GROUNDWATER CLASSIFICATION UNDER THE TEXAS RISK REDUCTION PROGRAM (TRRP)

PRESENTED BY

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Agenda

- INTRODUCTION
- CLASSIFICATION PROCESS
- WELL YIELD METHODOLOGIES
- CASE STUDIES

INTRODUCTION

Rule & Guidance

- TRRP Rule: 30 Texas Administrative Code Section 350.52
- TCEQ Regulatory Guidance: TRRP-8 Groundwater Classification

TRRP Regulatory Requirements

30 TAC Section 350.52

All groundwater-bearing units affected by, or reasonably anticipated to be affected by, chemicals of concern (COCs) having concentrations at or above residential groundwater assessment levels must be characterized with regard to the applicable groundwater resource classification.

30 TAC Section 350.4(a)(40)

Groundwater-bearing unit (GWBU): A saturated geologic formation, group of formations, or part of formation which has a hydraulic conductivity (K) greater than $1x10^{-5}$ cm/s.

Basics of Groundwater Resource Classification

Identify and describe GWBU(s)

Determine current GWBU use

Determine potential GWBU use
(i.e., evaluate water quality and well yield)

Class 1 Groundwater Resource

Public Water Supply Aquifer

- GWBU is within 0.5 miles of a public water supply (PWS) well and COCs could impact the groundwater production zone for the well.

Only Reliable Source

- GWBU is the only reliable source of water in vicinity (i.e., no public water system available) and depth to unit ≤ 800 feet bgs.
- TDS < 1,000 mg/L & Q > 5,000 gpd

High Quality/High Yield

- TDS ≤ 3,000 mg/L & Q ≥ 144,000 gpd
- Meets primary drinking water standard (PDWS)

Can be assumed by default

30 TAC Section 350.52(1)

Class 2 Groundwater Resource

Production Zone for Existing Water Supply

- GWBU is production zone for existing water supply well (other than PWS well) located within 0.5 miles of the affected property which is used to supply groundwater for human consumption, agriculture, etc.

Fresh or Brackish/Moderate to High Yield

- TDS ≤ 10,000 mg/L & Q ≥ 150 gpd

Cannot meet Class 1 use criteria

30 TAC Section 350.52(2)

Class 3 Groundwater Resource

Saline

- TDS > 10,000 mg/L

Low Yield

- Q < 150 gpd

Cannot meet Class 1 or Class 2 use criteria

30 TAC Section 350.52(3)

Why Classify Groundwater?

Determine groundwater ingestion assessment levels:

- For Class 1 and Class 2 GWBUs, groundwater ingestion exposure pathways are applicable.
- Class 3 soil-to-groundwater and groundwater ingestion PCLs are 100 times higher.

Dictate response actions:

- For Class 1 GWBUs, groundwater must be removed and/or decontaminated to the critical PCL.
- For Class 2 and 3 GWBUs, plume management zones can be established.
- Response action objectives must be protective of any hydraulically-interconnected GWBUs.

What if the affected saturated zone does not meet the TRRP definition of a GWBU?

Saturated Soils

Must provide the following supporting information:

- Data requirements for a Class 3 demonstration
- Field measurements supporting a representative K < 1 x 10^{-5} cm/s
- Laboratory USCS classification as clay or silty clay (i.e. CH or CL)

A GWBU will be assumed unless ALL of the above criteria are demonstrated.

Groundwater Classification Steps

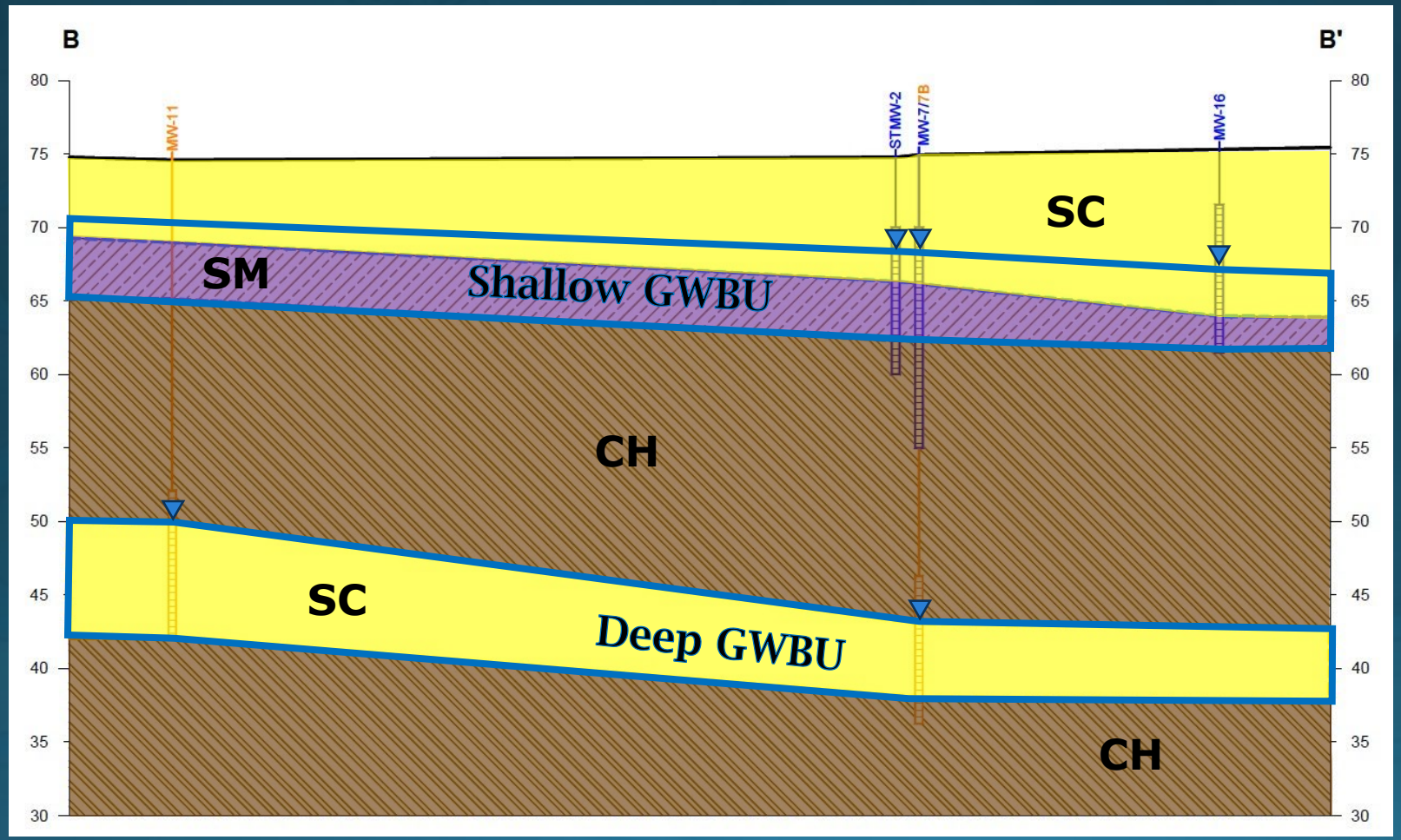
Classification Process

Step 1	Describe Affected Groundwater-bearing Units
Step 2	Determine Hydraulic Interconnectivity
Step 3	Determine Current Groundwater Use
Step 4	Evaluate Natural Groundwater Quality
Step 5	Evaluate GWBU Productivity
Step 6	Evaluate GWBU Sustainability
Step 7	Document Results

Step 1: Describe Affected Groundwater-Bearing Unit(s)

- Characterize the site-specific stratigraphy and relevant water-saturated units with soil borings and USCS soil classification.
- Indicate depth of occurrence, thickness, lateral continuity, upper and lower confining units, etc.
- Evaluate depositional environment and hydrostratigraphic considerations.

Step 1: Describe Affected GWBU(s) (cont.)



Step 2: Determine Hydraulic Interconnectivity

- Determine if flow from one GWBU potentially causes an exceedance of a critical PCL in a receiving GWBU?
- Interconnectivity may occur as a result of:
  - 1) stratigraphic connections,
  - 2) the presence of artificial penetrations, or
  - 3) leakage through intervening confining layers.

Step 2: Determine Hydraulic Interconnectivity (cont.)

Stratigraphic Data
thickness, continuity and hydrologic properties of intervening confining layer

Static Water Levels
relative hydraulic head evaluations in separate GWBUs

Affected Groundwater
presence or absence of affected groundwater in GWBUs

Natural Water Quality
contrast in natural water quality characteristics (e.g., TDS, major ion distribution, etc.)

Field Hydraulic Conductivity Test
in-situ field hydraulic conductivity tests performed on intervening confining unit

Aquifer Pumping Test
field test conducted to evaluate effect of pumping from unaffected unit on SWL in affected unit

Step 3: Determine Current Groundwater use

- Identify current use of affected and interconnected GWBU's using:
  - Record searches for existing water supply wells within 0.5 miles in any direction from the affected groundwater zone.
  - Field reconnaissance surveys within 500-foot radius of affected property; and
- Determine availability of public water supply systems.

Step 4: Evaluate Natural Groundwater Quality

Characterize natural water quality based on

- Total Dissolved Solids (TDS) concentration, and
- PDWS Criteria (see 40 CFR Part 141) (situational).

Samples should NOT be collected from affected groundwater.

Step 5: Evaluate GWBU Productivity

Estimate or directly measure aquifer parameters and well yields using appropriate protocols and methods.

- Determination of GWBU hydraulic conductivities;
- Single- and multiple-well aquifer tests; and
- Well yield tests.

Step 6: Evaluate GWBU Sustainability

- Characterize the sustainability of each GWBU to be classified, based on:
  - Demonstration of historical or predicted permanence of saturation and/or
  - Analysis of the geologic extent and hydrologic character of GWBU.
- Classification may be downgraded if GWBU is demonstrated to not be sustainable.

Step 7: Document Results

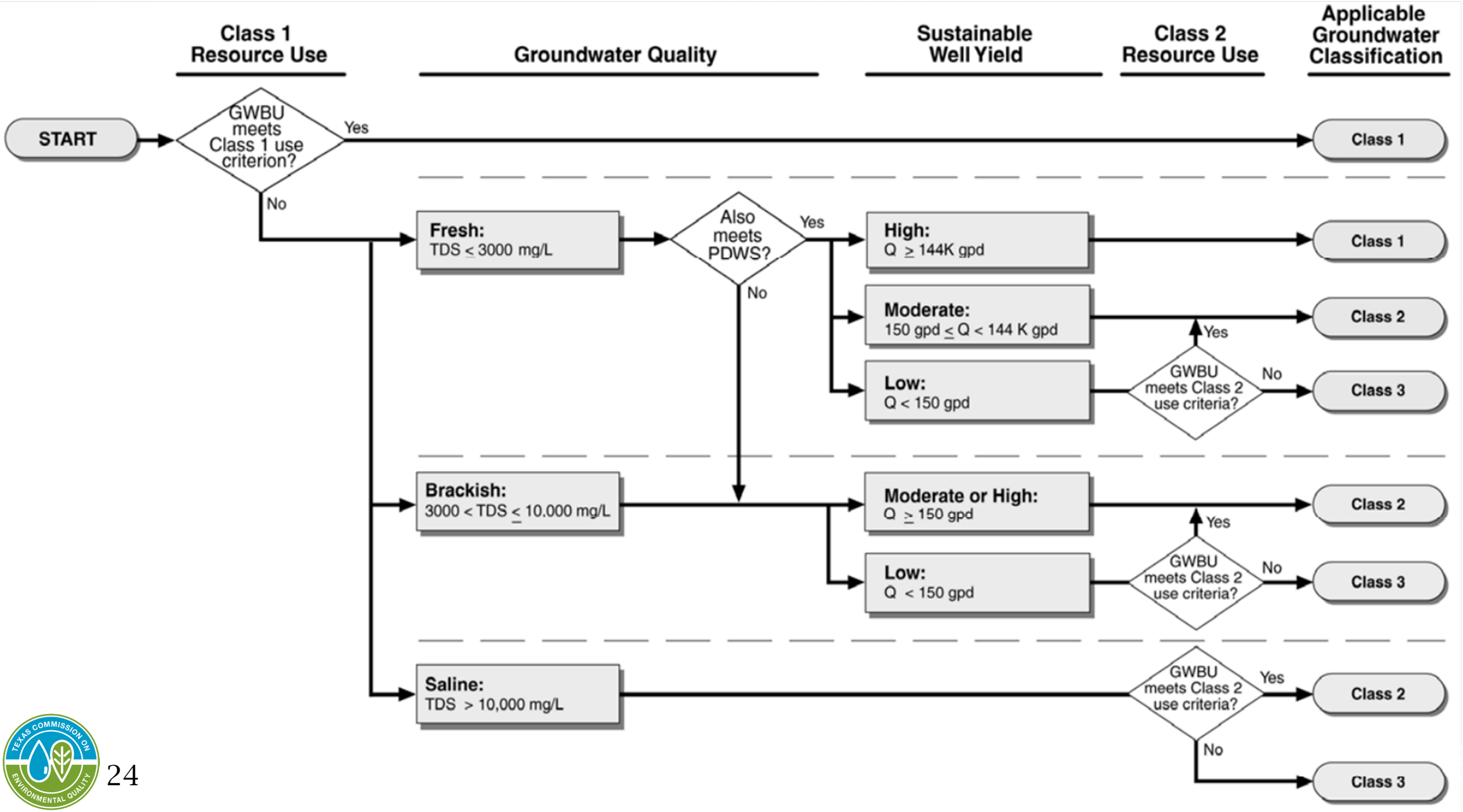
- Submit all supporting documentation with the APAR.
  - Identify GWBUs in the Executive Summary.

Affected groundwater-bearing unit(s) (in order from depth below ground surface), or uppermost groundwater-bearing unit if none affected

Unit No.	Name	Depth below ground surface (ft)	Resource Classification (1, 2, or 3)
1	Perched GWBU	8-10	Class 1 Default
2			
3			

Do not indicate a suspected classification. Identify as "default" if classification is assumed Class 1.

  - Discuss groundwater classification in Section 2.5
  - Include aquifer testing data in Appendix 7.
- May submit separate groundwater classification report for TCEQ approval prior to submitting the full APAR.


Class 1 Resource Use
Groundwater Quality
Sustainable Well Yield
Class 2 Resource Use
Applicable Groundwater Classification
START
GWBU meets Class 1 use criterion?
Yes
No
Class 1
Fresh:
TDS ≤ 3000 mg/L
Also meets PDWS?
Yes
No
High:
Q ≥ 144K gpd
Class 1
Moderate:
150 gpd ≤ Q < 144 K gpd
Class 2
Low:
Q < 150 gpd
GWBU meets Class 2 use criteria?
Yes
No
Class 3
Brackish:
3000 < TDS ≤ 10,000 mg/L
Moderate or High:
Q ≥ 150 gpd
Class 2
Low:
Q < 150 gpd
GWBU meets Class 2 use criteria?
Yes
No
Class 3
Saline:
TDS > 10,000 mg/L
GWBU meets Class 2 use criteria?
Yes
Class 2
No
Class 3

WELL YIELD METHODOLOGIES

DETERMINING WELL YIELD UNDER TRRP 8

Determining Well Yield

Why?

- Part of Groundwater Classification Requirement (Step 5) for **Potential Use Criteria**

How?

- Method 1 – Estimated Well Yield by Calculations or Graphs
- Method 2 – Direct Measurement

Basic Concepts

Well yield (Q)

How much water can be withdrawn from a well over a period of time.

High Yield ≥ 144,000 gpd

Moderate Yield <144,000 gpd and ≥150 gpd

Low Yield < 150 gpd

Hydraulic Conductivity (K)

Measure of how easily a fluid can pass through a porous material, such as soil or rock. K measured in cm/sec

Basic Concepts (cont.)

Saturated Thickness (b)

unconfined GWBUs

vertical distance from the static water level to the base of the saturated unit.

confined GWBUs

stratigraphic thickness of the GWBU, itself

Methods to Determine Well Yield

Method 1

- Obtain site-specific hydraulic conductivity (K);
- Measure saturated thickness (b); and
- Estimate yield based on provided well yield graphs or equations.

