area

## GW Flow Direction, Recharge/Discharge in Southern Section Study Area



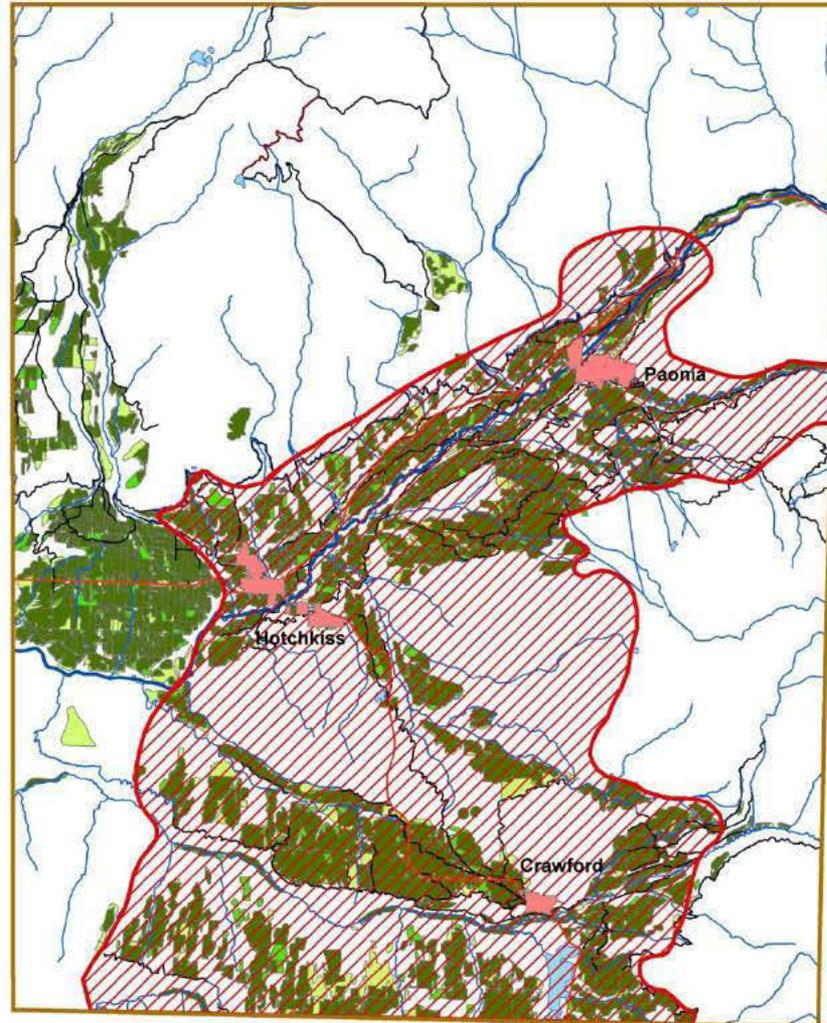
- R Recharge to Unconsolidated Material and Bedrock by Precipitation and Infiltration
- Ⓡ Regional Recharge to Bedrock by Losing Stream
- [R] Regional Recharge to Bedrock by Irrigation Ditch
- Ⓧ Discharge from Bedrock to Stream or Springs
- D Discharge from Unconsolidated Sediments (Qal, Qat, Qgf) to Streams or Springs

- Spring
- Stream
- Ditch or Enhanced Stream
- ← Direction Shallow Groundwater Flow (Qal, Qat, Qgf)
- ← Direction Flow in Unconfined Bedrock System (Kdb)
- ← Direction Flow in Confined Bedrock System (Kdb)

