Groundwater Assessment

Presented by:

Stefan Schuster, P.G.

Andrew Donnelly, P.G.

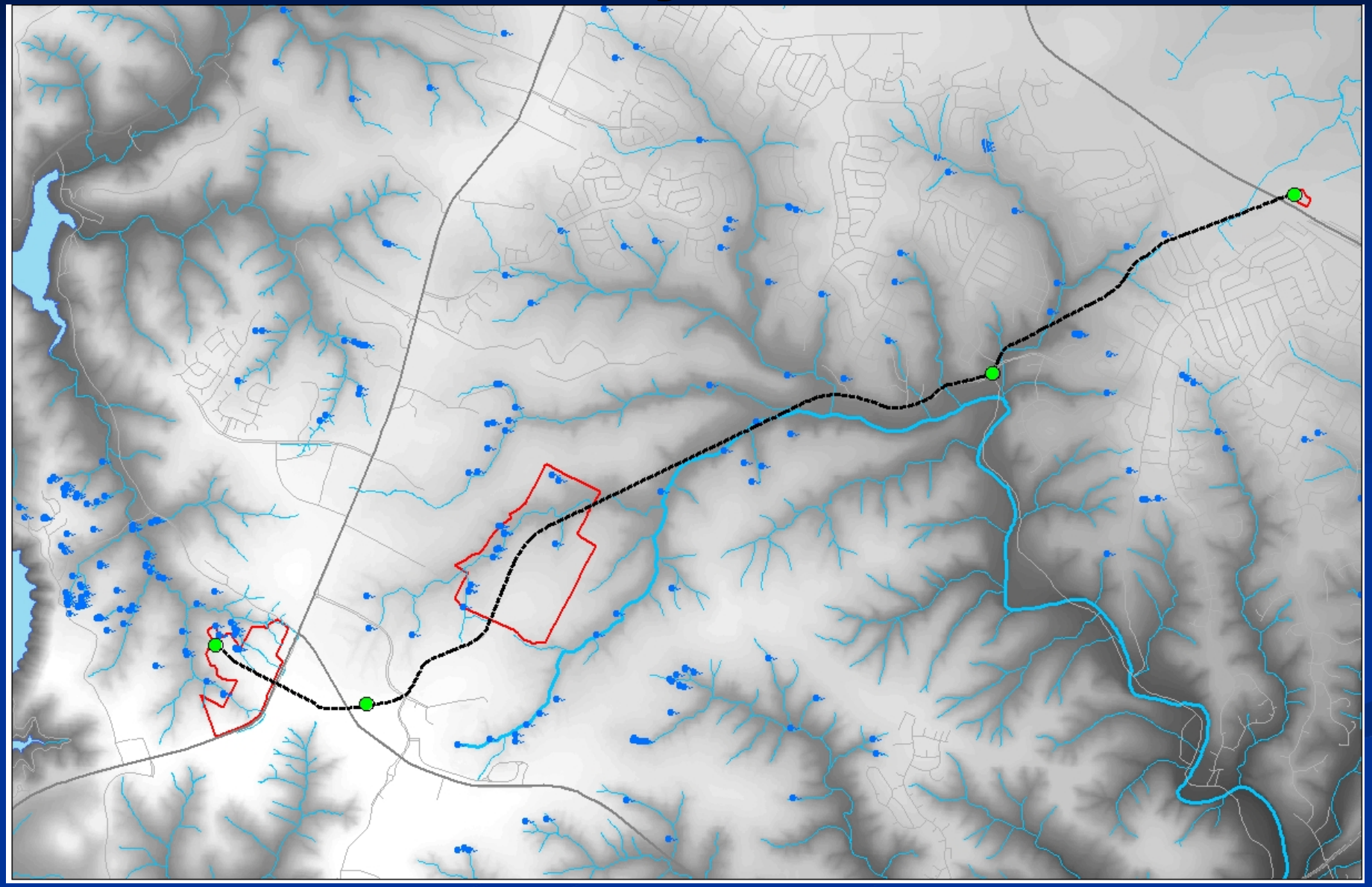
Daniel B. Stephens & Associates, Inc.

January 2011

Groundwater Assessment Purpose

- Address potential impacts JTM project, in particular to Bull Creek and the Jollyville Plateau Salamander
  1. Review and summarize all existing information on the groundwater systems in the study area
  2. Assess potential impacts of tunnel
  3. Assess potential impacts of shafts
  4. Review mitigation measures

Study Area



Groundwater Assessment Tasks

- Review all available data
- Conduct field investigations in support of the assessment:

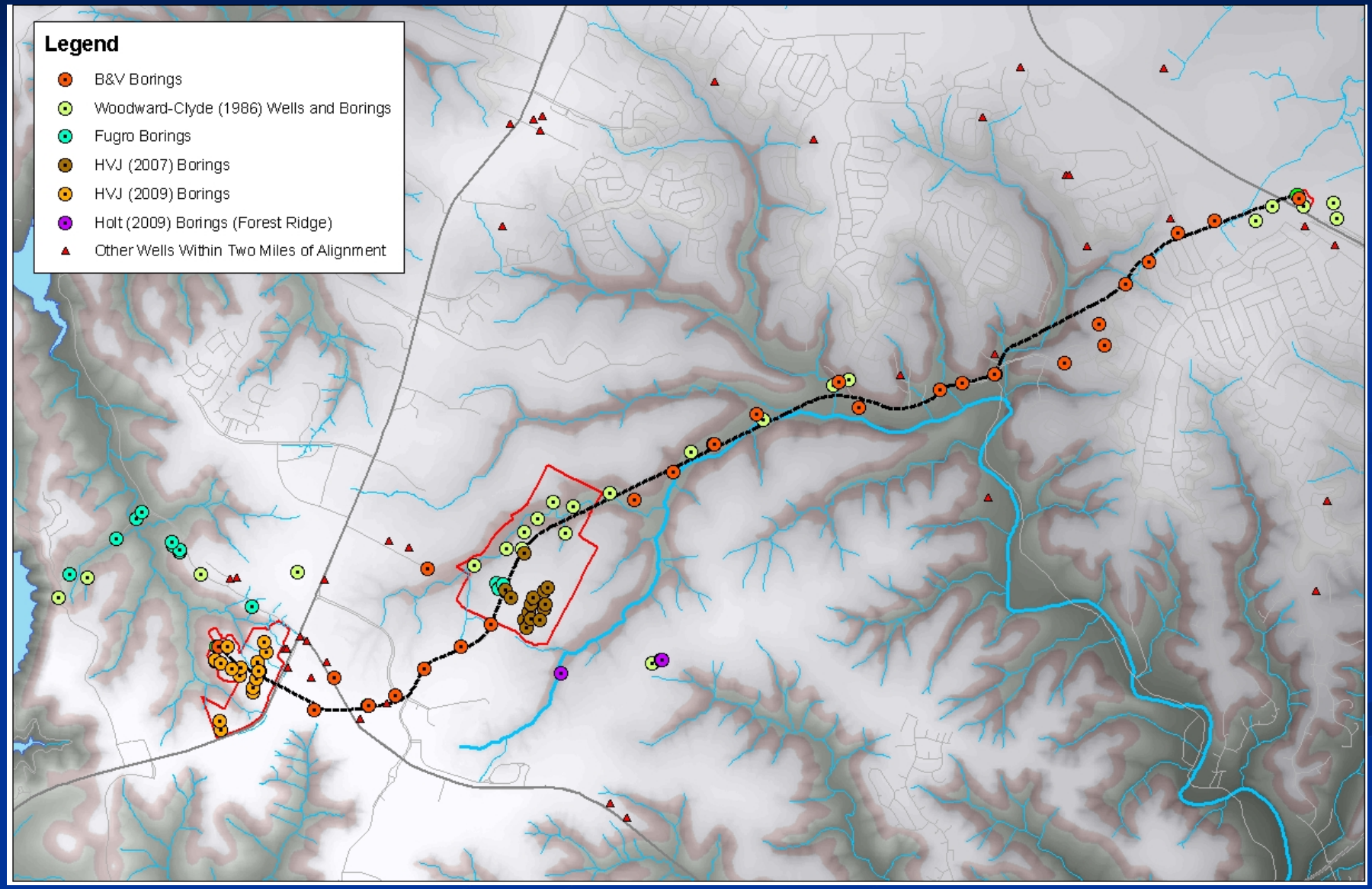
1. Field reconnaissance
2. Core boring program- included packer testing, well and piezometer installation
3. Bull Creek flow studies

- Initial effort included a numeric model
- Summarize in a comprehensive report

Why A Conceptual Model

- Numeric model determined not to be the best tool due to lack of data and uncertain ability of models to simulate flow in the study area
- Conceptual model would incorporate all known data about the study area into a single document

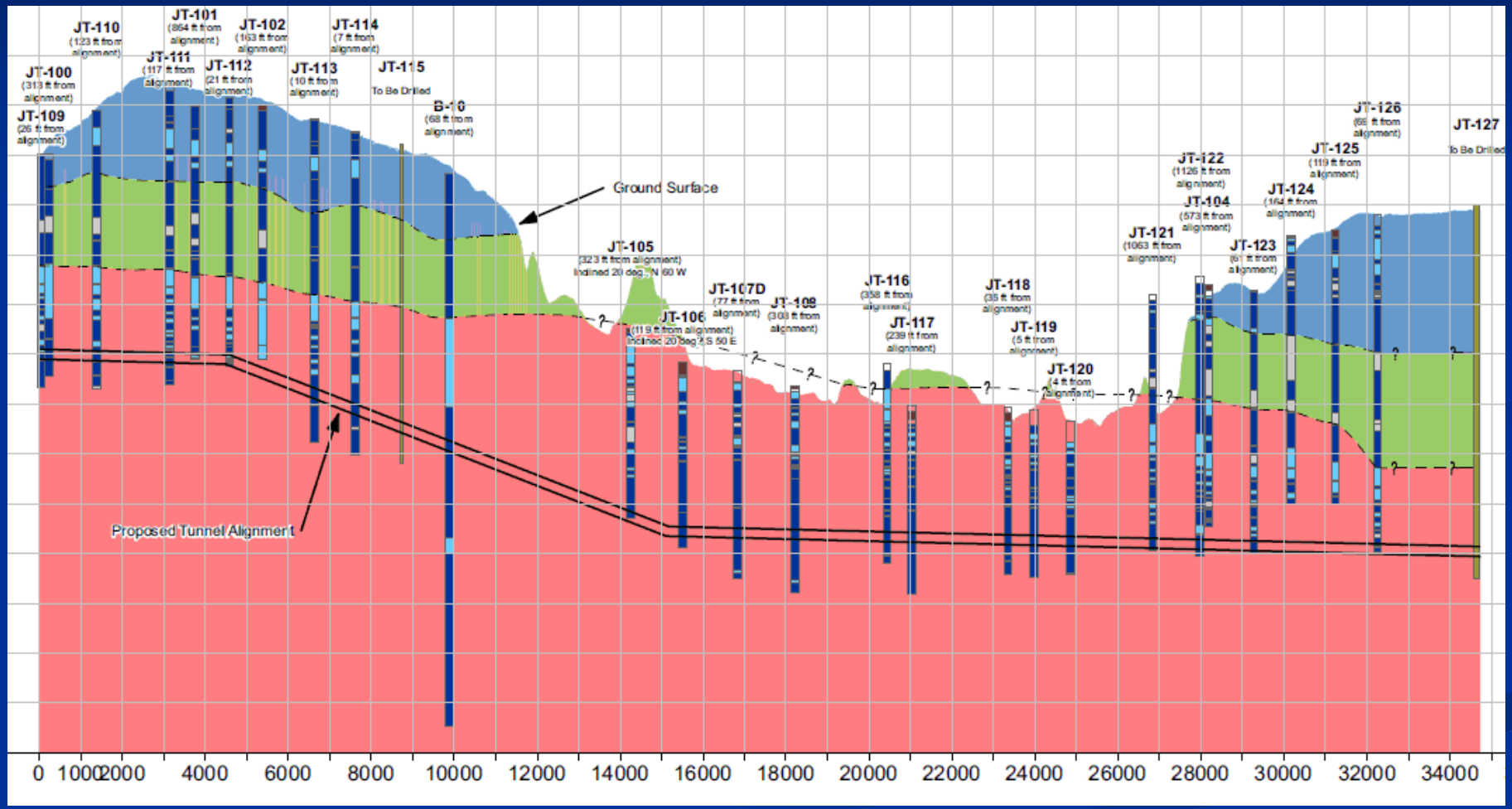
Subsurface Investigation



Geology

- Edwards Formation
- Comanche Peak Formation (in some areas)
- Walnut Formation
- Upper Glen Rose Formation

Geology


JT-100
(313 ft from alignment)
JT-101
(864 ft from alignment)
JT-102
(163 ft from alignment)
JT-109
(26 ft from alignment)
JT-110
(123 ft from alignment)
JT-111
(117 ft from alignment)
JT-112
(21 ft from alignment)
JT-113
(10 ft from alignment)
JT-114
(7 ft from alignment)
JT-115
To Be Drilled
B-10
(68 ft from alignment)
Ground Surface
JT-105
(323 ft from alignment)
Inclined 20 deg N 60 W
JT-106
(119 ft from alignment)
Inclined 20 deg S 50 E
JT-107D
(77 ft from alignment)
JT-108
(303 ft from alignment)
JT-116
(358 ft from alignment)
JT-117
(239 ft from alignment)
JT-118
(35 ft from alignment)
JT-119
(5 ft from alignment)
JT-120
(4 ft from alignment)
JT-121
(1063 ft from alignment)
JT-122
(1126 ft from alignment)
JT-104
(573 ft from alignment)
JT-123
(61 ft from alignment)
JT-124
(164 ft from alignment)
JT-125
(119 ft from alignment)
JT-126
(68 ft from alignment)
JT-127
To Be Drilled
Proposed Tunnel Alignment
0
1000
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
24000
26000
28000
30000
32000
34000

Edwards Formation

- Uppermost unit
- Primarily limestone and dolomite
- Up to 200 feet thick in the study area
- More resistant, found in the topographically higher areas
- Very karstic unit, solution features are common
- Very high hydraulic conductivities, generally unable to be packer tested