Method 2

- 2a. Cyclic Discharge
- 2b. Equilibrium Discharge
- 2c. Constant Discharge

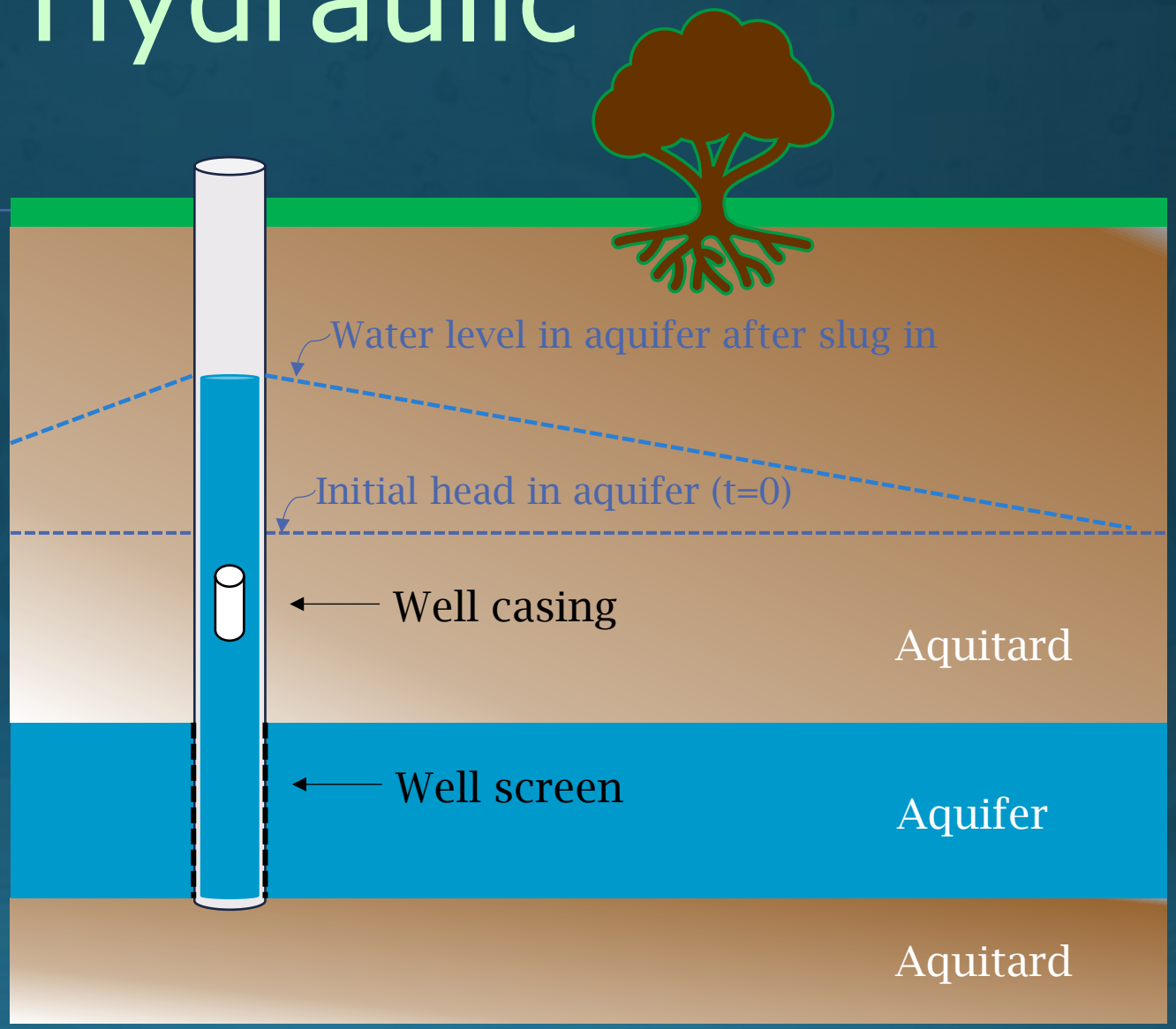
*Test wells must be fully-penetrating and appropriately screened and developed.

Method 1

Purpose	· Estimate well yield by known *K* and *b* via calculations or well yield graphs
Applicability	· High to low GWBU transmissivities
Requirements	· Site specific *K* and *b (Attachment A in TRRP 8)*
Caveats	· May require direct measurement

Determining Hydraulic Conductivity

Slug Test typical



Slug Tests

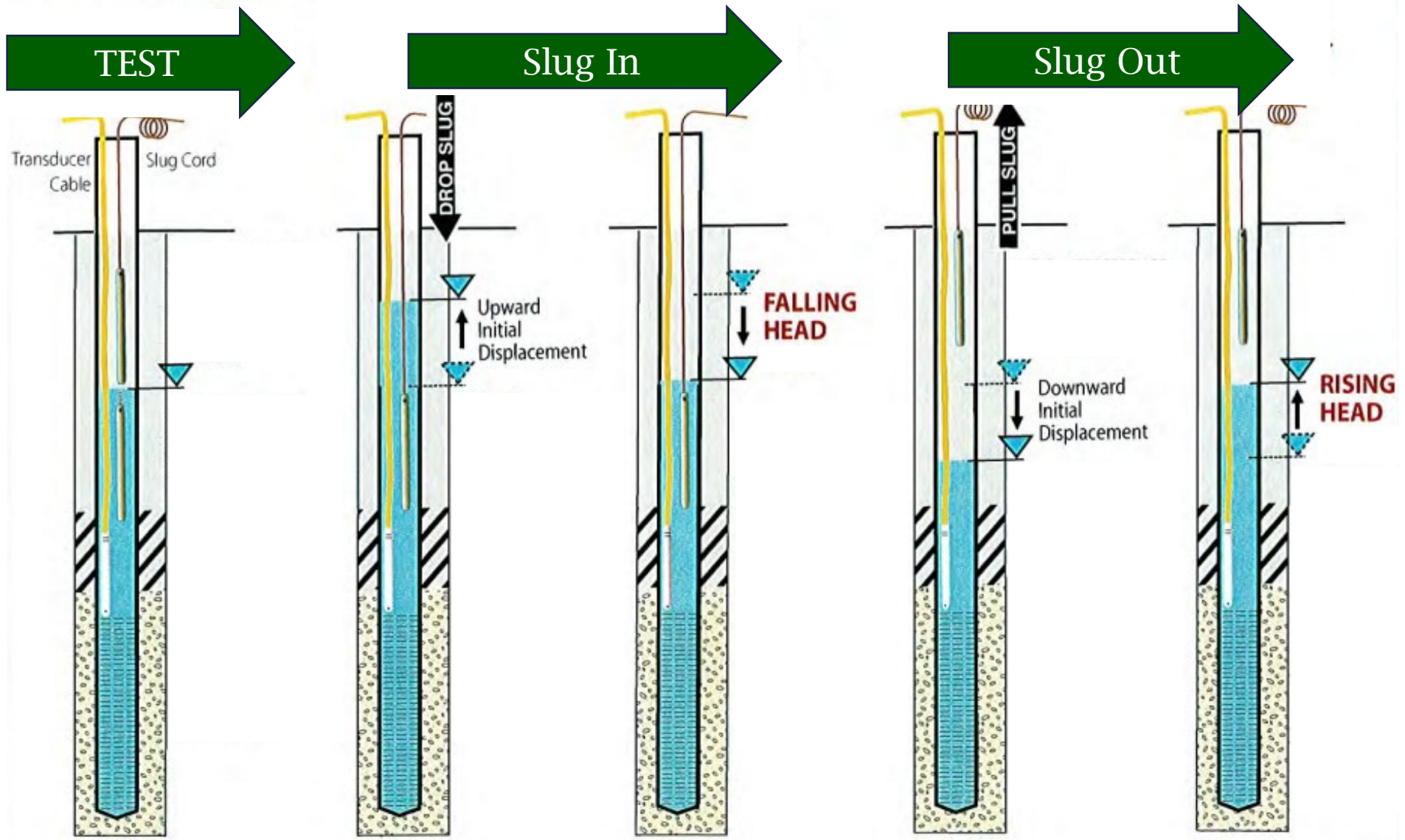
Three tests per well (minimum)

Determine single well hydraulic conductivity with an arithmetic mean.

Three well locations (minimum)

Determine inter-well site-specific representative hydraulic conductivity with geometric mean.

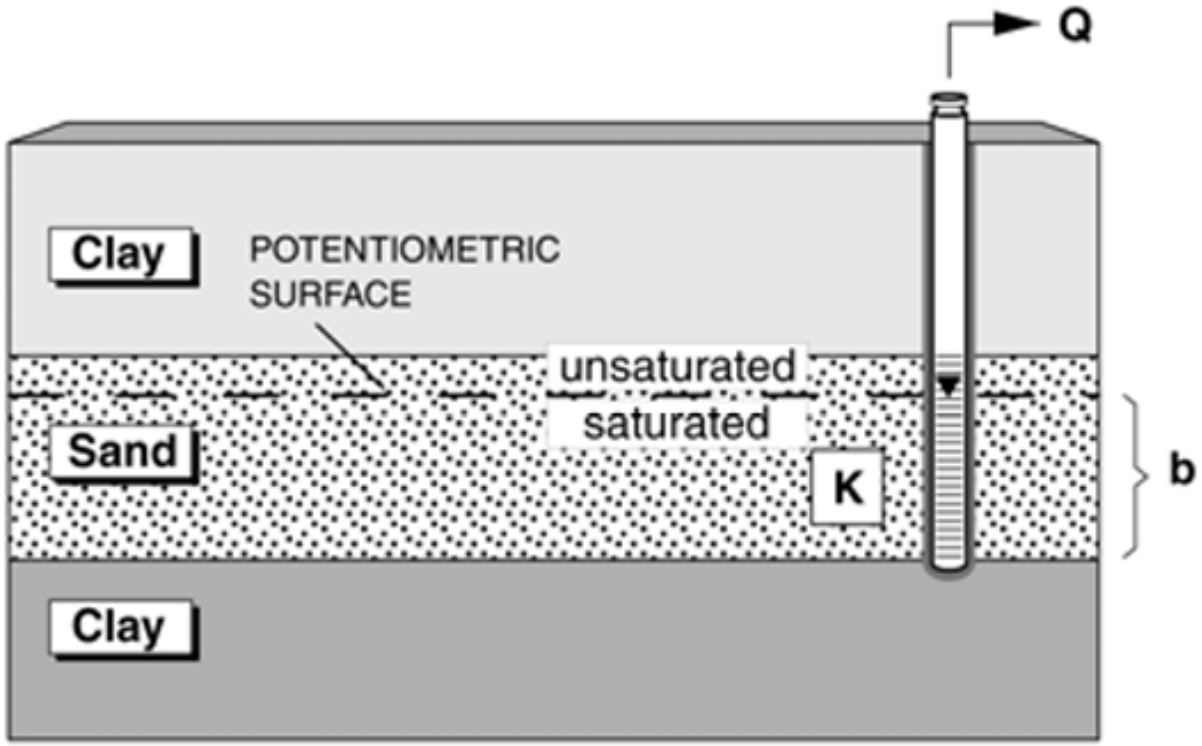
Slug Test (cont.)



Adapted from “Field Guide for Slug Testing and Data Analysis” Midwest Geosciences Group.

Method 1 Equation - Unconfined GWBU

Unconfined Groundwater-Bearing Unit



Unconfined Unit

Equation C: 4-inch Diam Well (Class 3)

$$Q = \frac{57923 \cdot K \cdot b^2}{7.2 + \log (K \cdot b)}$$

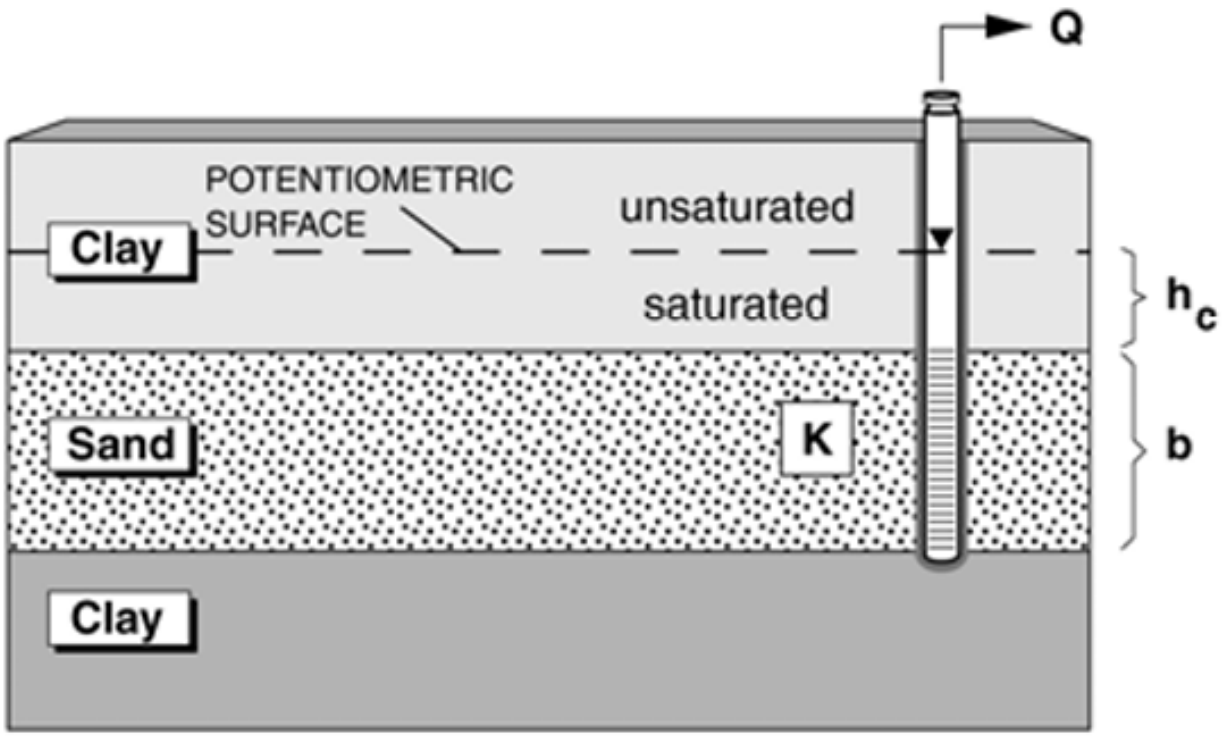
Equation D: 12-inch Diam Well (Class 1)

$$Q = \frac{57923 \cdot K \cdot b^2}{6.3 + \log (K \cdot b)}$$

Where Q = well yield in gpd
K = hydraulic conductivity in cm/sec
b = saturated thickness in ft

Method 1 Equation - Confined GWBU

Confined Groundwater-Bearing Unit



Confined Unit

Equation A: 4-inch Diam Well (Class 3)

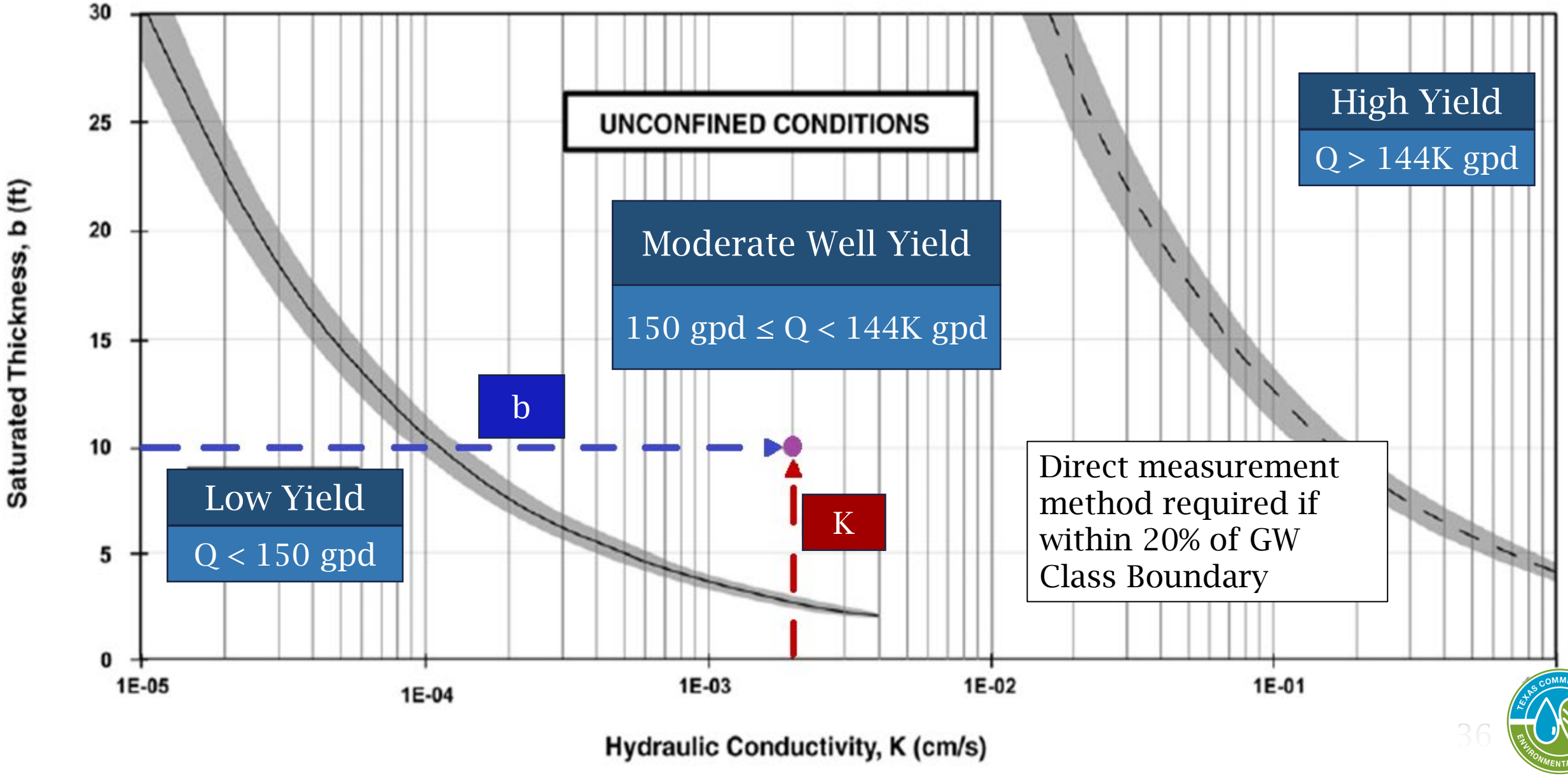
$$Q = \frac{115846 \cdot h_c \cdot K \cdot b}{10.2 + \log (K \cdot b)}$$

Equation B: 12-inch Diam Well (Class 1)

$$Q = \frac{115846 \cdot h_c \cdot K \cdot b}{9.3 + \log (K \cdot b)}$$

Where Q = well yield in gpd
K = hydraulic conductivity in cm/sec
b = saturated thickness in ft
h_c = mean annual confining head in ft

Method 1 Graph – Unconfined GWBU



Method 2 – Measuring Well Yield

2a - Cyclic Discharge

2b - Equilibrium Discharge

2c - Constant Discharge

Method 2a – Cyclic Discharge

Purpose	· Direct determination of well yield by cyclic discharge
Applicability	· High to low GWBU transmissivities
Requirements	· Measure total volume withdrawn and time to recharge
Caveats	· Minimum of 3 cycles recharge cannot exceed 90% of height to initial water level

Method 2a – Cyclic Discharge

1. Proper Well Construction
2. Initial Water Level
3. Water-Level Bail-Down

- Remove all water from the well using a pump or bailer. Contain removed water and measure the volume. Measure static water level immediately upon completion of water removal

Method 2a – Cyclic Discharge (cont.)