# Hydrogeology of NFVT Area

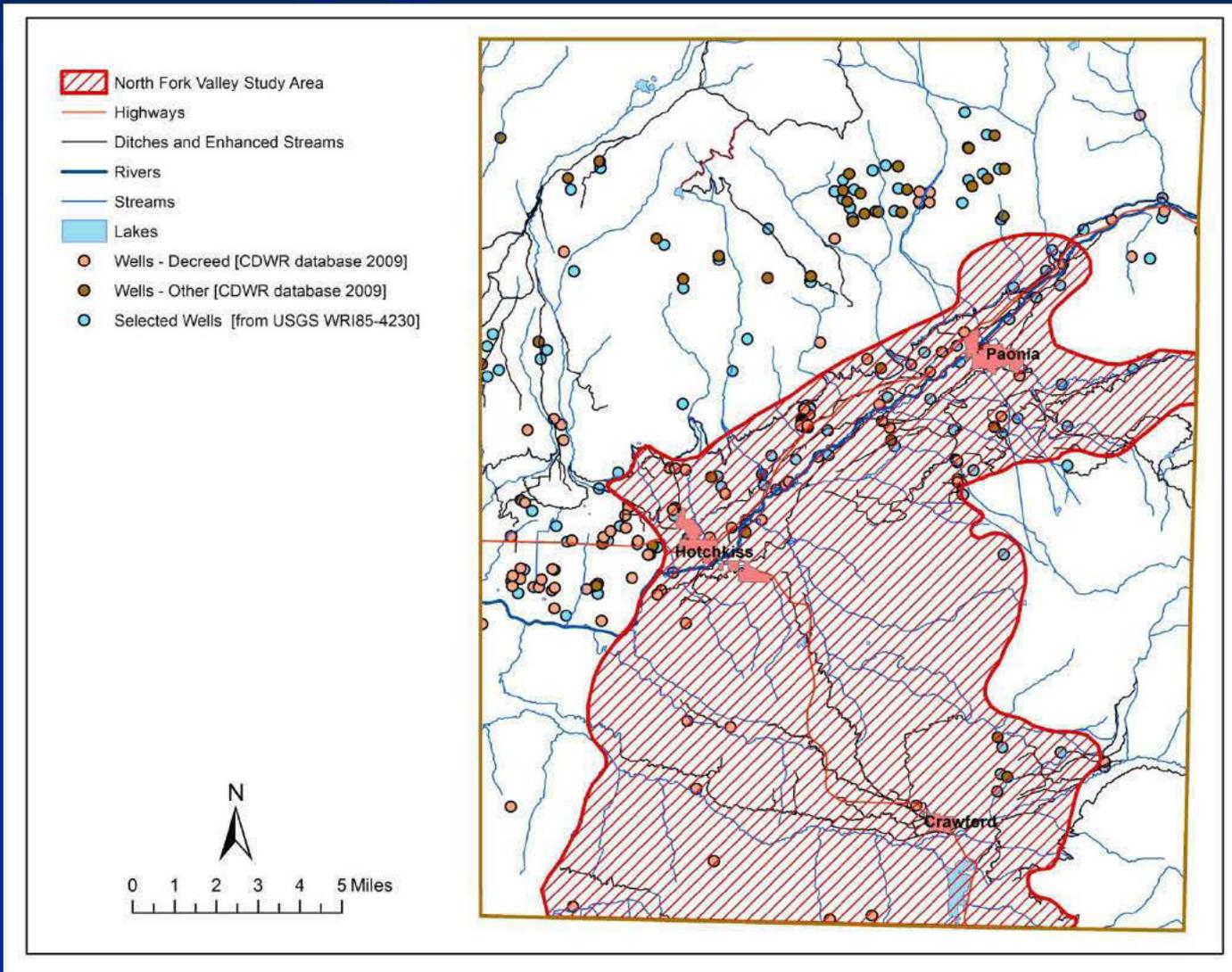
## Anthropogenic Elements – Irrigation

-  North Fork Valley Study Area
-  Highways
-  Ditches and Enhanced Streams
-  Rivers
-  Streams
-  Lakes
-  Irrigated Parcels 2005 [CDSS Div 4]
-  Irrigated Parcels 2000 [CDSS Div 4]
-  Irrigated Parcels 1993 [CDSS Div 4]