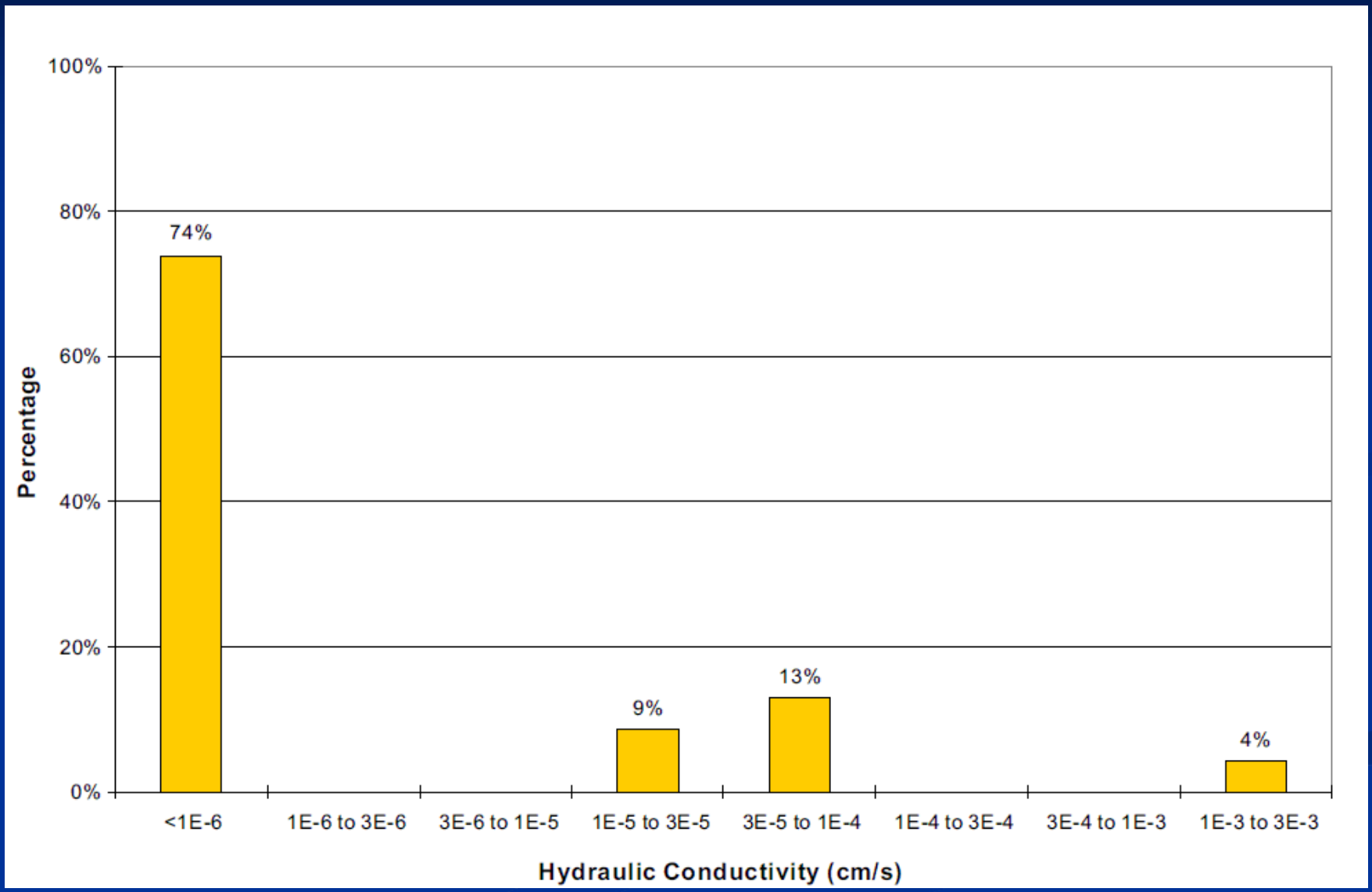
Comanche Peak Formation

- Limestone
- Often placed between Edwards and Walnut, but in study area it is actually interfingered within the Edwards
- Present only at eastern end of the alignment

Walnut Formation

- Limestone found beneath the Edwards
- 90 to 100 feet thick in the study area
- Comprised of three members: Bull Creek; Bee Cave; and Cedar Park
- Much less permeable than the Edwards, but has been shown to have some zones of significant permeability

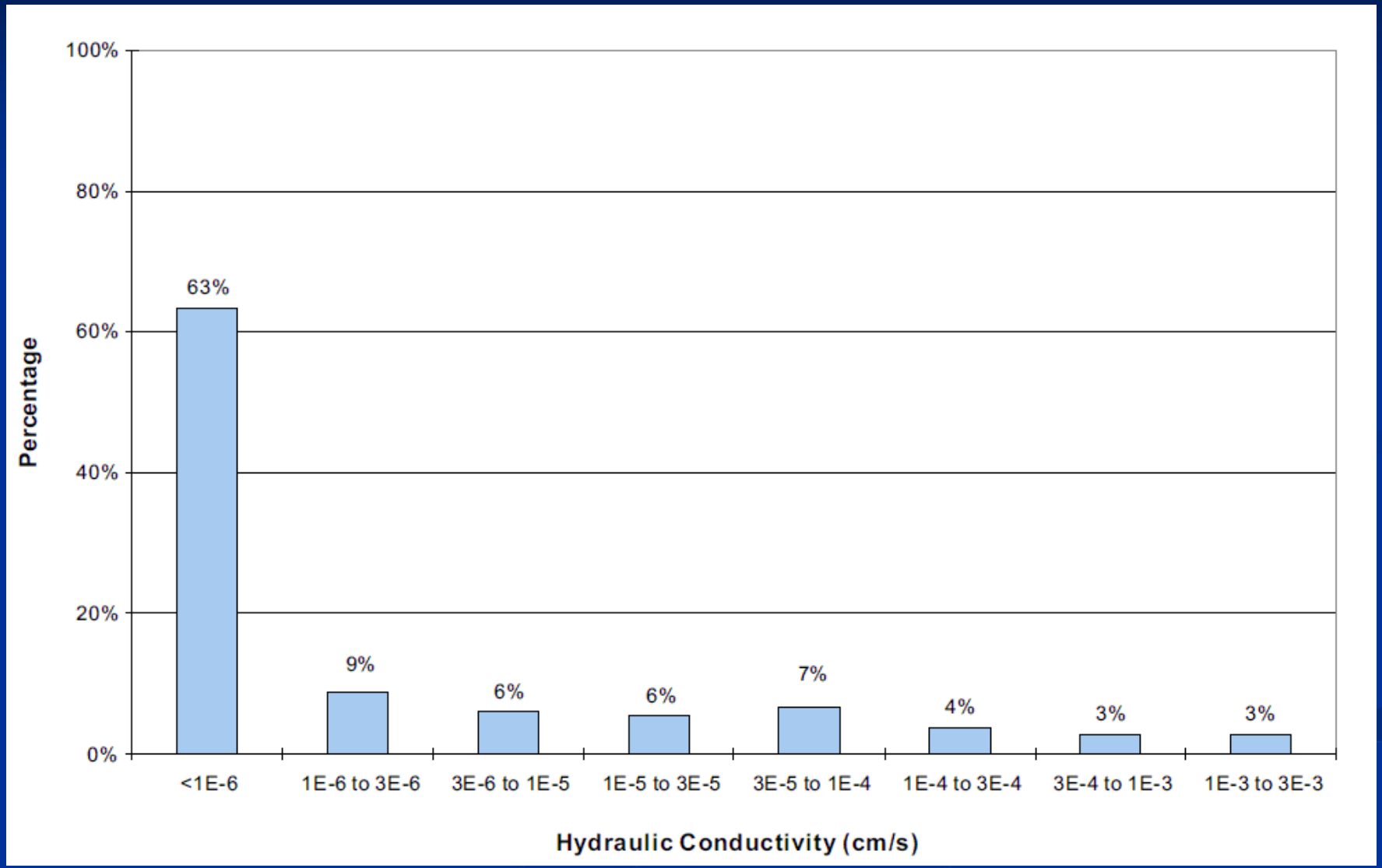
Walnut Hydraulic Conductivities



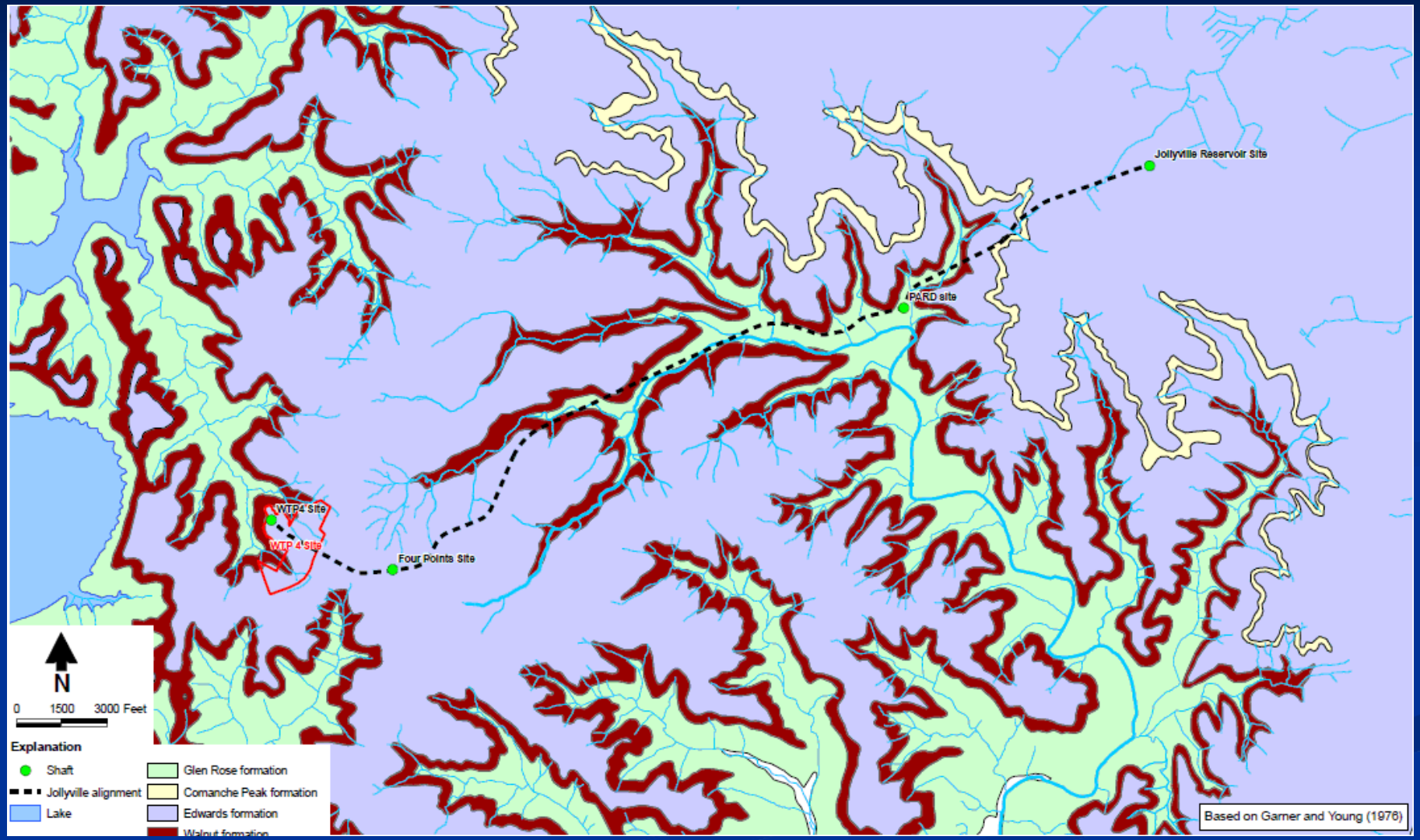
Upper Glen Rose Formation

- Deepest formation of interest in study area
- Primarily consists of alternating beds of limestone and dolomite
- Present at ground surface only at lowest elevations, primarily in stream valleys
- Estimated to be more than 600 feet thick in the area
- Very tight, much lower hydraulic conductivities than in the Edwards
- However, upper 50 feet can be more permeable than rest of the Glen Rose section

Glen Rose Hydraulic Conductivities



Study Area Geology



Groundwater Systems

- Edwards/Walnut Formation- Forms the uppermost flow system
- Upper Glen Rose Formation- Forms the deeper flow system
- Neither truly are an “aquifer”
- Provide baseflow for upper Bull Creek via spring discharge and important habitat for the Jollyville Plateau Salamander

