

INVESTIGATIONS AND ABATEMENT OF PRODUCED WATER IMPACTS AND SEEPS TO SURFACE WATER

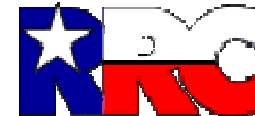
Petronila Creek, Nueces County, Texas
Nueces-Rio Grande Coastal Basin (Segment 2204)

SECTION 319 NONPOINT SOURCE GRANT PROJECT

16th International Petroleum & BioFuels Environmental Conference
Houston, Texas, November 2009



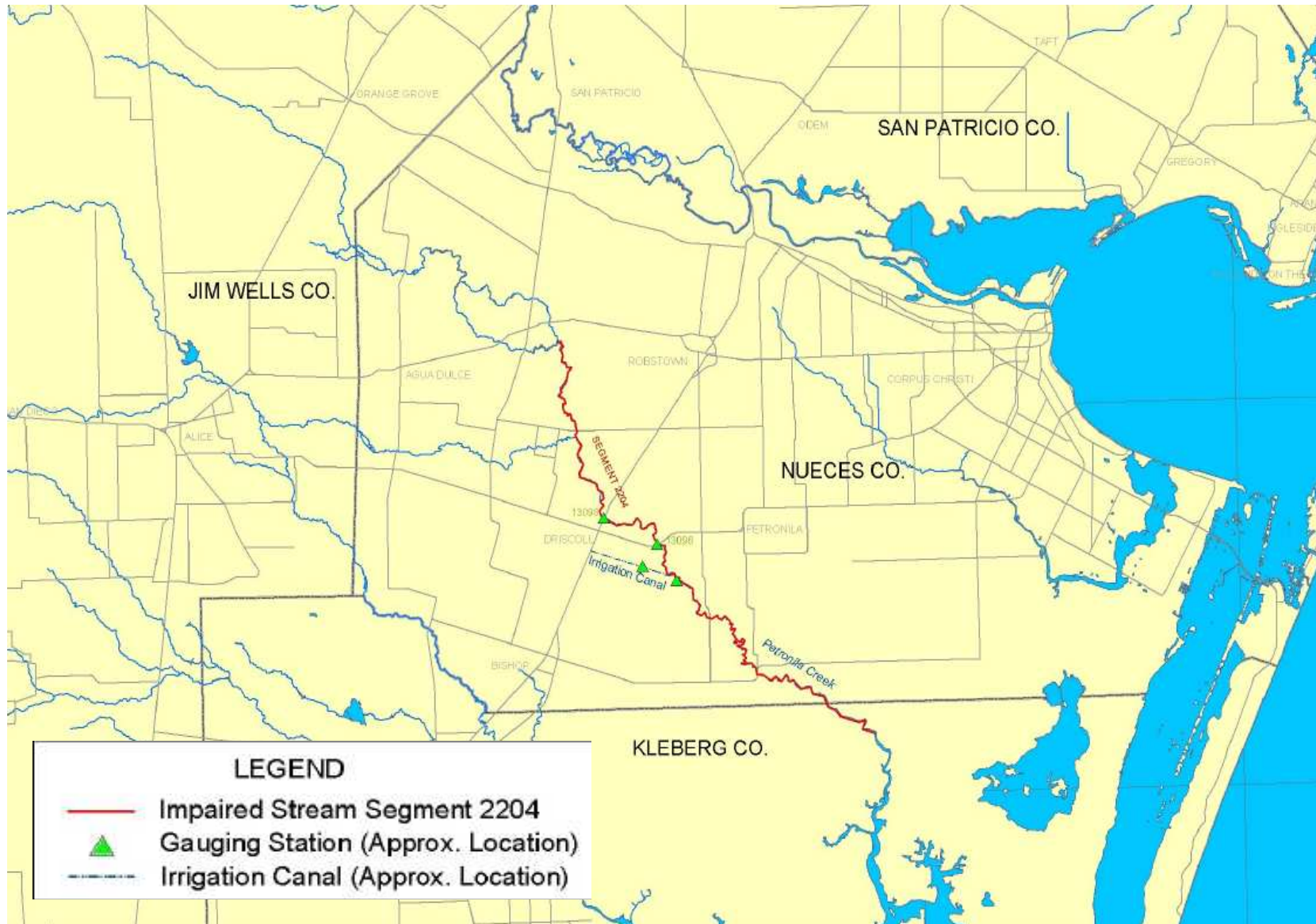
Railroad Commission of Texas
Heidi Bojes



Section 310 Nonpoint Source Grant

- In 2006 RRC awarded a Section 310 Nonpoint Source Grant from United States Environmental Protection Agency (US EPA) and administered through Texas Commission on Environmental Quality (TCEQ)
- 1) Investigate the nature and extent of known salinity contamination from oil field activity thought to be contributing to water quality problems in Petronila Creek (Segment 2204)
- 2) Develop remediation/abatement alternatives or Best Management Practices (BMPs)

Petronila Creek Watershed



Petronila Creek Watershed



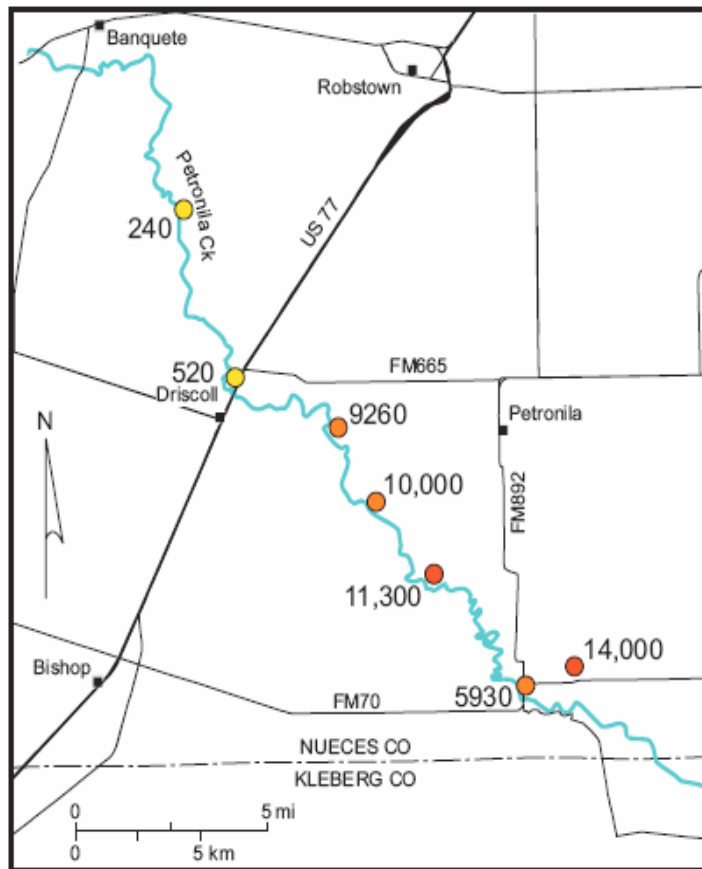
Clean Water Act Section 303(d) list

- In 2000 Segment 2204 of Petronila Creek included on the Section 303(d) list of the Clean Water Act because it did not meet applicable water quality standards for chloride, sulfate and total dissolved solids (TDS).
- Current numeric standards to support designated uses: chloride concentration of 1,500 milligrams per liter (mg/L), sulfate of 500 mg/L, and TDS of 4,000 mg/L.
- The designated uses for Petronila Creek above Tidal are contact recreation use and intermediate aquatic life use (30 TAC 307, §307.7). Aquatic life uses recognize the natural variability of aquatic community requirements and local environmental conditions.
- High concentrations of chloride and sulfate can cause water to taste and smell badly. Chloride can be corrosive. High levels of TDS can be toxic to fresh water aquatic species.