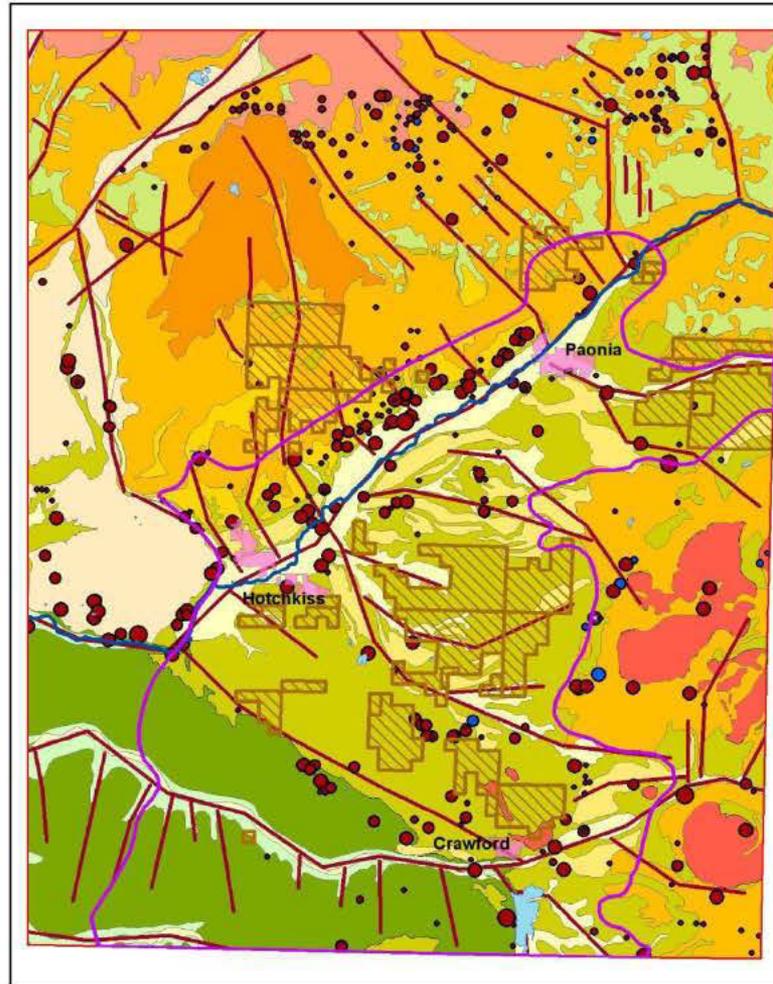
# Hydrogeology of NFVT Area

## Anthropogenic Elements – Wells

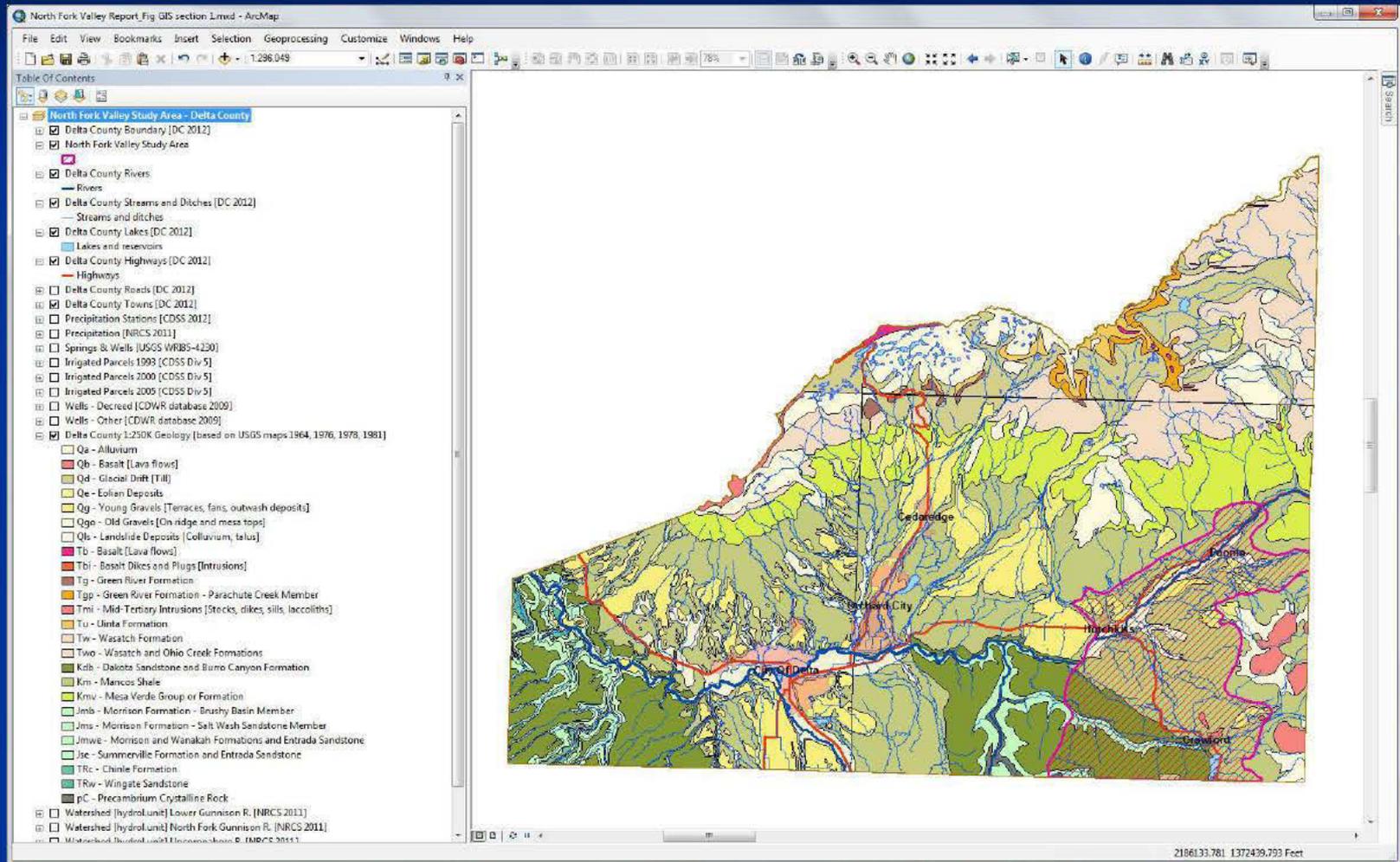