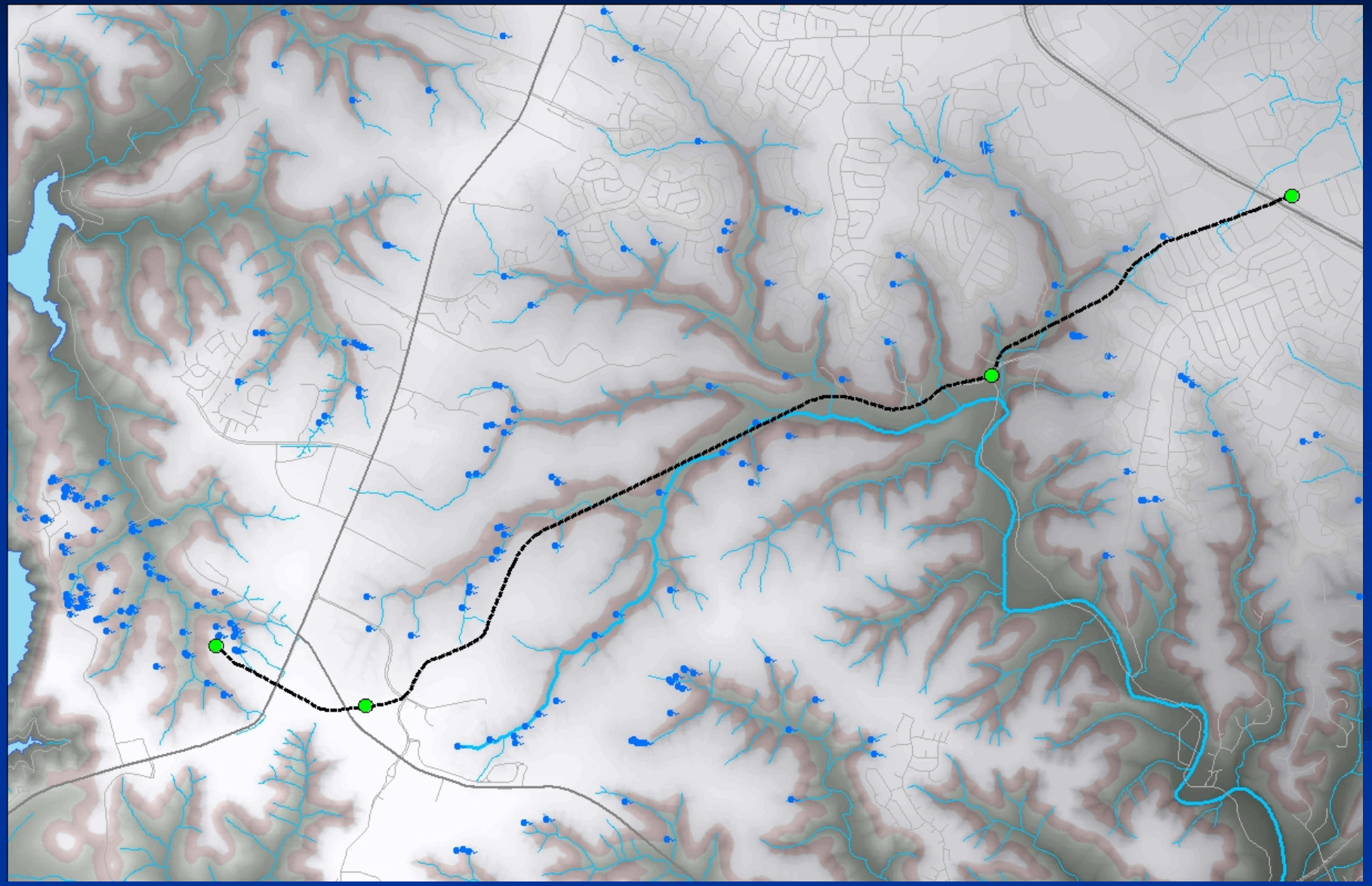
Edwards/Walnut Flow System

- Recharge occurs on Edwards outcrop in the topographically higher areas
- Water infiltrates into the subsurface and moves downward until a less permeable zone is encountered
- Less permeable zones may be the Walnut Formation or other individual beds in the Edwards
- Water then moves laterally, discharging at springs and seeps along steep incised stream valleys
- Water movement is rapid--tens of feet per day

Edwards/Walnut Flow System (cont.)

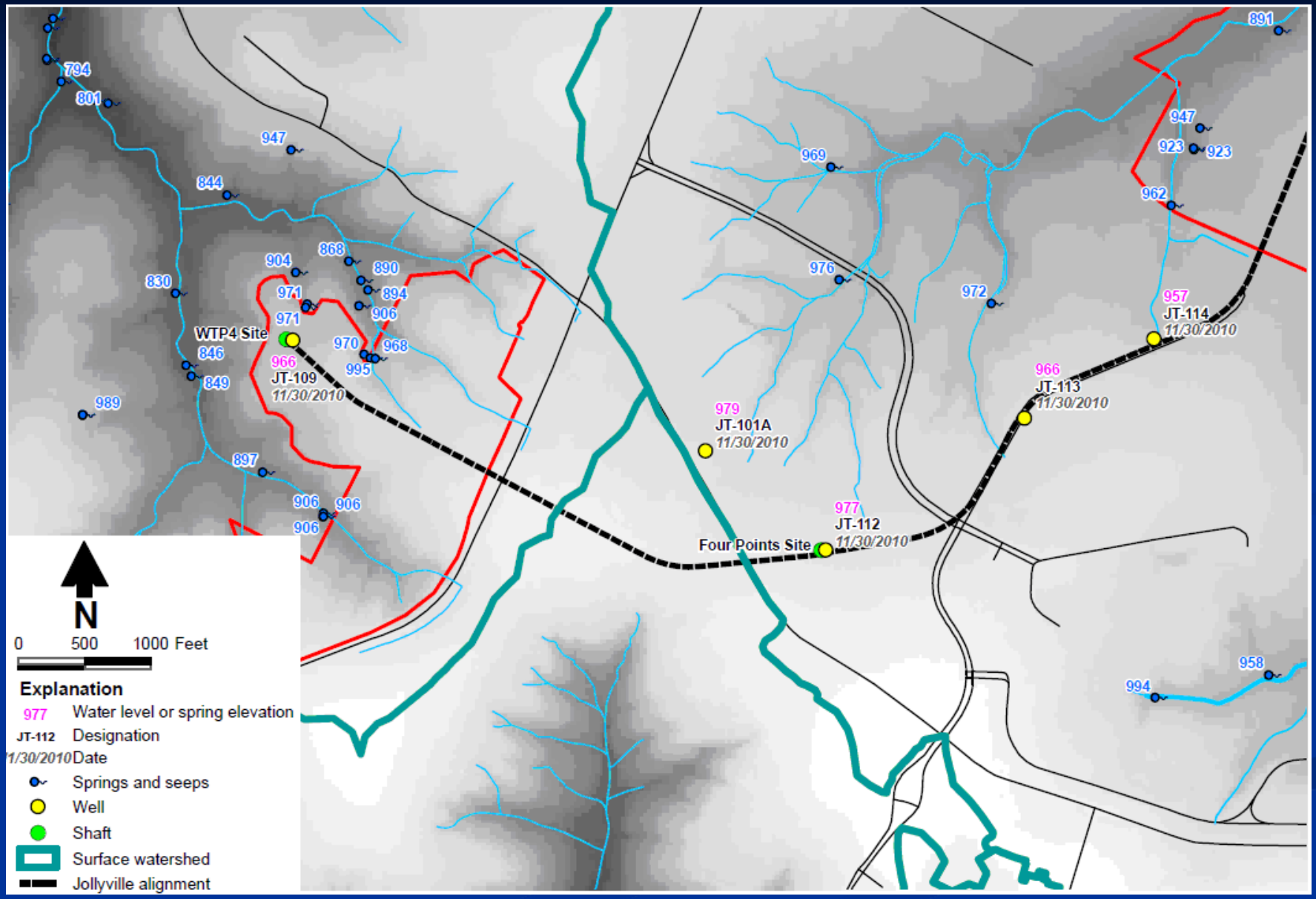
- Although Walnut is generally tight, it can allow water to move through it, primarily along fractures/joints
- Water that moves into the Walnut will also move laterally and discharge at springs when it encounters a less permeable zone
- Some springs emanating from the Glen Rose also part of the Edwards/Walnut flow system
- 184 springs and seeps within one mile of the alignment:
  - 40% are from the Edwards Formation
  - 38% are from the Walnut Formation
  - 5% are from the Comanche Peak Formation
  - 18% are from the Upper Glen Rose Formation

Springs



Edwards/Walnut Flow System (cont.)

- The Edwards/Walnut system is separate from the Glen Rose system, but does provide a small amount of recharge to the Glen Rose system
- Water levels and flow appear to reflect topography


794
801
947
844
830
904
868
890
894
906
971
971
WTP4 Site
846
849
966
JT-109
11/30/2010
970
968
995
989
897
906
906
906
969
976
947
923
923
962
891
972
957
JT-114
11/30/2010
966
JT-113
11/30/2010
979
JT-101A
11/30/2010
977
JT-112
11/30/2010
Four Points Site
958
994
N
0
500
1000 Feet
Explanation
977 Water level or spring elevation
JT-112 Designation
11/30/2010 Date
Springs and seeps
Well
Shaft
Surface watershed
Jollyville alignment

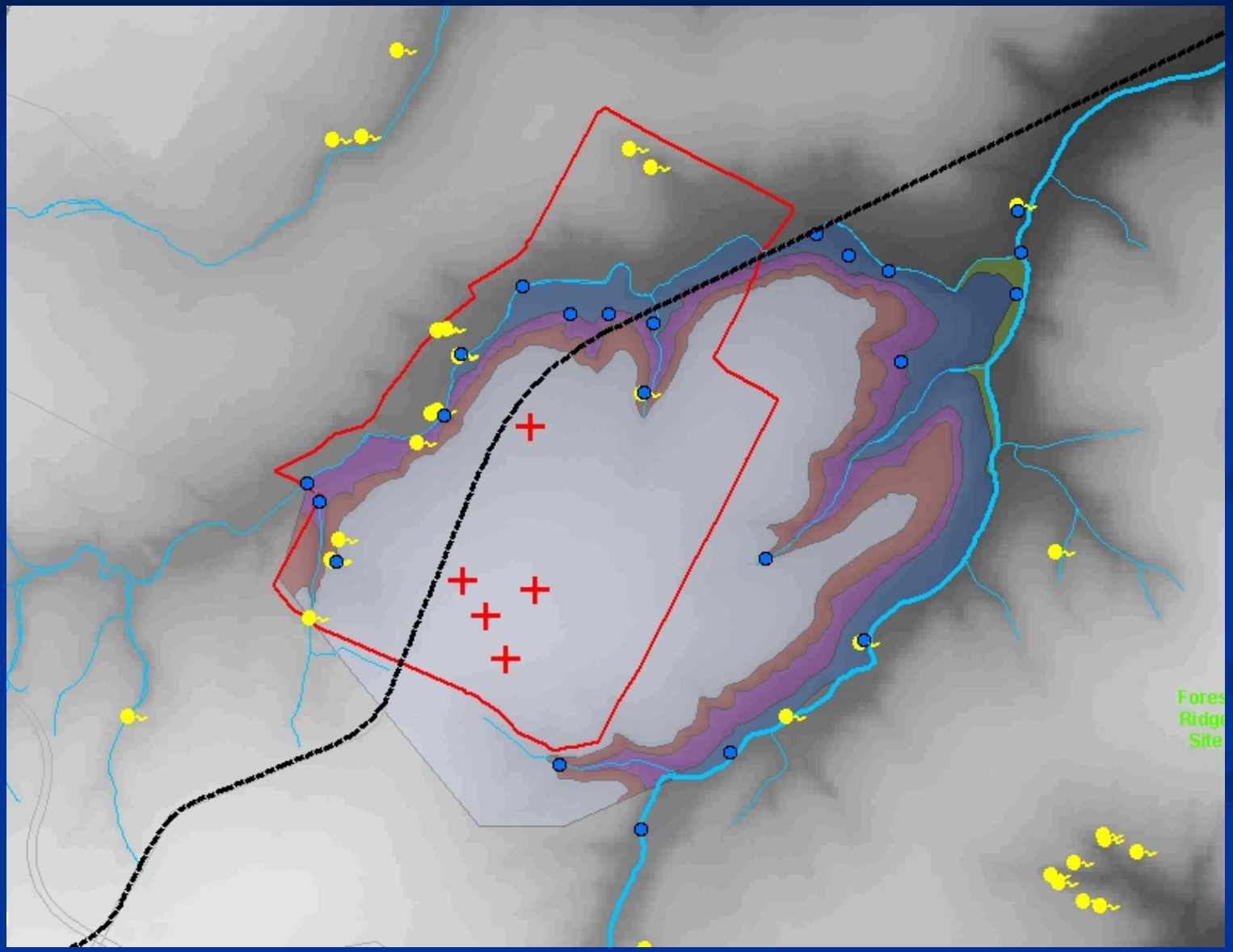
Dye Tracing Studies

- In karst flow systems, there really are not any “hard and fast” rules
- The only way to really know how groundwater is moving is with a dye tracing study
- Dye is introduced into the aquifer and then springs, wells, etc. are monitored to determine where the dye is moving

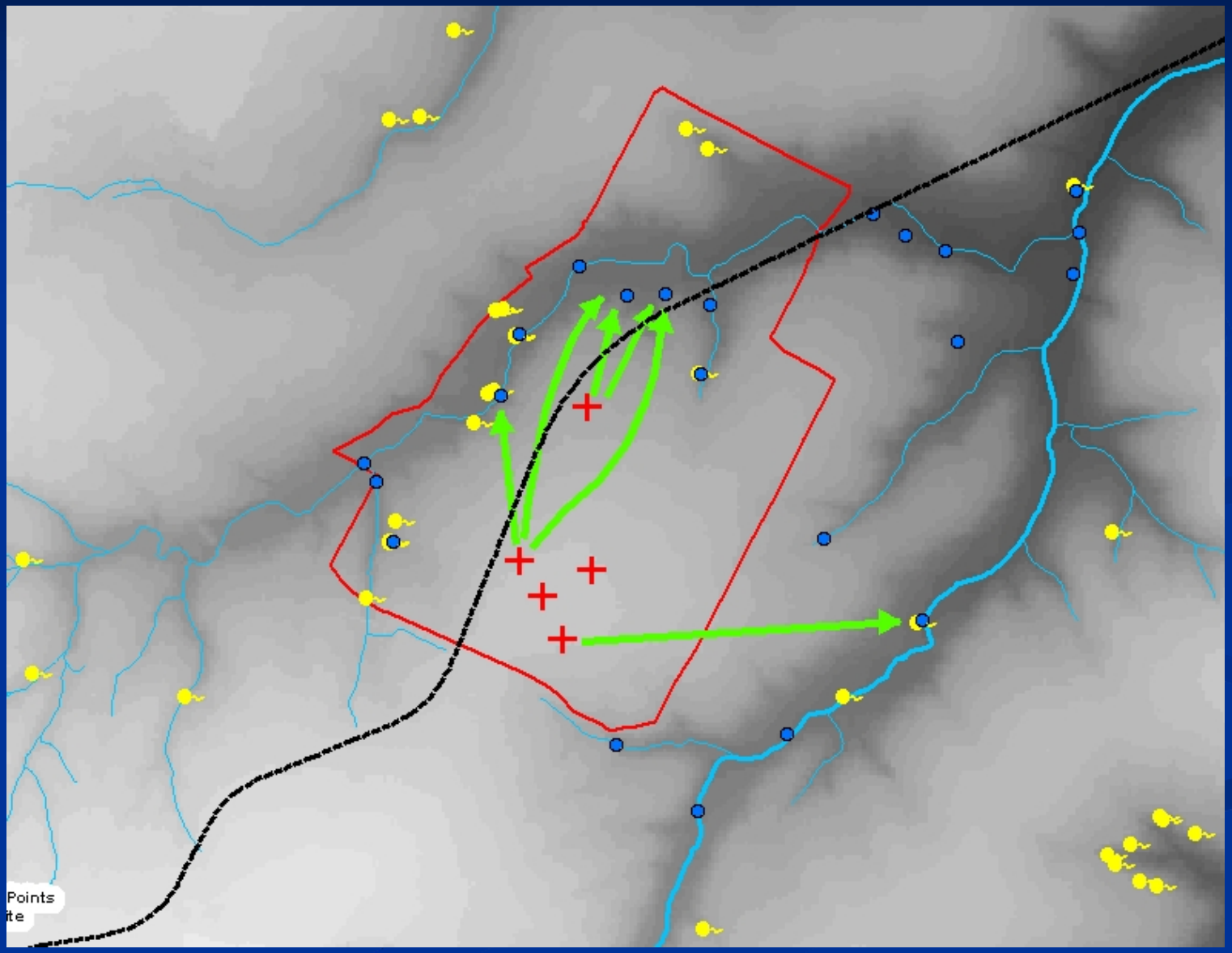
Dye Tracing

Dye tracing studies have been conducted by City of Austin staff for many years to help delineate flowpaths in the Edwards Aquifer