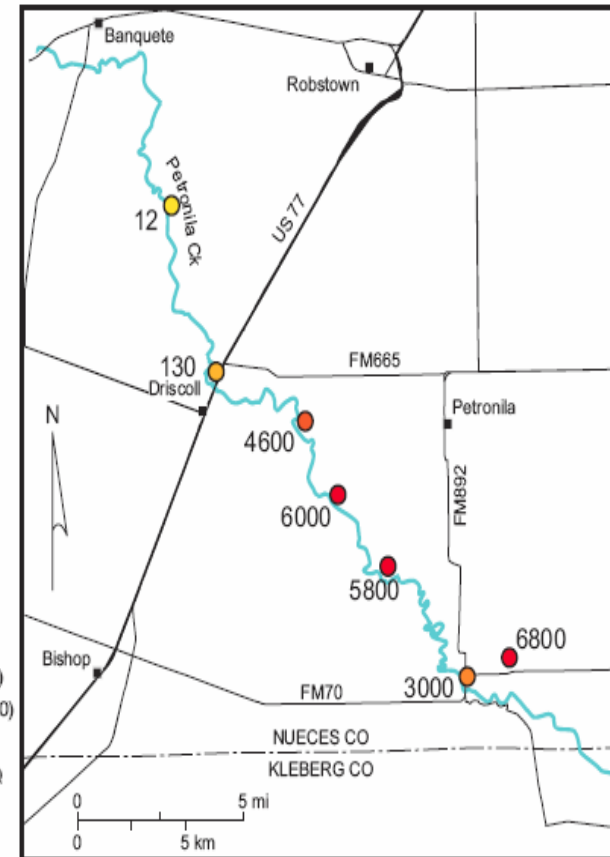
Total Maximum Daily Loads (TMDLs)

- The state must develop a total maximum daily load (TMDL) for each pollutant that contributes to the impairment of the water.
 - Texas Commission on Environmental Quality (TCEQ) is responsible for developing TMDLs for impaired waters in Texas.
 - TMDLs for Segment 2204 of Petronila Creek approved by EPA in March 2007.
(http://www.tceq.state.tx.us/implementation/water/tmdl/32-colorado_petronila.html#petronila)
- TMDL is a calculation of the maximum amount of a pollutant(s) that a body of water can receive and still safely meet water quality standards.
- TMDL is an estimate of how much pollutant load must be reduced from current levels in order to achieve water quality standards.
- TMDL process requires the identification of pollutant sources.

Total Dissolved Solids (TDS) and Chloride in Surface Water Samples from Petronila Creek



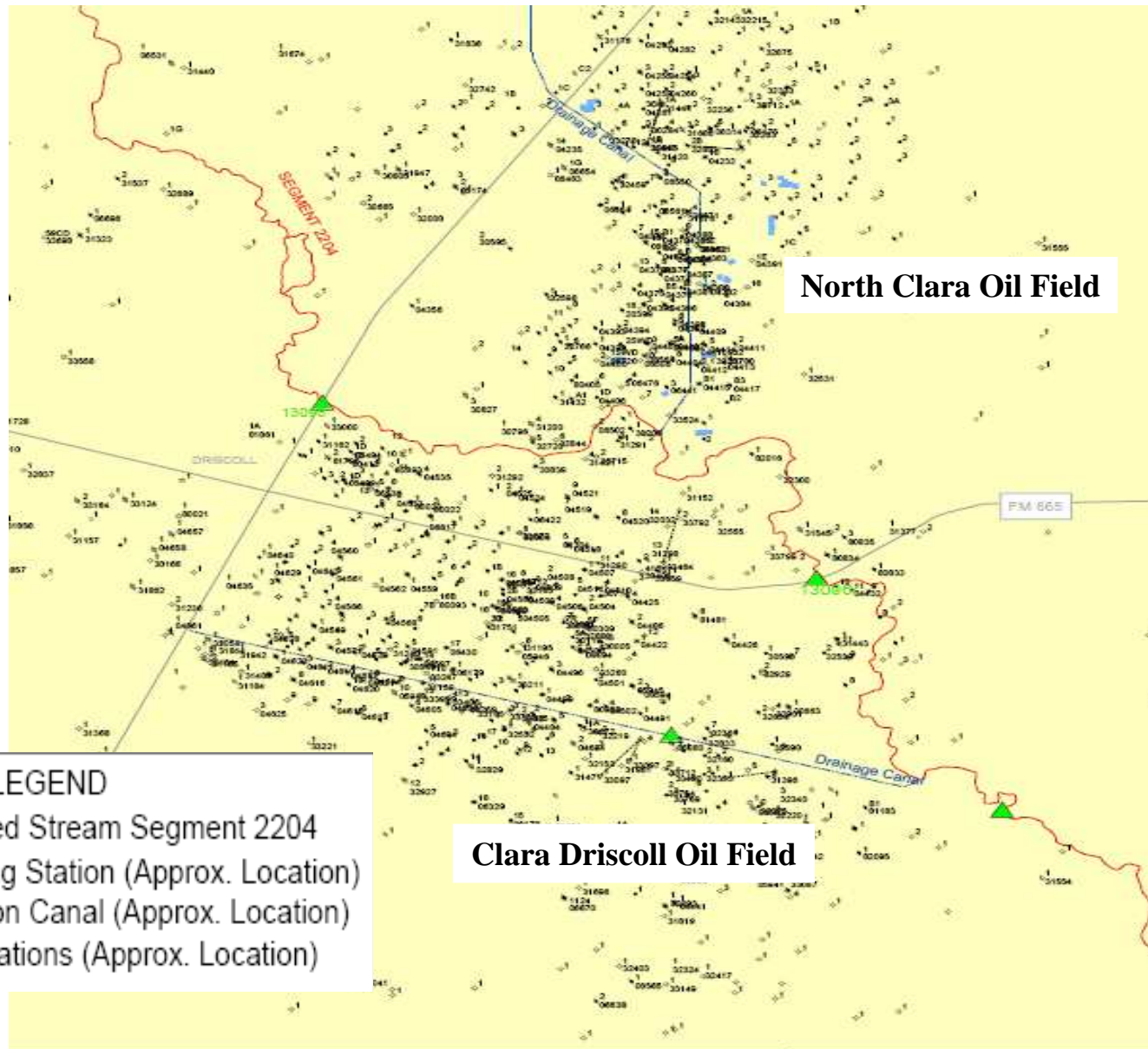
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- BEG geophysical survey results revealed elevated conductivities at Petronila Creek, adjacent areas and drainage ditches.
- Results suggested that salinity is from nearby oil field activity.
- (TDS and chloride data collected by Texas Commission on Environmental Quality (TCEQ) in November 2003).

