# Stream Depletion Zones

## Montana Bureau of Mines and Geology

presented to:
Water Policy Interim Committee
March 18, 2014
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Montana Bureau of Mines and Geology

WATER POLICY INTERIM
COMMITTEE. 2013-14

March 18, 2014 Exhibit No. 5

# Some ground rules…

Stream Depletion from ground water pumping results from reduced ground water flow to the stream (sometimes called "capture") and/or induced flow from the stream. NOTE: this discussion assumes 100% consumptive use.

Stream Depletion is independent of stream discharge
same effect whether 1000 cfs or 10 cfs

Unless, of course, you dry up the stream

Stream Depletion is independent of well interference
it is both **cumulative** and additive
1 well pumping 500 gpm
has the same effect as
50 wells pumping 10 gpm

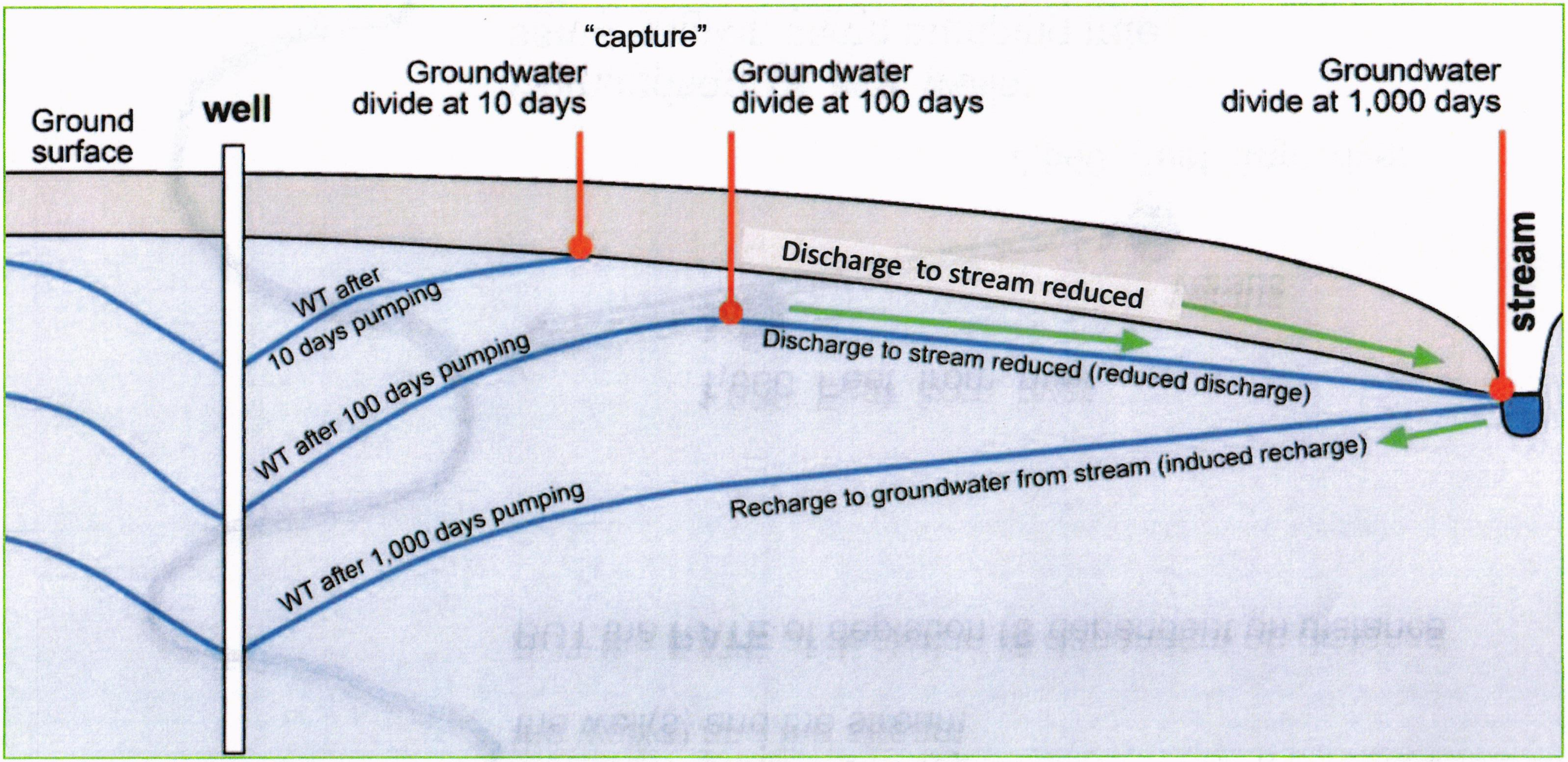
No difference between one and many

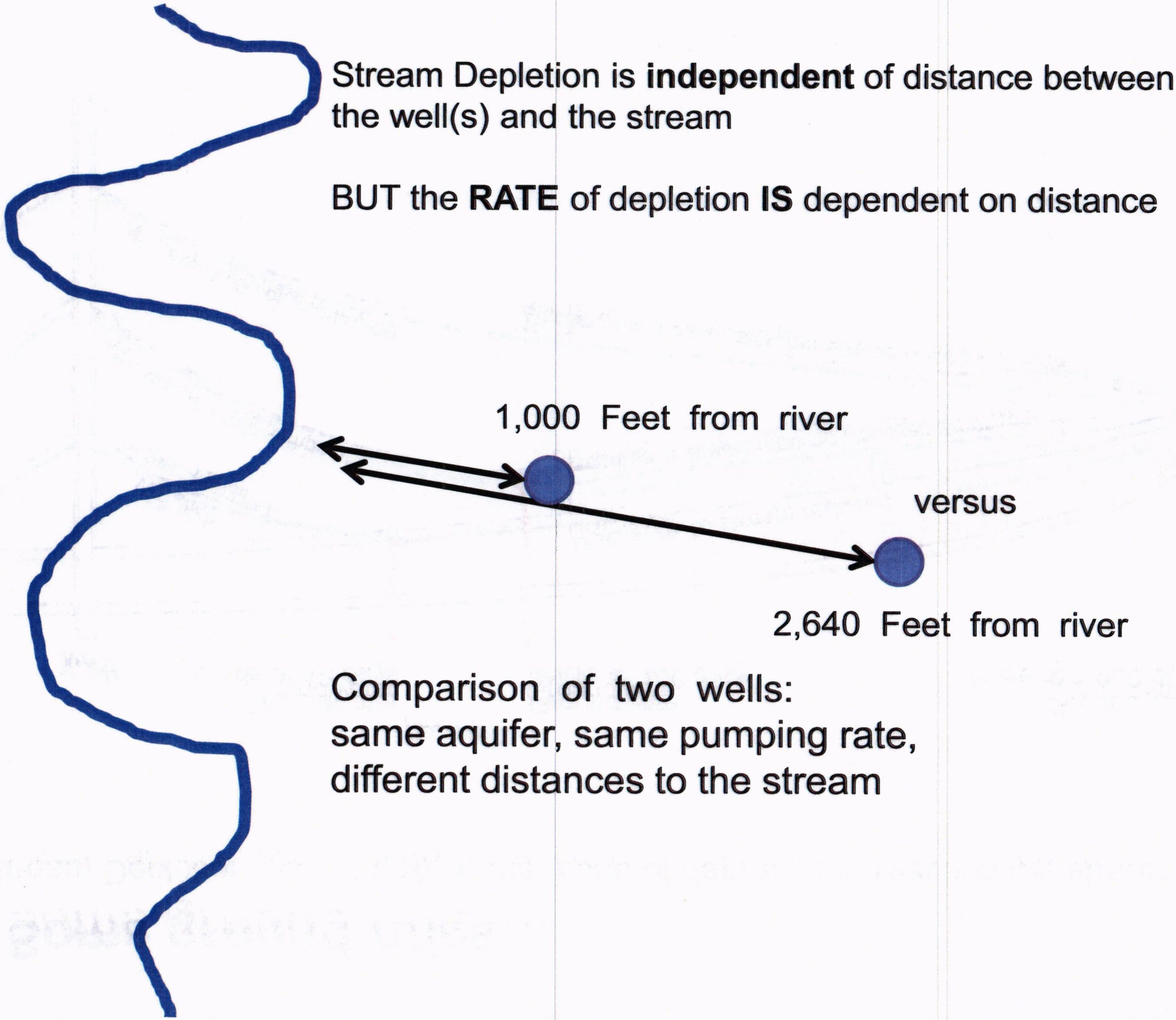
Stream Depletion is **independent** of distance between the well(s) and the stream

BUT the **RATE** of depletion **IS** dependent on distance

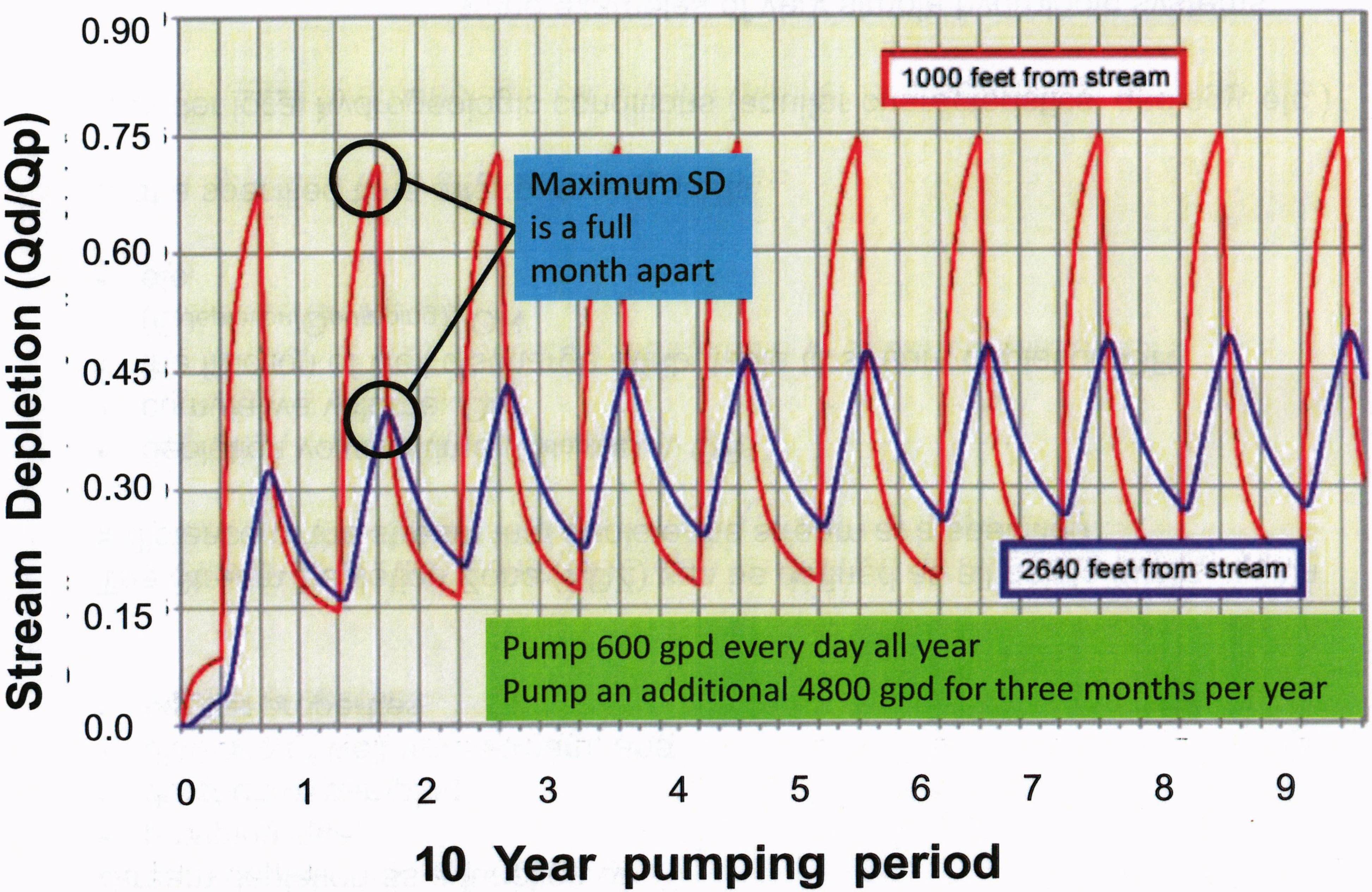
# Some ground rules…

Stream Depletion occurs **before** the "cone of depression" reaches the stream




Stream Depletion is **independent** of distance between the well(s) and the stream
BUT the **RATE** of depletion **IS** dependent on distance
1,000 Feet from river
versus
2,640 Feet from river
Comparison of two wells:
same aquifer, same pumping rate,
different distances to the stream

Depletion rate versus distance from stream



Stream depletion as a function of

- pumping rate,
- duration of pumping,
- distance of well from stream, and
- aquifer properties

The Stream Depletion Zone (SDZ) can be defined as all points (wells) within x-distance of the stream that deplete the stream at a specified…

- depletion volume/time ($Q_{depletion}$), OR
- cumulative volume, OR
- the fraction of well discharge attributable to stream depletion OR ($Q_{depletion}/Q_{pumping}$), OR
- etc.

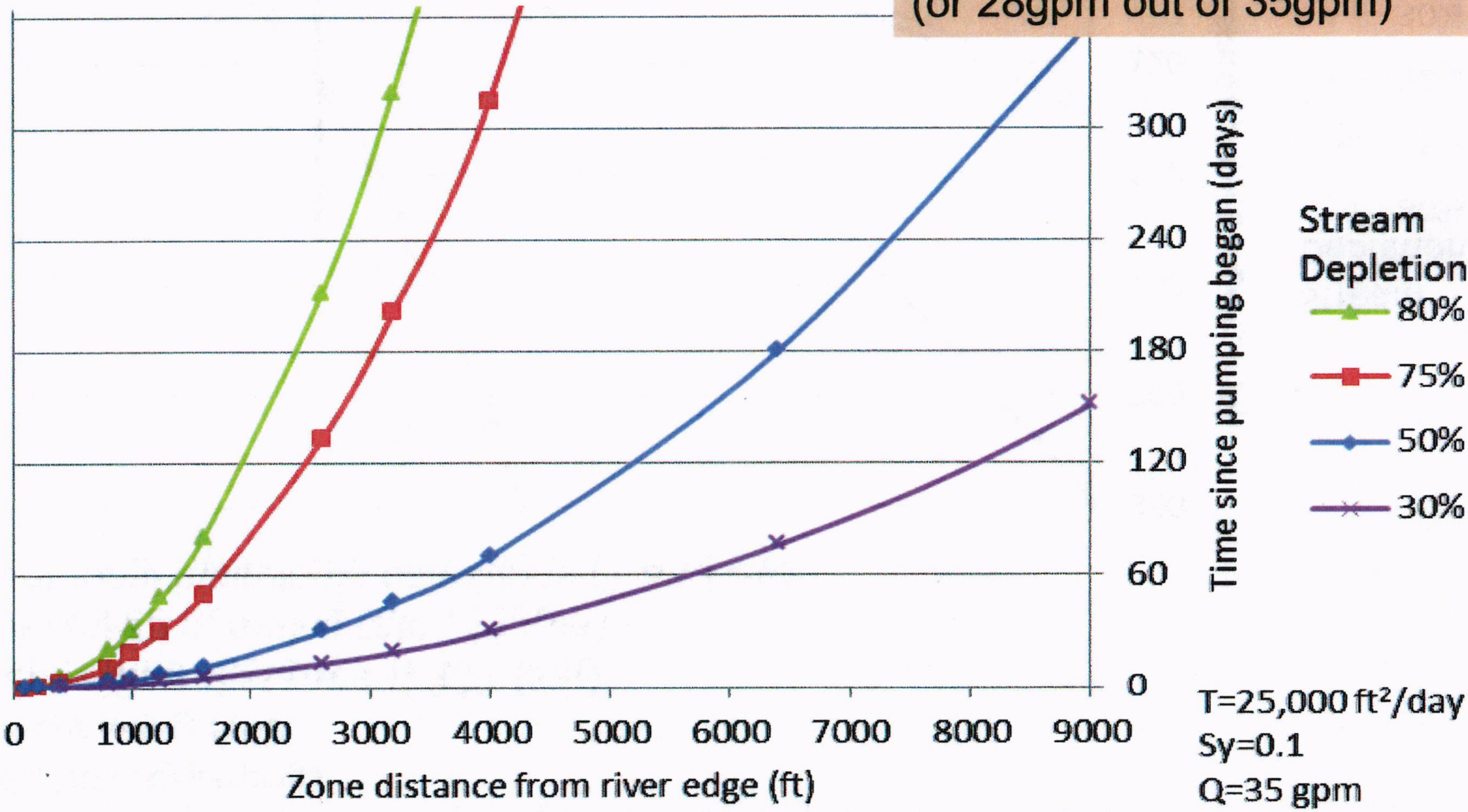
…at a specified time after pumping starts…

…under local hydrogeologic conditions (aquifer characteristics, geology, etc.)