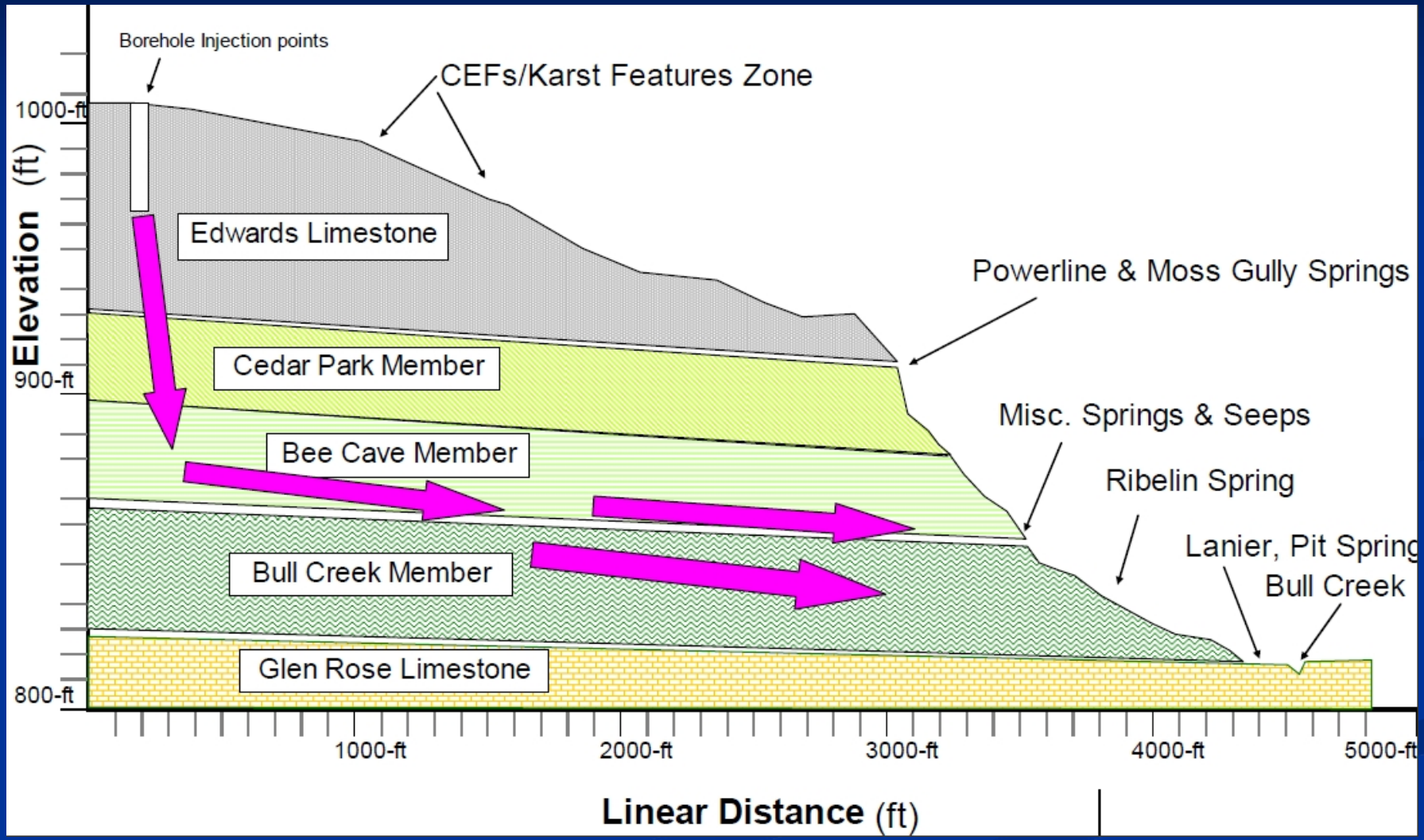
Dye Tracing



Dye Tracing Results



Dye Tracing Results



Additional Dye Tracing

- At least two more dye tracing studies are planned:
  1. Upper Bull Creek- in progress
  2. Four Points Area

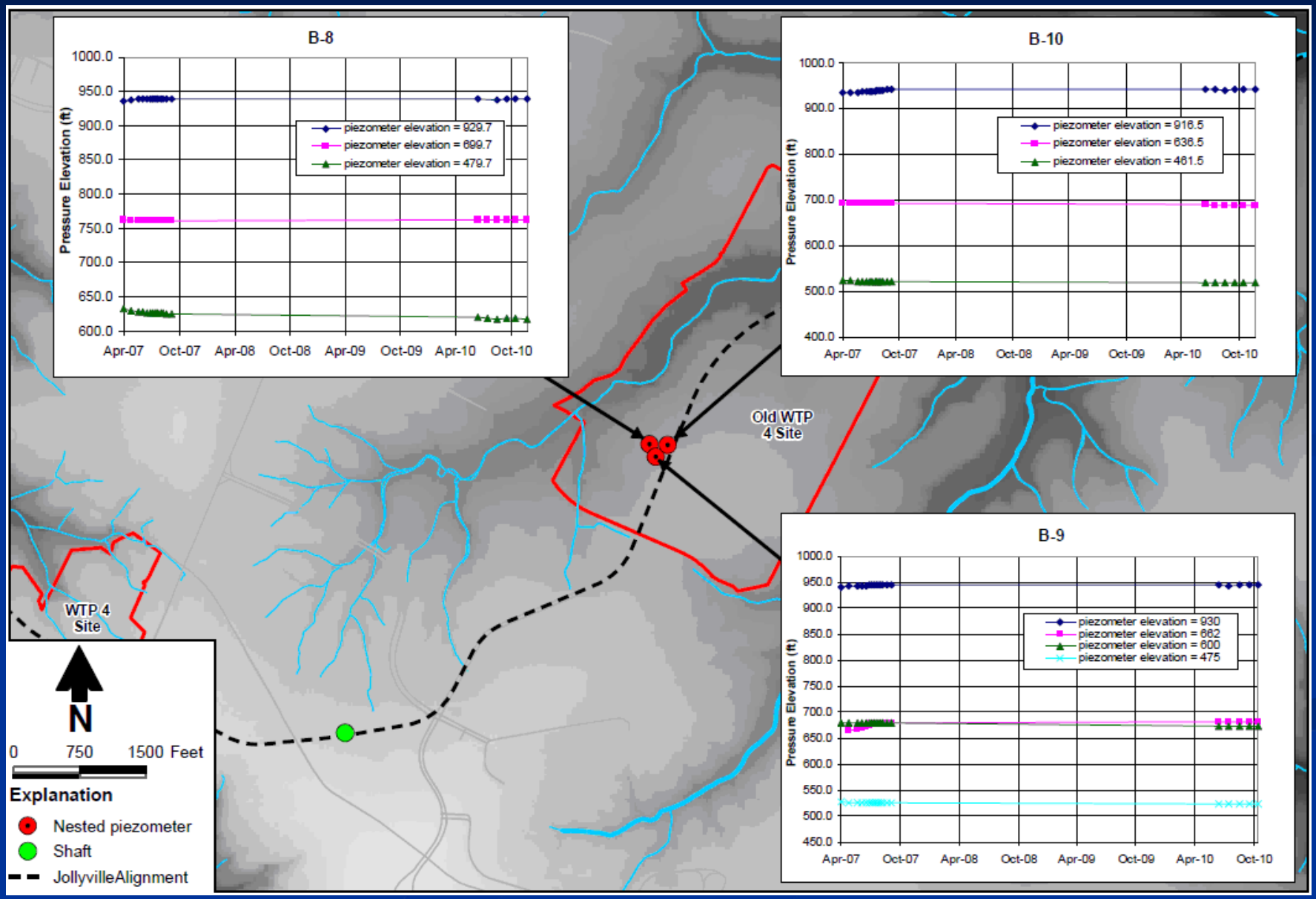
Upper Glen Rose Flow System

- Deeper flow system located in the Upper Glen Rose Formation
- Low hydraulic conductivities

Nested Piezometers

- Several piezometers (wells) installed at a single location, with screens at different vertical intervals
- Allows the determination of vertical gradients

Nested Piezometers



Glen Rose Flow System

- Limited water entering from overlying Edwards/Walnut flow system and infiltration of precipitation directly on outcrop
- Very low permeabilities
- Steep vertical hydraulic gradient, indicating movement of groundwater downward

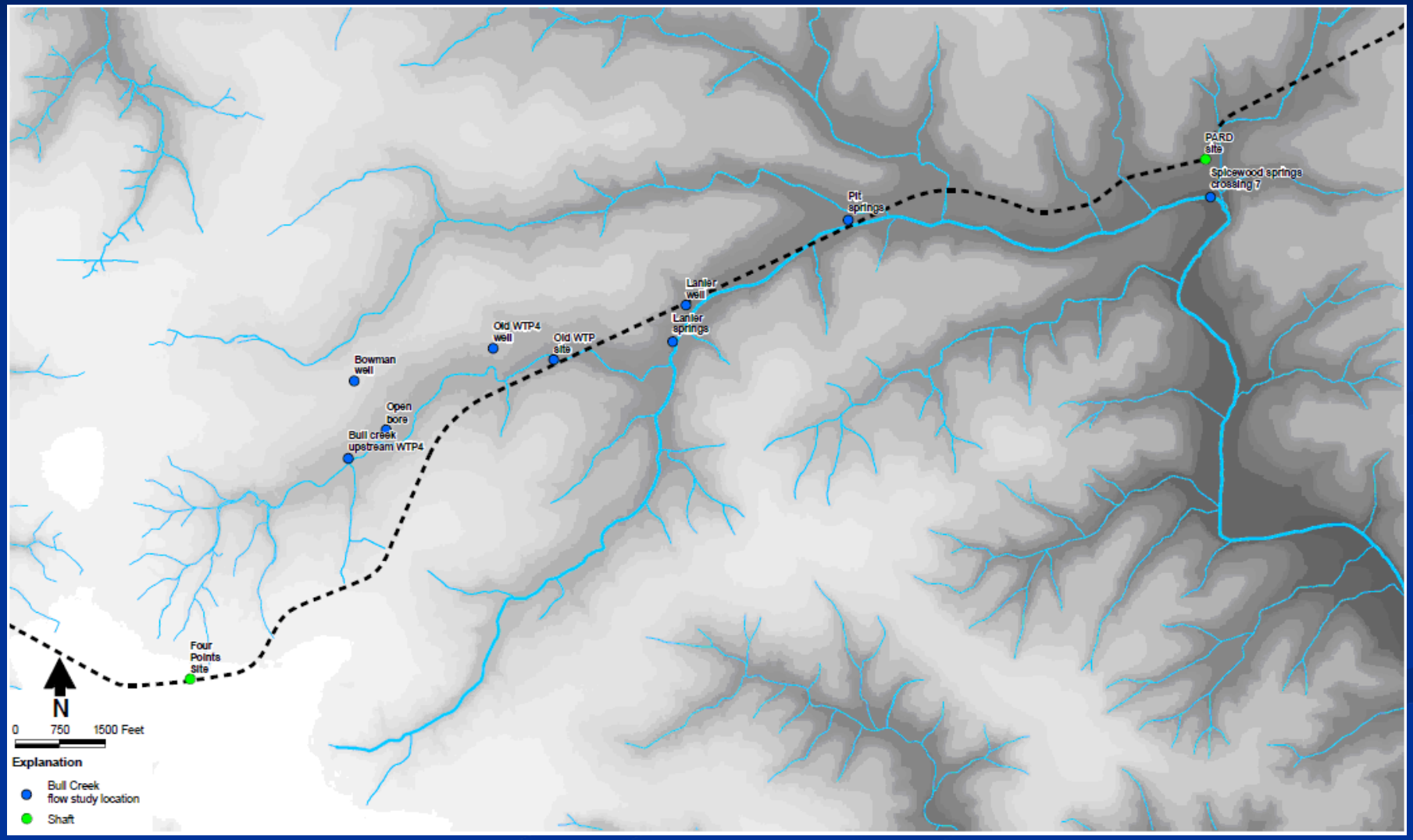
Bull Creek Studies

- Low-flow study
- Gain-loss study

Low-Flow Study

- Conducted by Raymond Slade
- April, 2009 to April, 2010
- Can gaged flow at USGS gage downstream be used to evaluate conditions in study area?
- Covered extremely dry period for first six months and then extremely wet period