Oil Fields Surrounding Petronila Creek Segment 2204



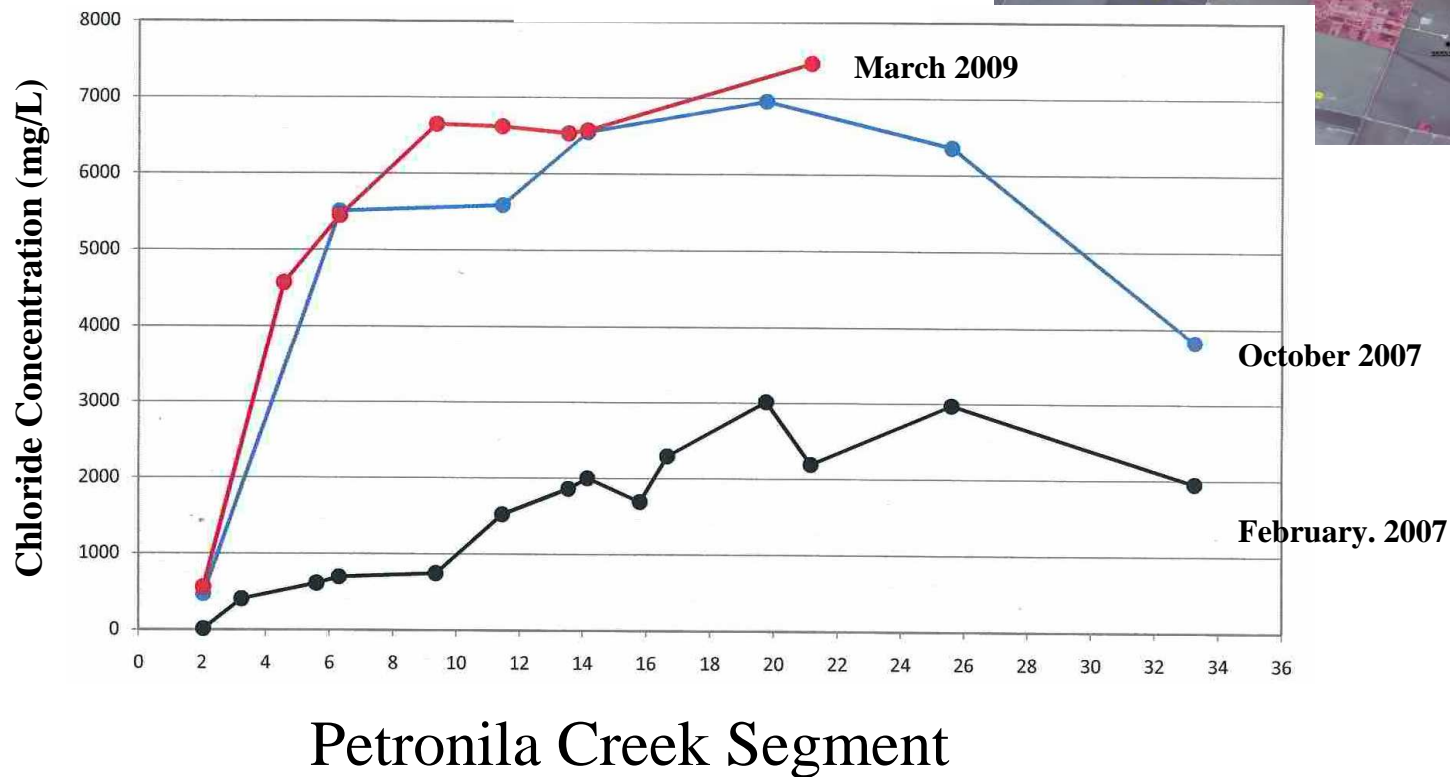
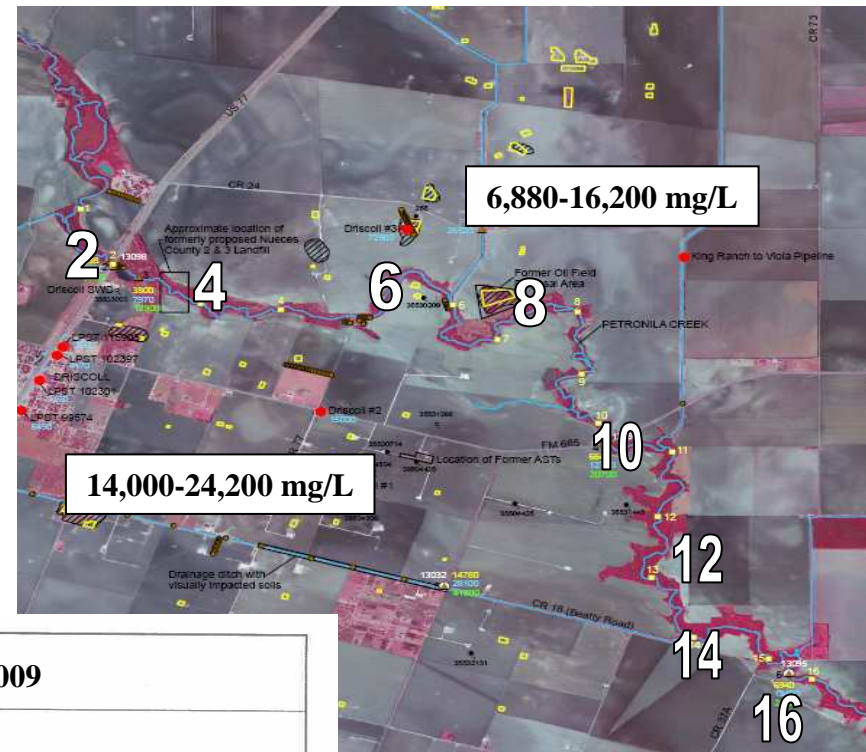
Produced Water (Oil Field Brine)

- Produced water is water trapped in underground formations that is brought to the surface along with oil or gas production.
- Largest volume byproduct or waste stream associated with oil and gas production
- Volume varies throughout the lifetime of an oil reservoir.
- Chemical and physical characteristics depend on geographic location of the field, the geological formation with which the produced water has been in contact for thousands of years, and the type of hydrocarbon product being produced.
- Produced water salinity (chlorides) in the US ranges from 100 mg/L to 400,000 mg/L (seawater is 35,000 mg/L).
- Produced water salinity in Clara Driscoll Oilfield (Vicksburg Formation) averages TDS 49,300 mg/L and chloride 28,904 mg/L.