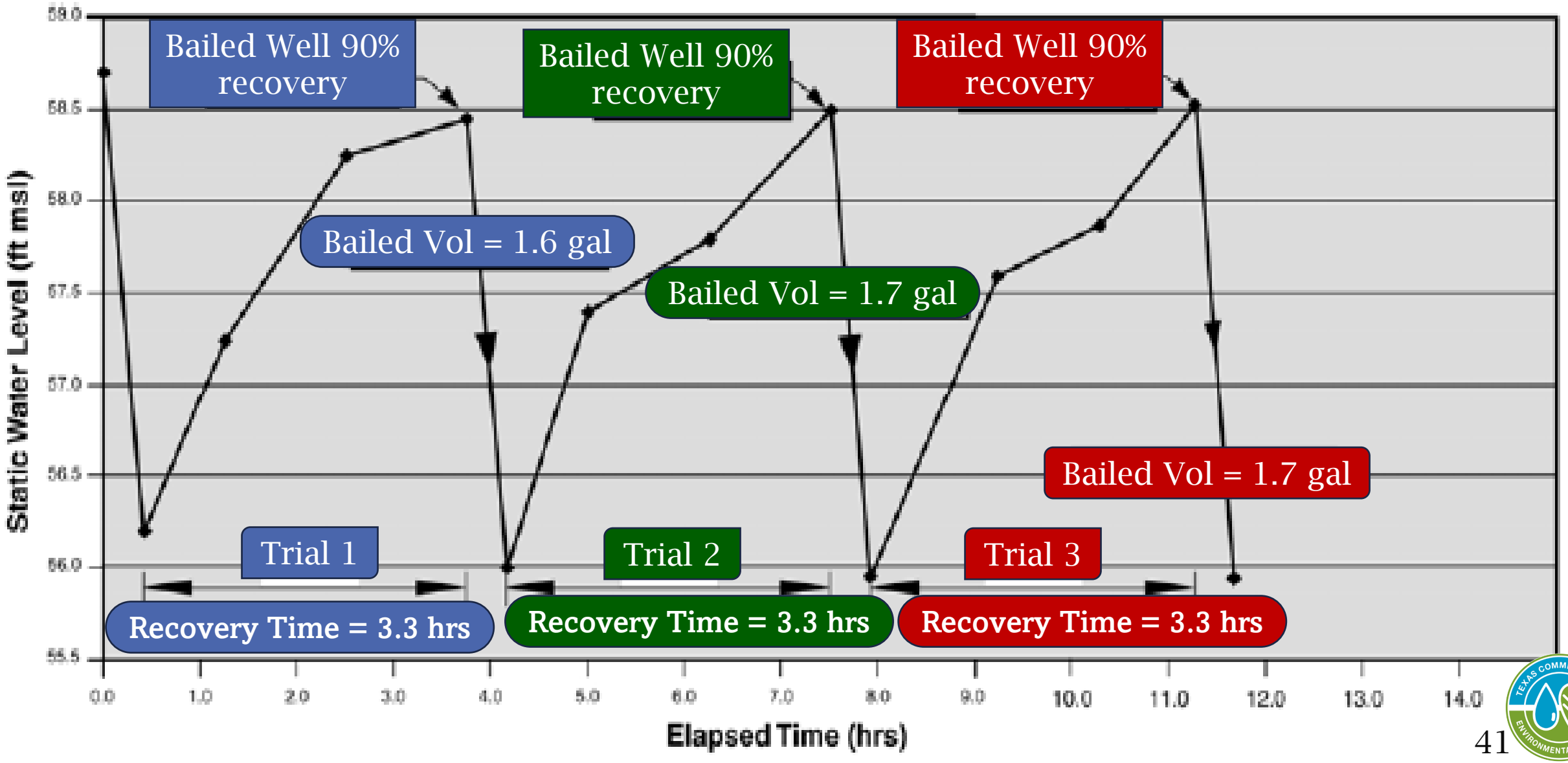
4. Time for Water – Level Recovery

- Monitor static water level and time until water level recovers to same specified level, up to but not greater than 90 percent of initial static water level.

5. Repeat Bail-Down and Recovery

- For at least 3 bail-down and recovery cycles. Record total volume removed and time until recovery. Calculate yield from total bailed volume divided by cumulative recovery time for all cycles.

Method 2a – Cyclic Discharge Graph



Cyclic Discharge – Yield Calculation

Well Yield Calculation

$$Q_{well} = \frac{V_{bail}}{t} \cdot \frac{(24\ hrs)}{(day)}$$

where:

V_{bail} = Volume of water bailed after the 90 % recovery time for Trials 1, 2, and 3 in gallons.

t = Recovery time for Trials 1, 2, and 3 in hrs.

Q = Estimated daily flowrate for well based on baildown yield test.

$$Q_{well} = \frac{(1.6 + 1.7 + 1.7)\ gals}{(3.3+3.3+3.4)\ hrs} \cdot \frac{(24\ hrs)}{(day)}$$

$$Q_{well} = 12.0\ gallons/day$$

FINDING:
Maximum well yield < 150 gpd.

Method 2b – Equilibrium Water Level Test

Purpose	· Direct determination of well yield by equilibrium discharge
Applicability	· Low GWBU transmissivities
Requirements	· Constant discharge rate (pumped or bailed)
Caveats	· Wells should not be pumped dry

Method 2b – Equilibrium Water Level Test

1. Properly Constructed Well
2. Initial Water Level
3. Pump Installation

- Maintain constant drawdown near bottom of the well

Method 2b – Equilibrium Water Level Test (cont.)

4. Water Level Equilibrium

- Monitor static water level until well has re-equilibrated

5. Well Pumping

- Set discharge rate so water level is near the base of the well screen. Adjust pumping rate until water level remains constant

6. Measure Equilibrium Discharge Rate

- After water level equilibrium is established determine pump discharge rate and convert to units of gpd

Method 2c – Constant Discharge

Purpose	· Direct determination of Class 2/Class 3 yield boundary by constant discharge
Applicability	· Low GWBU transmissivities
Requirements	· Constant discharge rate (0.1 gpm)*
Caveats	· Discharge rate and water level should be monitored continuously

Method 2c - Well Yield by Constant Discharge Test

1. Properly Constructed Well

2. Initial Water Level

3. Pump Installation

- Pump capable of maintaining constant discharge rate of 0.1 gpm (4-inch well) and placed near bottom of well

Method 2c - Well Yield by Constant Discharge Test (cont.)

4. Water Level Equilibrium

- If water level remains constant or falls to new static level, well yield is greater than 150 gpd

5. Well Pumping

- Monitored and discharge rate corrections for deviations with hydrostatic pressure when water level falls

6. Test Termination

- When 150 gallons of water is produced, when water level falls to bottom of well, or testing duration reaches 8 hours, whichever occurs first.

Method 2 - Screen Diameter Correction Factor

Method 2 for Class 3 yield limit

- Assumes a 4-inch well or equivalent for 150 gpd

Well size other than 4 inch used?

- **MUST** do a correction factor.

Correction Factor for Equivalent Yield for a 4–inch diameter well

Nominal Screen diameter of Test Well	Confined Unit	Unconfined Unit
2 –inch	1.08	1.10
4 - inch	1.00	1.00
6 - inch	0.95	0.94
8 – inch	0.92	0.90
10 – inch	0.89	0.87
12 – inch	0.87	0.85
16 – inch	0.84	0.80
24 – inch	0.79	0.75

Multiply well yield measured in test well by the correction factor to obtain the equivalent yield of a well with a 4-inch diameter

Correction Factor for Equivalent Yield for a 12–inch diameter well

Nominal Screen diameter of Test Well	Confined Unit	Unconfined Unit
2 –inch	1.24	1.30
4 - inch	1.14	1.18
6 - inch	1.09	1.12
8 – inch	1.05	1.07
10 – inch	1.02	1.03
12 – inch	1.00	1.00
16 – inch	0.96	0.95
24 – inch	0.91	0.88

CASE STUDIES

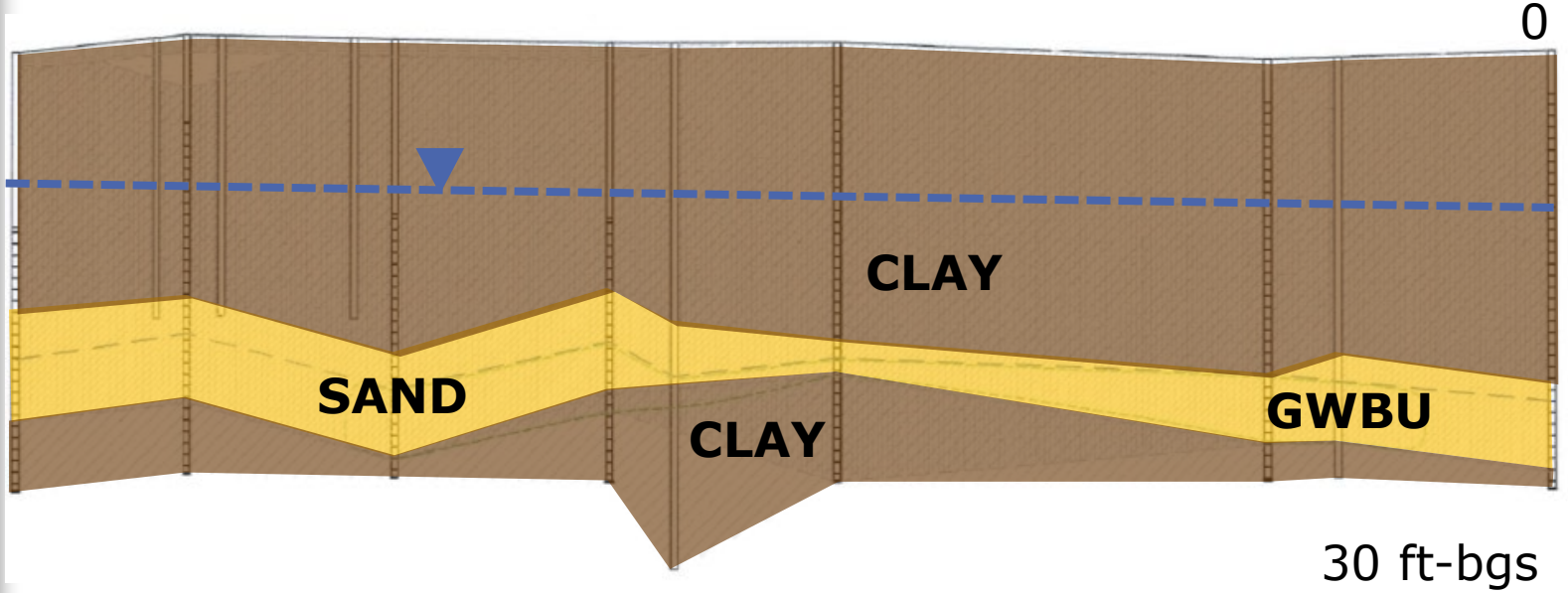
CASE STUDY 1

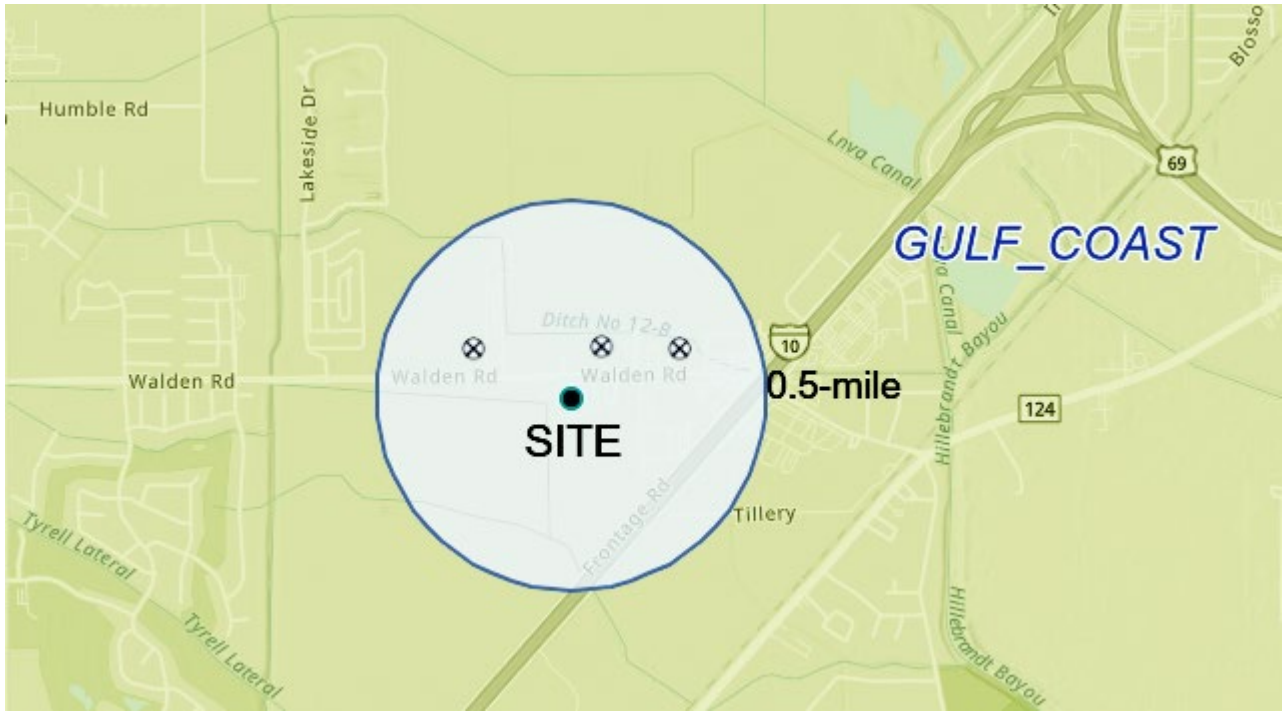
Class 2 using Method 1

Step 1: Upper GWBU is a saturated sand layer at 20 ft deep

Step 2: Thick cconfining clay unit with low hydraulic conductivity. No apparent interconnectivity.

Step 3: Three water wells within 0.5 miles in a lower GWBU. No current use of the shallow GWBU.