Low-Flow Study



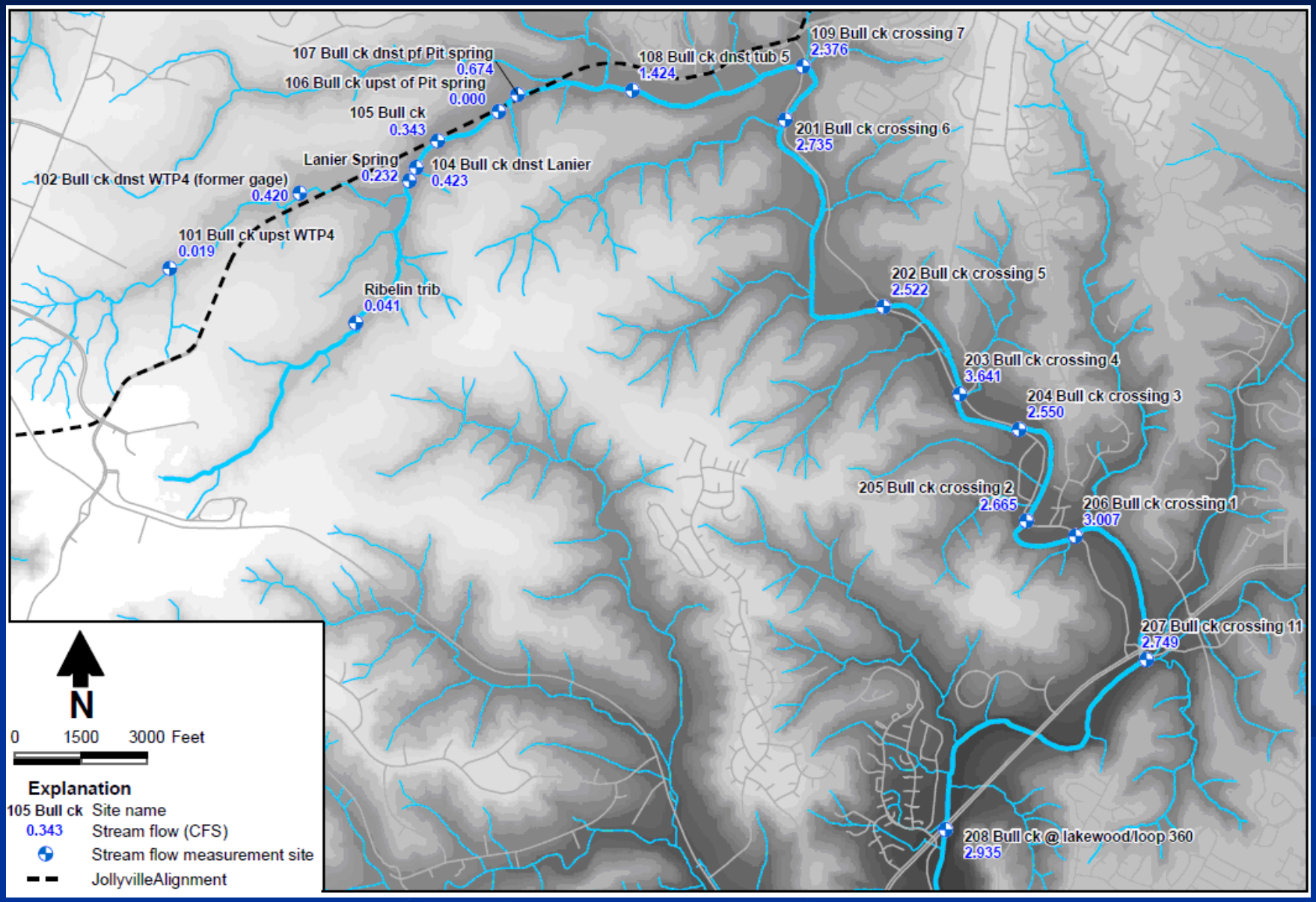
Low-Flow Study Results

- Provided good baseline data- both wet and dry periods monitored
- All locations monitored went dry during at least one month during the study
- Streamflow variation related to drainage area size
- Cannot draw a relationship between USGS gage downstream and flow in study area

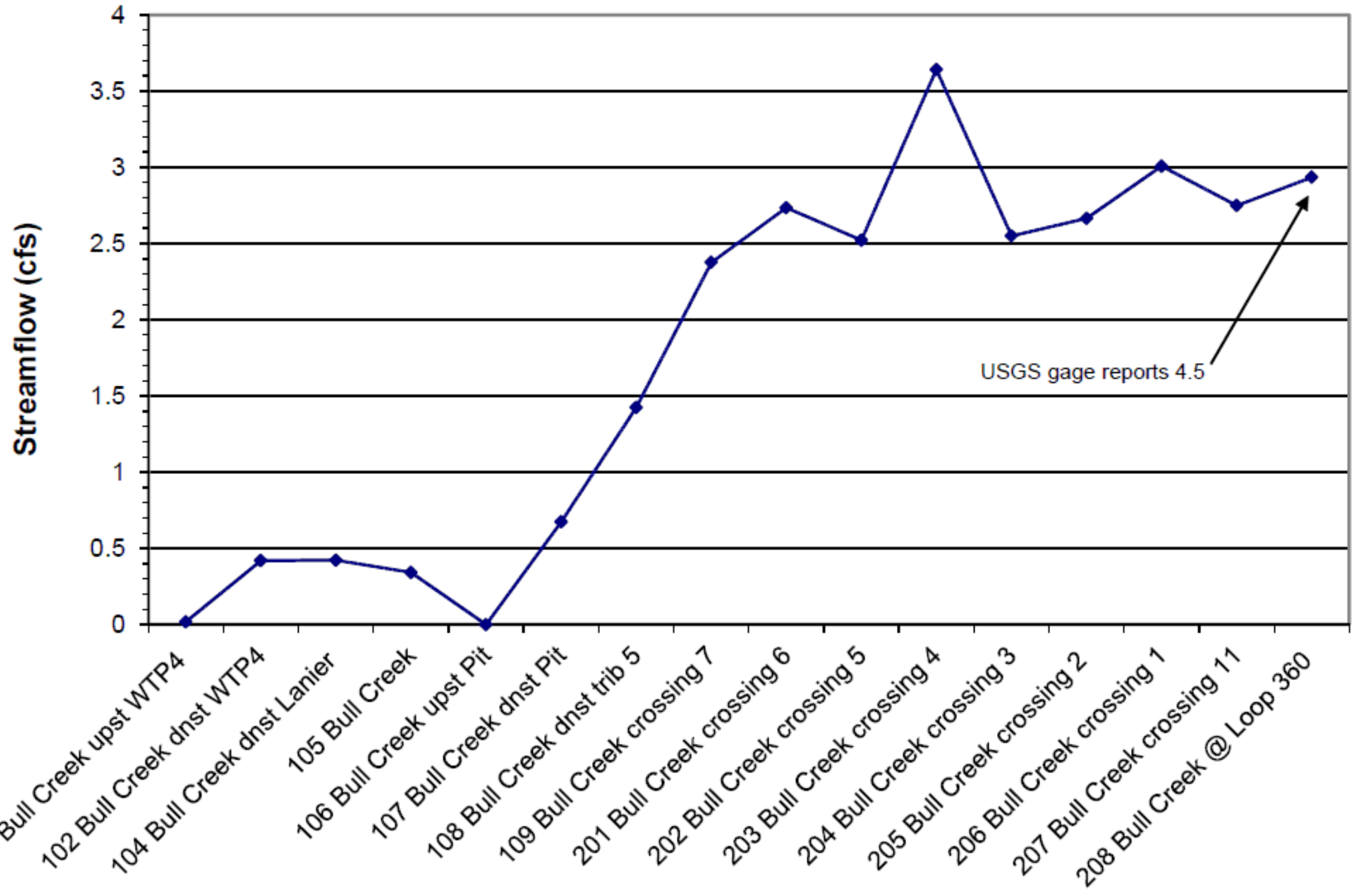
Gain-Loss Study

- Conducted by City of Austin staff
- Conducted over a single day
- Intent was to measure streamflow along Bull Creek to determine gains and/or losses along Bull Creek

Gain-Loss Study



Gain-Loss Study Results



Bull Creek Study Results

- Bull Creek streamflow went dry at all locations in at least one month during the year-long low-flow study
- Bull Creek streamflow increases through the study area and down to Lake Austin
- One area where Bull Creek dries up is where streamflow is lost into gravel in the channel and flow reemerges downstream

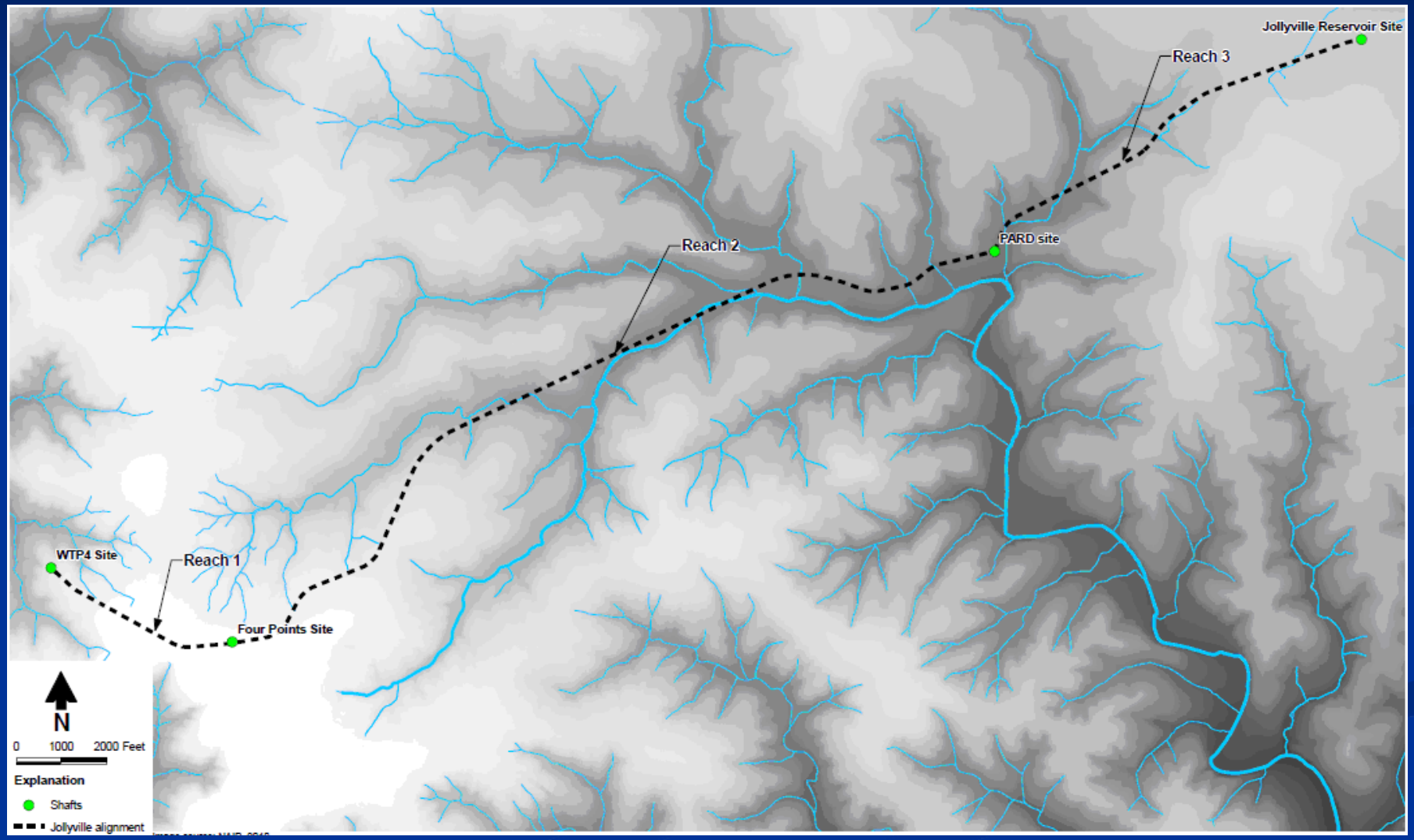
Project Specific Impact Assessments

- Shafts- Four proposed shaft locations (WTP4, Four Points, PARD, Jollyville Reservoir)
- Tunnel- Divided up into three reaches, separated by shaft locations

Shaft Locations

- Water Treatment Plant No. 4
- Four Points
- PARD
- Jollyville Reservoir

Shaft Locations



WTP4, Four Points, and Jollyville Reservoir Shafts

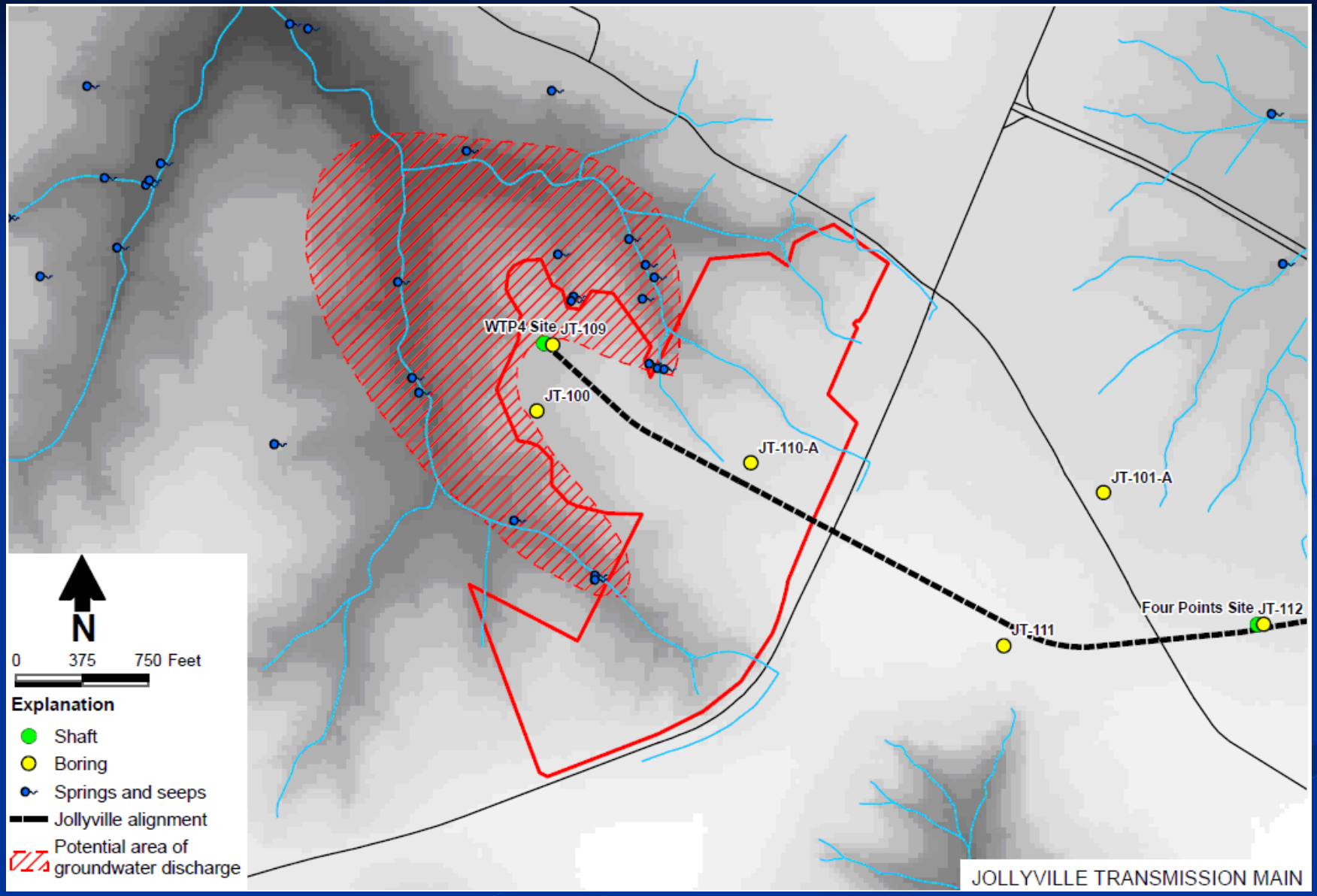
- Shaft will be completed through Edwards, Walnut, and Upper Glen Rose
- Unable to determine if individual conduits will be encountered when installing the shaft, and if they are, what the impact will be
- Inflow to shafts will be minimal, and are not expected to dewater the formation

Potential outcomes of a shaft near a spring....