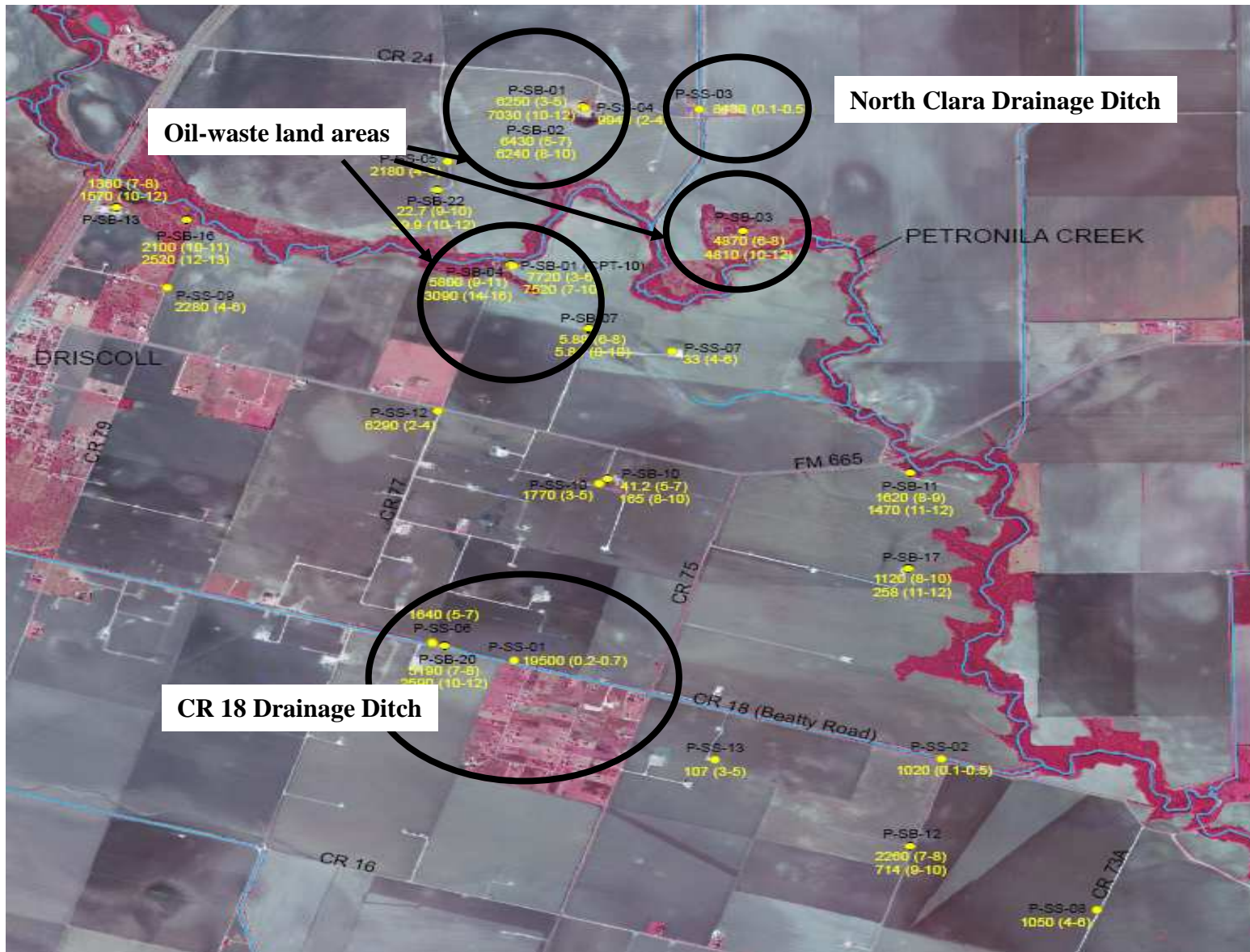
Possible Oil Field Sources of Salinity

- Tidal discharge
 - The release/discharge of produced water to a surface water body that is tidally influenced.
 - In the late 1990s EPA banned the discharge of produced water to tidally influenced water bodies.
- Saltwater evaporation pits
 - Non-permitted large, shallow, unlined pits where water would be lost due to evaporation and seepage.
 - Railroad Commission's "no-pit order" in 1969 for saltwater pits
- Injection wells
 - Injecting brine into subsurface strata is used for both disposal of excess brine and for recovering oil from under-pressurized formations.