# Hydrogeology of NFVT Area

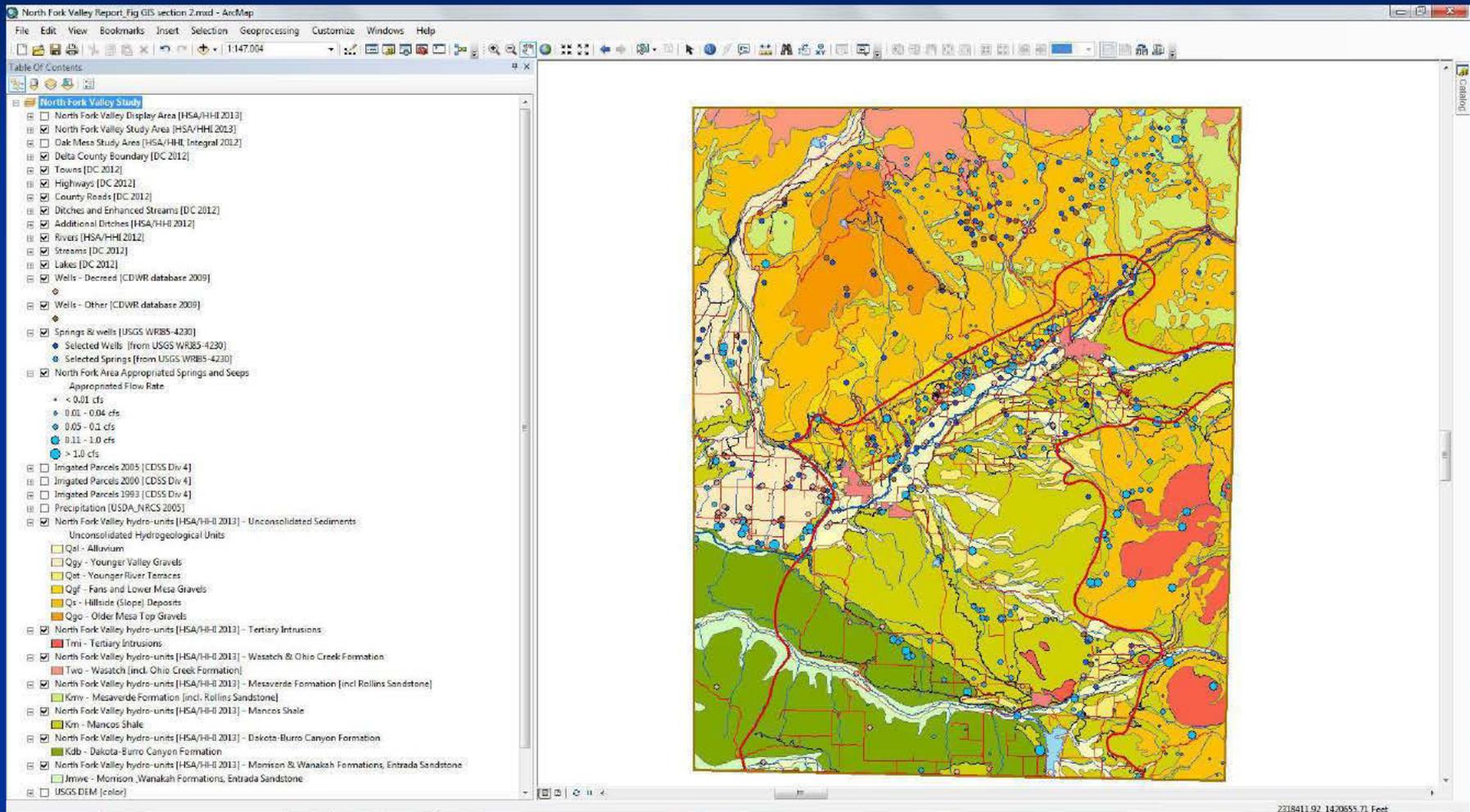
## Anthropogenic Elements – Oil/Gas Leases