- No conduits are intersected by the shaft
- A conduit is intersected but groundwater flow to the spring is not via that conduit
- A conduit is intersected but the groundwater finds an alternate path to the original discharge point
- A conduit is intersected but the groundwater flow is restored through mitigation measures
- A conduit is intersected and groundwater flow is not restored along the same path, but this conduit is not the sole source of water for a particular spring
- A conduit is intersected, groundwater flow is not restored, and the springflow is eliminated or reduced

Water Treatment Plant 4

- Less potential impact to Upper Bull Creek
- Opposite side of groundwater divide
- No significant mapped springs nearby

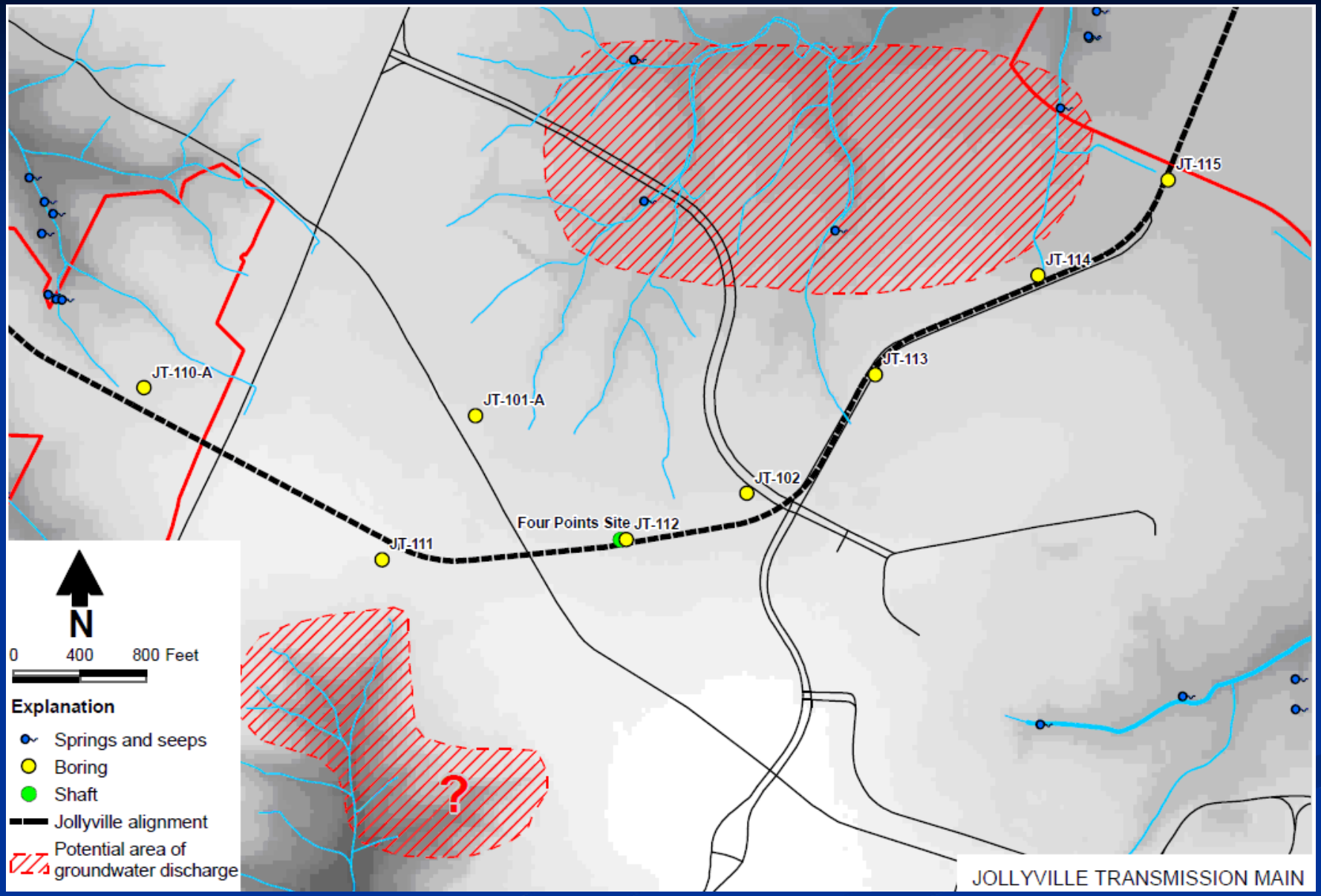

WTP4 Site JT-109
JT-100
JT-110-A
JT-101-A
JT-111
Four Points Site JT-112
N
0 375 750 Feet
Explanation
Shaft
Boring
Springs and seeps
Jollyville alignment
Potential area of groundwater discharge
JOLLYVILLE TRANSMISSION MAIN

Jollyville Reservoir

- Little potential environmental impact
- In heavily developed area
- Large distance to nearest spring

Four Points

- Likely near groundwater divide
- In upper portions of watershed on topographic high
- Closest spring ~2,000 feet away
- Water movement presumed to be to the north/northeast
- Will require dye tracing to definitively delineate direction of groundwater movement


JT-115
JT-114
JT-113
JT-110-A
JT-101-A
JT-102
Four Points Site JT-112
JT-111
?
N
0 400 800 Feet
Explanation
Springs and seeps
Boring
Shaft
Jollyville alignment
Potential area of groundwater discharge
JOLLYVILLE TRANSMISSION MAIN

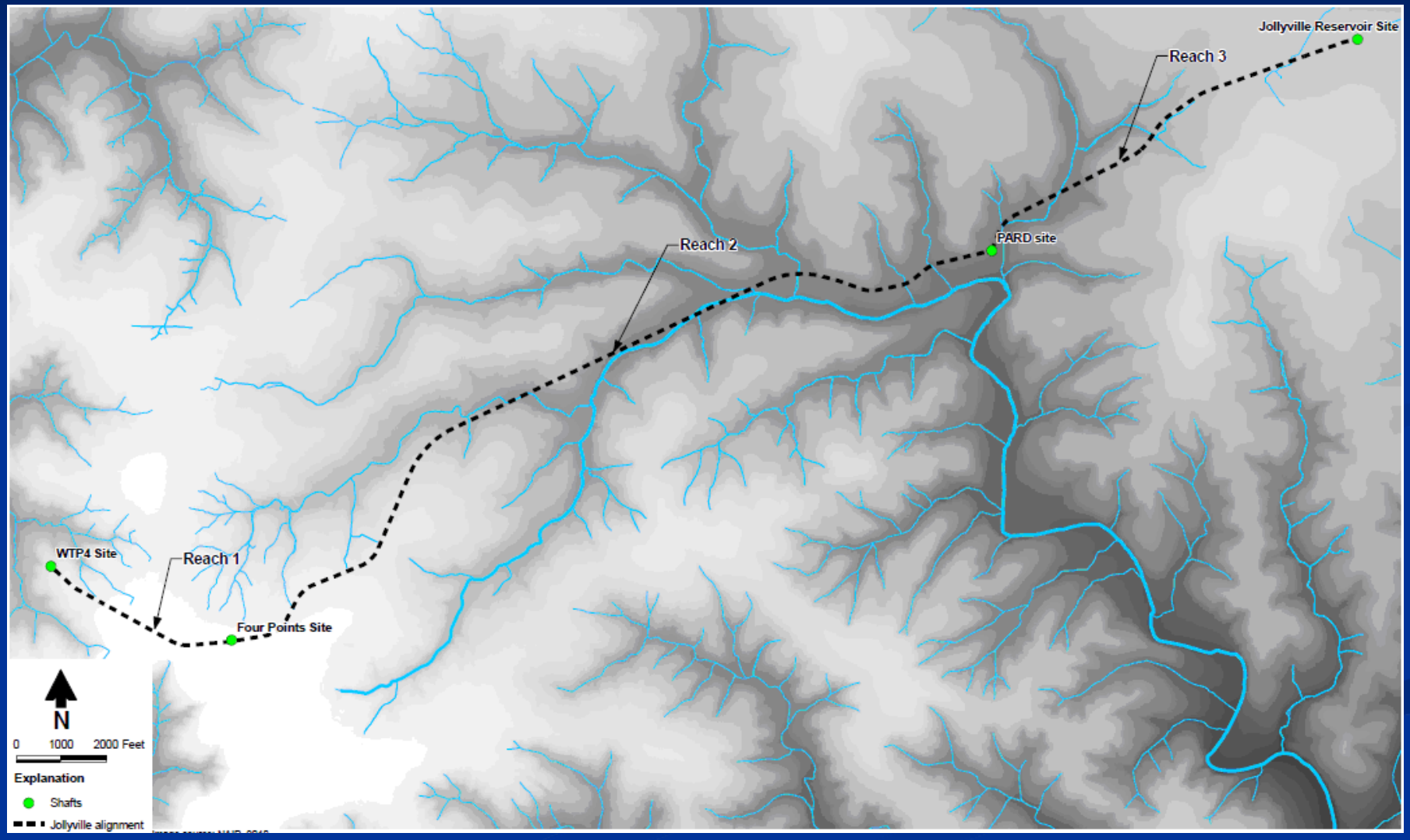
PARD Shaft

- Located in a stream valley and not on the hilltops
- Shaft will be completed through only the Upper Glen Rose Formation
- Should not directly impact any springs
- Will not impact Bull Creek because the water level in the shaft is above the creek

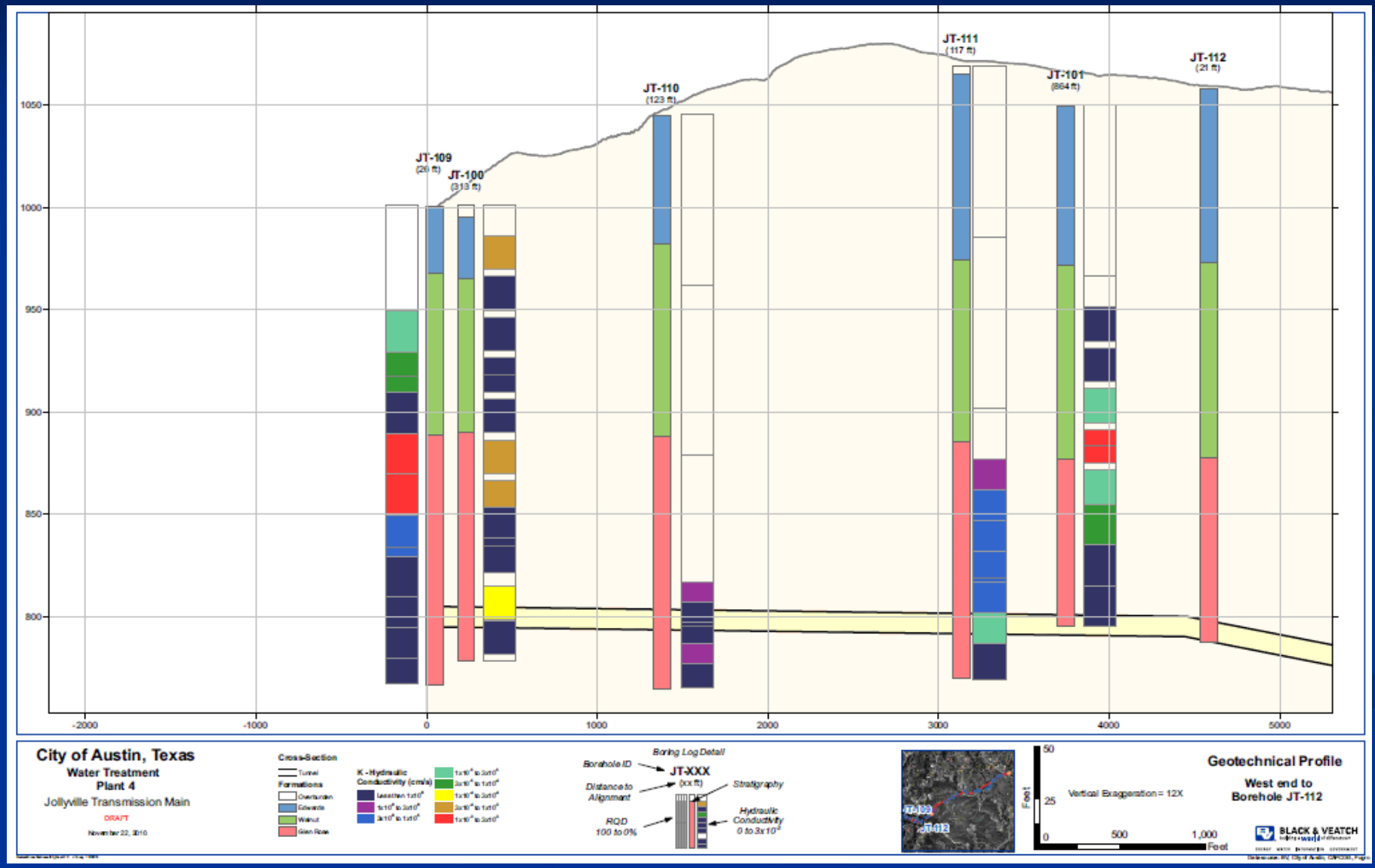
Tunnel

- Can generally be divided up into three “reaches”
- Reaches 1, 2, and 3 area separated by the four shafts