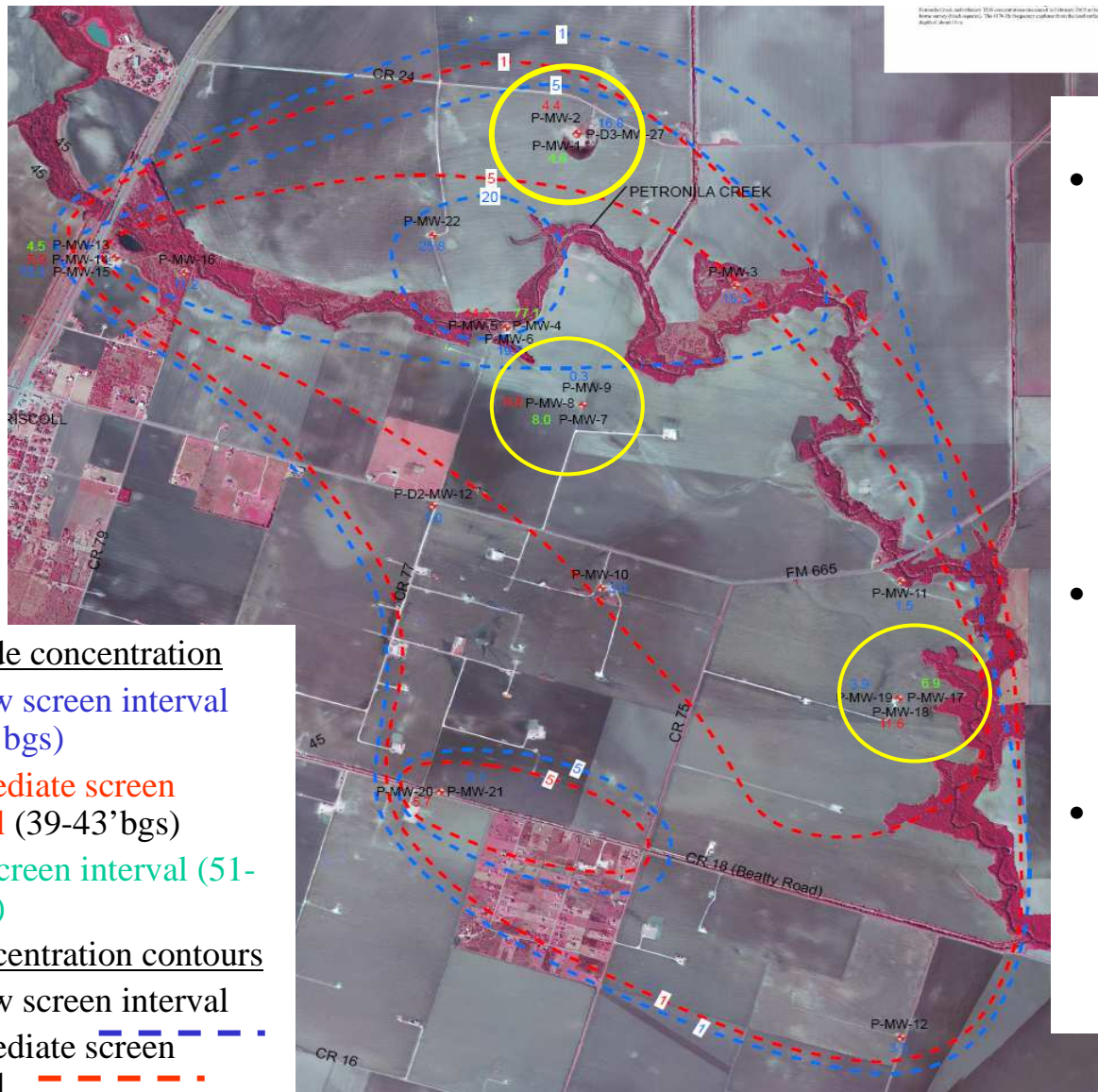
Chloride Concentration in Surface Water



Chloride Concentration in Soil



Chloride-Sulfate Ratio Map (Oct. 2007)



- Chloride concentration
- Shallow screen interval (18-26' bgs)
- Intermediate screen interval (39-43' bgs)
- Deep screen interval (51-61' bgs)
- Isoconcentration contours
- Shallow screen interval
- Intermediate screen interval

- Chloride/sulfate ratio >1 , suggests chloride is from produced water, oil field activities, or water migrating from deeper pressurized zones.
- Highest ratios observed in shallow and intermediated wells.
- Results suggest that contamination is related to oil field activities.

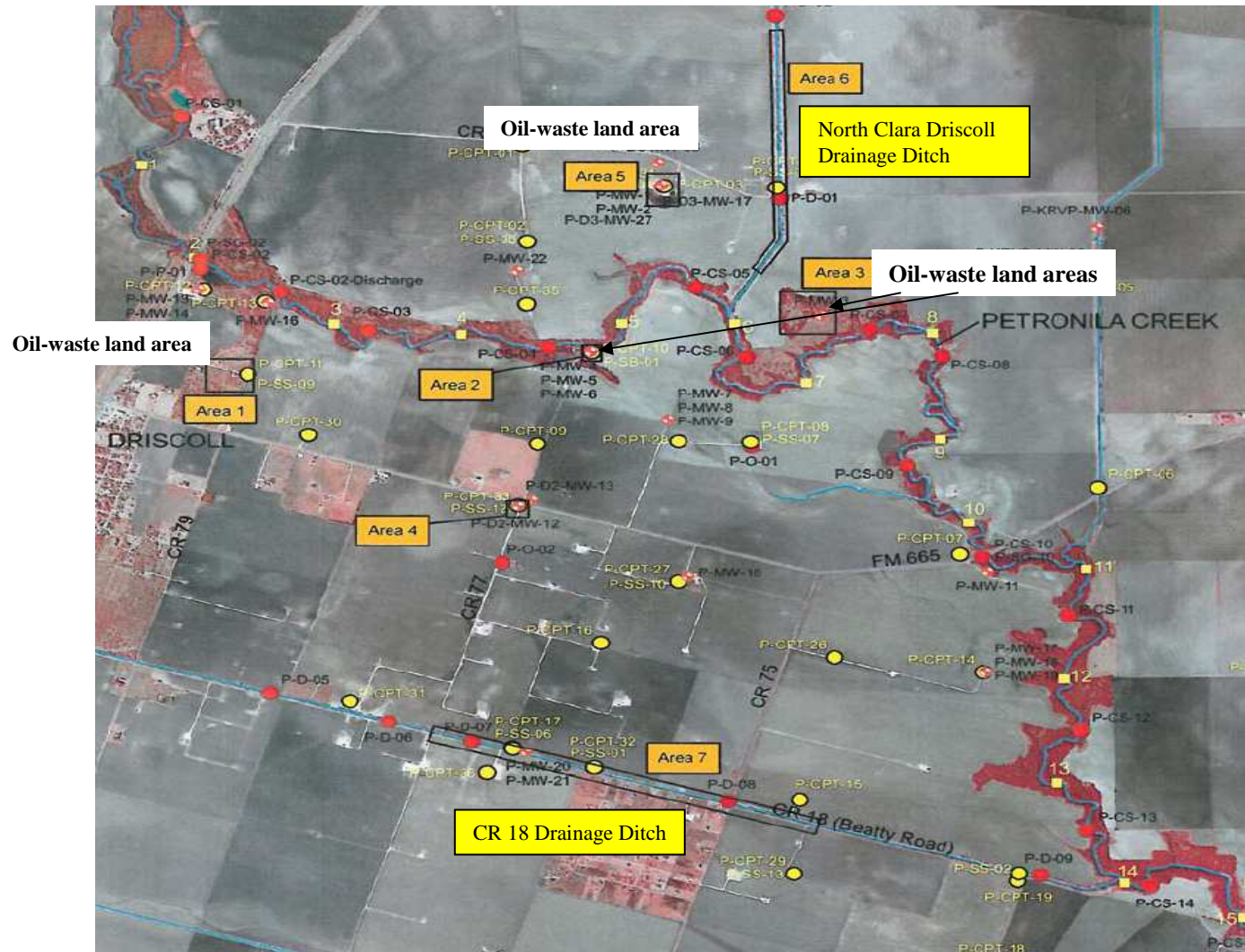
Investigation Results

- Surface water results indicate salinity contamination along the creek and in North Clara and CR 18 drainage ditches – consistent with TCEQ and BEG study results.
- Identified seven main areas of salinity contamination in soils.
- Identified widespread groundwater contamination.
- Groundwater appears to be contributing elevated salinity into Petronila Creek.