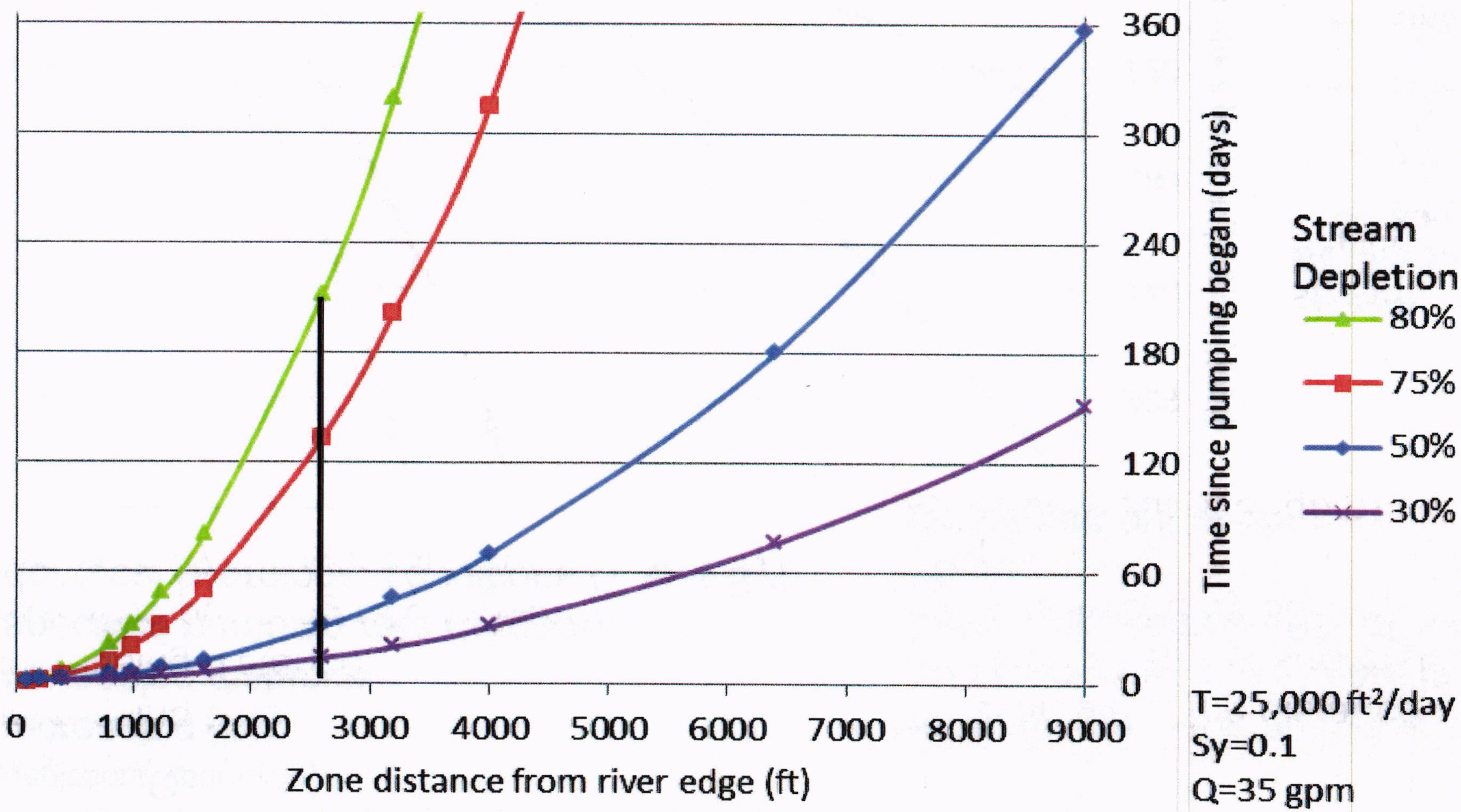
some examples of very simple hydrologic systems…

the fraction (%) of well discharge attributable to stream depletion ($Q_{depletion}/Q_{pumping}$)
at increasing time
at increasing distance
at specified pumping rate (35gpm),
under local hydrologic conditions (T and Sy)

for example… the distance and time when the stream is being depleted by 80% of 35gpm
(or 28gpm out of 35gpm)



the fraction (%) of well discharge attributable to stream depletion
($Q_{depletion}/Q_{pumping}$)
at increasing time
**at specified distance (2500 feet)**
at specified pumping rate (35gpm),
under local hydrologic conditions (T and Sy)



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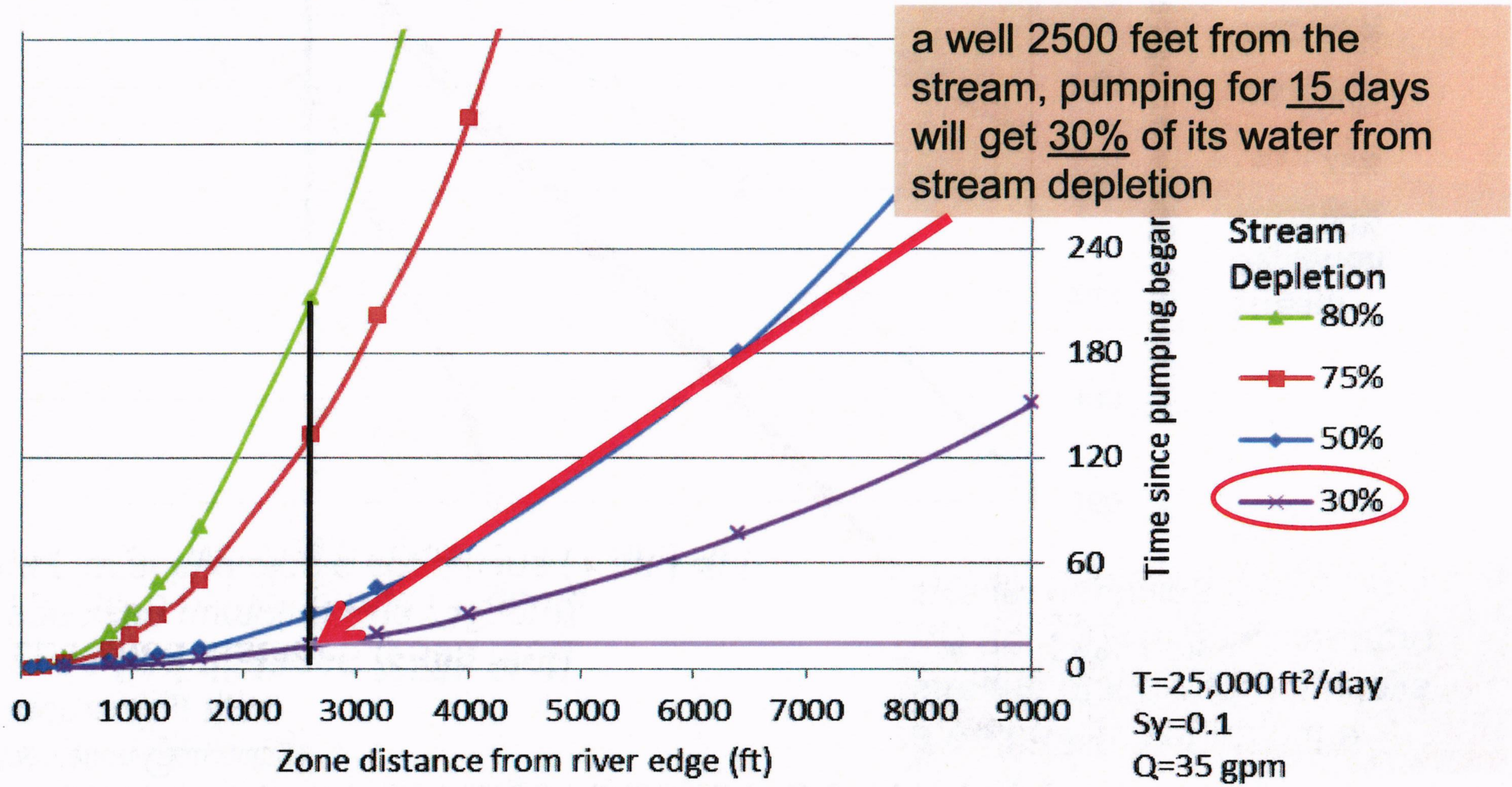

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**at specified distance (2500 feet)**
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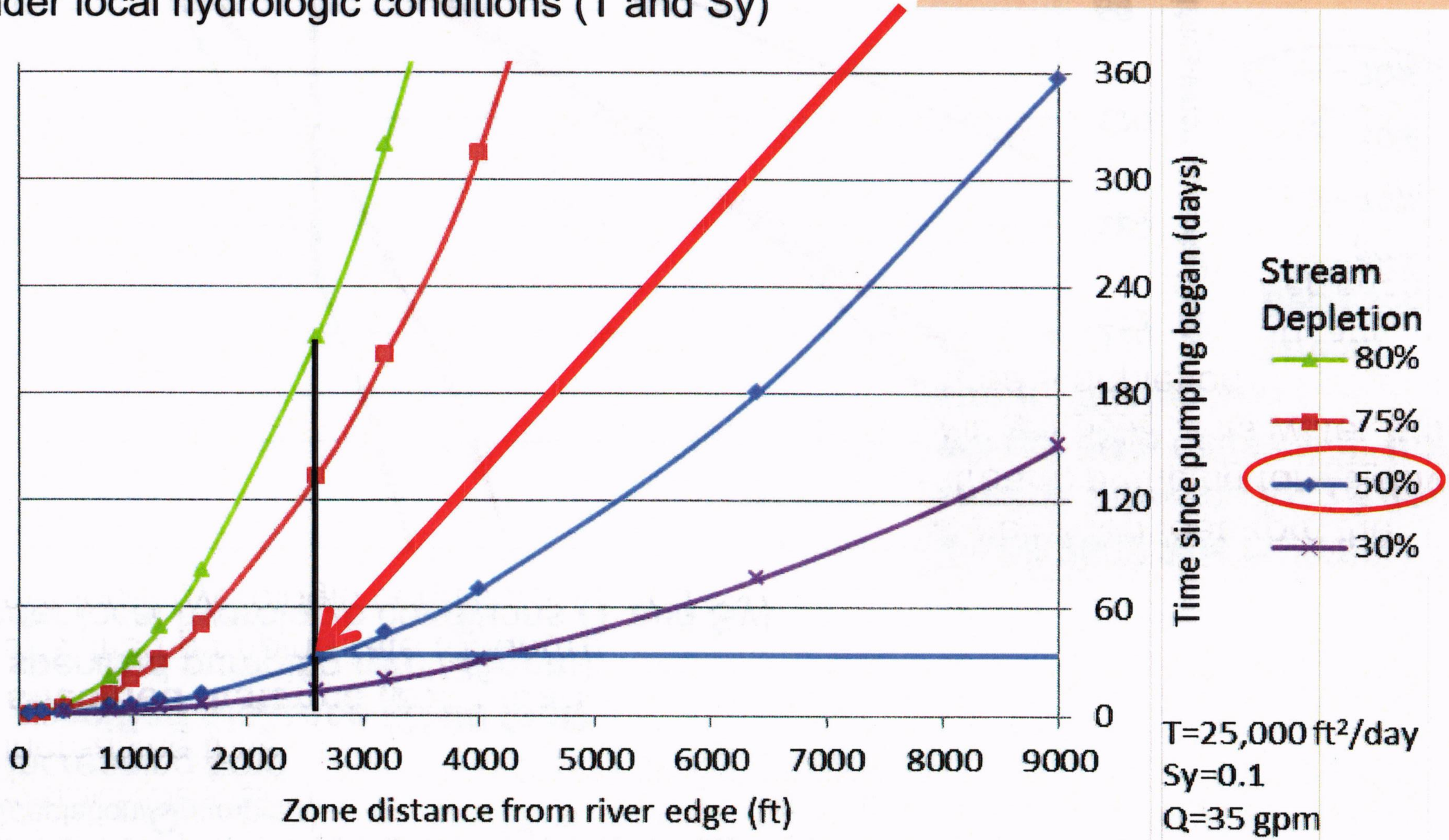
a well 2500 feet from the stream, pumping for 30 days will get 50% of its water from stream depletion



the fraction (%) of well discharge attributable to stream depletion
(Qdepletion/Qpu

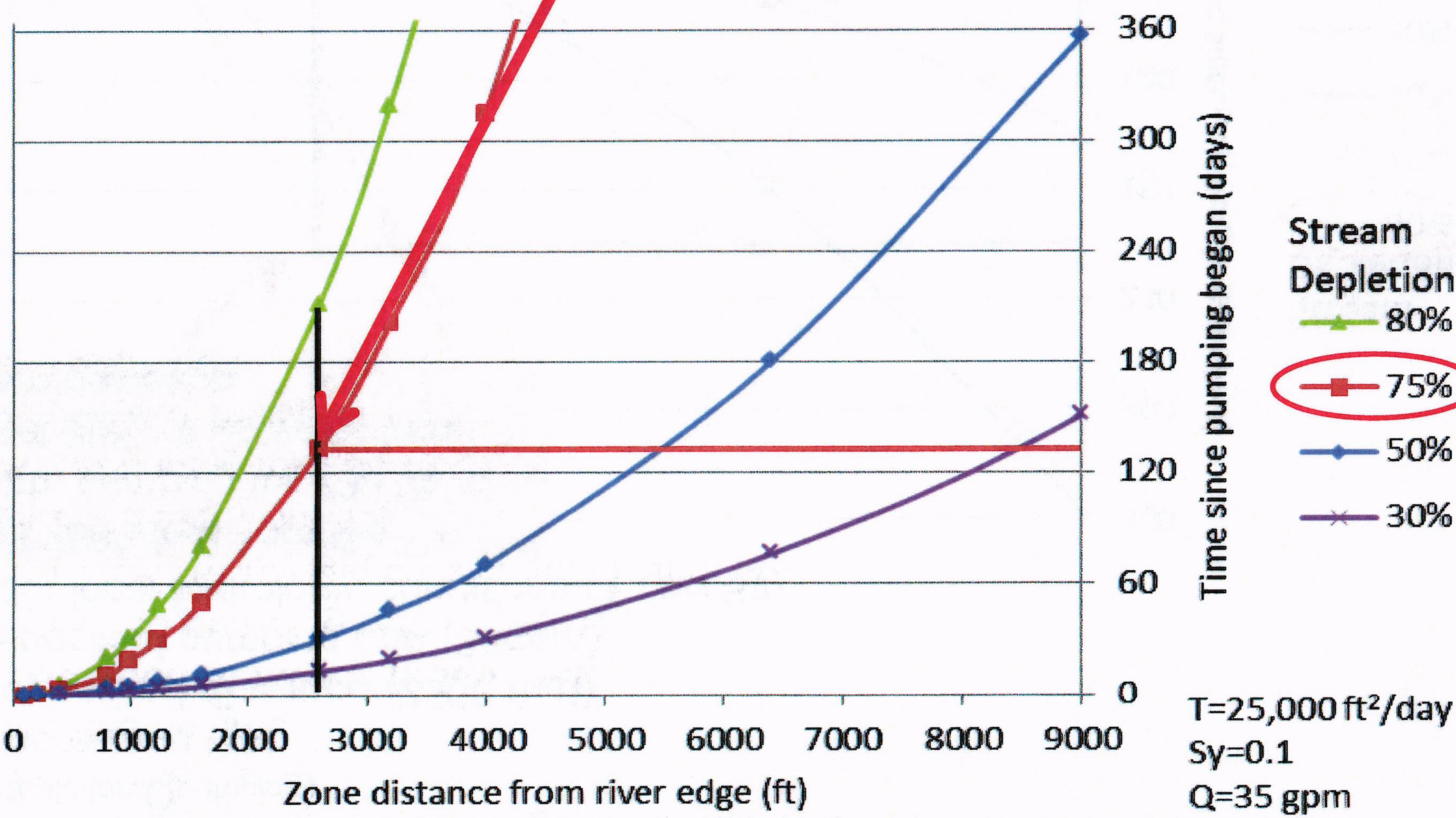
at increasing

**at specified**

at specified p

under local hydrologic conditions (T and Sy)

a well 2500 feet from the stream, pumping for 140 days will get 75% of its water from stream depletion