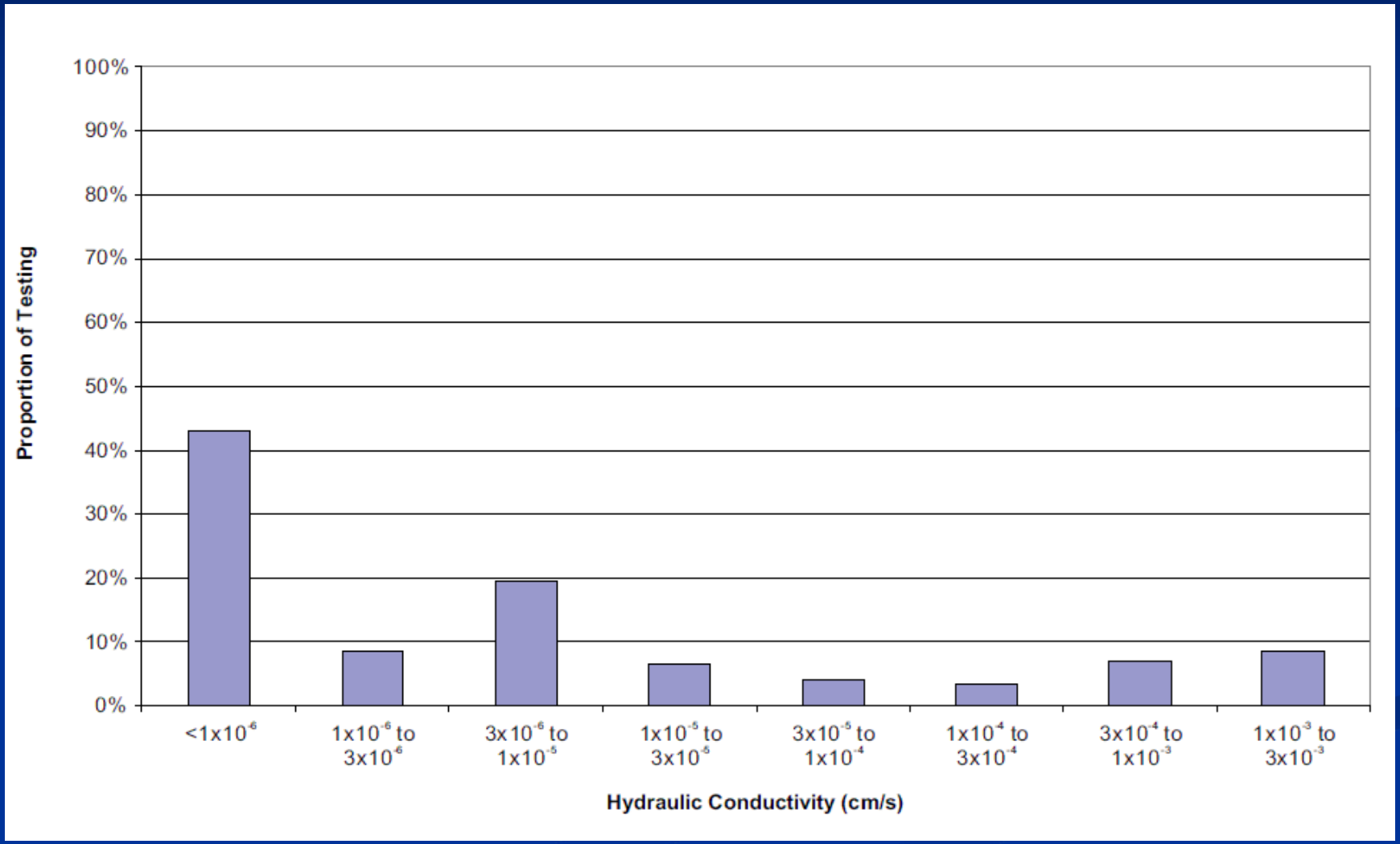
Tunnel Reaches



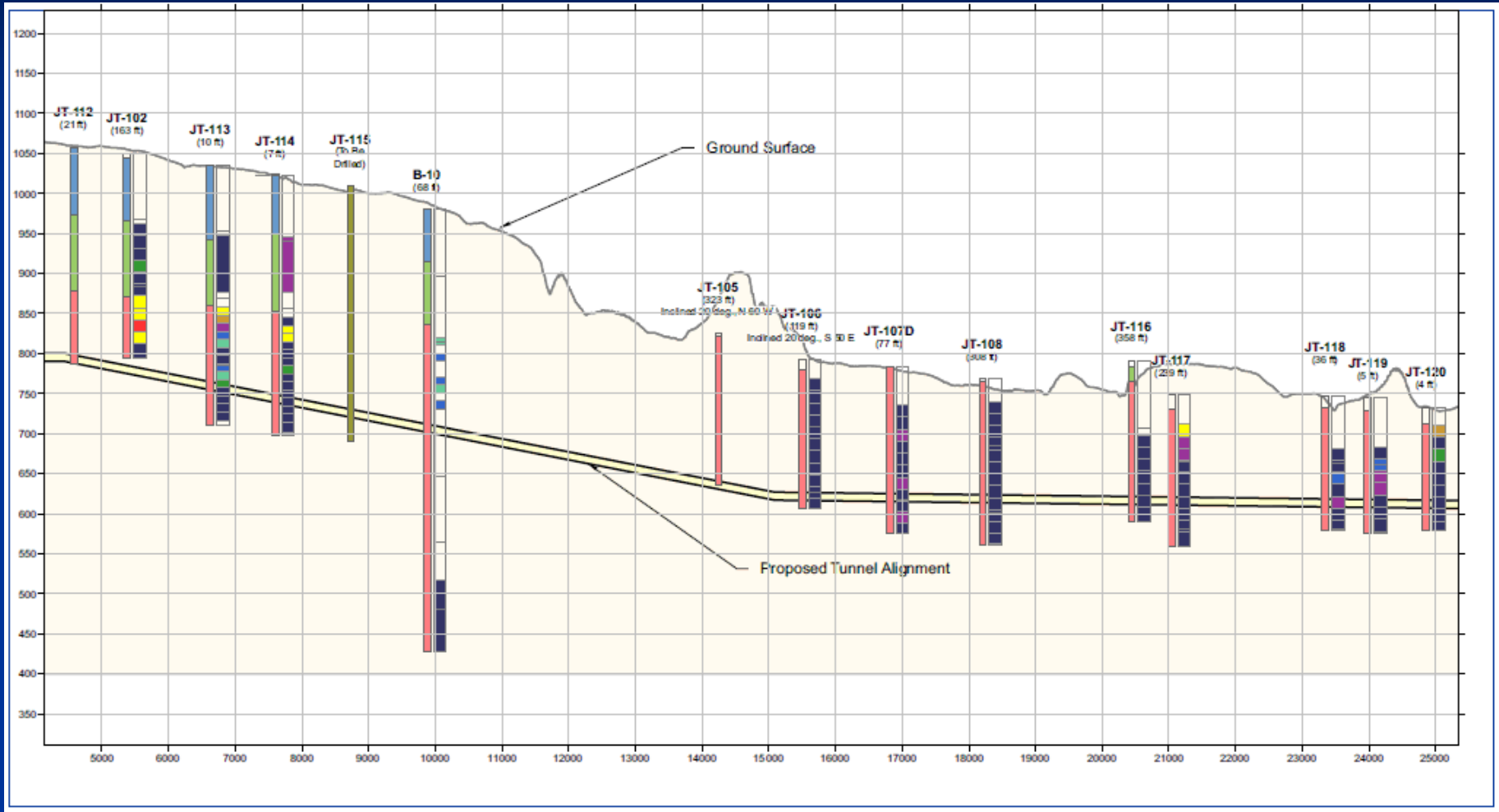
Reach 1


JT-109
(26 ft)
JT-100
(313 ft)
JT-110
(123 ft)
JT-111
(117 ft)
JT-101
(864 ft)
JT-112
(21 ft)
1050
1000
950
900
850
800
-2000
-1000
0
1000
2000
3000
4000
5000
City of Austin, Texas
Water Treatment
Plant 4
Jollyville Transmission Main
DRAFT
November 22, 2010
Cross-Section
Tunnel
Formations
Overburden
Edwards
Walnut
Glen Rose
K - Hydraulic
Conductivity (cm/s)
Boring Log Detail
Borehole ID
JT-XXX
(xx ft)
Distance to
Alignment
Stratigraphy
RQD
100 to 0%
Hydraulic
Conductivity
0 to 3x10
JT-109
JT-112
Feet
50
25
0
Vertical Exaggeration = 12X
500
1,000
Feet
Geotechnical Profile
West end to
Borehole JT-112
BLACK & VEATCH

Reach 1 Hydraulic Conductivities



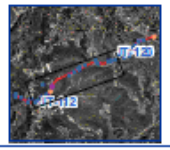
Reach 2



City of Austin, Texas
Water Treatment Plant 4
Jollyville Transmission Main
DRAFT
November 22, 2010

Cross-Section
Tunnel
Formations
Overburden
Edwards
Walnut
Glen Rose
K - Hydraulic Conductivity (cm/s)
Less than $1x10^{-6}$
$1x10^{-6}$ to $3x10^{-6}$
$3x10^{-6}$ to $1x10^{-5}$
$1x10^{-5}$ to $3x10^{-5}$
$3x10^{-5}$ to $1x10^{-4}$
$1x10^{-4}$ to $3x10^{-4}$
$3x10^{-4}$ to $1x10^{-3}$
$1x10^{-3}$ to $3x10^{-3}$

Boring Log Detail
Borehole ID → JT-XXX (xx ft)
Distance to Alignment
RQD 100 to 0%
Stratigraphy
Hydraulic Conductivity 0 to $3x10^{-3}$