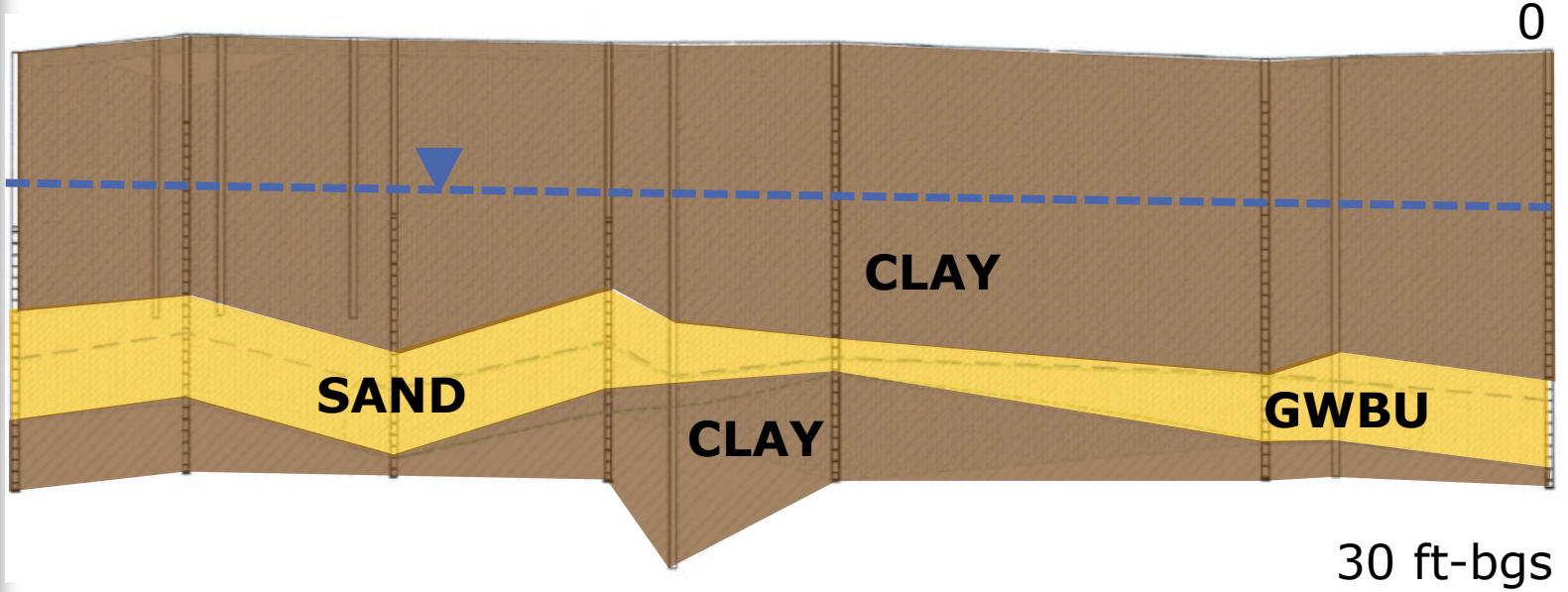


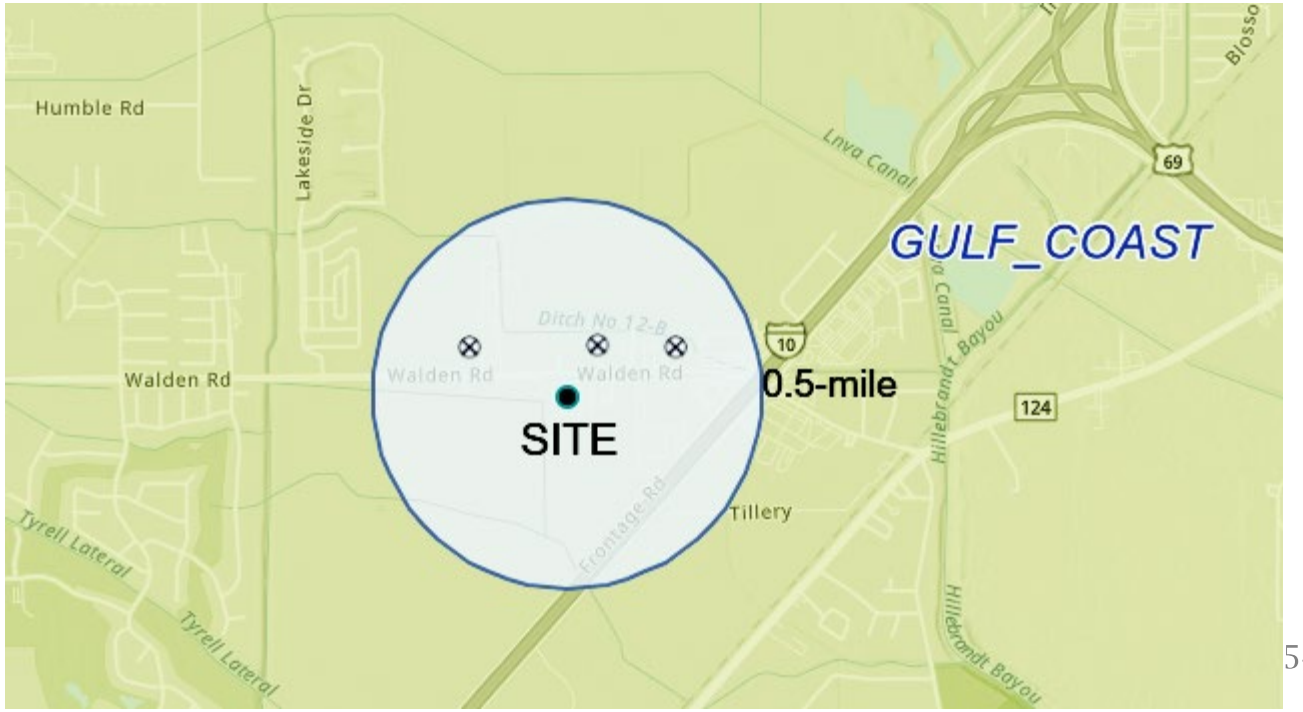
CASE STUDY 1 (CONT.)

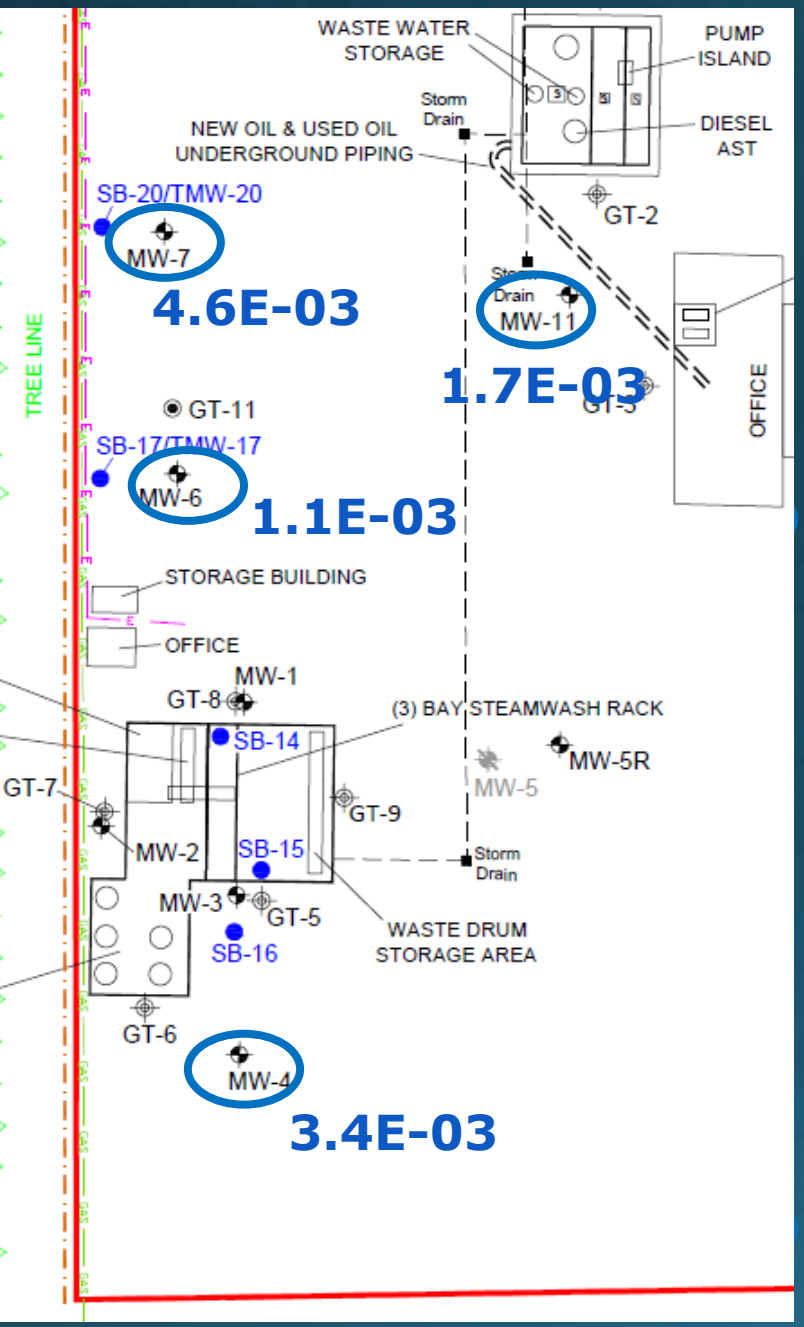
Step 4: TDS of 1,400 mg/L
Water quality is fresh
Assumed to meet PDWS

Step 5: Well yield estimated via Method 1

Step 6: GW resource aassumed sustainable



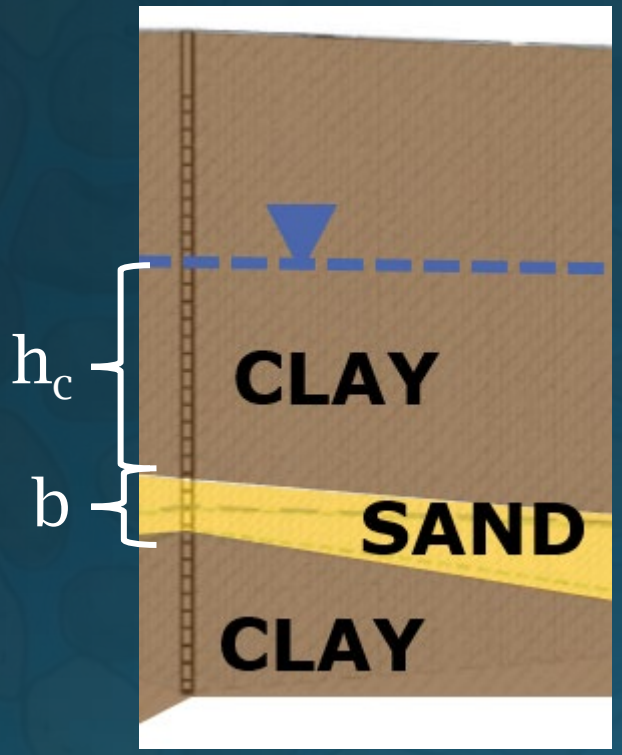




CASE STUDY 1 (CONT. 2)

- Step 5: Well yield estimation – determine hydraulic conductivity (K)
- Three slug tests per well at four monitoring wells
- Average K (arithmetic mean) at each well
- K of the GWBU (geometric mean) = 2.0×10^{-3} cm/s

CASE STUDY 1 (CONT. 3)



Well yield Q (confined aquifer)

$$Q = \frac{(115{,}846)(h_c)(K)(b)}{10.2 + \log[(K)(b)]}$$

K = hydraulic conductivity: 2.0E-03 cm/s

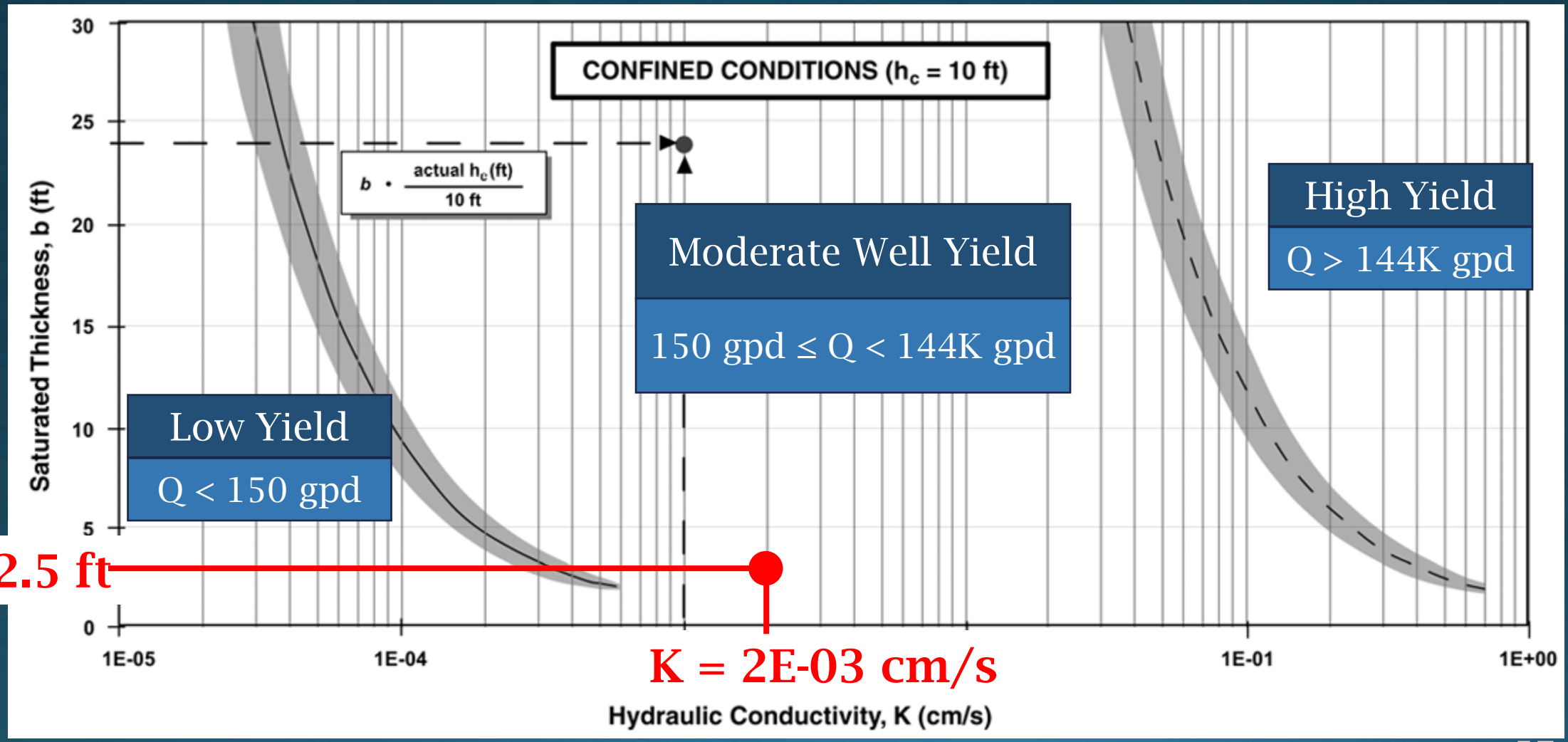
b = saturated thickness: 2.5 ft

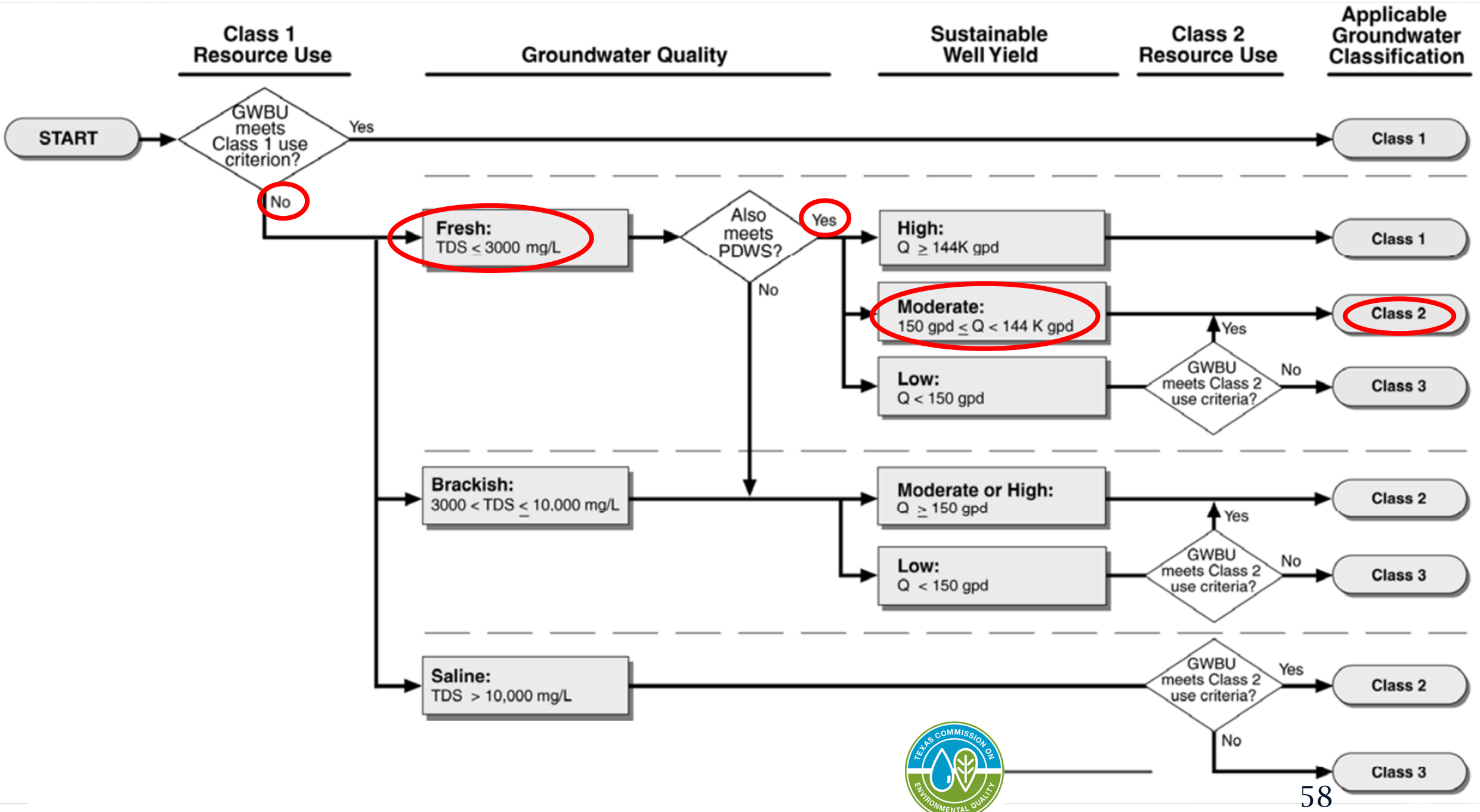
h_c = confining head above top of GWBU: 10 ft

Average yield of approximately 700 gpd

CASE STUDY 1 (CONT. 4)