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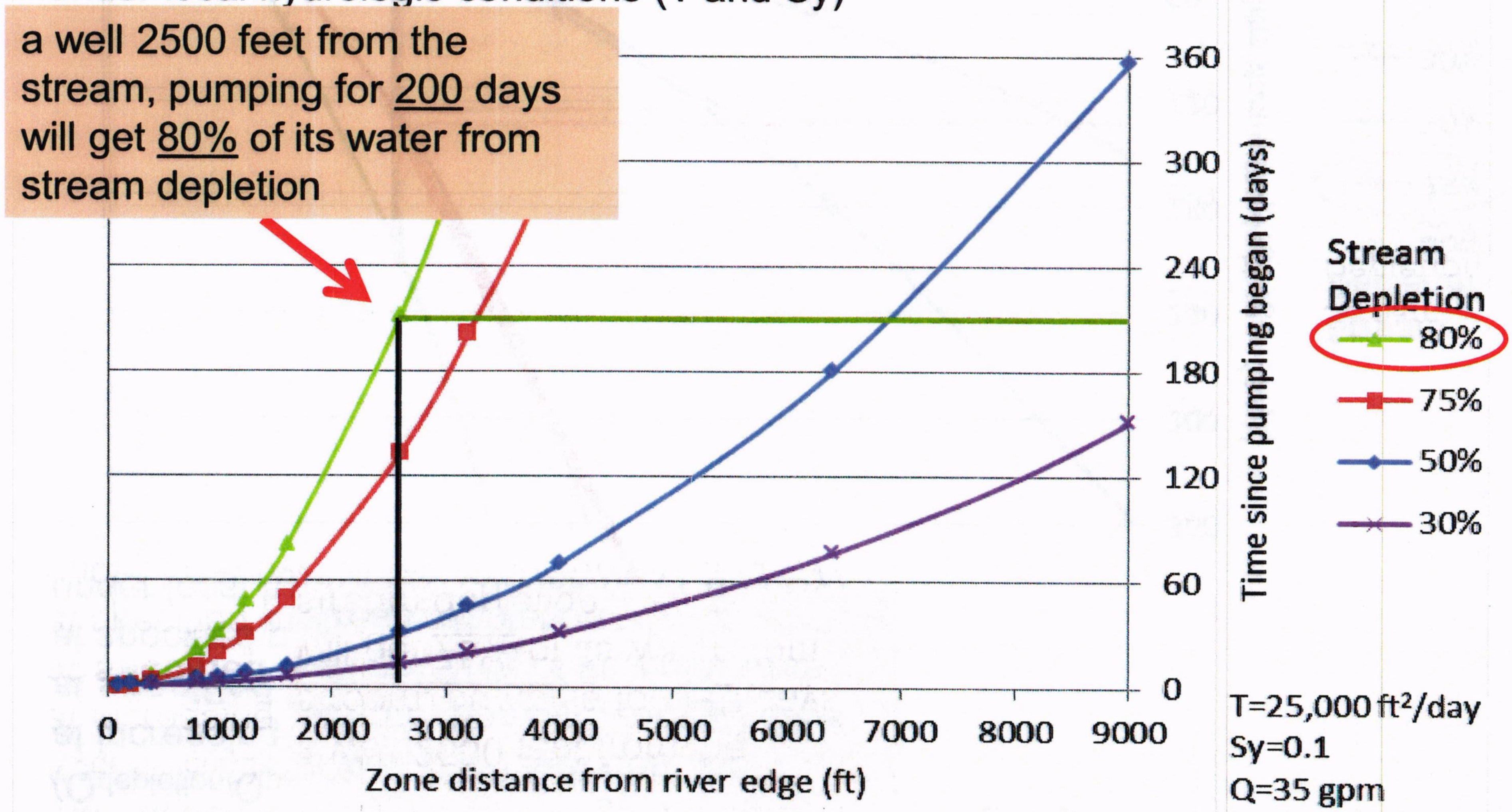
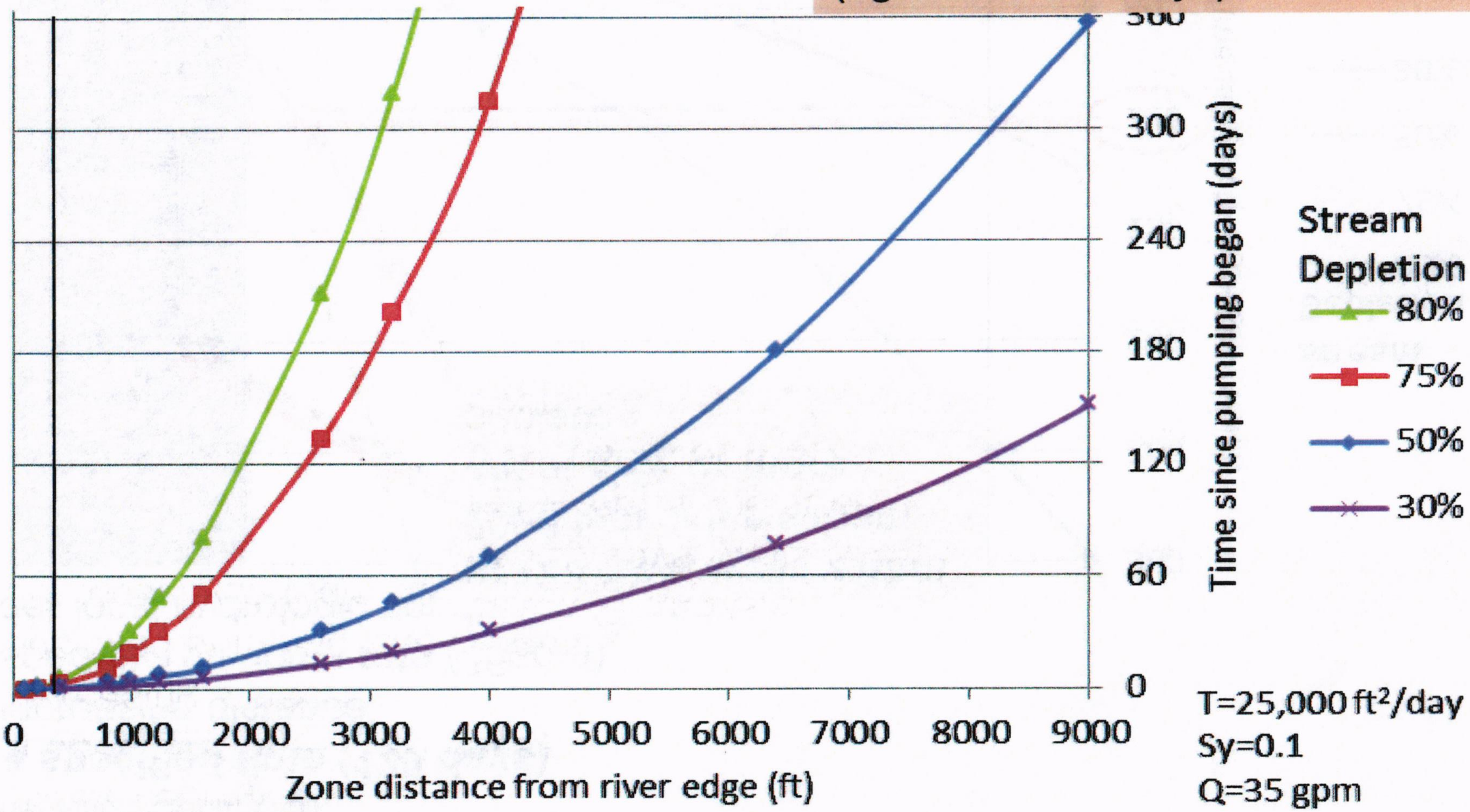


the fraction (%) of well discharge attributable to stream depletion ($Q_{depletion}/Q_{pumping}$)
**at a <u>specified</u> time (120 days)**
at increasing distance
at specified pumping rate (35gpm),
under local hydrologic conditions (T and Sy)

rather than use the same <u>distance</u> from the stream,
use the same pumping <u>duration</u>
(eg time = 120 days)



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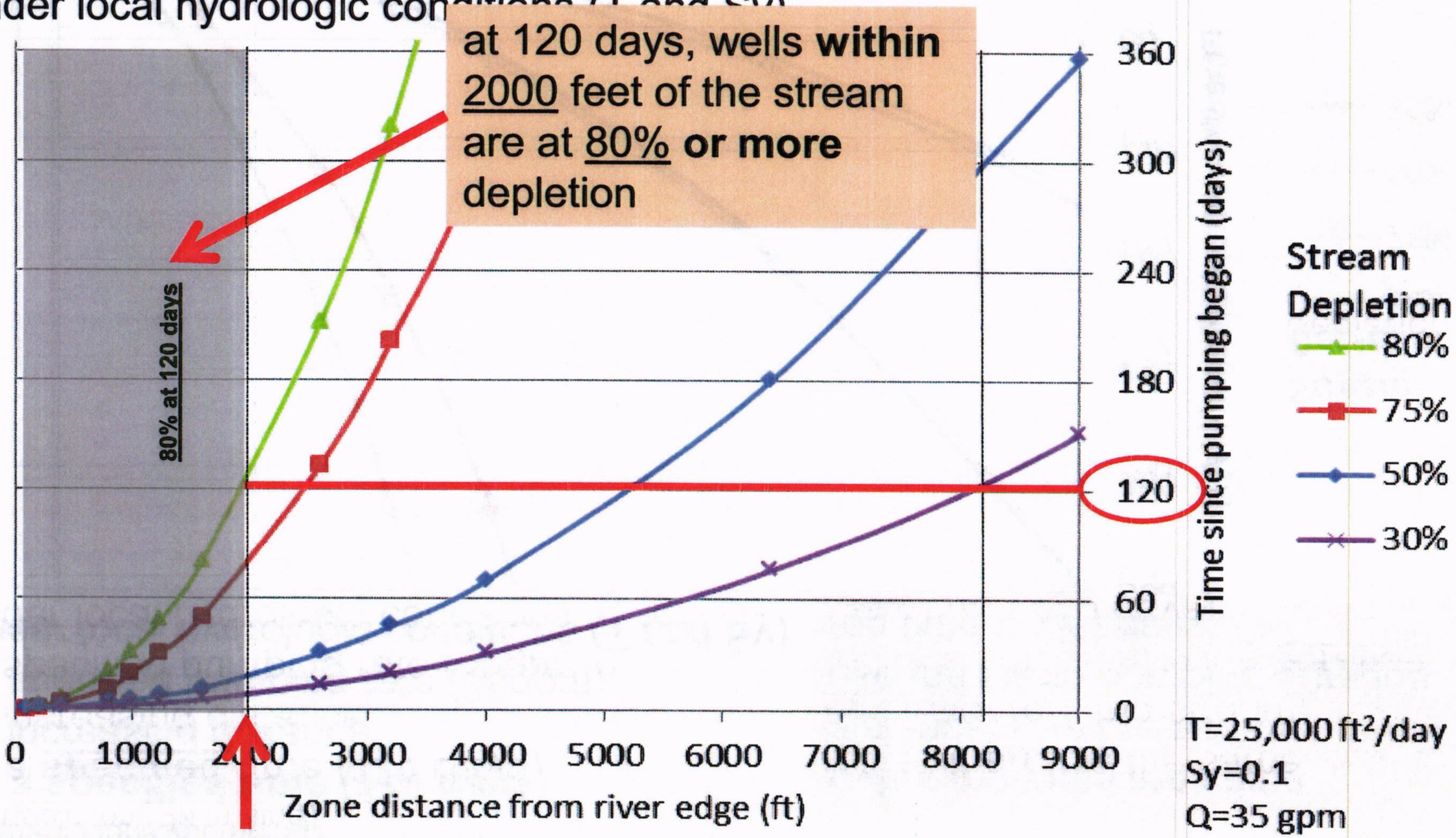

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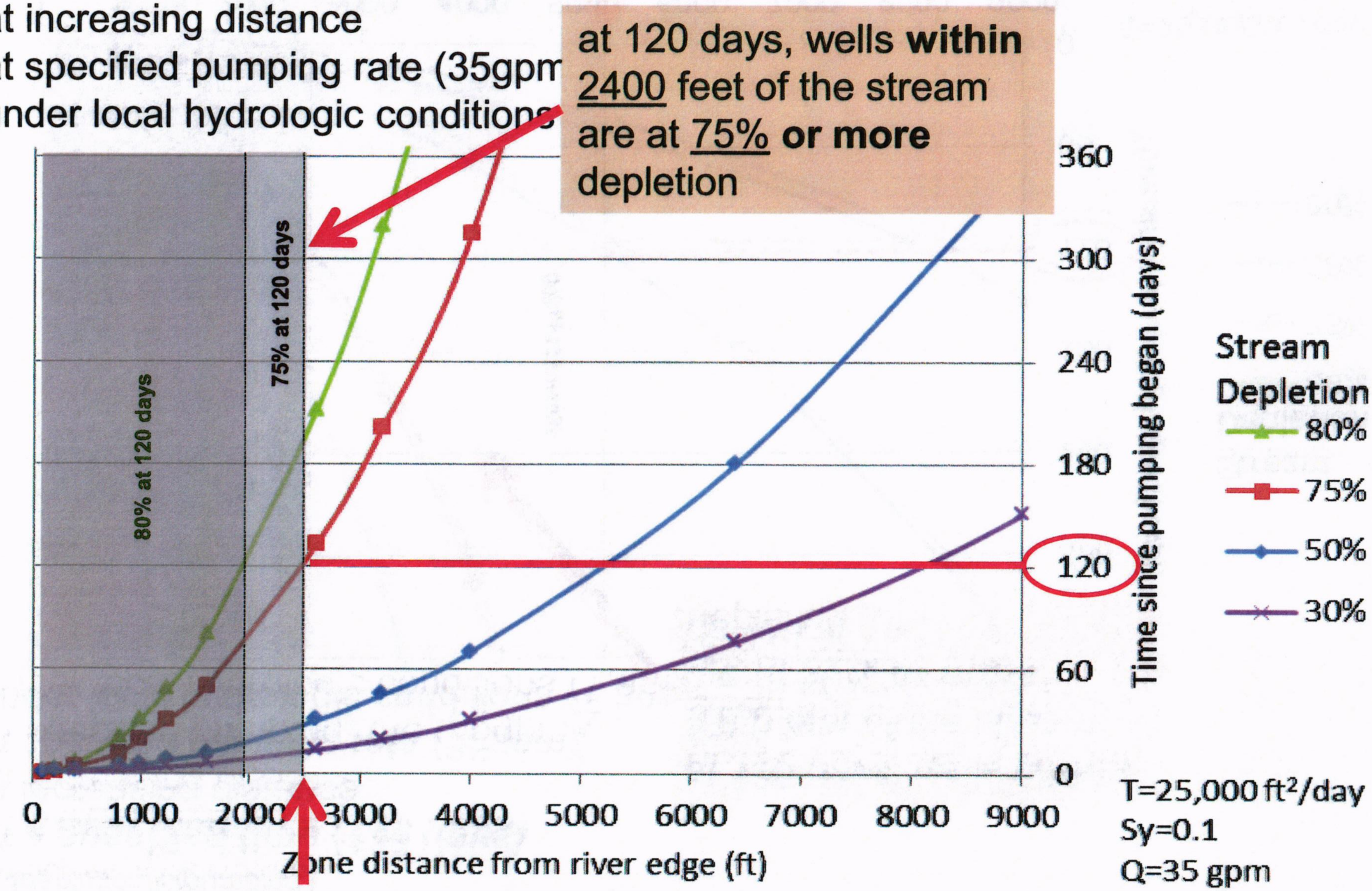
at increasing distance

at specified pumping rate (35gpm)

under local hydrologic conditions



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**at a <u>specified</u> time (120 days)**