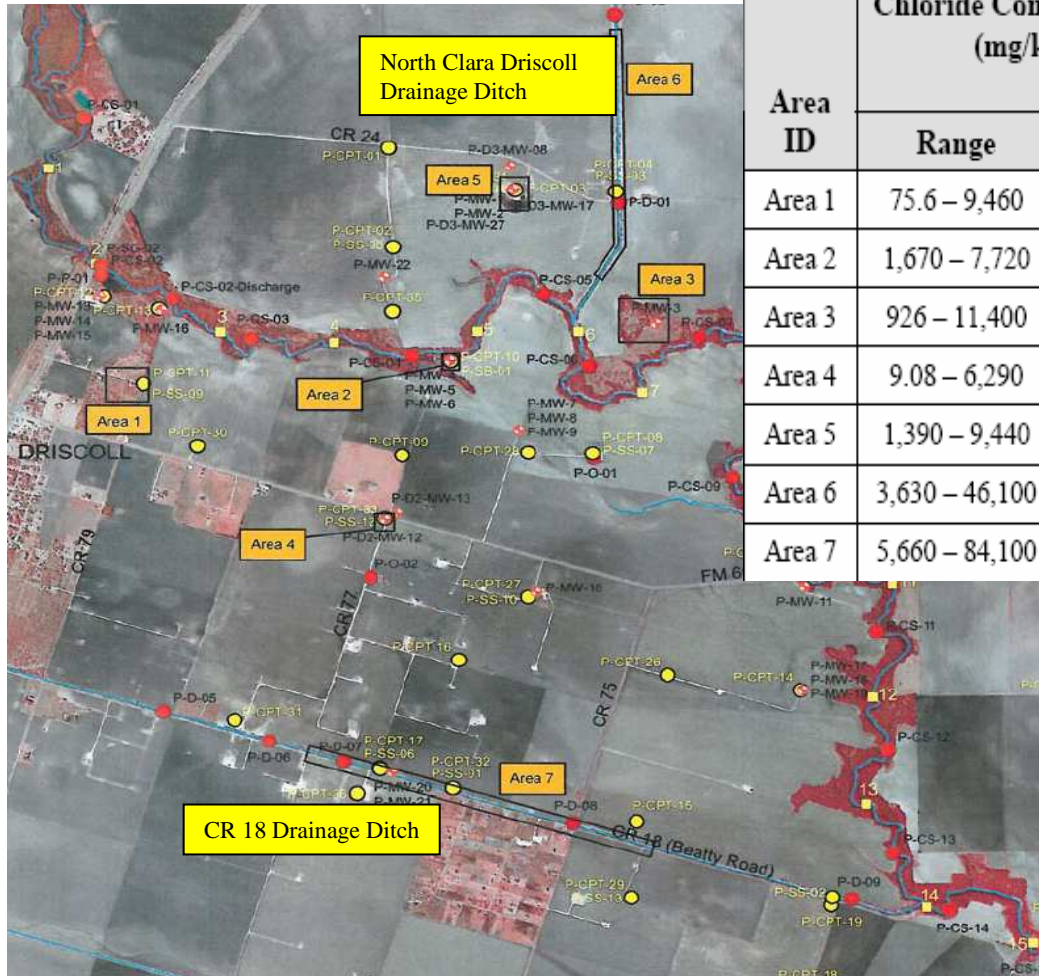
Best Management Practices (BMPs)

- Soil Feasibility Study
 - Ranked seven contaminated areas according to chloride/ conductivity concentrations and their potential to contaminate the creek
 - BMP selection was based on its effectiveness, ability to be implemented, regulatory agency and stakeholder acceptance, and cost.
- Groundwater Conceptual Site Model
 - Widespread groundwater contamination and variable hydrogeology in upper 60 feet of subsurface
 - Salinity distribution in groundwater
 - Hydraulic relationship between groundwater and surface water
 - Presence of continuous sand lenses as potential preferential pathways to contaminant the creek

Soil Feasibility Study: Seven Potential Areas of Concern



Soil Feasibility Study

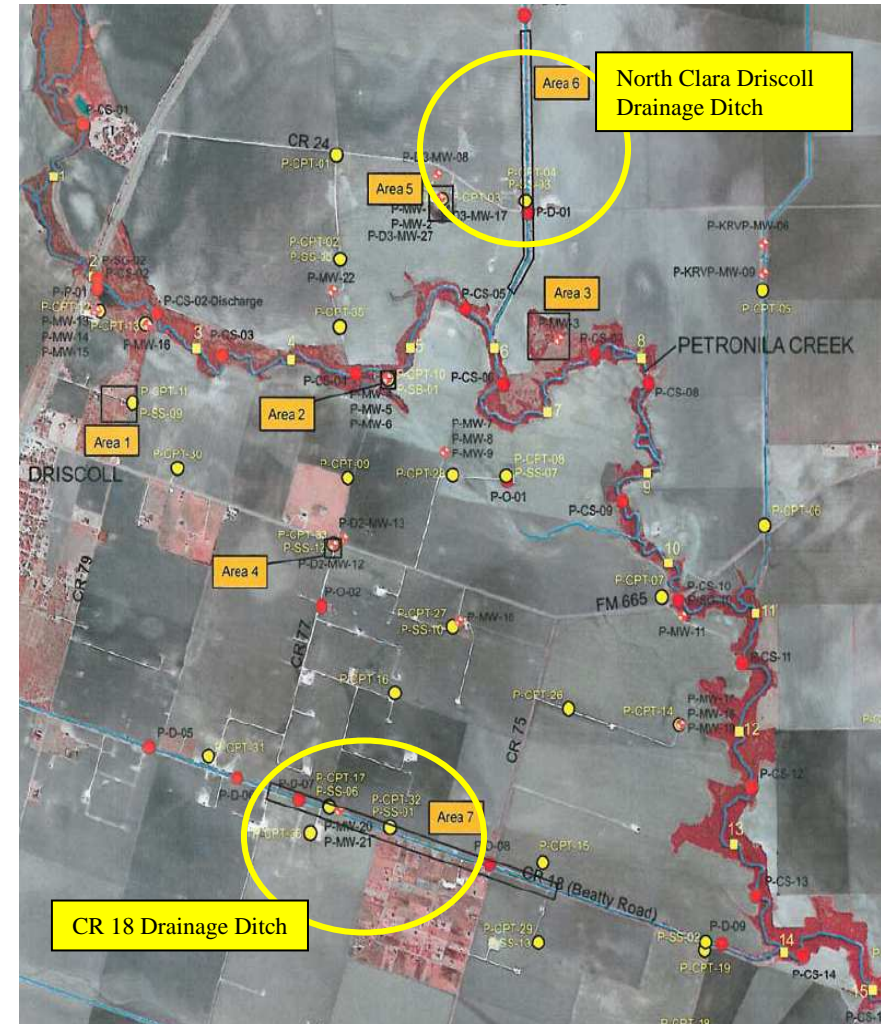


Area ID	Chloride Concentration (mg/kg)		Conductivity Concentration (µmhos/cm)		Area of Elevated Salinity* (ft ²)	Depth of Elevated Salinity* (feet)
	Range	Average	Range	Average		
Area 1	75.6 – 9,460	2,421	461 – 11,800	4,995	39,600	9
Area 2	1,670 – 7,720	5,215	2,910 – 12,000	7,347	30,000	10.5
Area 3	926 – 11,400	4,647	1,600 – 25,400	9,271	111,300	9
Area 4	9.08 – 6,290	1,593	1,690 – 7150	3,679	2,900	7
Area 5	1,390 – 9,440	5,242	3,910 – 17,100	9,428	166,000	10.5
Area 6	3,630 – 46,100	15,108	5,920 – 90,200	28,804	91,200	3
Area 7	5,660 – 84,100	39,320	7,800–166,000	74,048	120,000	3