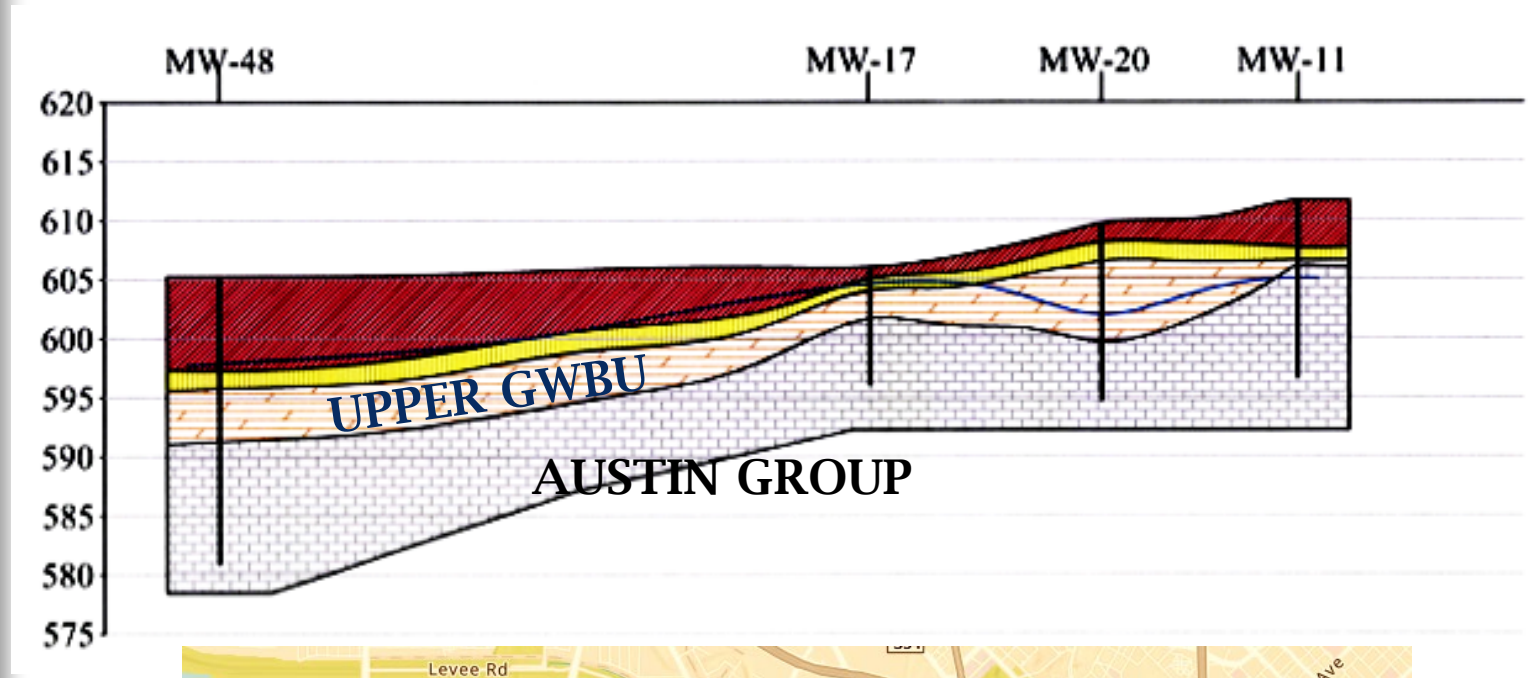
- Moderate yield (between 150 and 144K gpd)

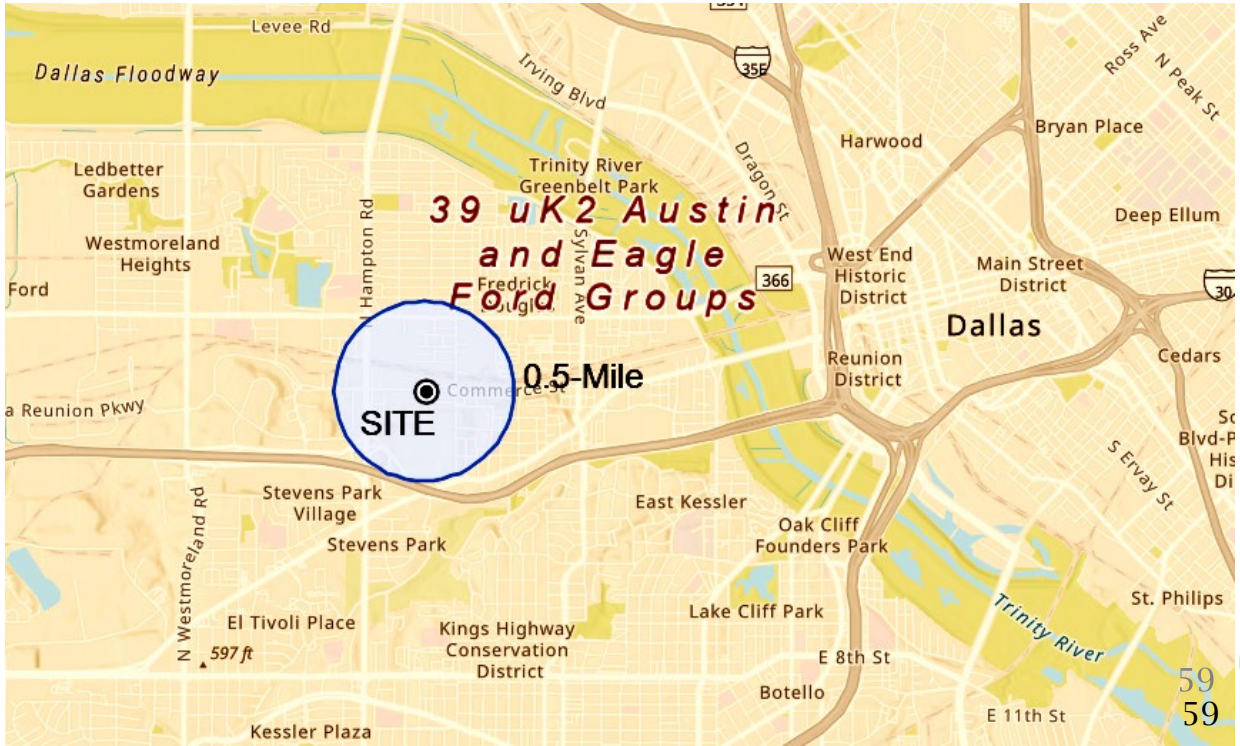



Class 1 Resource Use
Groundwater Quality
Sustainable Well Yield
Class 2 Resource Use
Applicable Groundwater Classification
START
GWBU meets Class 1 use criterion?
Yes
No
Class 1
Fresh:
TDS ≤ 3000 mg/L
Also meets PDWS?
Yes
No
High:
Q ≥ 144K gpd
Class 1
Moderate:
150 gpd ≤ Q < 144 K gpd
Class 2
Low:
Q < 150 gpd
GWBU meets Class 2 use criteria?
Yes
No
Class 3
Brackish:
3000 < TDS ≤ 10,000 mg/L
Moderate or High:
Q ≥ 150 gpd
Class 2
Low:
Q < 150 gpd
GWBU meets Class 2 use criteria?
Yes
No
Class 3
Saline:
TDS > 10,000 mg/L
GWBU meets Class 2 use criteria?
Yes
Class 2
No
Class 3

CASE STUDY 2

- Class 3 by Method 2a
- Step 1: Upper GWBU within weathered limestone (5-15 ft-bgs)
- Step 2: Austin Group (aquitard) 300 ft thick above the Woodbine Aquifer. No apparent interconnectivity
- Step 3: No water wells within 0.5 miles. No current use of the shallow GWBU.





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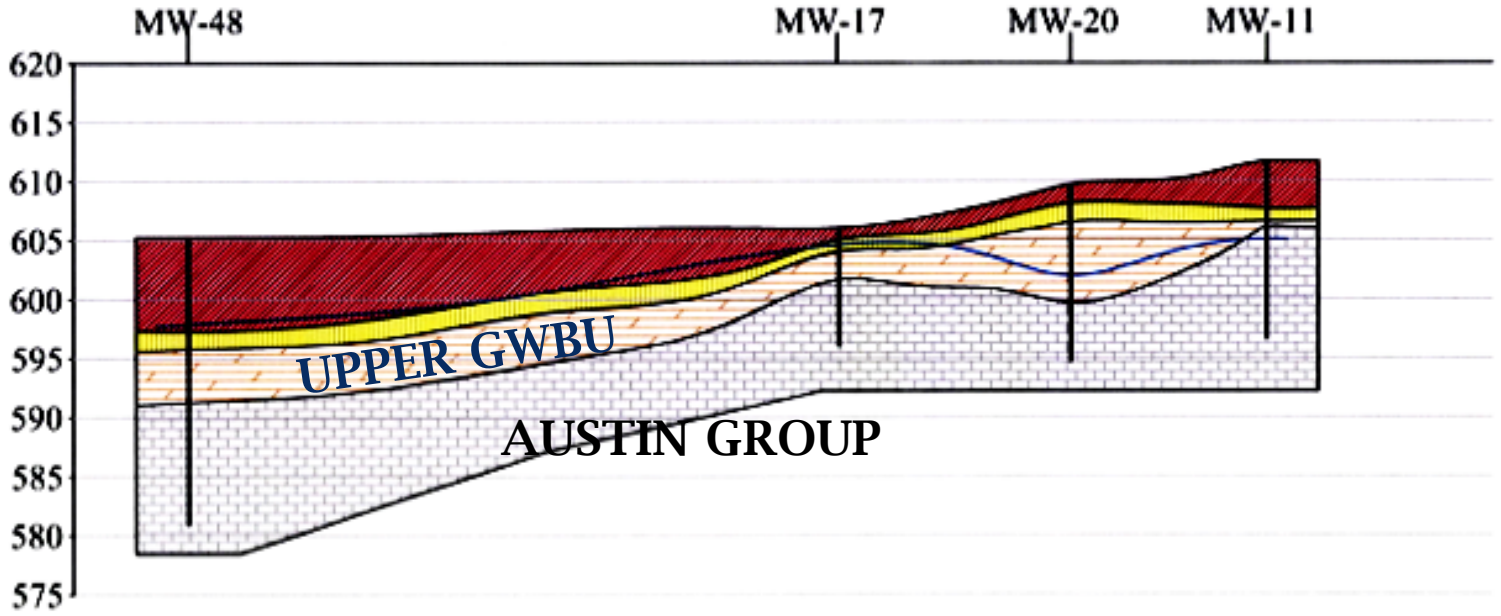
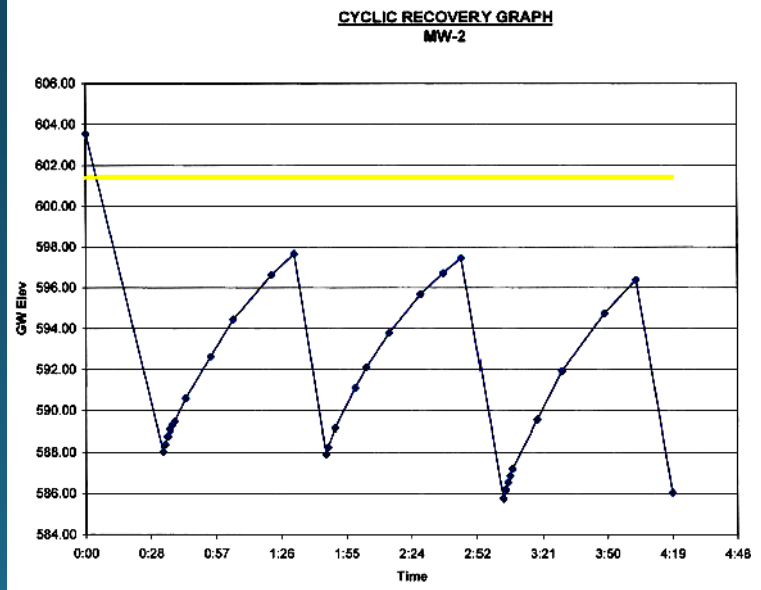
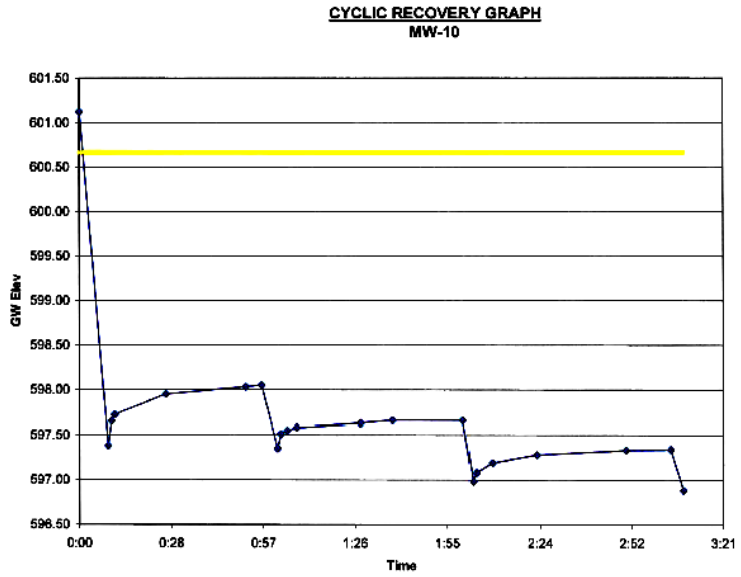
CASE STUDY 2 (CONT.)

- Step 4 : TDS assumed <3,000 mg/L and meet PDWS
- Step 5: Well yield by Method 2a: cyclic discharge
  Test on 14 MWs