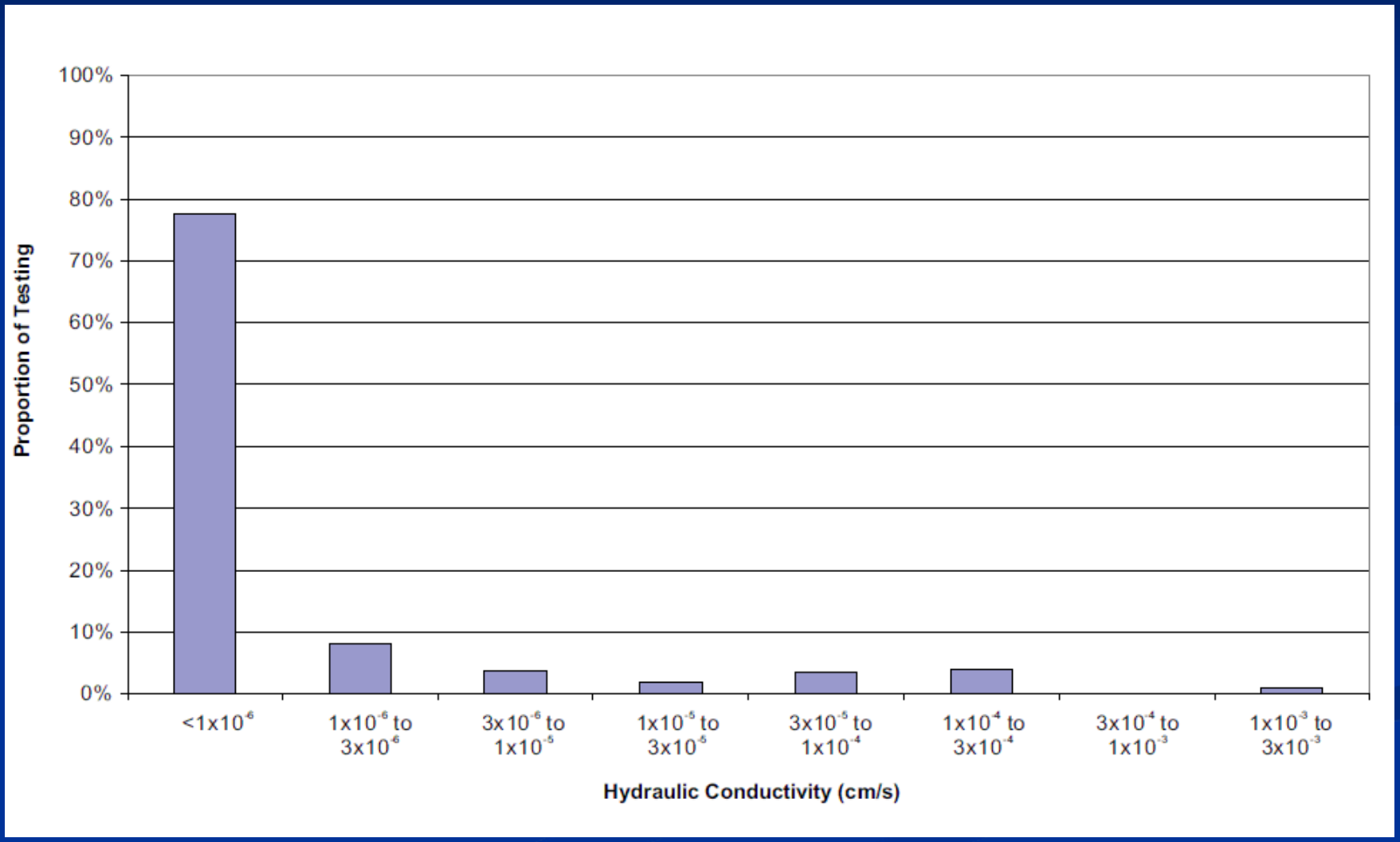


Feet
50
25
0
0 500 1,000
Feet

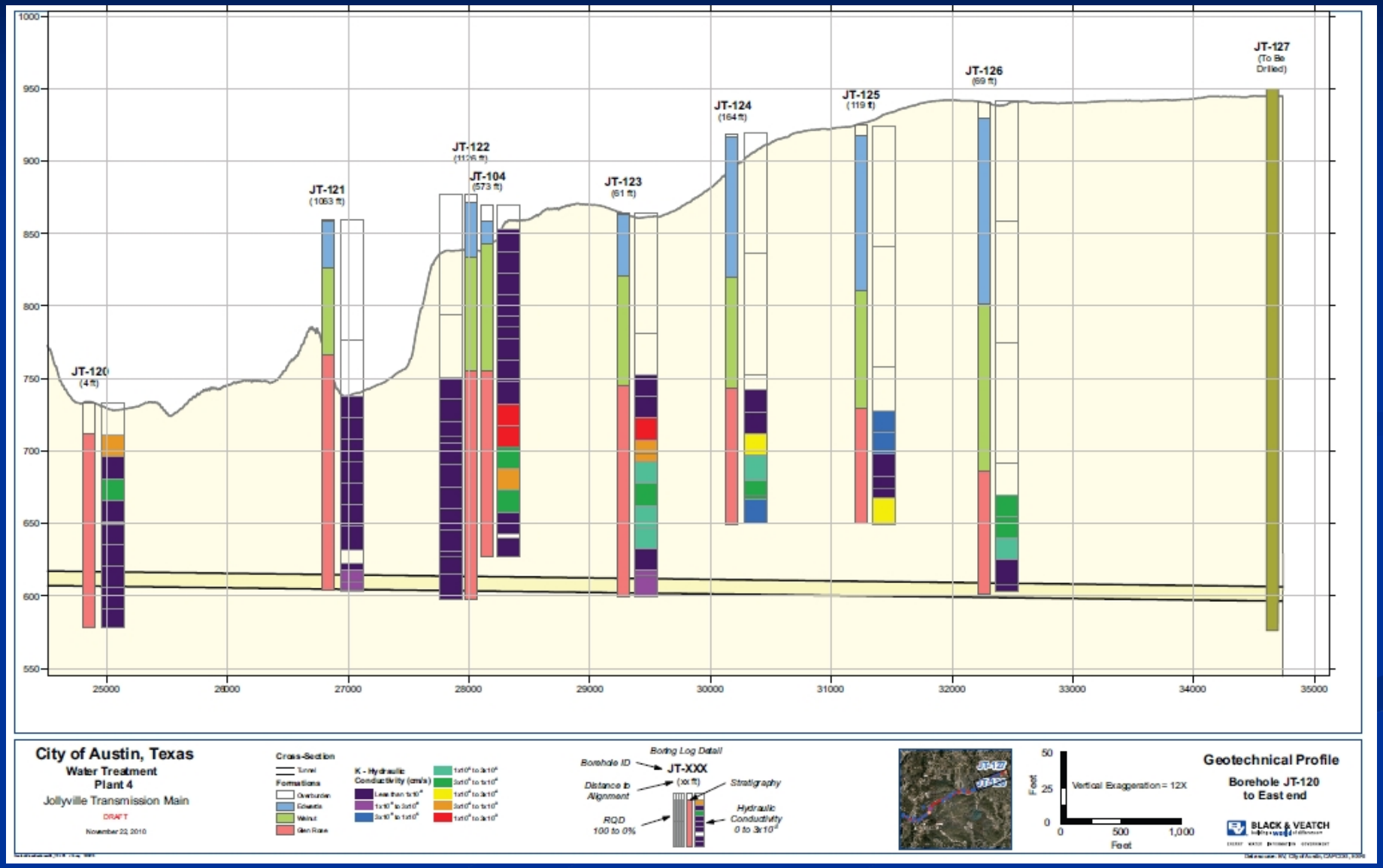
Geotechnical Profile
Boreholes JT-112 to JT-120

BLACK & VEATCH

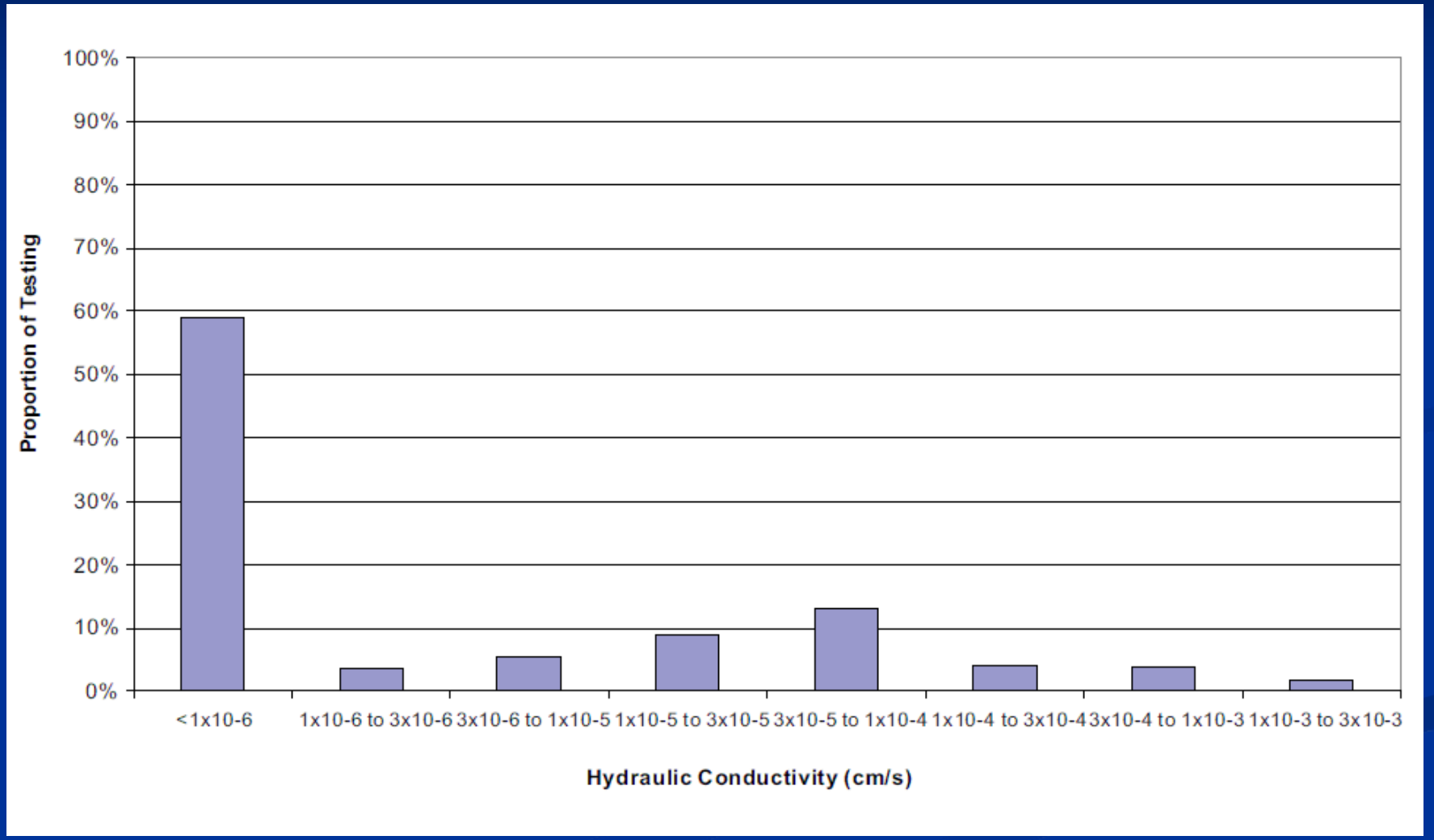
Reach 2 Hydraulic Conductivities



Reach 3


JT-120
(4 ft)
JT-121
(1083 ft)
JT-122
(1126 ft)
JT-104
(573 ft)
JT-123
(61 ft)
JT-124
(164 ft)
JT-125
(119 ft)
JT-126
(69 ft)
JT-127
(To Be Drilled)
1000
950
900
850
800
750
700
650
600
550
25000
26000
27000
28000
29000
30000
31000
32000
33000
34000
35000
City of Austin, Texas
Water Treatment Plant 4
Jollyville Transmission Main
DRAFT
November 22, 2010
Cross-Section
Tunnel
Formations
Overburden
Edwards
Walnut
Glen Rose
K - Hydraulic Conductivity (cm/s)
Less than 1x10⁻⁶
1x10⁻⁶ to 3x10⁻⁶
3x10⁻⁶ to 1x10⁻⁵
1x10⁻⁵ to 3x10⁻⁵
3x10⁻⁵ to 1x10⁻⁴
1x10⁻⁴ to 3x10⁻⁴
3x10⁻⁴ to 1x10⁻³
1x10⁻³ to 3x10⁻³
Boring Log Detail
Borehole ID
JT-XXX
(xx ft)
Distance to Alignment
RQD
100 to 0%
Stratigraphy
Hydraulic Conductivity
0 to 3x10⁻³
50
25
0
Feet
Vertical Exaggeration = 12X
0
500
1,000
Feet
Geotechnical Profile
Borehole JT-120
to East end
BLACK & VEATCH

Reach 3 Hydraulic Conductivities



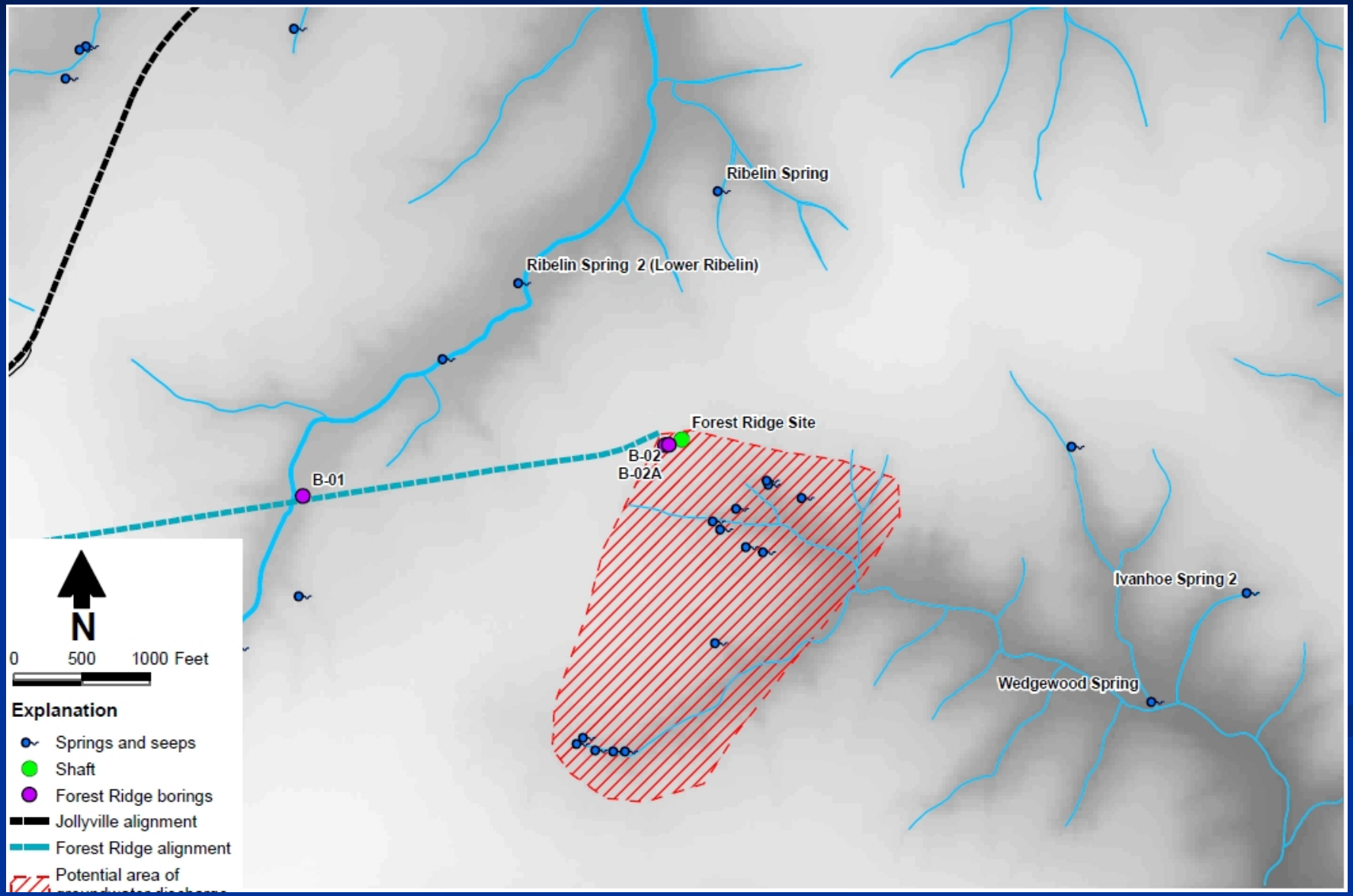
Tunnel Summary

- Constructed in deeper section of Upper Glen Rose Formation
- Hydraulic conductivities are much lower in this portion of the Upper Glen Rose, groundwater flow is primarily downward
- Not expected to impact shallower flow system, and therefore not expected to impact spring and seep discharge

Forest Ridge

- Although not part of the JTM project, impacts of the proposed Forest Ridge shaft location similar to those for the JTM project
- Forest Ridge shaft impacts similar to WTP4, Four Points, and Jollyville Reservoir

Forest Ridge



Conclusions

- Two groundwater flow systems--Edwards/Walnut and Upper Glen Rose
- Springs and seeps in study area supplied by discharge from the Edwards/Walnut system
- Impossible to determine if any individual shaft will intersect conduits supplying discharge to any particular spring
- Tunnel being installed in deeper portions of Glen Rose, where hydraulic conductivities are low--will not impact upper flow system

Questions???