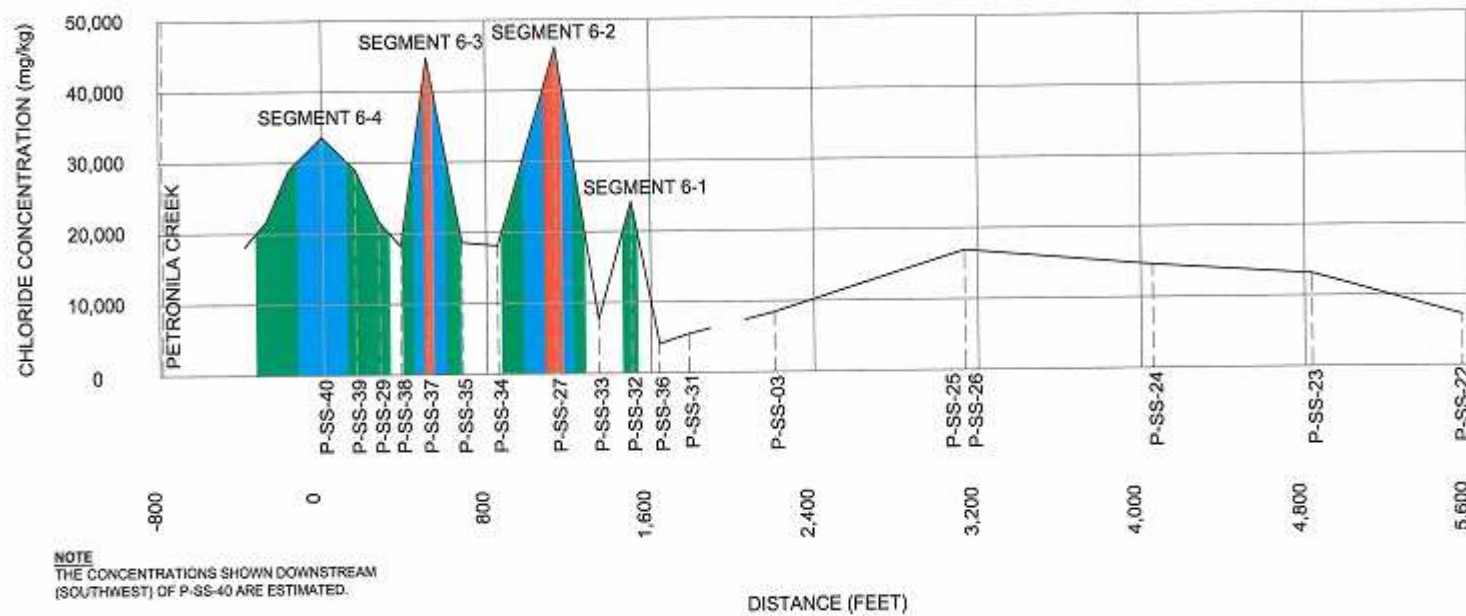
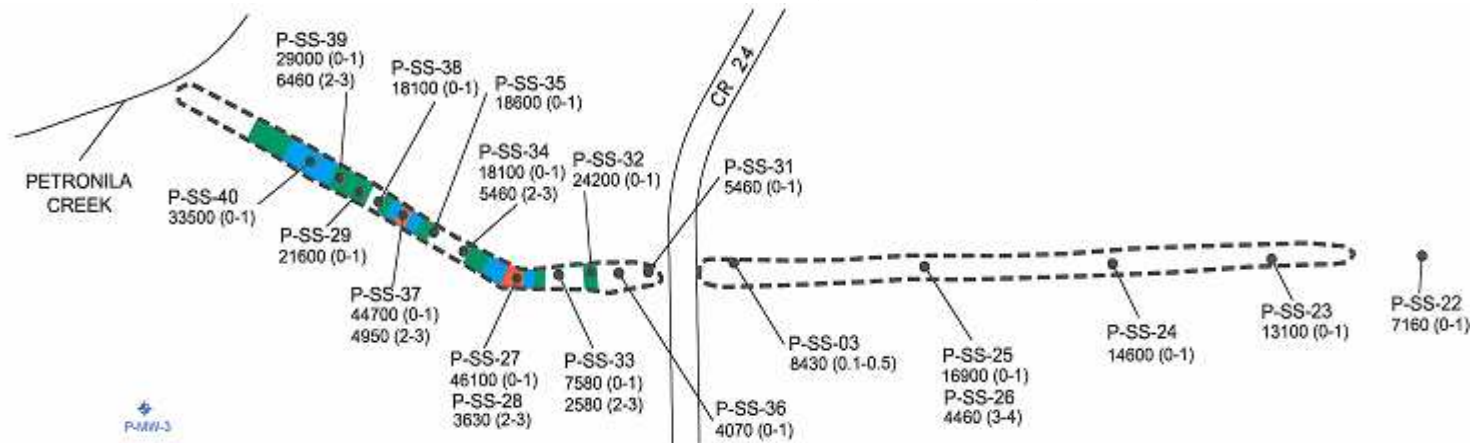
Area	Chloride Mass (kilograms)
1	19,610
2	37,334
3	105,793
4	735
5	207,654
6	79,706
7	318,451

BMP Alternatives for Salinity Abatement

- Excavation of contaminated sediments at the North Clara and CR 18 Drainage Ditches (Areas 6 and 7)
- High average salinity concentration (North Clara Drainage Ditch - Chloride 15,108 mg/kg; conductivity 28,804 $\mu\text{mhos/cm}$ and CR 18 Drainage Ditch - Chloride 39,320 mg/kg; conductivity 74,048 $\mu\text{mhos/cm}$)
- Direct salinity loading via runoff into Petronila Creek.
 - Leaching from saline-contaminated sediments to storm water that flows into the creek
 - Mobilization of saline-contaminated sediments into the creek via erosion/entrainment.