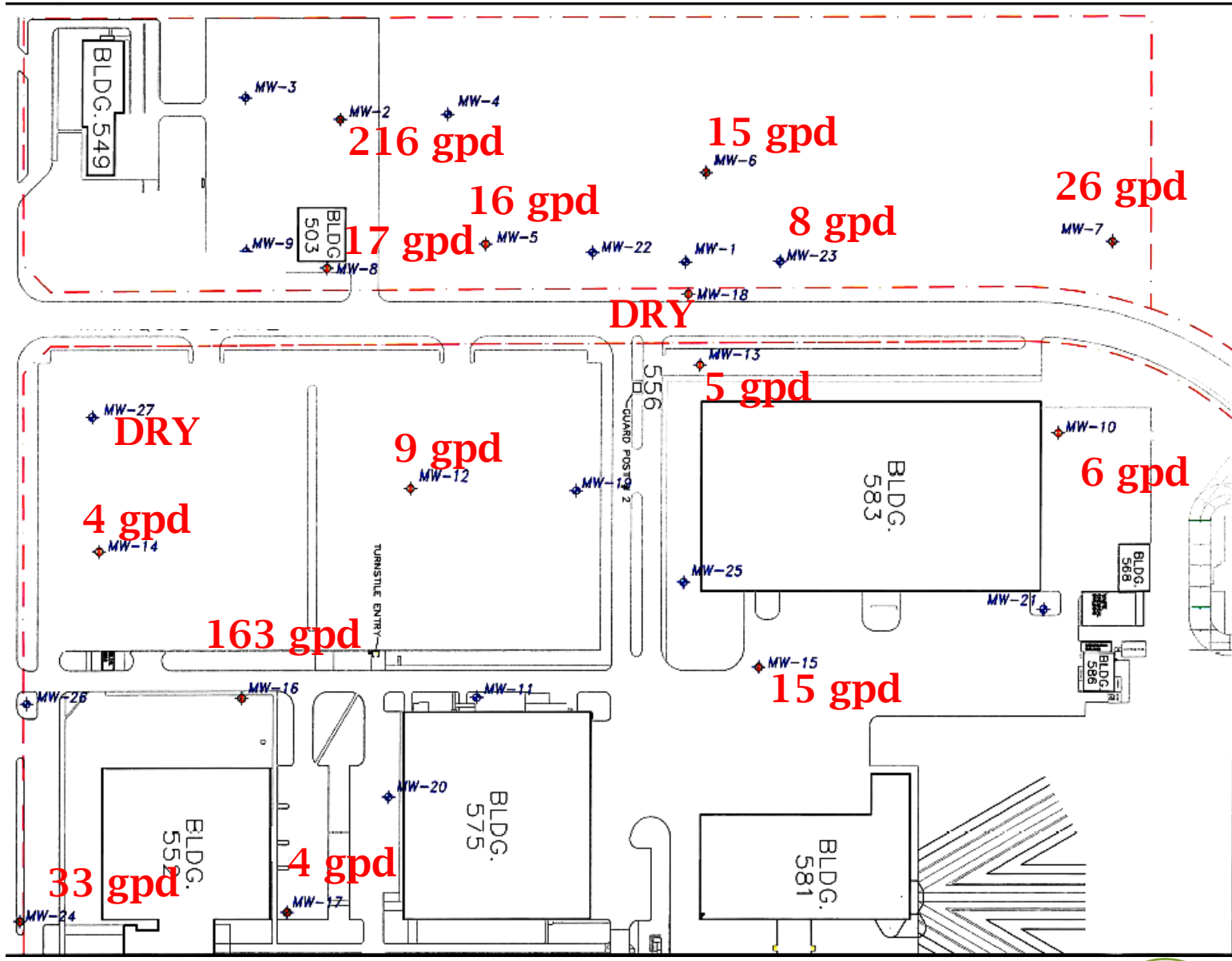


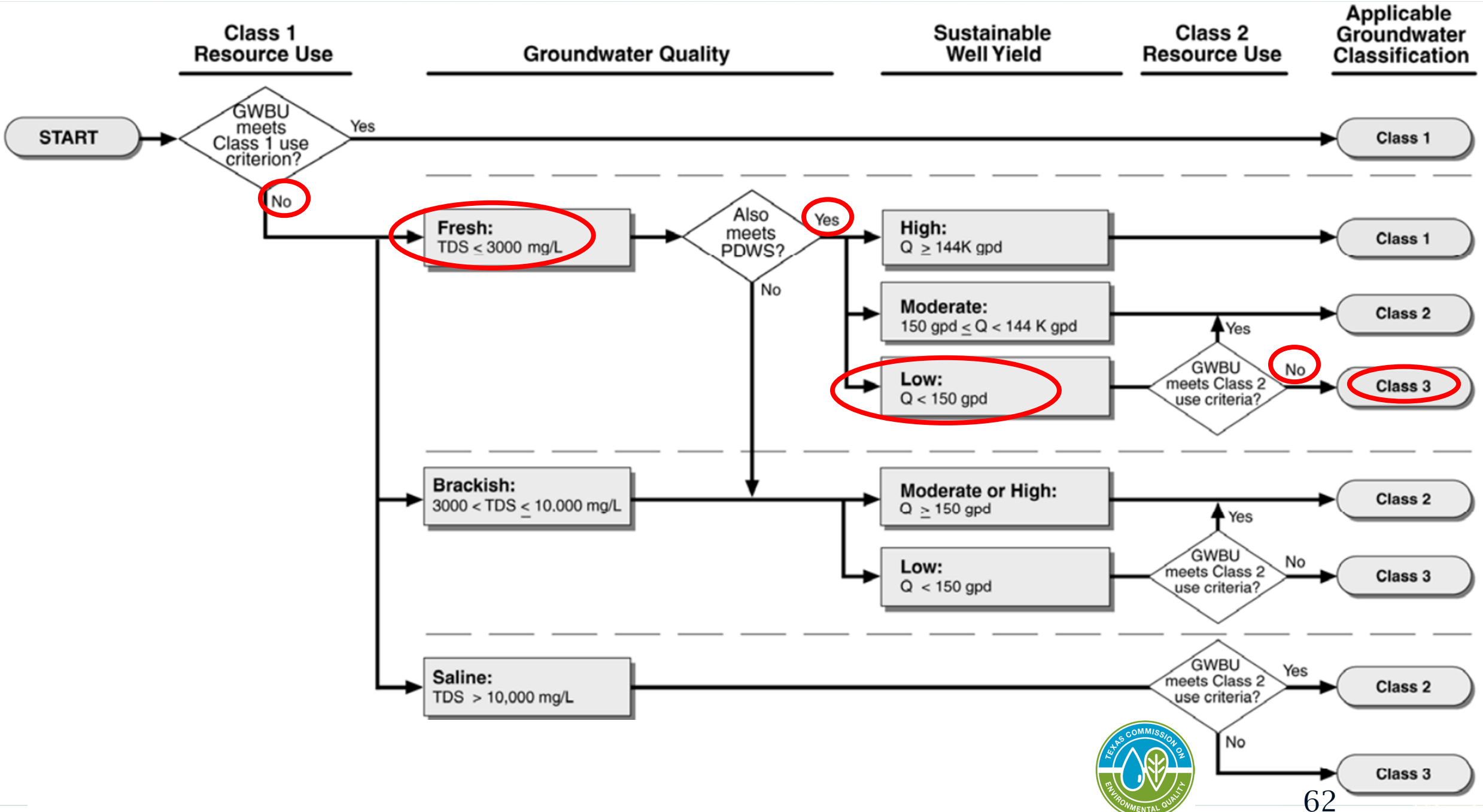


CASE STUDY 2 (CONT. 2)

- Various well yields, various degree of weathering
- Average (geometric mean) yield of 16 gpd

Step 6: GW resource assumed sustainable – except for two dry MWs

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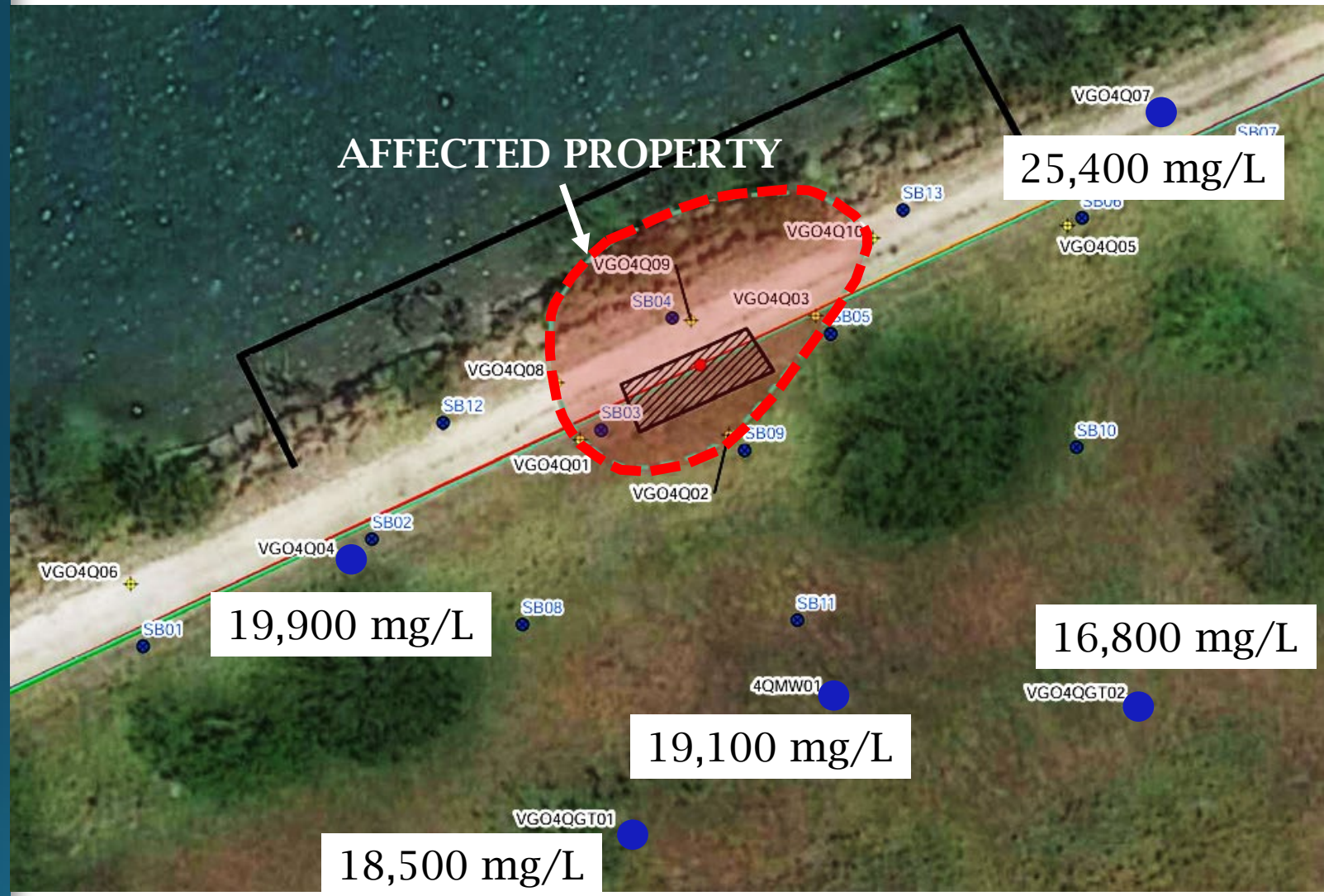
GWBU meets Class 2 use criteria?
Yes
No
Class 3
Brackish:
3000 < TDS ≤ 10,000 mg/L
Moderate or High:
Q ≥ 150 gpd
Class 2
Low:
Q < 150 gpd
GWBU meets Class 2 use criteria?
Yes
No
Class 3
Saline:
TDS > 10,000 mg/L
GWBU meets Class 2 use criteria?
Yes
Class 2
No
Class 3

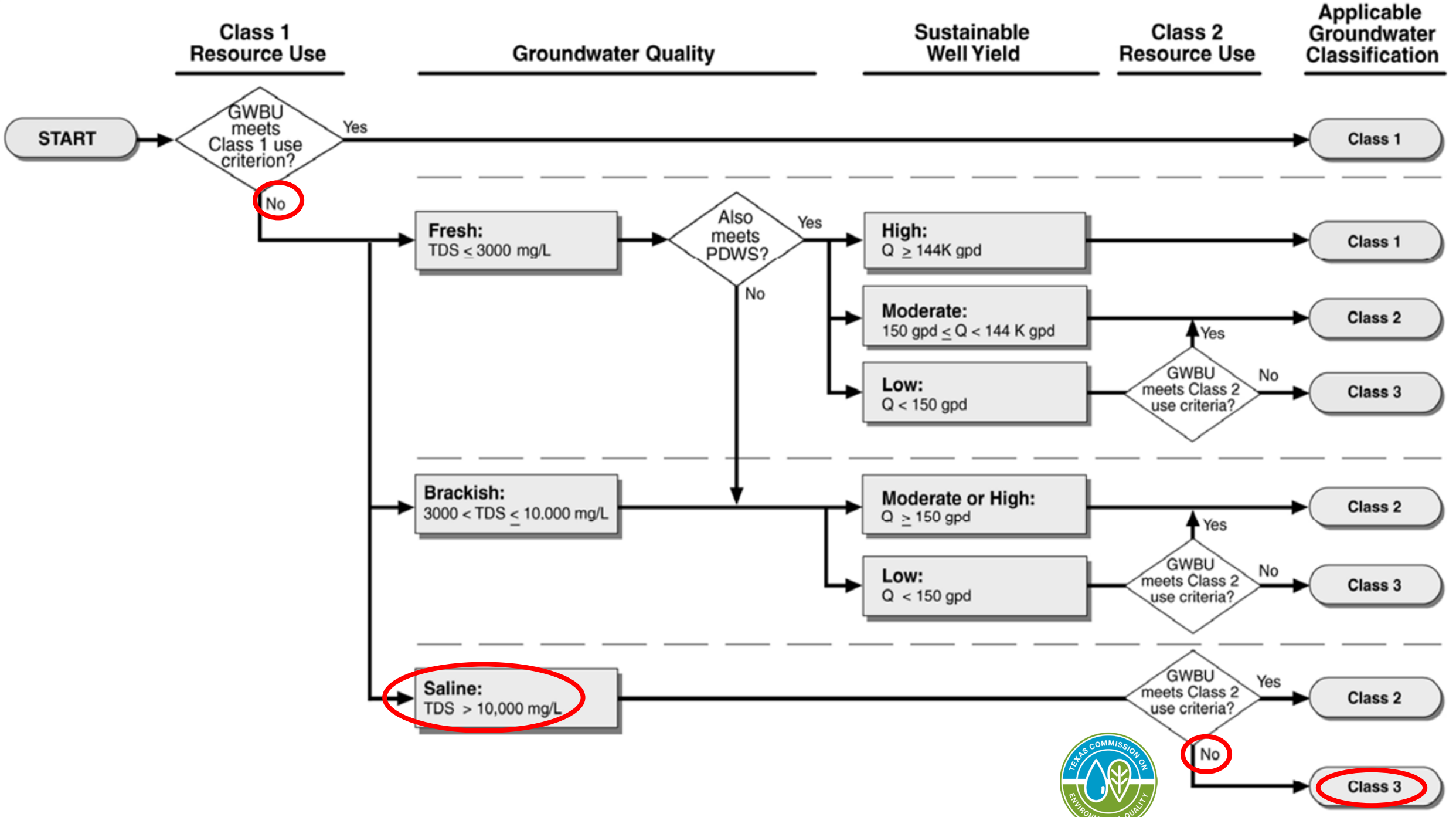
CASE STUDY 3

- Class 3 demonstration based on water quality
- Step 1: GWBU between 5 and 20 ft-bgs within sand layers
- Step 2: Next GWBU not impacted, no apparent interconnectivity
- Step 3: No water wells within 0.5-mile

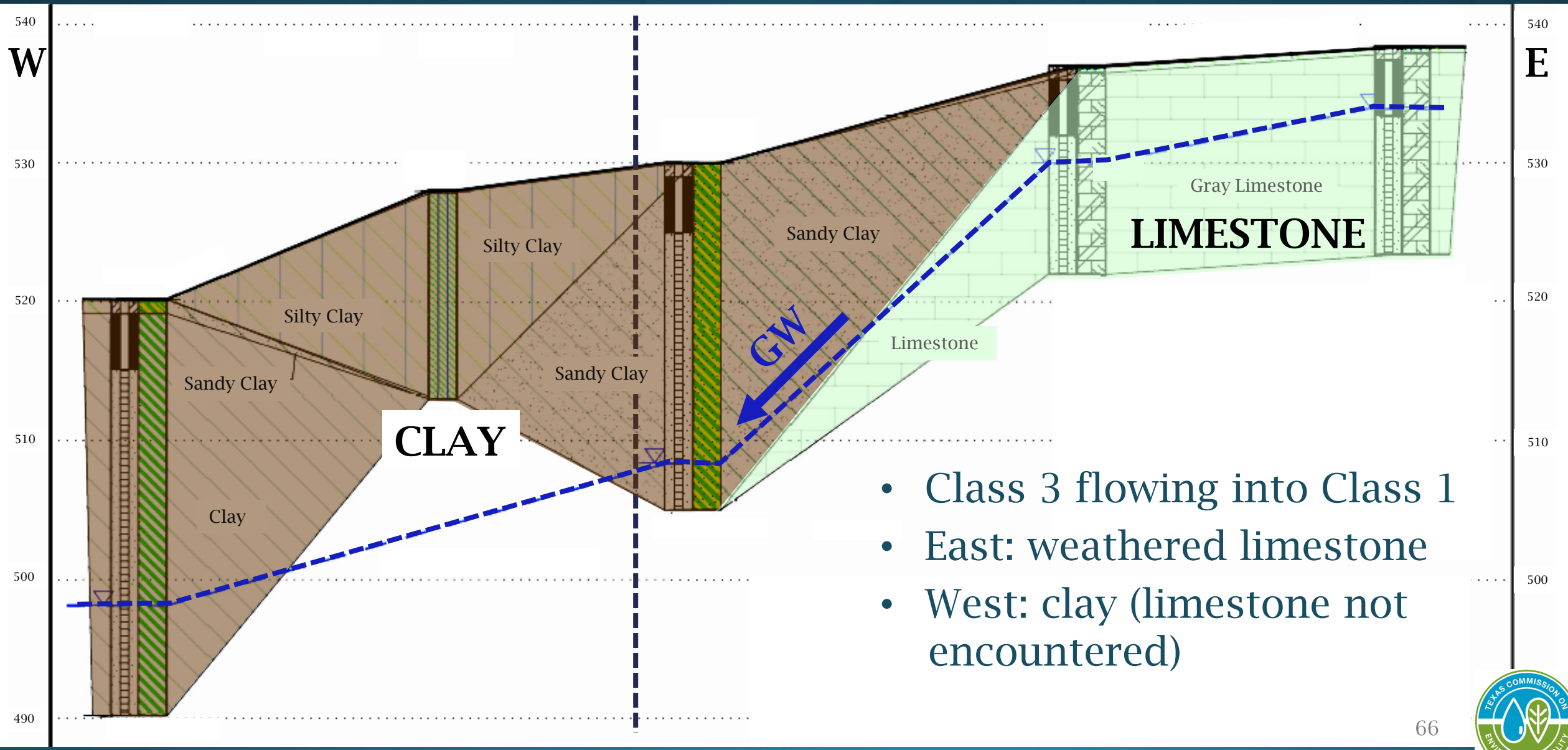
CASE STUDY 3 (CONT.)