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at specified pumping rate (35gpm),

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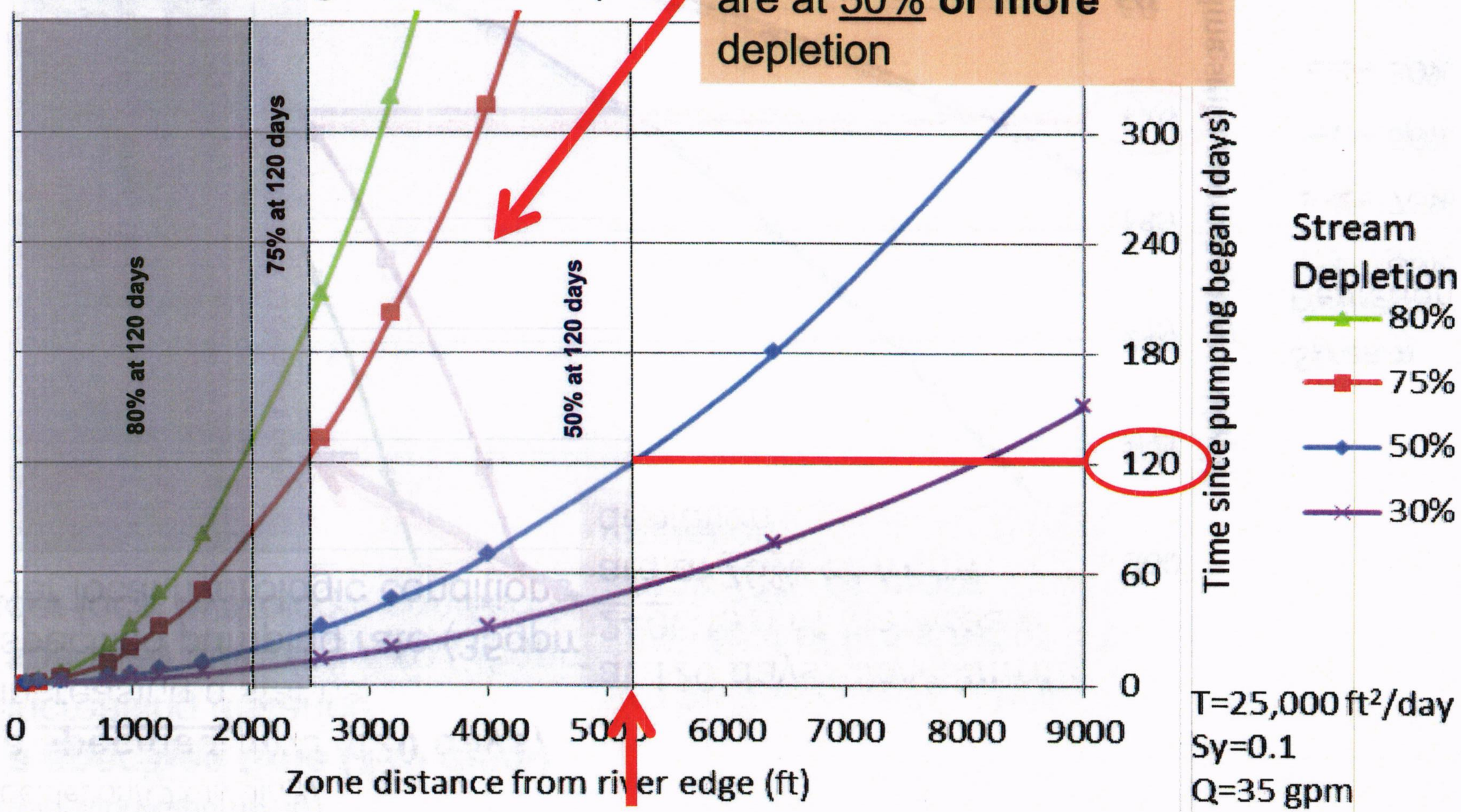
at 120 days, wells **within** 5100 feet of the stream are at 50% **or more** depletion



the fraction (%) of well discharge attributable to stream depletion ($Q_{depletion}/Q_{pumping}$)

**at a <u>specified</u> time (120 days)**

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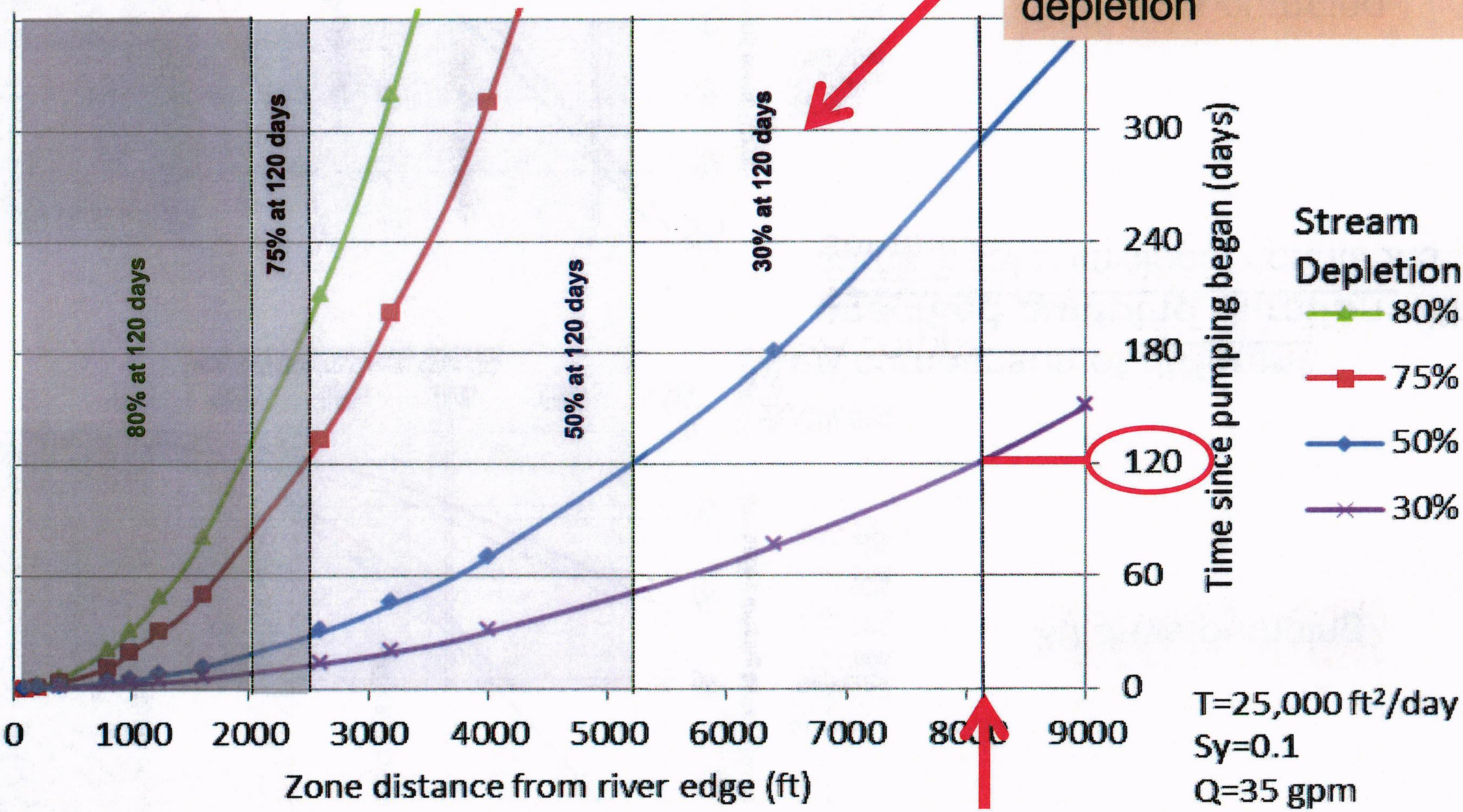
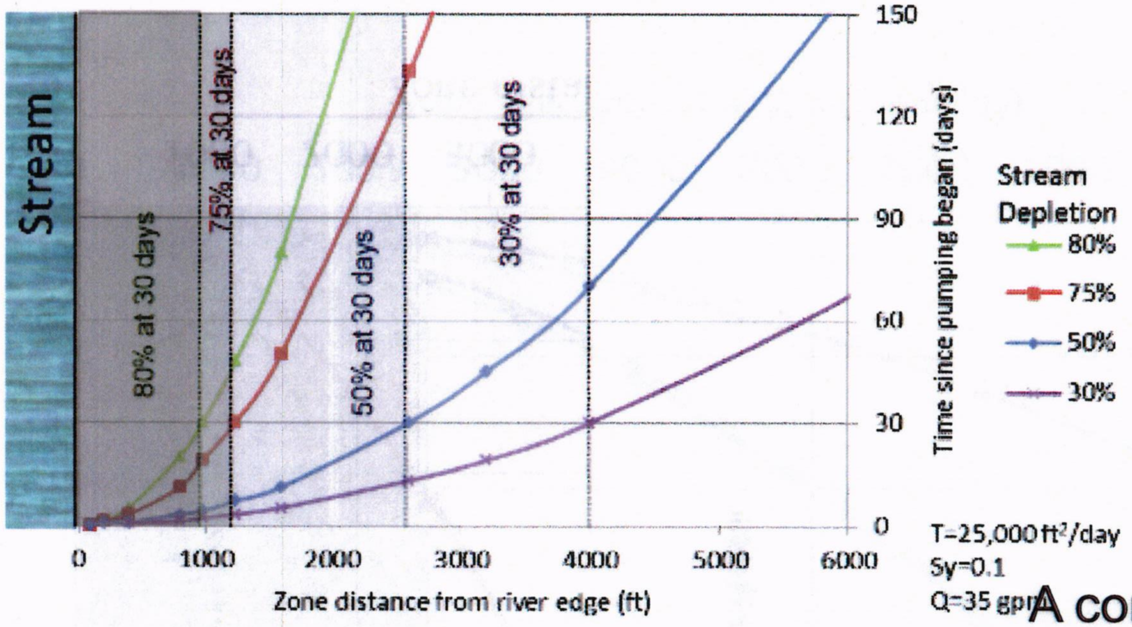
at specified pumping rate (35gpm),

under local hydrologic conditions (T and Sy)

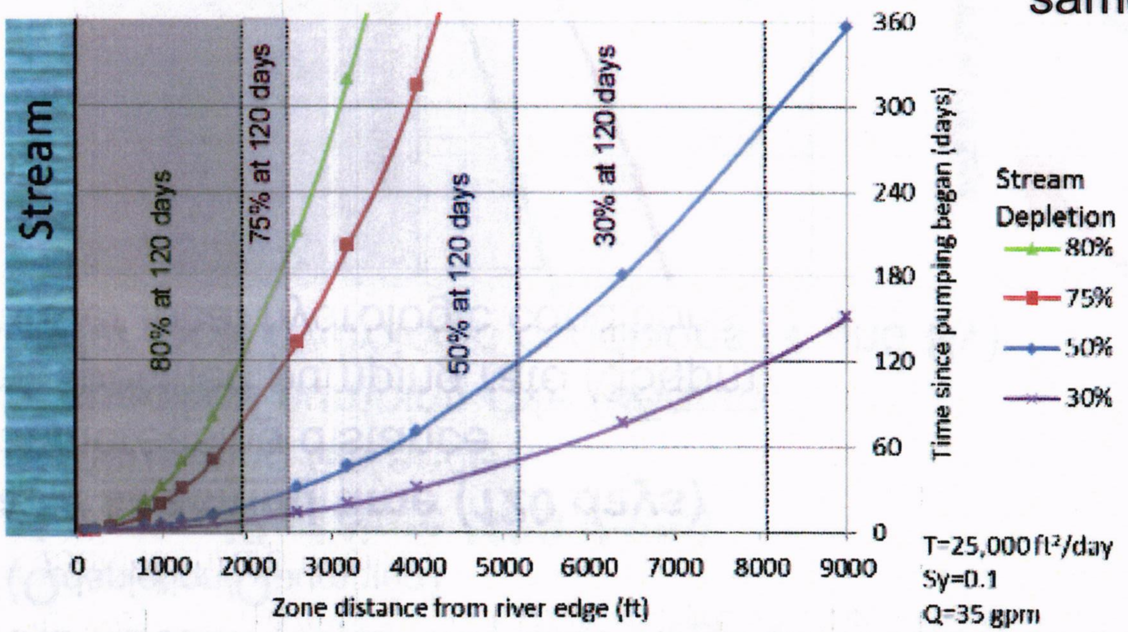
at 120 days, wells **within** 8100 feet of the stream are at 30% **or more** depletion



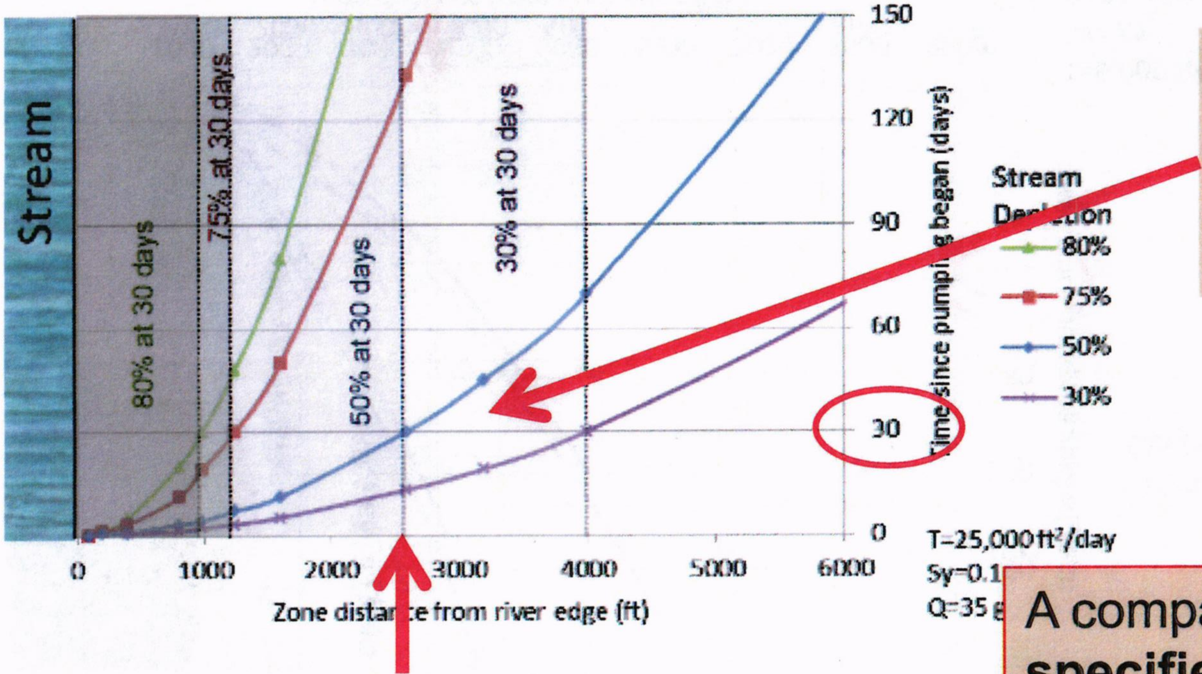



30 days pumping

A comparison of **<u>different specified pumping duration</u>** with same local hydrologic conditions