# GIS MAPS: Delta County



# GIS MAPS: NFVT Area



# GIS MAPS: Database Detail

North Fork Valley Report\_Fig GIS section 3.mxd - ArcMap

File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help

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  - North Fork Valley hydro-units [HSA/HI 2013] - Tertiary Intrusions
  - North Fork Valley hydro-units [HSA/HI 2013] - Wasatch & Ohio Creek Formation
  - North Fork Valley hydro-units [HSA/HI 2013] - Mesaverde Formation [incl Rollins Sandstone]
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  - North Fork Valley hydro-units [HSA/HI 2013] - Dakota-Burro Canyon Formation
  - North Fork Valley hydro-units [HSA/HI 2013] - Morrison & Wanakah Formations, Entrada Sandstone
  - USGS DEM [color]
  - USGS DEM [B/W]
  - Delta County 1:250K Geology [based on USGS maps 1964, 1976, 1978, 1981]

Table

North Fork / Oak Mesa hydro-structures

FID	Shape *	Name
25	Polyline	
26	Polyline	Cedar Gulch Lineament
27	Polyline	Lower Laroux Creek Lineament
28	Polyline	Cow Creek Lineament
29	Polyline	Dever Creek Lineament
30	Polyline	Jay Creek Lineament - Fracture Zone
31	Polyline	Cedar Gulch Lineament
32	Polyline	Cedar Gulch Lineament
33	Polyline	Upper Camard Creek Lineament
34	Polyline	West Fork, Terror Creek Lineament
35	Polyline	Hubbard Creek Fault Zone
36	Polyline	Upper Laroux Creek Fault Zone
37	Polyline	Upper North Fork Lineament - Fracture Zone
38	Polyline	Middle North Fork Lineament
39	Polyline	Smith Fork Lineament - Fracture Zone
40	Polyline	
41	Polyline	
42	Polyline	
43	Polyline	
44	Polyline	
45	Polyline	
46	Polyline	
47	Polyline	
48	Polyline	
49	Polyline	
50	Polyline	
51	Polyline	
52	Polyline	
53	Polyline	
54	Polyline	Cottonwood Creek Lineament - Fracture Zone
55	Polyline	
56	Polyline	
57	Polyline	
58	Polyline	
59	Polyline	
60	Polyline	
61	Polyline	Minnesota Creek Lineament - Fracture Zone
62	Polyline	Red Canyon Creek Lineament - Fracture Zone
63	Polyline	
64	Polyline	

1 (0 out of 78 Selected)

North Fork / Oak Mesa hydro-structures

2376792.29 1384479.02 Feet

# 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**