- Step 4: TDS analyzed in five unaffected wells; aabove 10,000 mg/L = saline groundwater
- Step 5: Well yield not provided
- Step 6: GW resource assumed sustainable



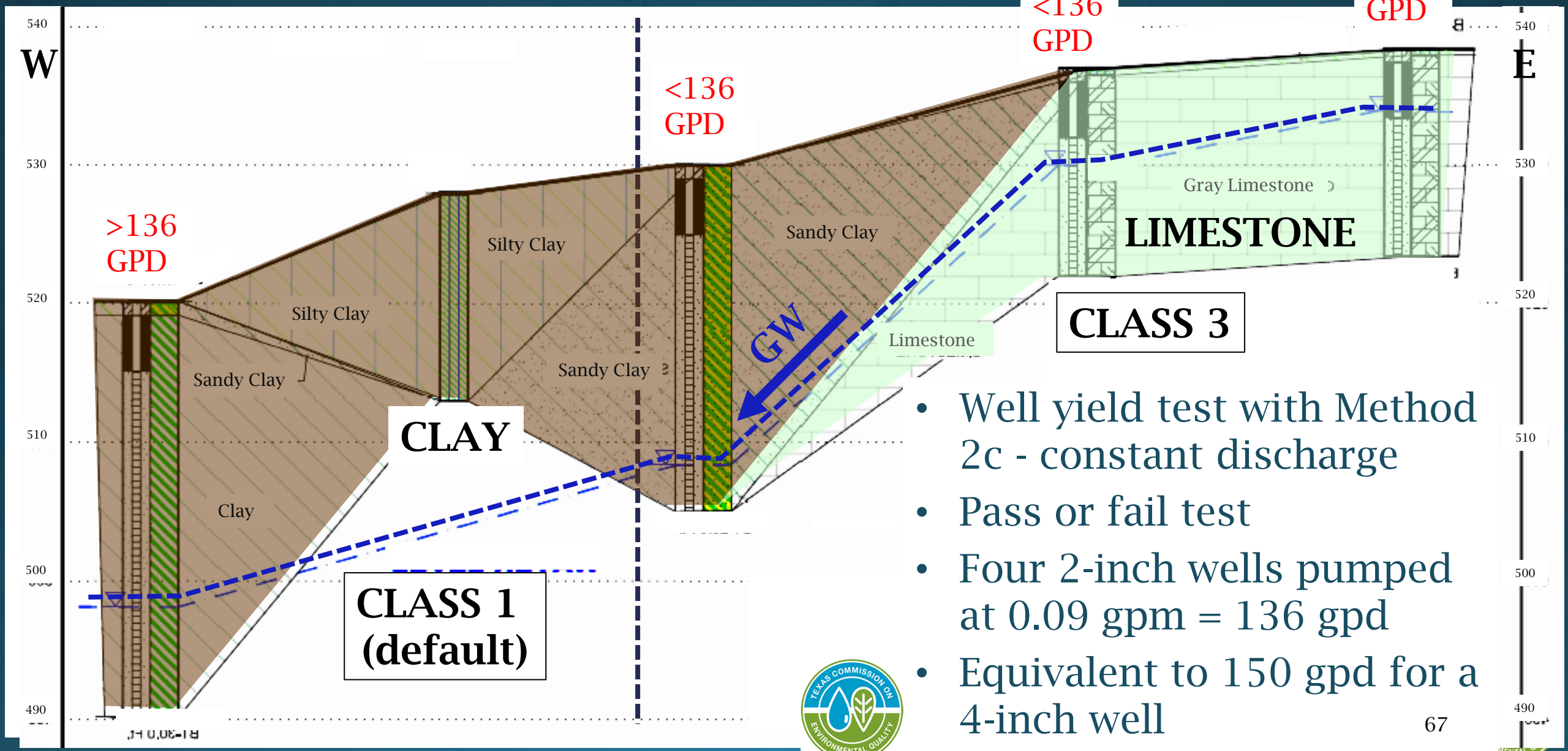

Class 1 Resource Use
Groundwater Quality
Sustainable Well Yield
Class 2 Resource Use
Applicable Groundwater Classification
START
GWBU meets Class 1 use criterion?
Yes
No
Class 1
Fresh:
TDS ≤ 3000 mg/L
Also meets PDWS?
Yes
No
High:
Q ≥ 144K gpd
Class 1
Moderate:
150 gpd ≤ Q < 144 K gpd
Class 2
Low:
Q < 150 gpd
GWBU meets Class 2 use criteria?
Yes
No
Class 3
Brackish:
3000 < TDS ≤ 10.000 mg/L
Moderate or High:
Q ≥ 150 gpd
Class 2
Low:
Q < 150 gpd
GWBU meets Class 2 use criteria?
Yes
No
Class 3
Saline:
TDS > 10,000 mg/L
GWBU meets Class 2 use criteria?
Yes
Class 2
No
Class 3

CASE STUDY 4



- Class 3 flowing into Class 1
- East: weathered limestone
- West: clay (limestone not encountered)

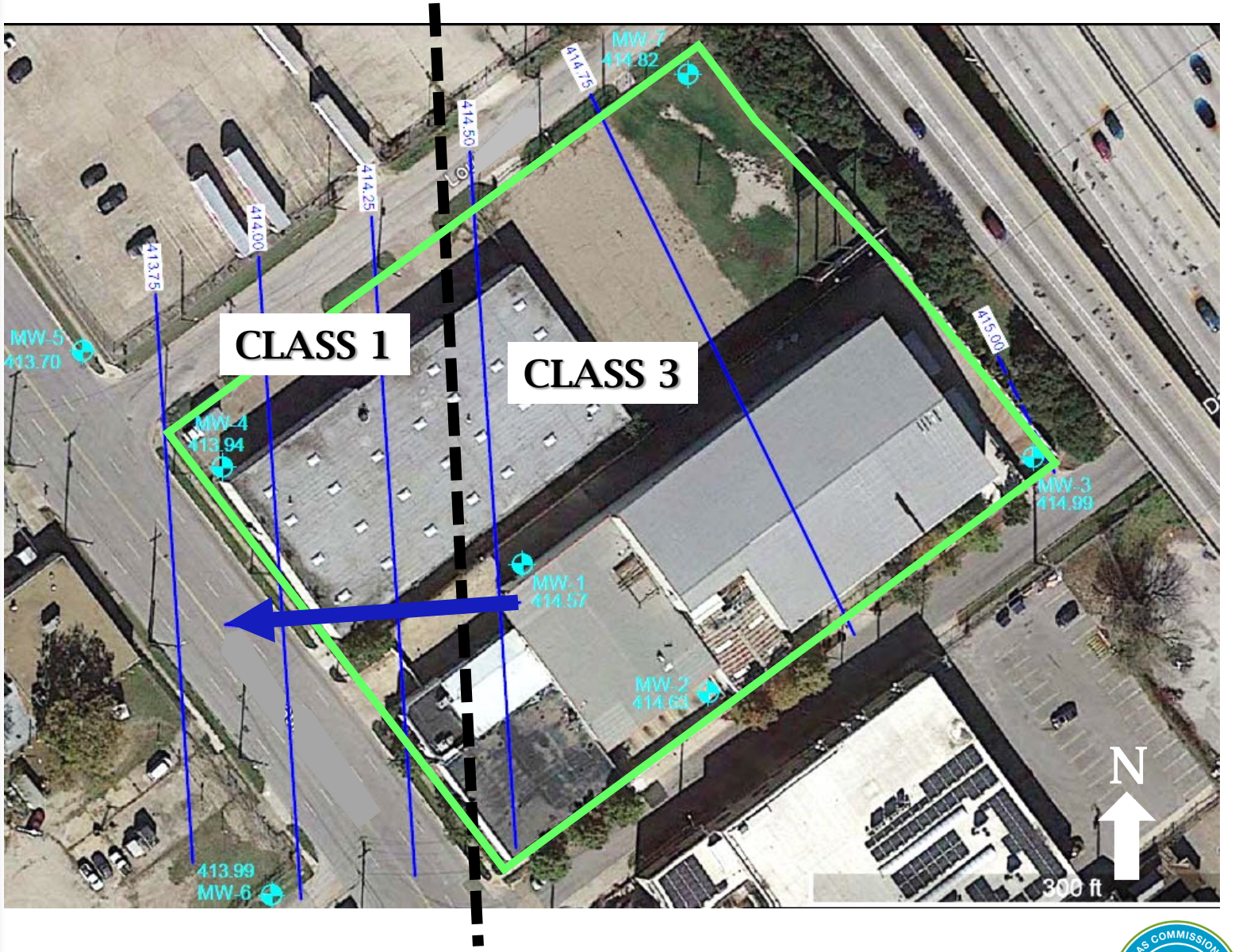
CASE STUDY 4 (CONT.)



- Well yield test with Method 2c - constant discharge
- Pass or fail test
- Four 2-inch wells pumped at 0.09 gpm = 136 gpd
- Equivalent to 150 gpd for a 4-inch well

CASE STUDY 4 (CONT. 2)

- Class 1 PCLs used on the western portion
- Class 3 PCLs used on the eastern portion
- Must be delineated to Class 1 PCL at the Class 1 boundary and demonstrate stability / no migration
- Remediation must meet the response objectives for Class 1 GWBU



CASE STUDY 5

Step 1: GWBU at 40 ft bgs

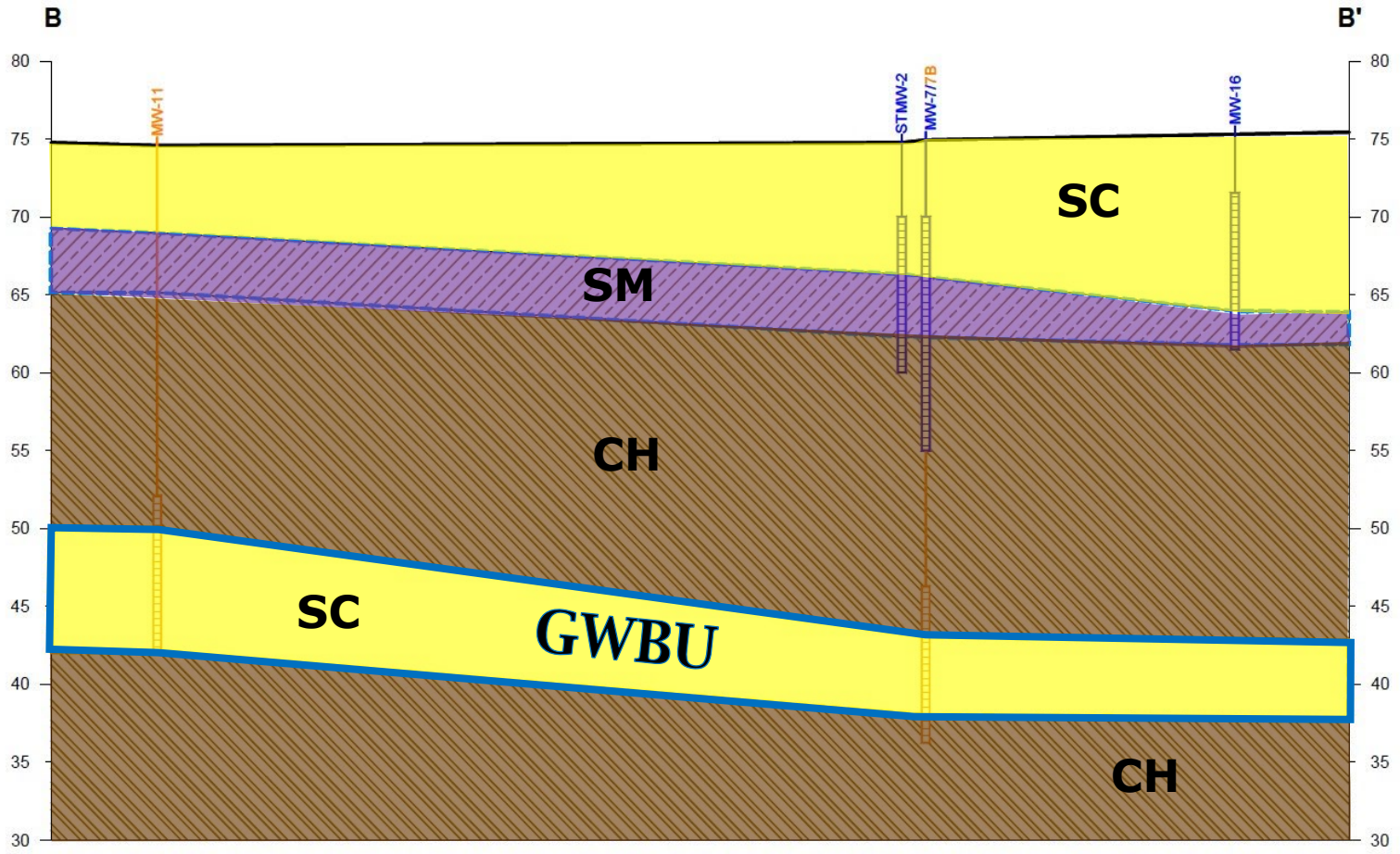
Step 2: Thick lower cconfining clay unit. Unlikely to impact another GWBU

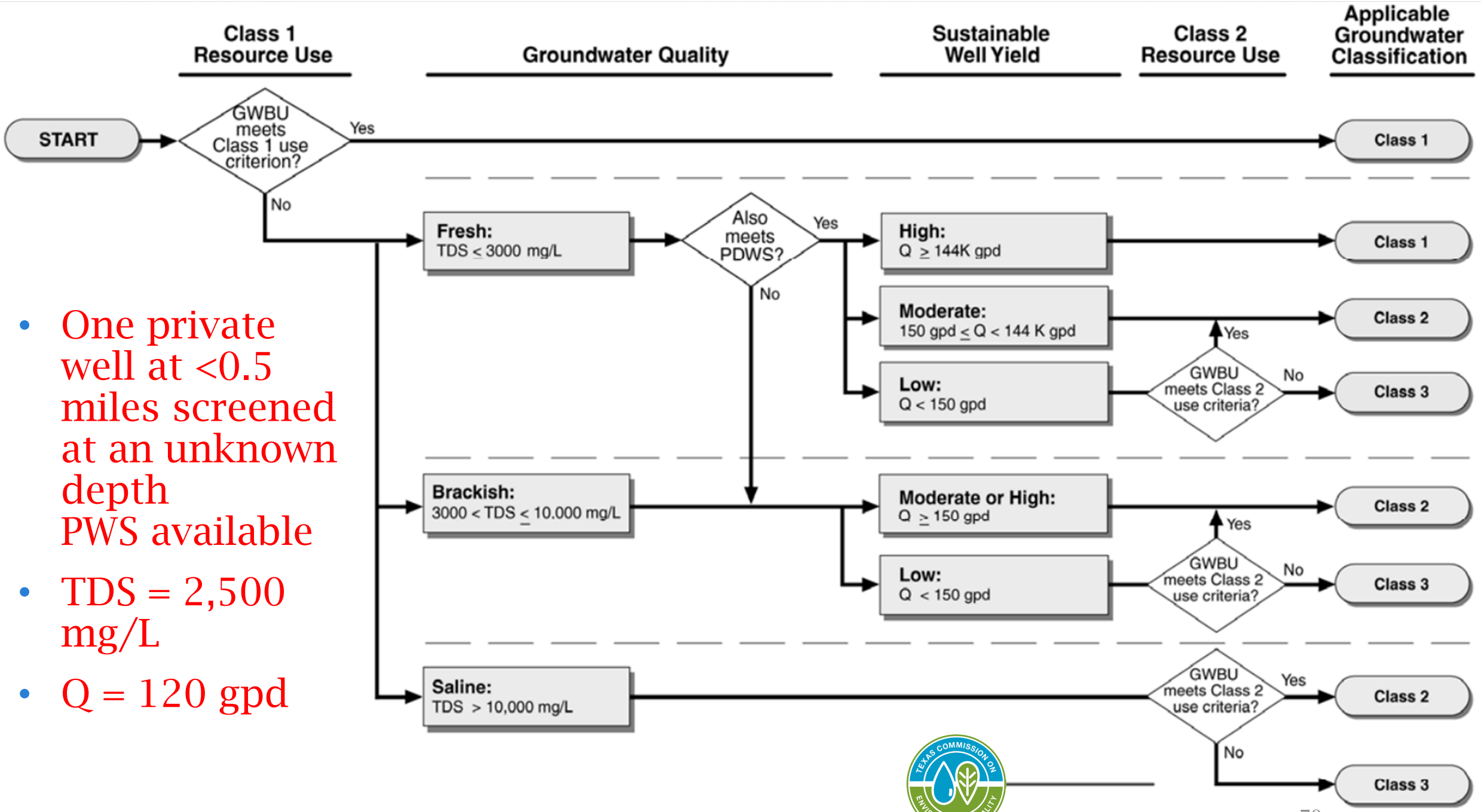
Step 3: One private well at ~0.30 miles unknown screened depth PWS system available

Step 4: TDS = 2,500 mg/L

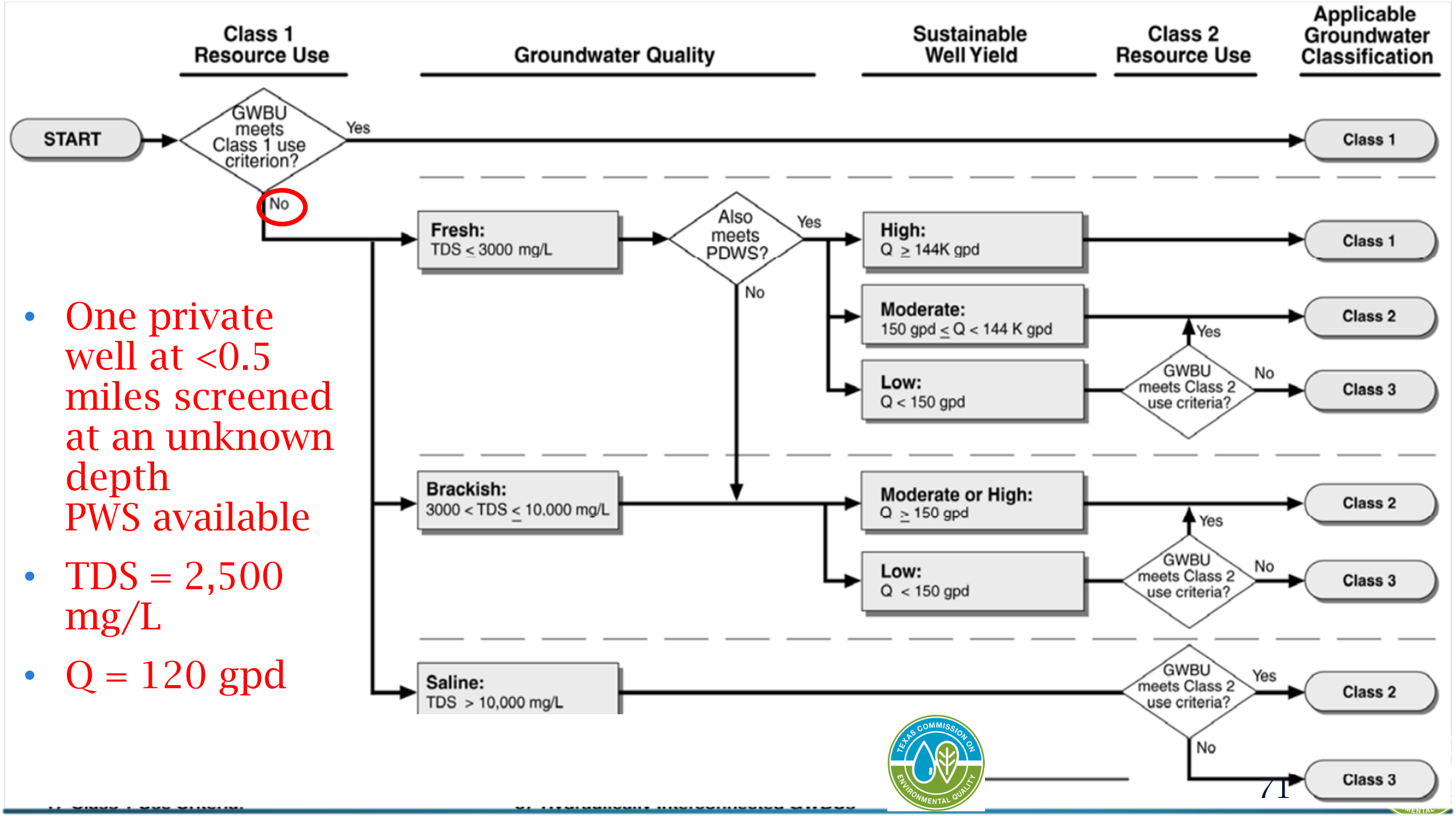
Step 5: Q = 120 gpd

Step 6: Assumed sustainable.