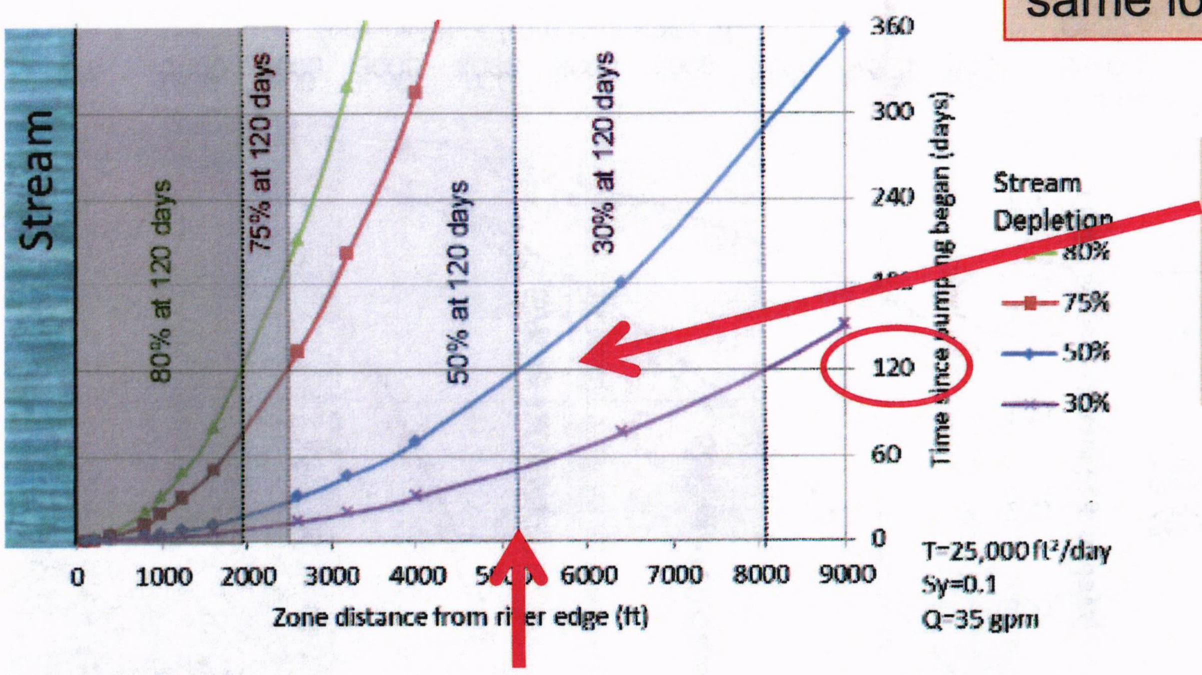

120 days pumping




at 30 days, wells **within** 2500 feet of the stream are at 50% **or more** depletion

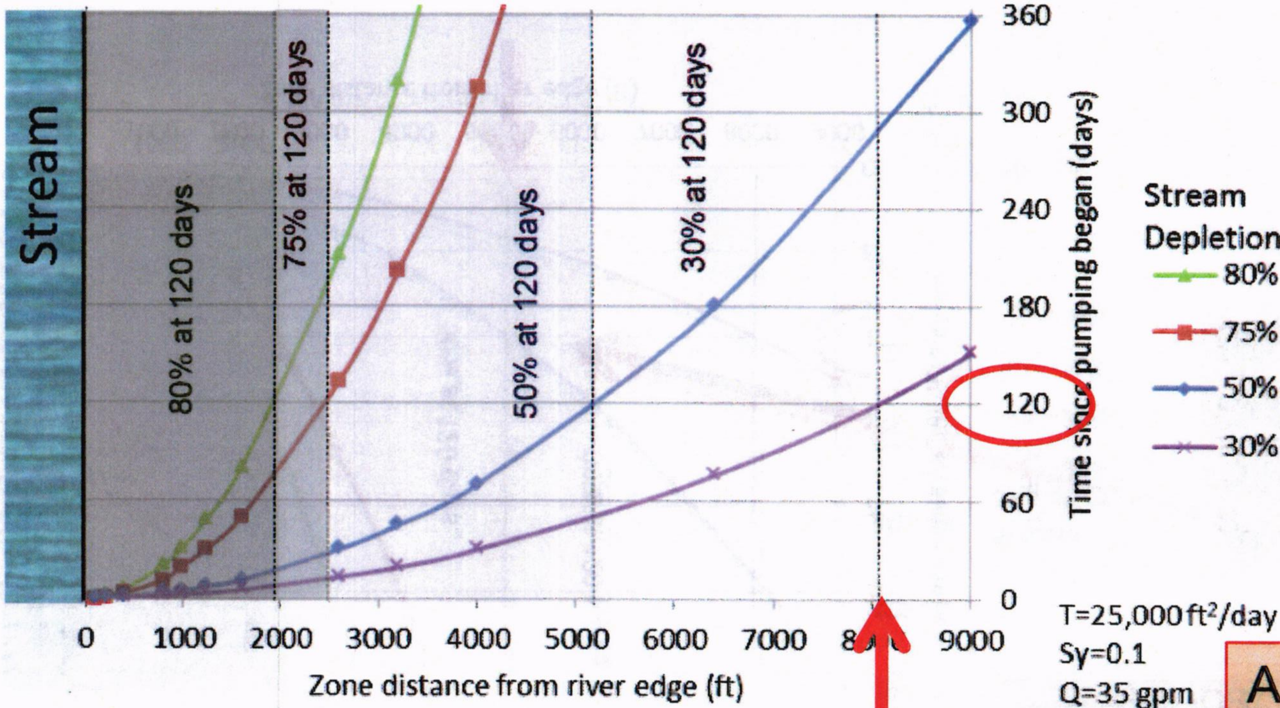
30 days pumping

A comparison of **different specified pumping duration** with same local hydrologic conditions




at 120 days, wells **within** 5100 feet of the stream are at 50% **or more** depletion

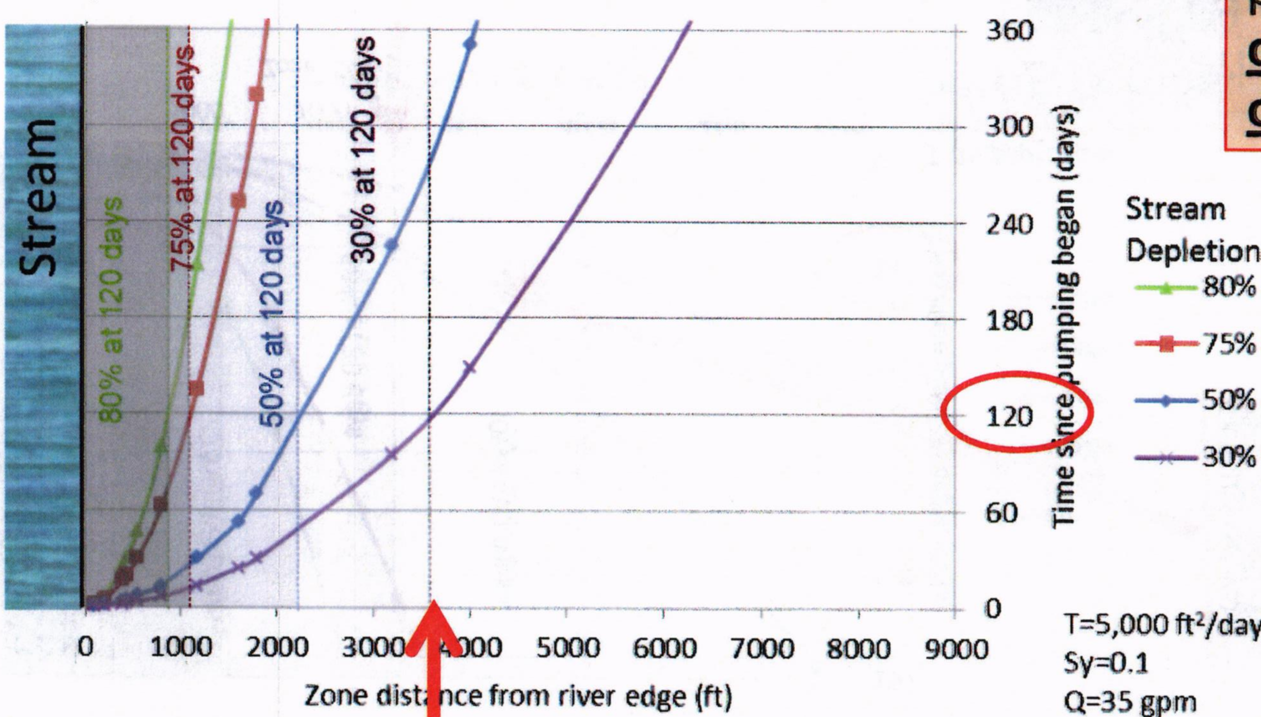
120 days pumping




at <u>120 days</u>, wells **within** <u>8100</u> feet of the stream are at 30% **or more** depletion

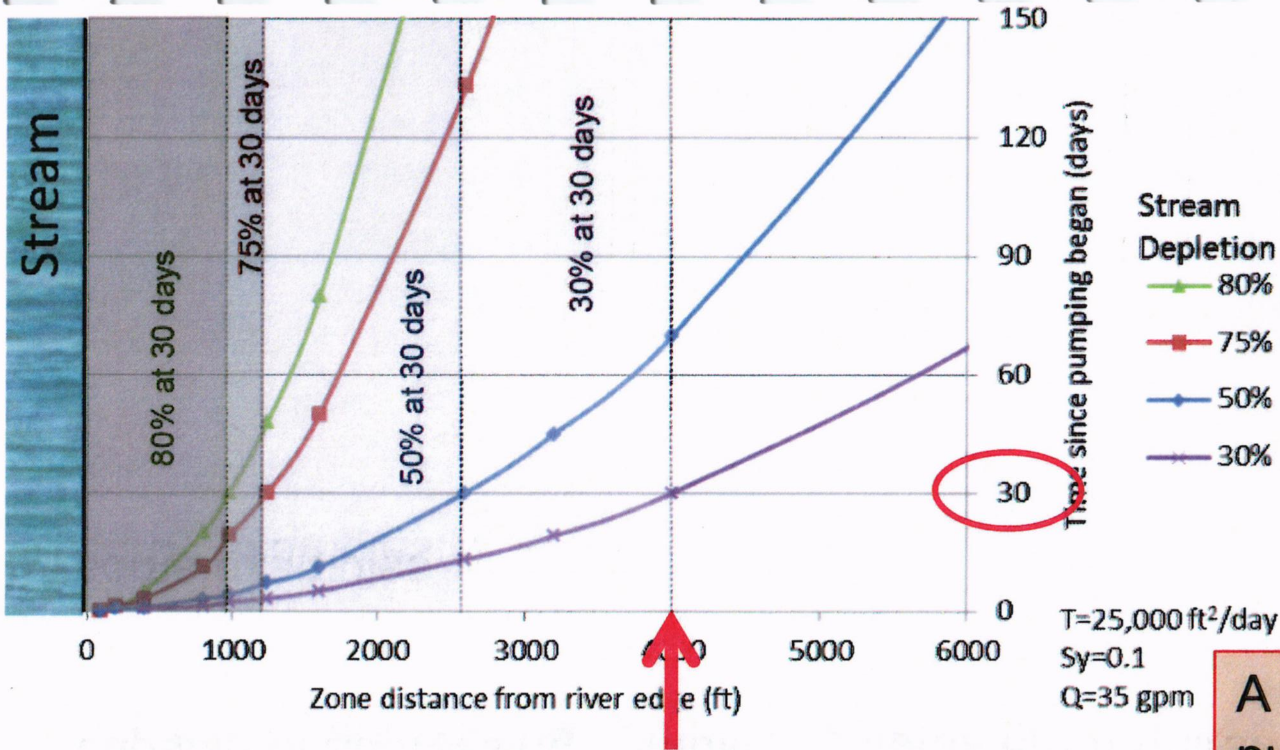
Transmissivity 25,000 ft²/d

A comparison of same pumping duration with **<u>different local hydrologic conditions</u>**




at <u>120 days</u>, wells **within** <u>3600</u> feet of the stream are at 30% **or more** depletion

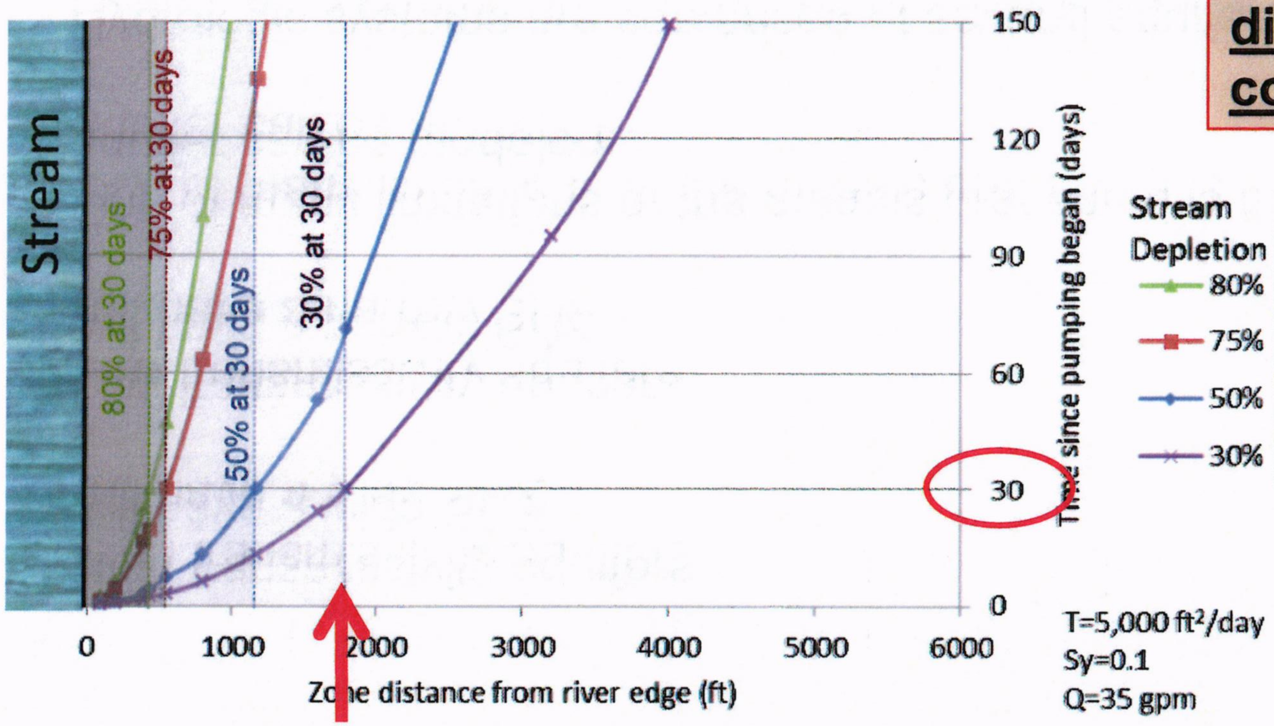
Transmissivity 5,000 ft²/d




at <u>30 days</u>, wells **within** <u>4000</u> feet of the stream are at 30% **or more** depletion

Transmissivity 25,000 $ft^2/d$

A comparison of same pumping duration with **<u>different local hydrologic conditions</u>**




at <u>30 days</u>, wells **within** 1800 feet of the stream are at 30% **or more** depletion