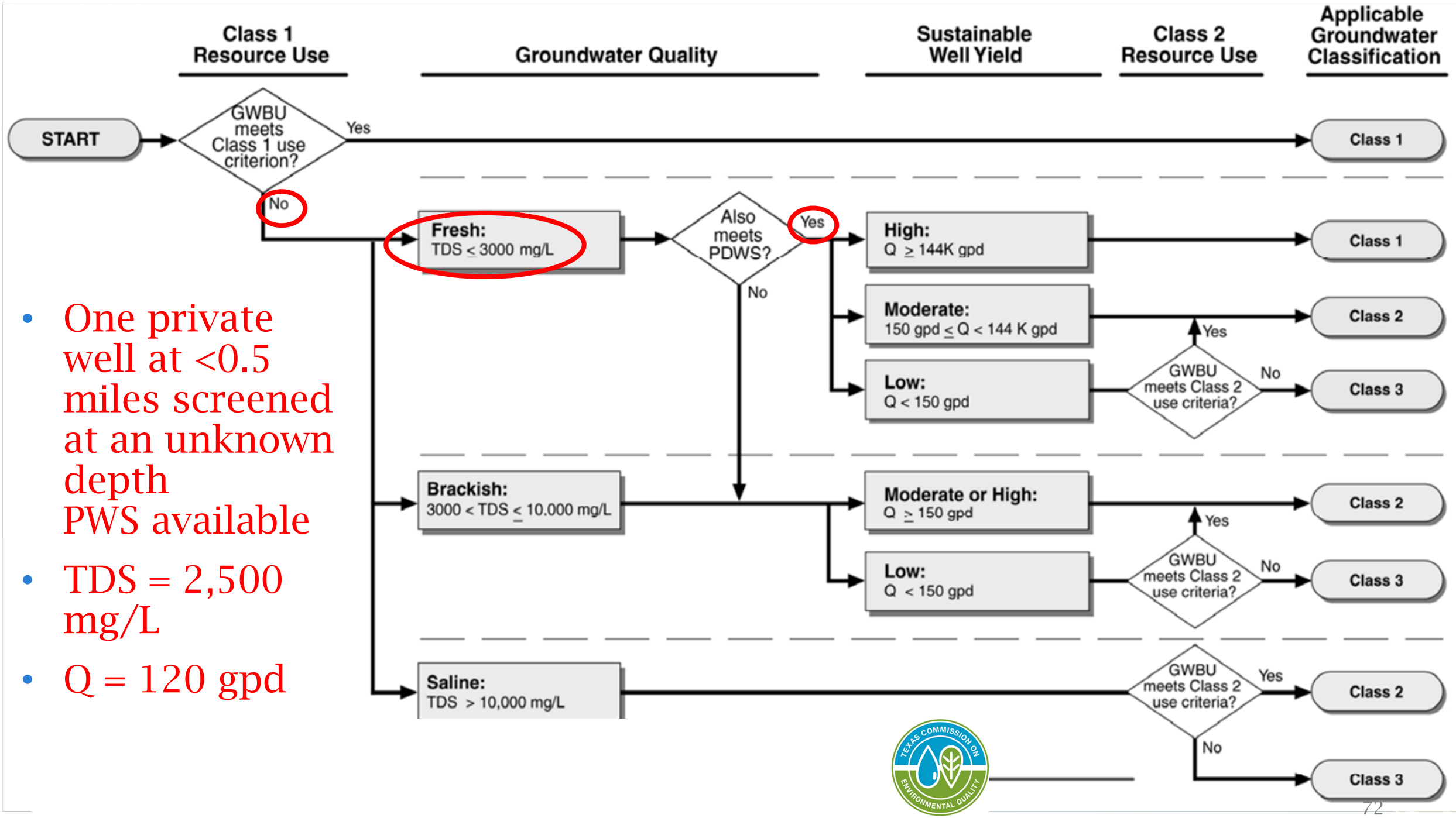




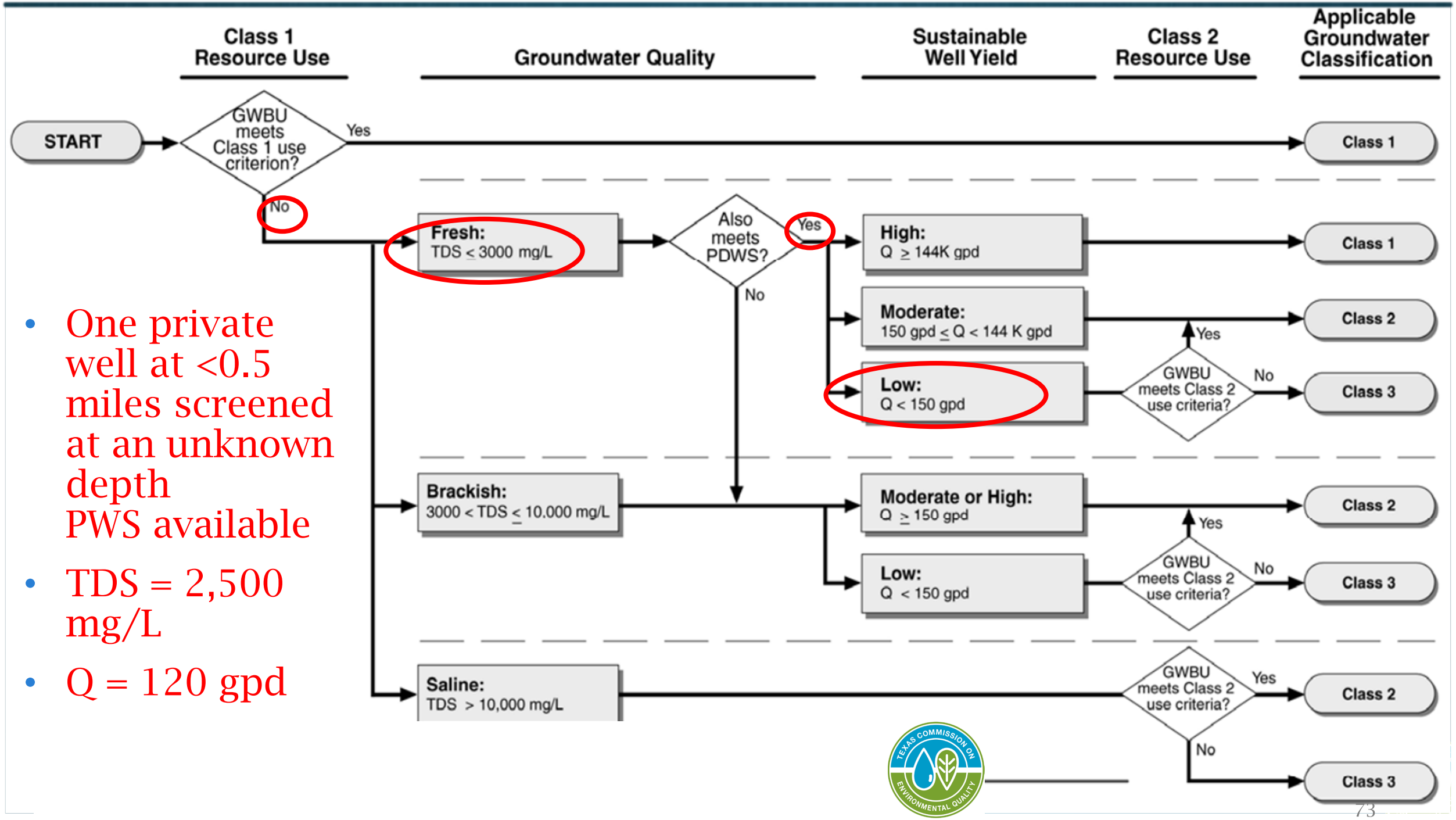
- One private well at <0.5 miles screened at an unknown depth
  PWS available
- TDS = 2,500 mg/L
- Q = 120 gpd



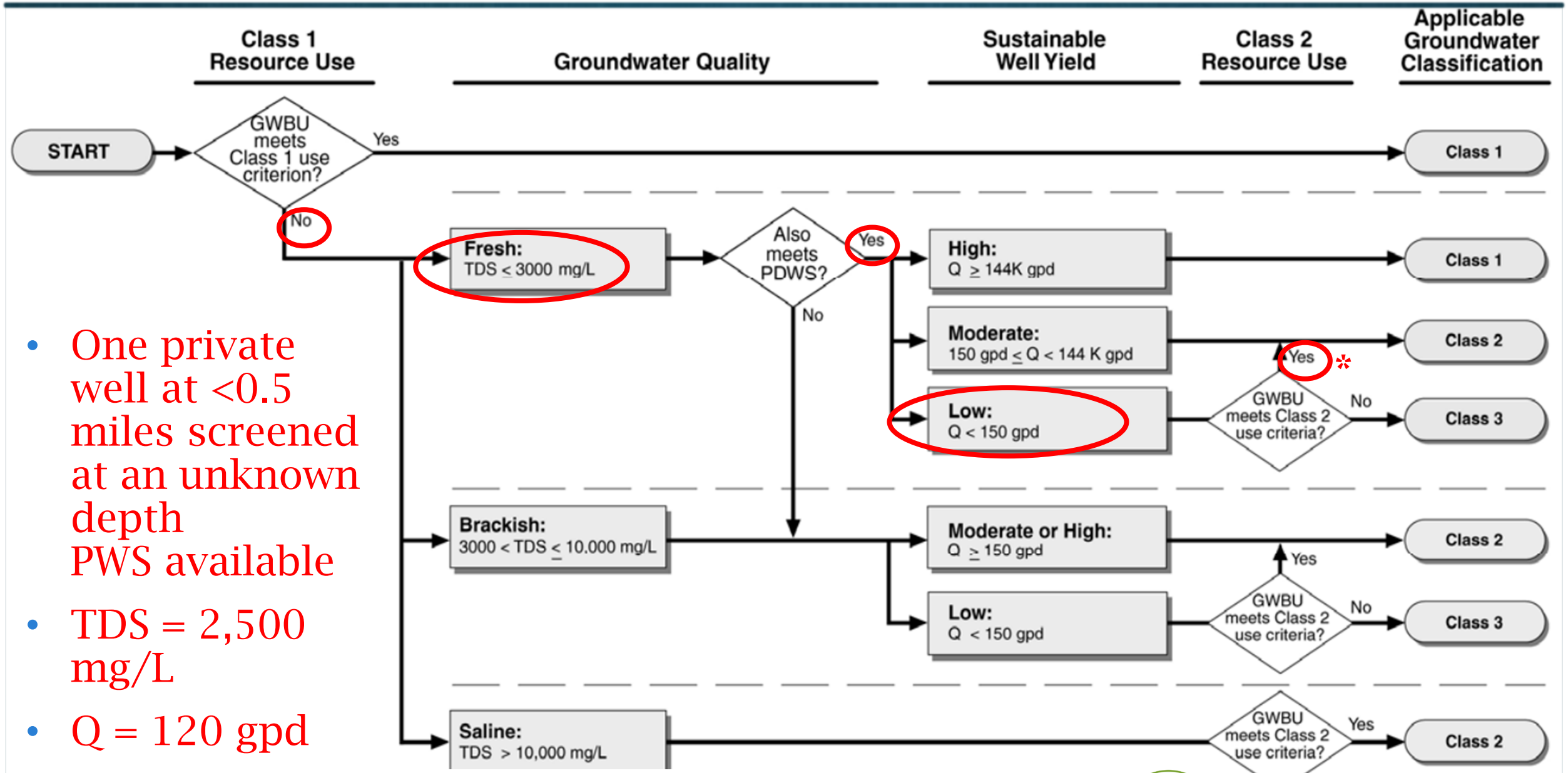
- One private well at <0.5 miles screened at an unknown depth
  PWS available
- TDS = 2,500 mg/L
- Q = 120 gpd



- One private well at <0.5 miles screened at an unknown depth
  PWS available
- TDS = 2,500 mg/L
- Q = 120 gpd

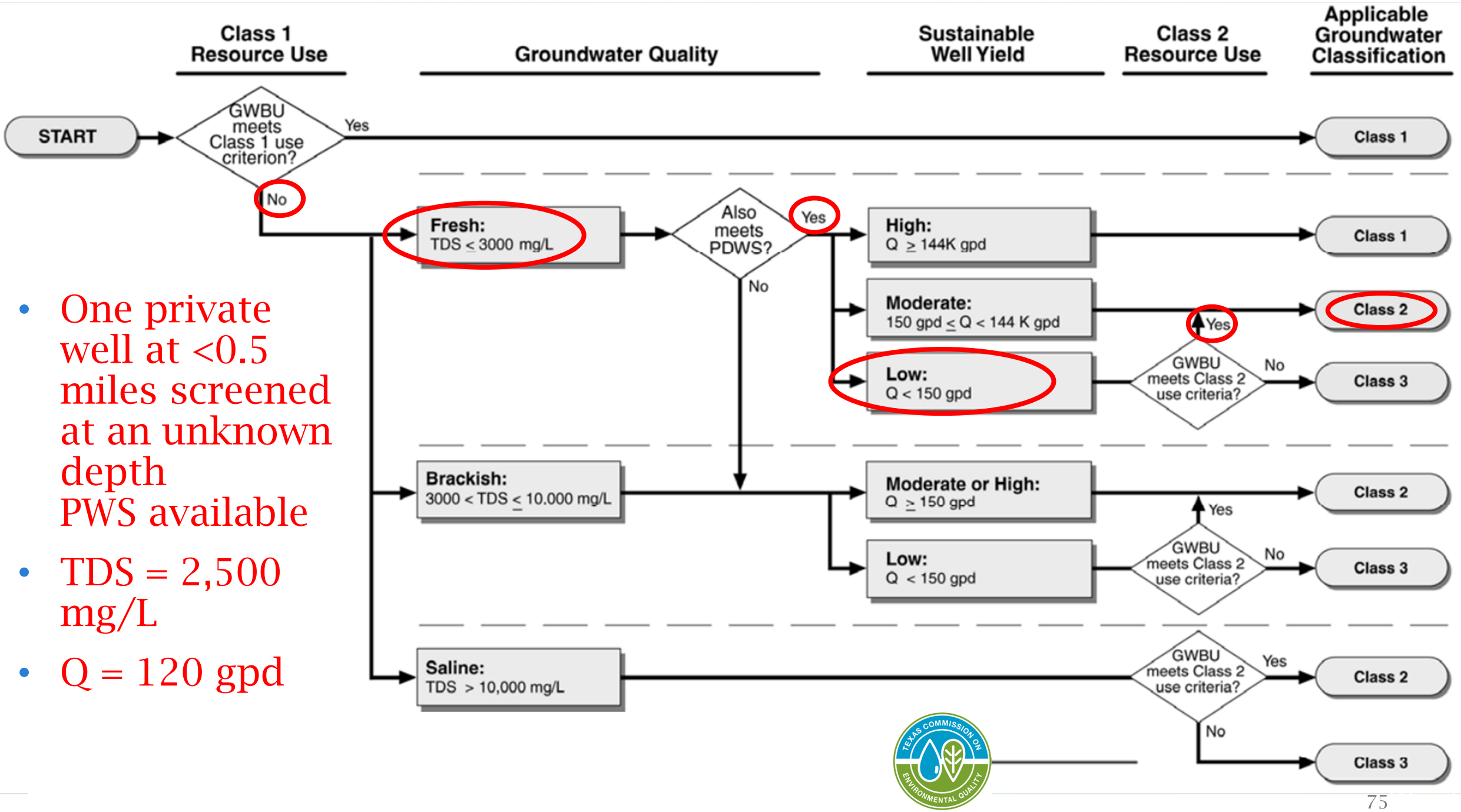


- One private well at <0.5 miles screened at an unknown depth
  PWS available
- TDS = 2,500 mg/L
- Q = 120 gpd



- One private well at <0.5 miles screened at an unknown depth
  PWS available
- TDS = 2,500 mg/L
- Q = 120 gpd

* Conservatively assumed to be screened in the production zone



- One private well at <0.5 miles screened at an unknown depth
  PWS available
- TDS = 2,500 mg/L
- Q = 120 gpd

Key Acronyms and Abbreviations

APAR = Affected Property Assessment Report

b = saturated thickness

bgs = below ground surface

CFR = Code of Federal Regulations

COC = chemical of concern

gpd – gallons per day

GWBU = groundwater bearing unit

h_c = confining head

K = hydraulic conductivity

PCL = protective concentration level

PDWS = primary drinking water standard

PWS = public water supply

Q = well yield

TAC = Texas Administrative Code

TDS = total dissolved solids

TRRP = Texas Risk Reduction Program

USCS = Unified Soil Classification System

THANK YOU

QUESTIONS?

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