Transmissivity 5,000 $ft^2/d$

High transmissivity aquifers
will have a wide SDZ

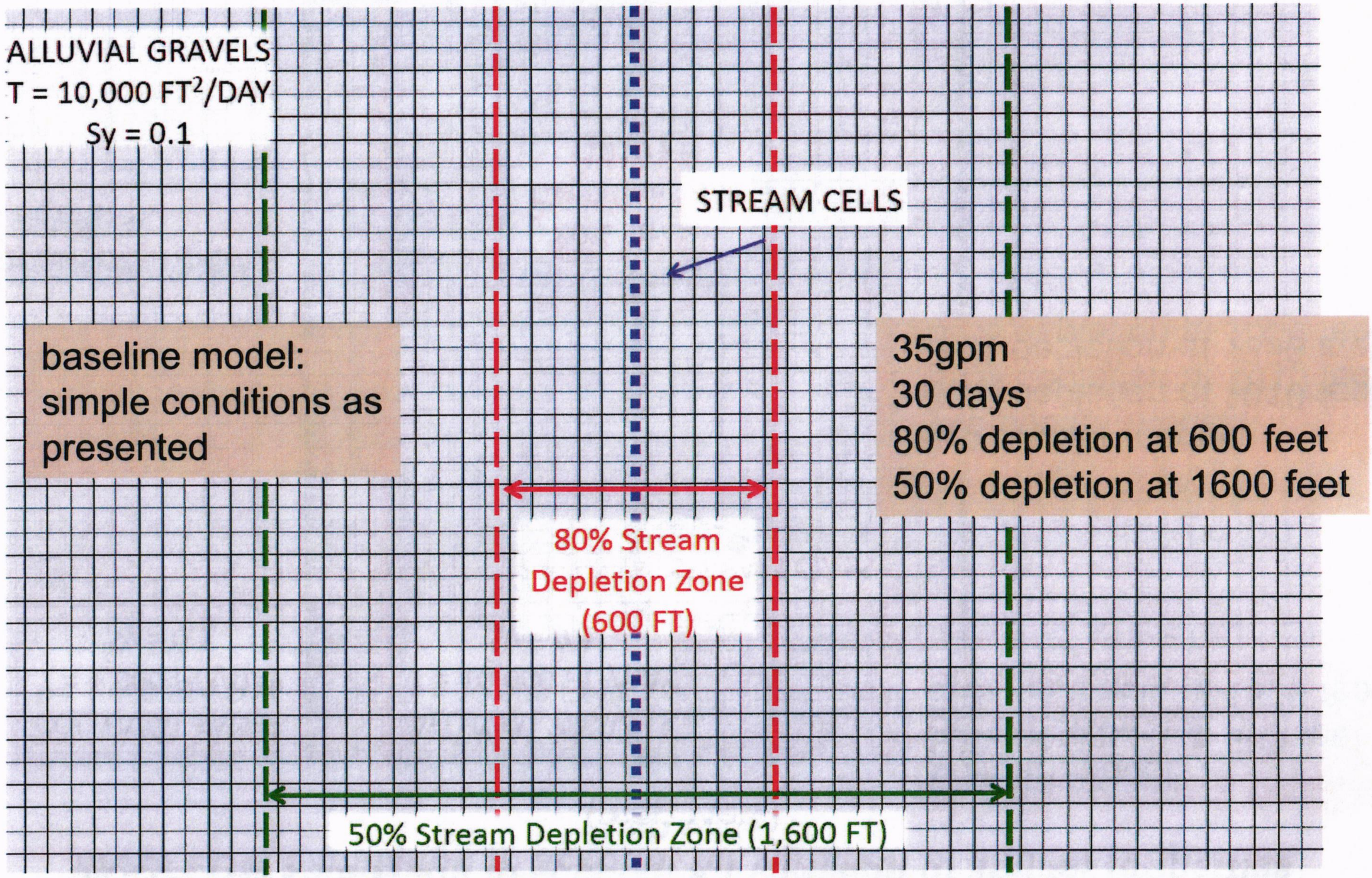
Low transmissivity aquifers
will have a narrow SDZ

One of many limitations of the models presented is that only one aquifer can be modeled…

Hydrologic systems are comprised of several aquifers… so, models capable of addressing complex systems are required…

some examples…

## MODFLOW simulation to account for variation of aquifer properties (map view)



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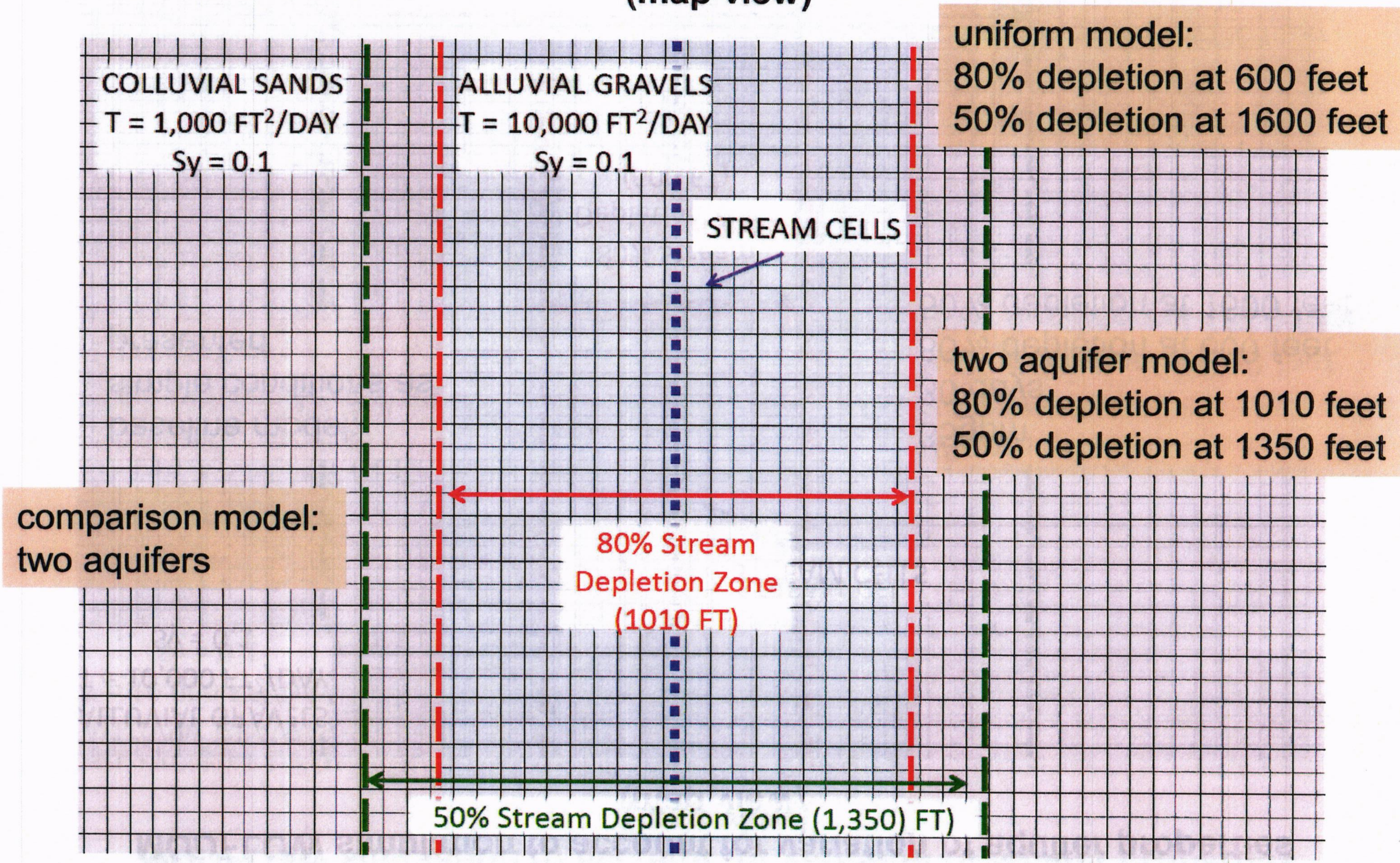
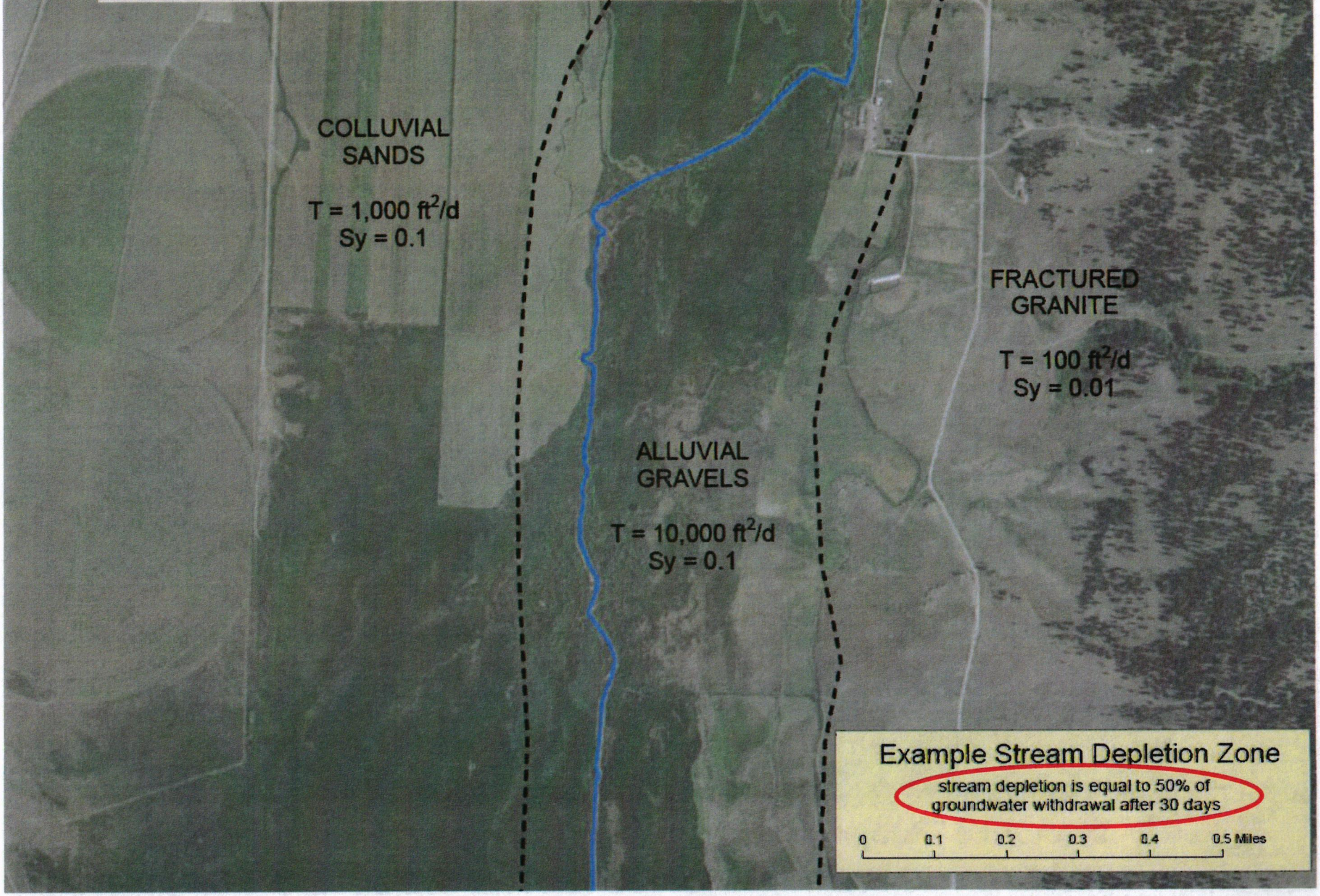


# Approximations based on simple, multiple aquifers - examples



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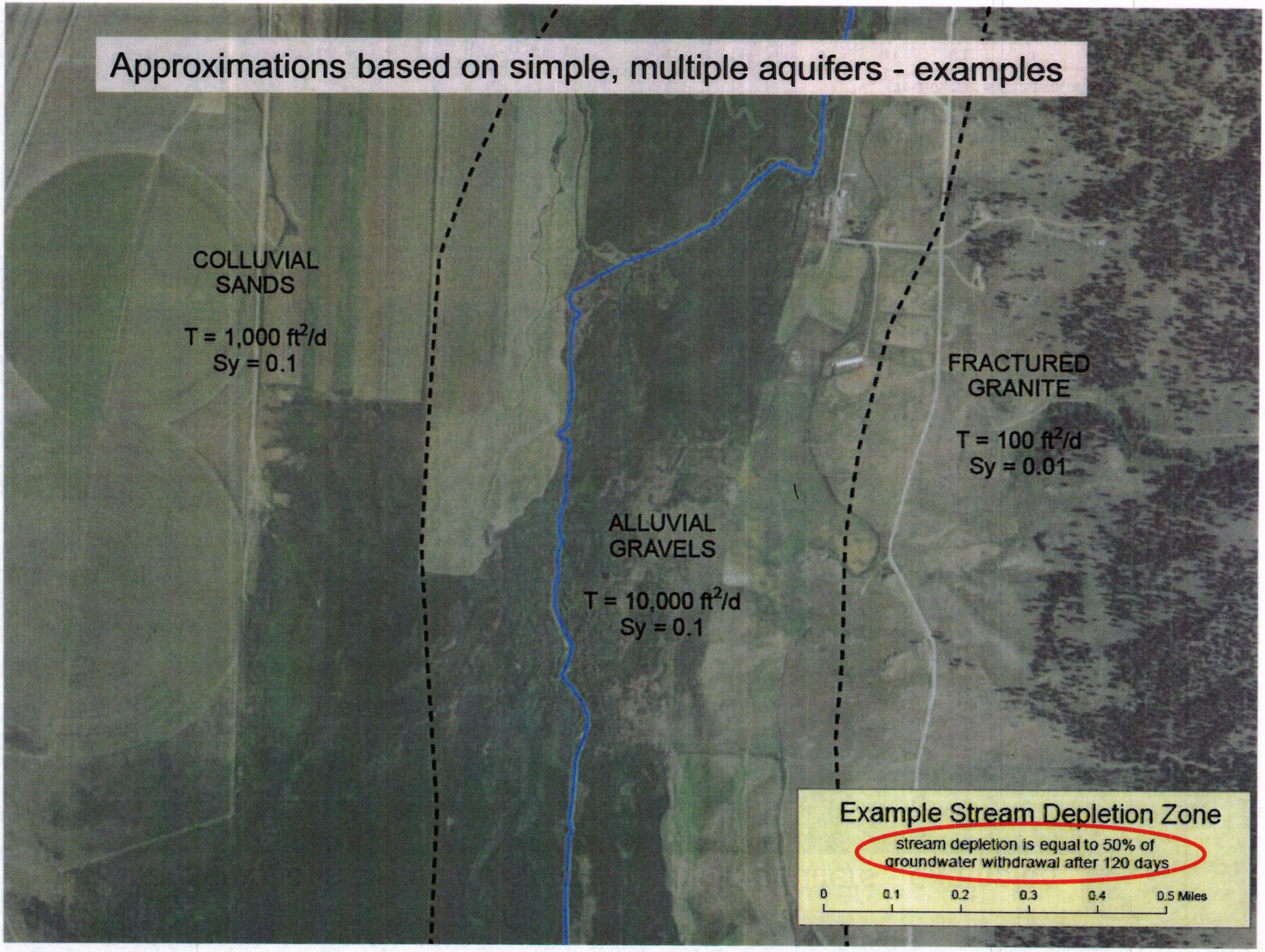
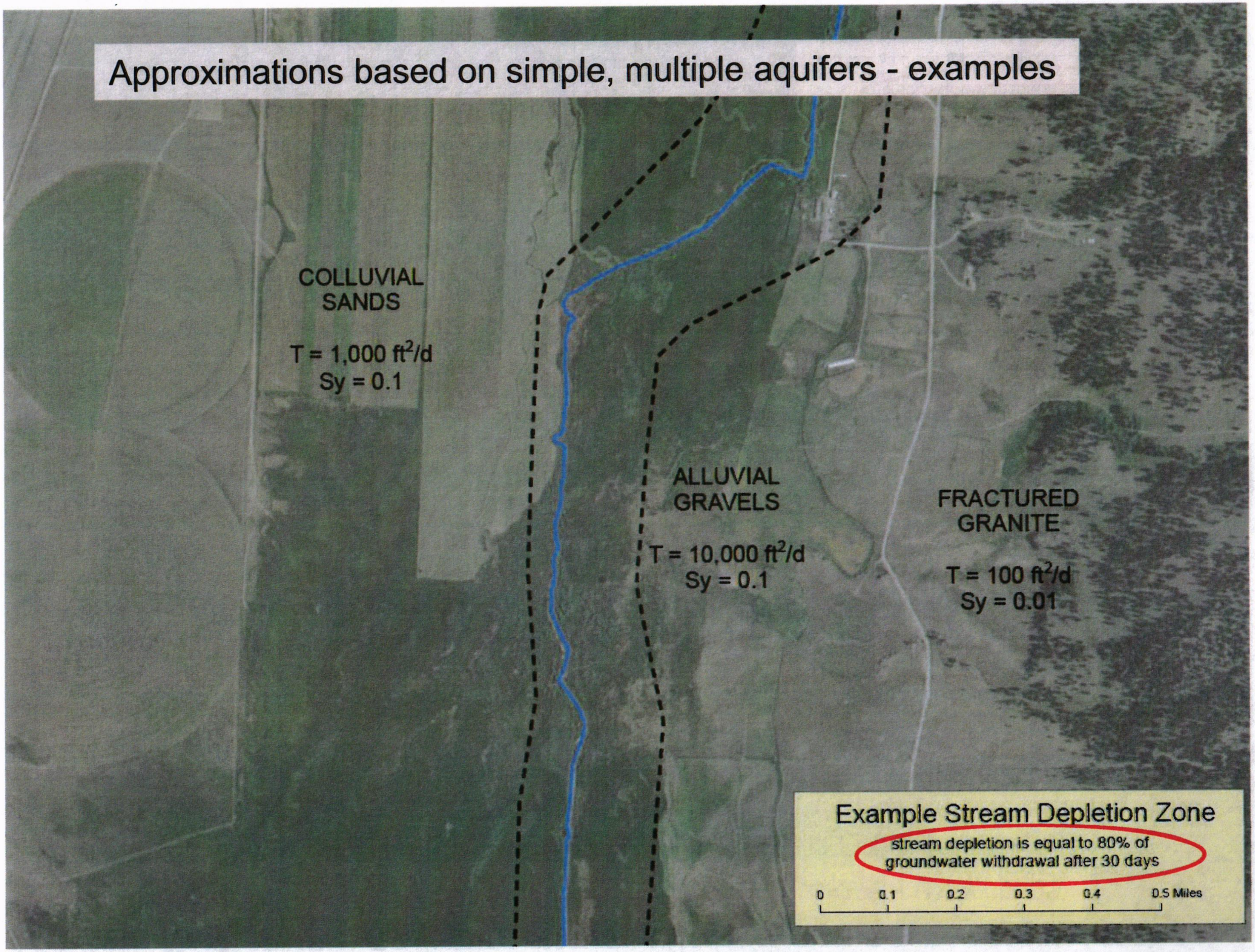
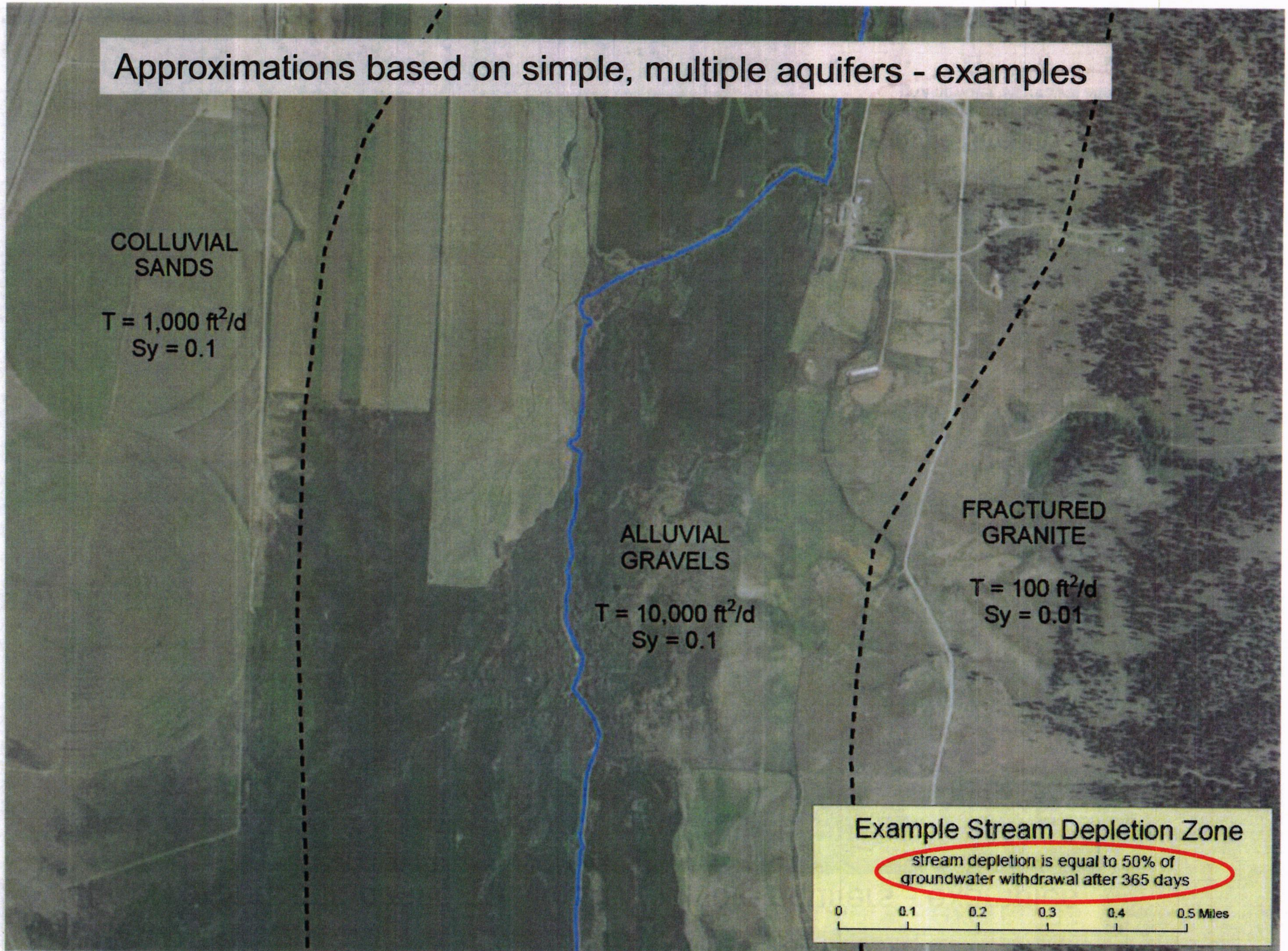



Approximations based on simple, multiple aquifers - examples
COLLUVIAL SANDS
T = 1,000 ft²/d
Sy = 0.1
ALLUVIAL GRAVELS
T = 10,000 ft²/d
Sy = 0.1
FRACTURED GRANITE
T = 100 ft²/d
Sy = 0.01
Example Stream Depletion Zone
stream depletion is equal to 80% of groundwater withdrawal after 30 days
0 0.1 0.2 0.3 0.4 0.5 Miles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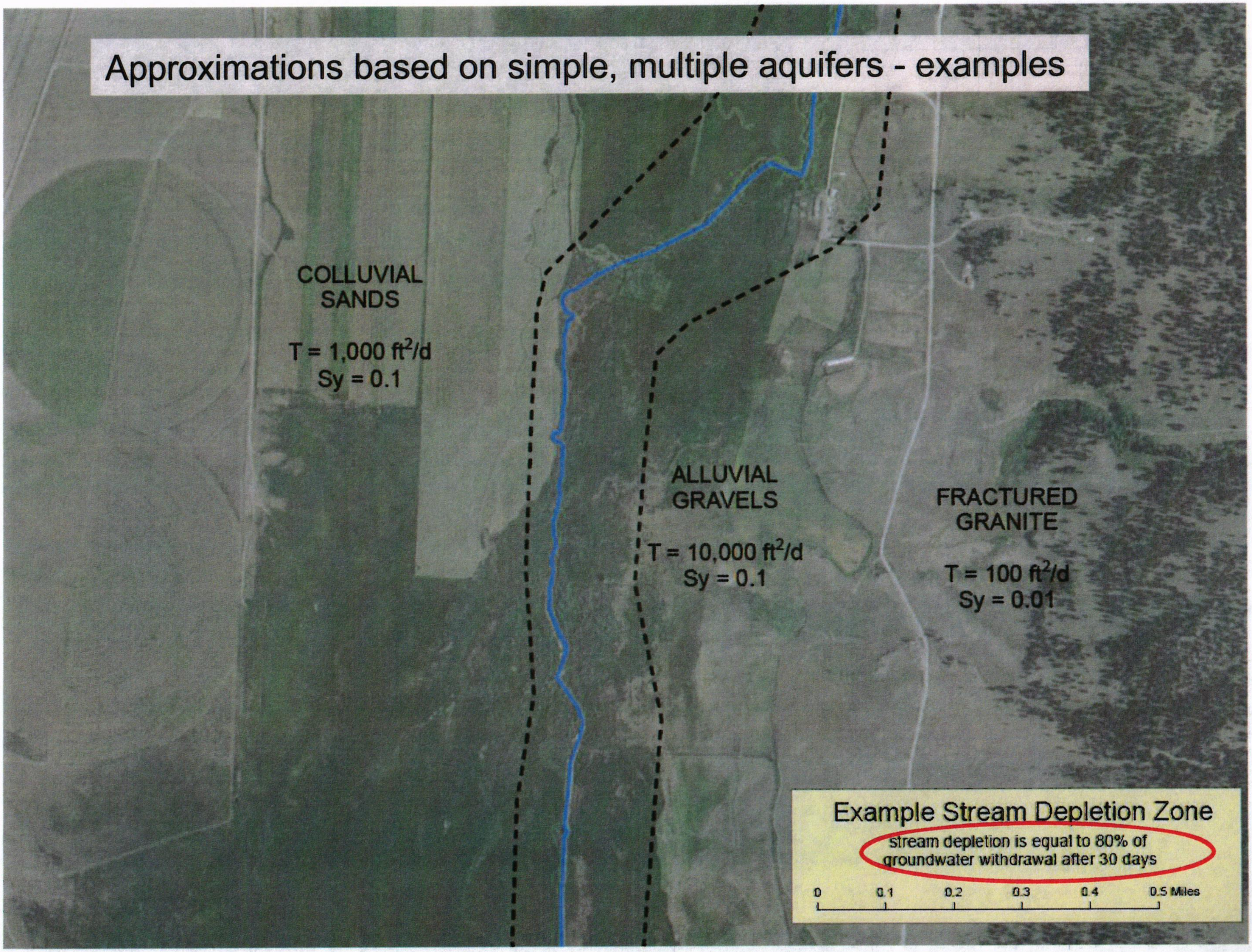
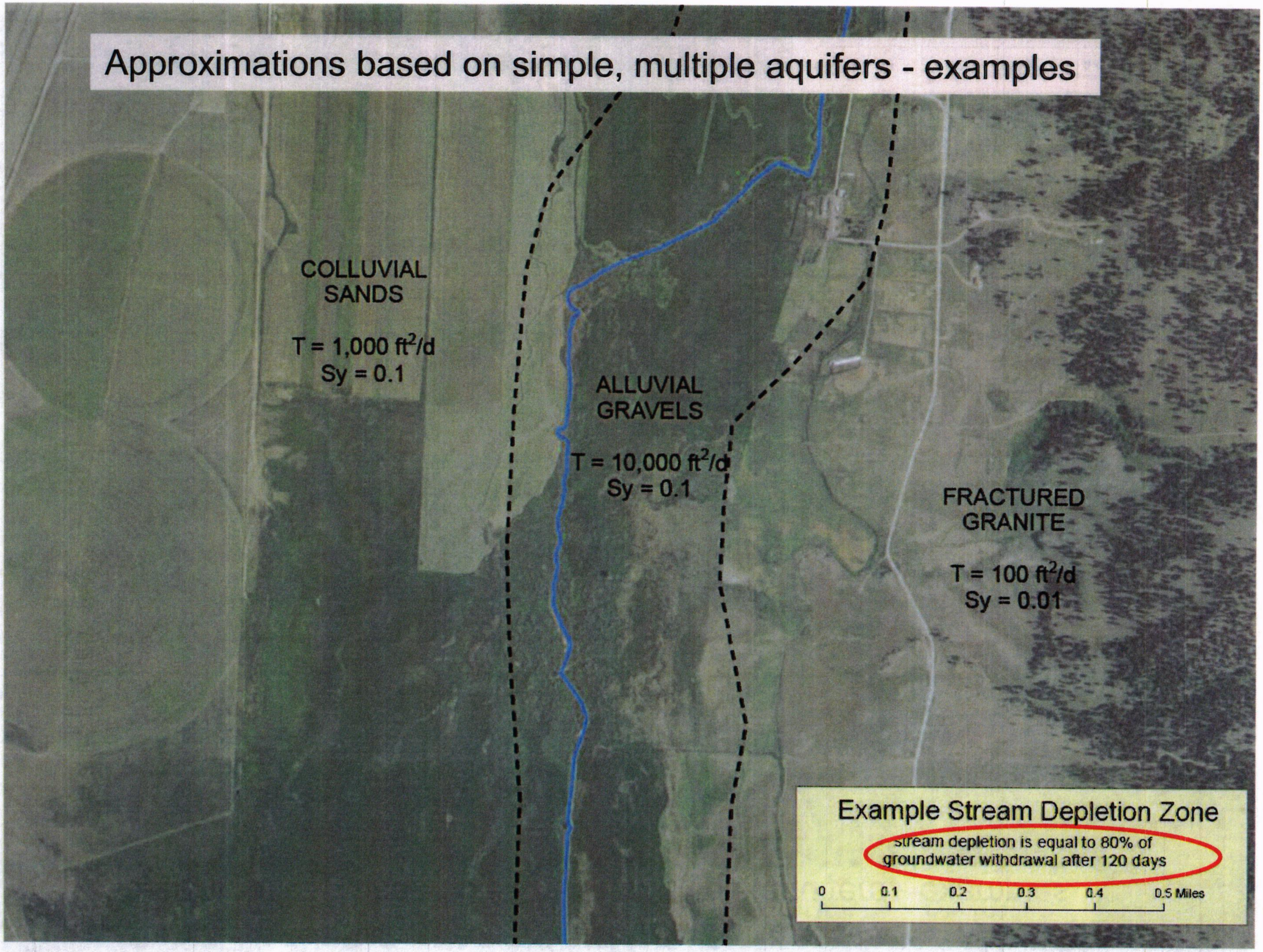
FRACTURED GRANITE
T = 100 ft²/d
Sy = 0.01
Example Stream Depletion Zone
stream depletion is equal to 50% of groundwater withdrawal after 365 days
0 0.1 0.2 0.3 0.4 0.5 Miles

# Approximations based on simple, multiple aquifers - examples





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Example Stream Depletion Zone
stream depletion is equal to 80% of groundwater withdrawal after 120 days
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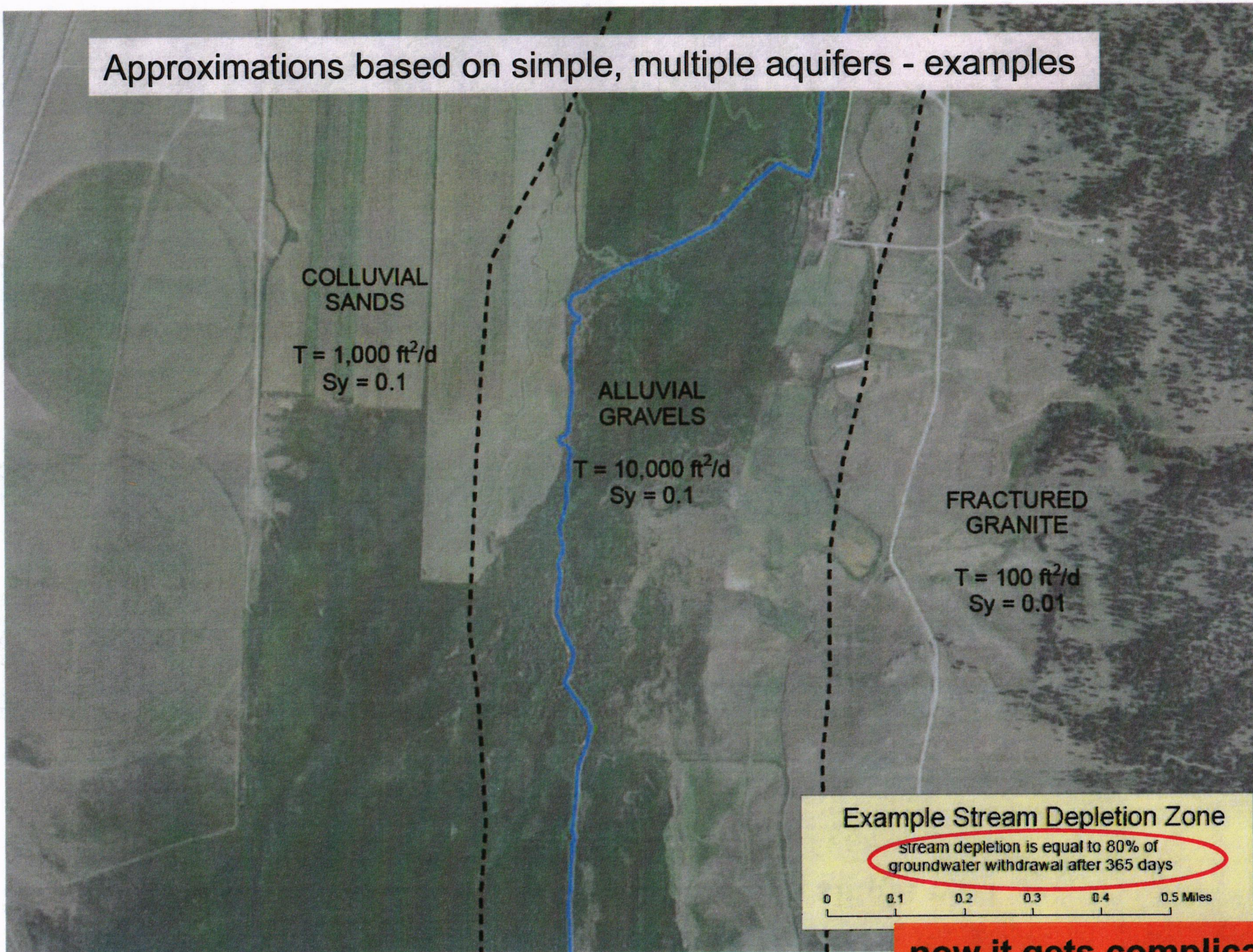
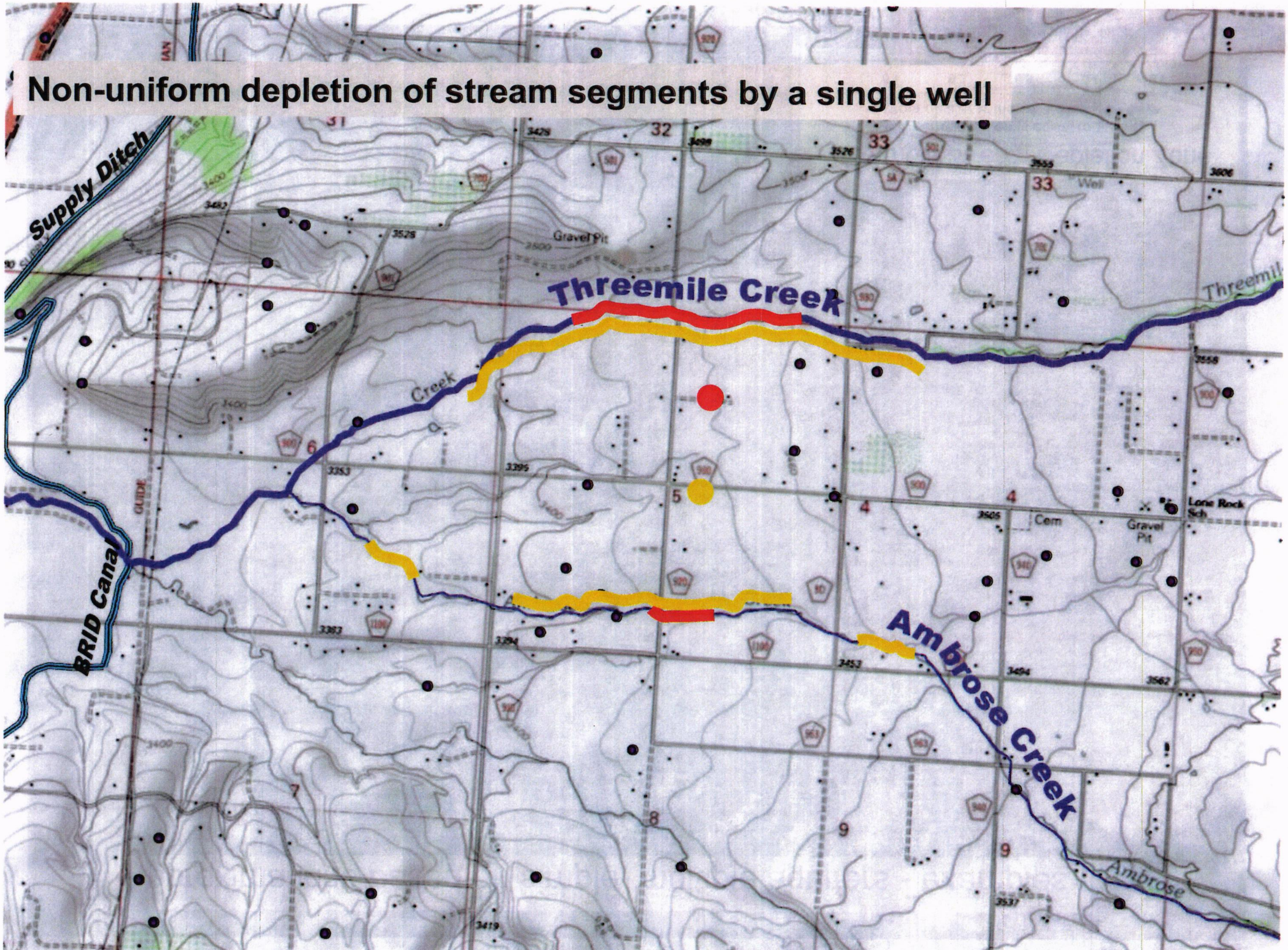
# Approximations based on simple, multiple aquifers - examples

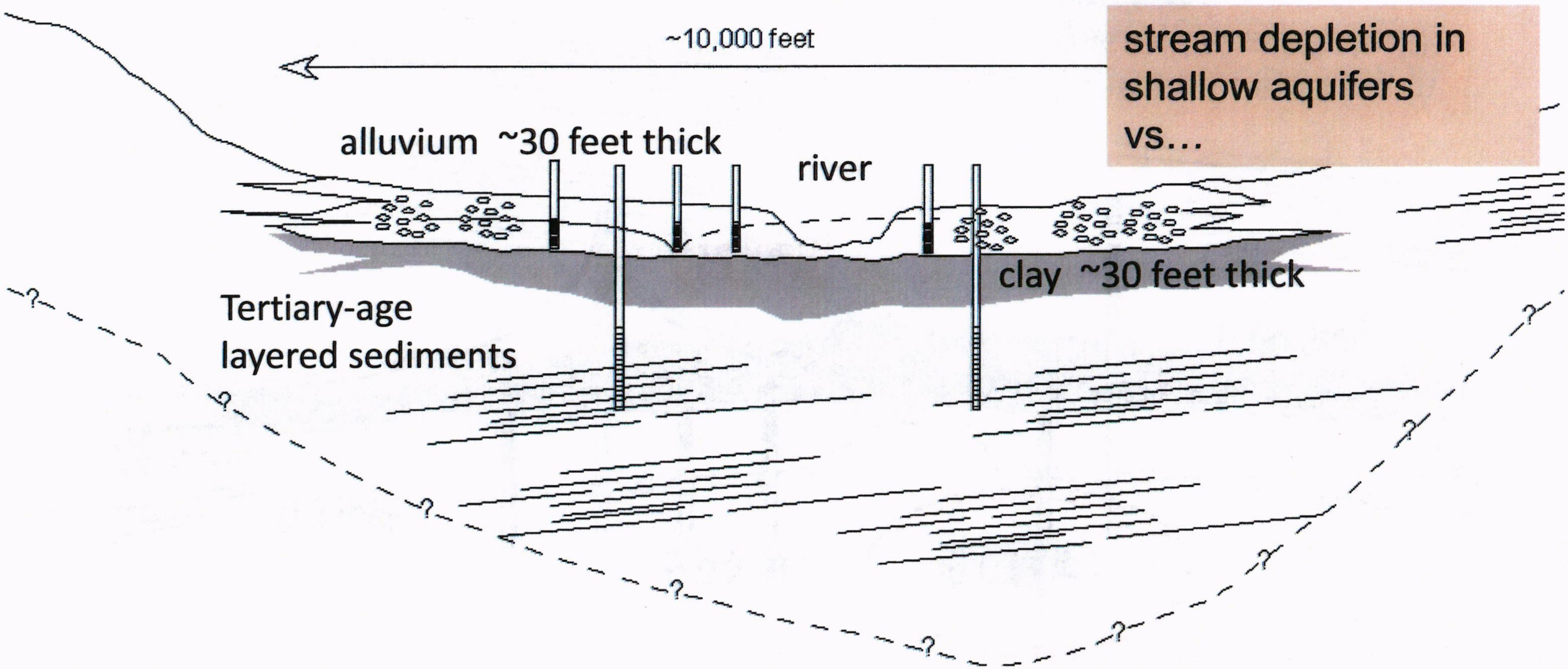


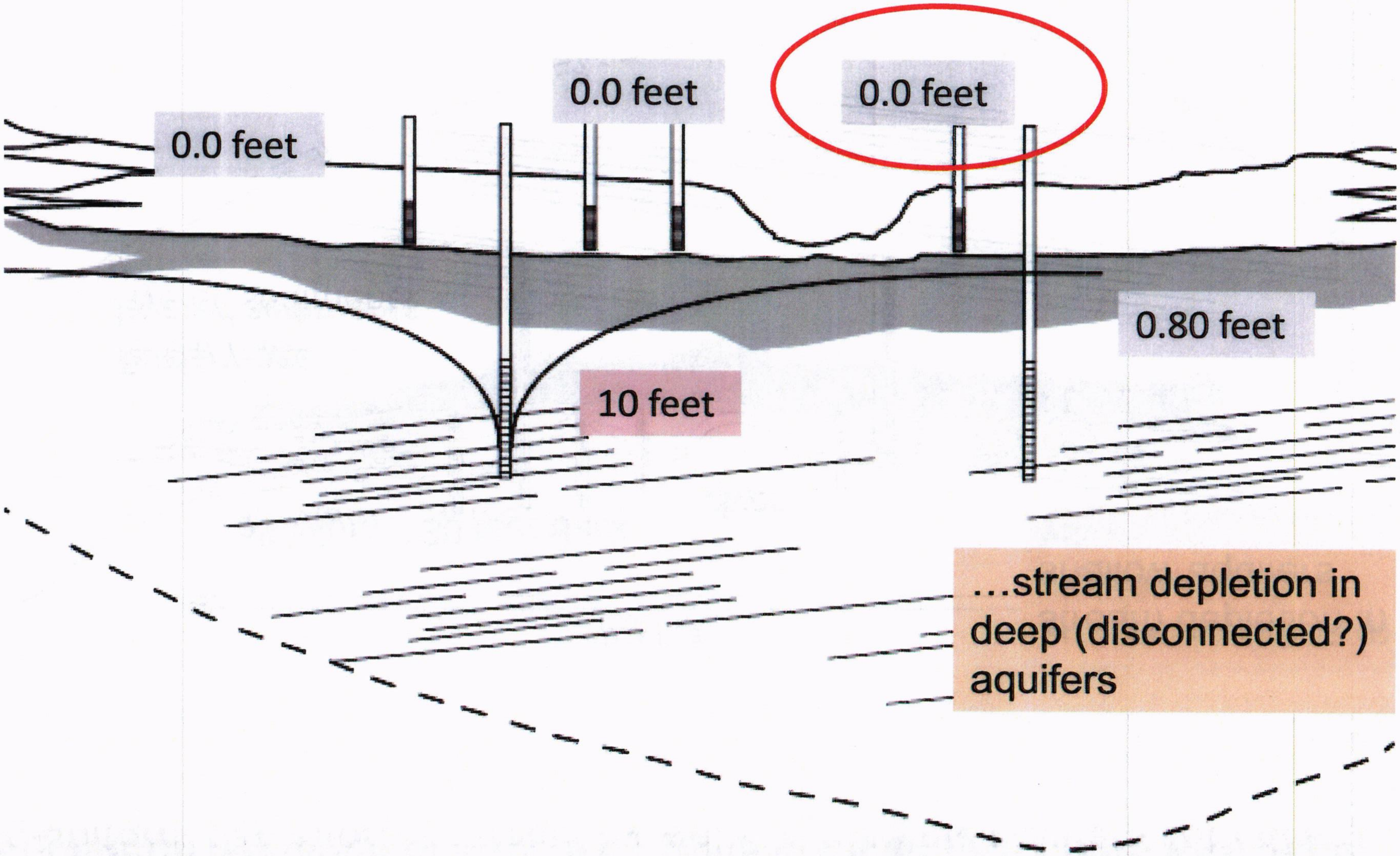

**now it gets complicated**

# Non-uniform depletion of stream segments by a single well



## Non-uniform depletion of stream by wells in multiple aquifers with depth




0.0 feet
0.0 feet
0.0 feet
0.80 feet
10 feet
…stream depletion in deep (disconnected?) aquifers

**SDZ construction – level of effort**

The essence of good estimates of stream depletion or delineating SDZ is mapping aquifer properties.

Components of the "hydrogeologic assessment"

Data compilation

- aquifer test data from GWAP/GWIP, subdivision apps, other studies
- existing assessments (will vary in scope and area)

Subsurface mapping starts with surficial geologic maps

- GWIC wells,
- monitoring wells

Aquifer tests where needed

- test well 2+ monitoring wells
- variability in vertical and horizontal = multiple tests

**SDZ construction – level of effort**

The essence of good estimates of stream depletion or delineating SDZ is mapping aquifer properties.

<u>Components of the "hydrogeologic assessment"</u>

Modeling (should reflect the complexity of the hydrologic system)

- estimates/approximations (as presented here)
- superposition models
- calibrated, sub-basin scale models

Drawing the zone boundary –

- legal vs physical (watershed boundary vs legislative district boundary…one may move based on better data, will the other?)
- wells outside the SDZ are still depleting the stream

## SDZ construction – level of effort

The essence of good estimates of stream depletion or delineating SDZ is mapping aquifer properties.

Components of the "hydrogeologic assessment"

The SDZ report (that supports the decision)

- the data (compiled and new)
- subsurface data/maps
  - uncertainty of lithologic contacts, aquifer test data, etc.
- model
  - methods,
  - data used,
  - assumptions,
  - limitations,
  - uncertainty – can "move" SDZ boundary 10 to 100s of feet