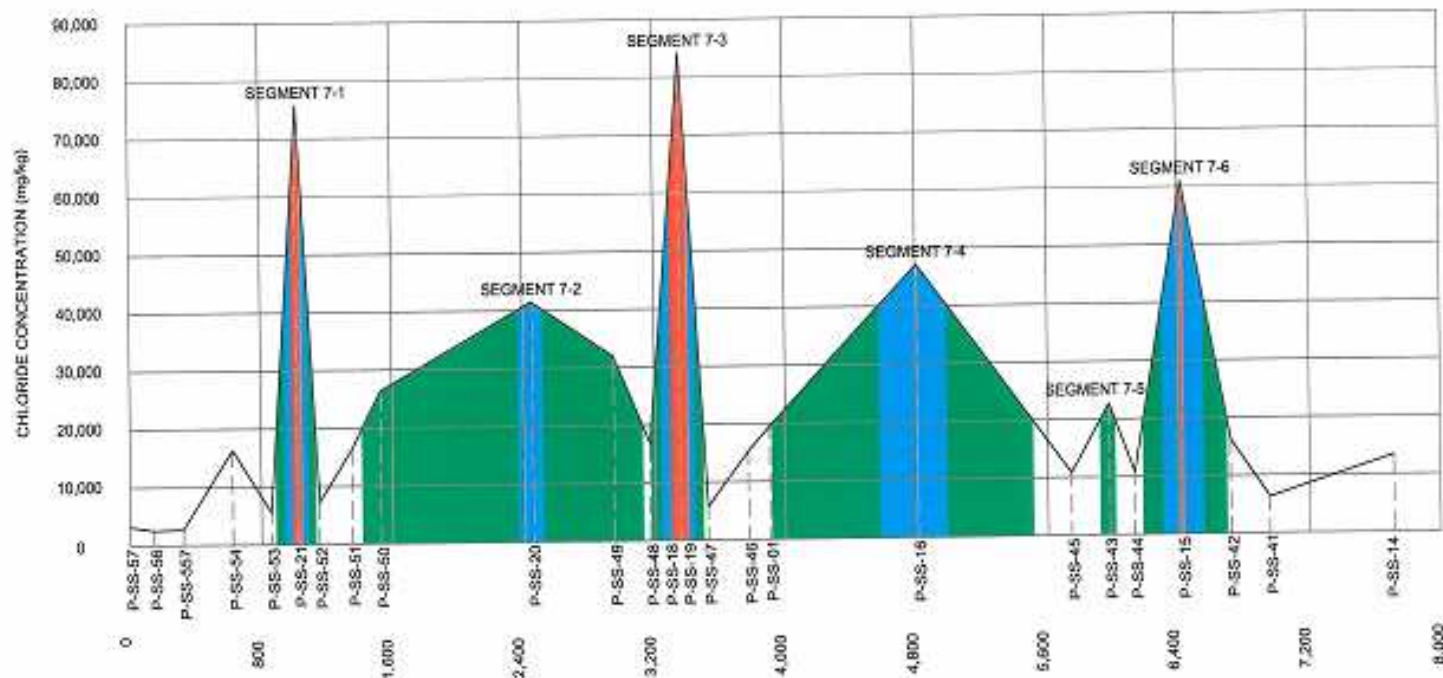
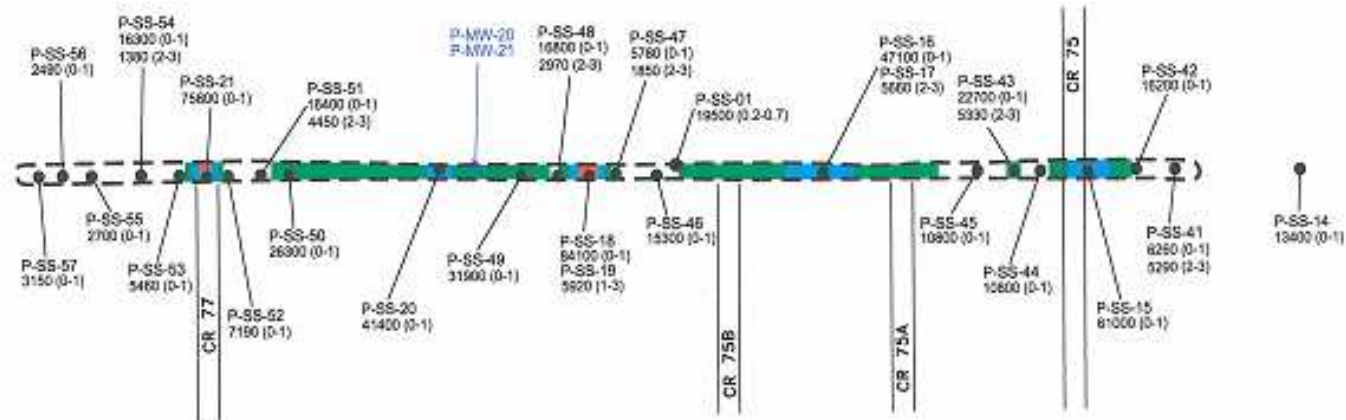


Chloride Distribution in North Clara Drainage Ditch (Area 6)



NOTE
THE CONCENTRATIONS SHOWN DOWNSTREAM
(SOUTHWEST) OF P-SS-40 ARE ESTIMATED.

Chloride Distribution in CR 18 Drainage Ditch (Area 7)



Estimated Potential Chloride Loading

Segment	Mass of Soil (kg)	Concentration (mg/kg)	Potential Chloride Loading (kg to solution)
North Clara Driscoll Drainage Ditch (Area 6)			
6-1	938,700	24,200	22,700
6-2	426,682	46,100	19,700
6-3	580,287	44,700	25,900
6-4	93,870	28,033	2,630
TOTAL	2,039,539	143,033	70,930
CR 18 Drainage Ditch (Area 7)			
7-1	318,589	75,800	24,100
7-2	2,400,796	33,200	79,700
7-3	455,127	84,100	38,300
7-4	2,218,745	47,100	105,000
7-5	113,782	22,700	2,580
7-6	739,582	61,000	45,100
TOTAL	6,246,621	323,900	294,780

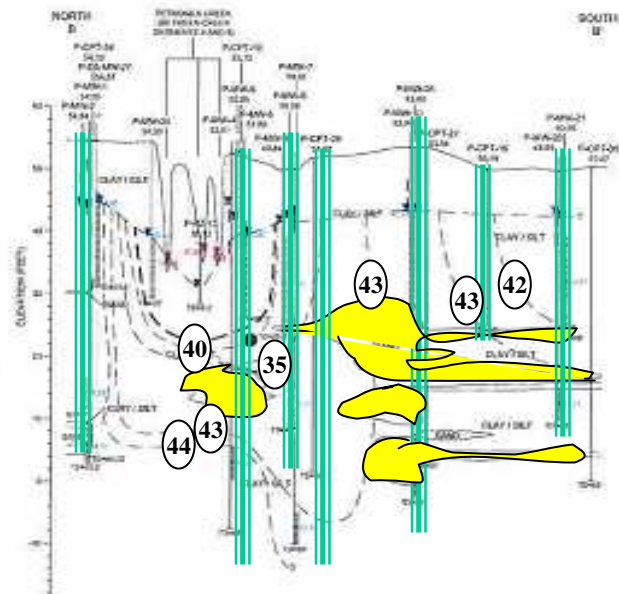
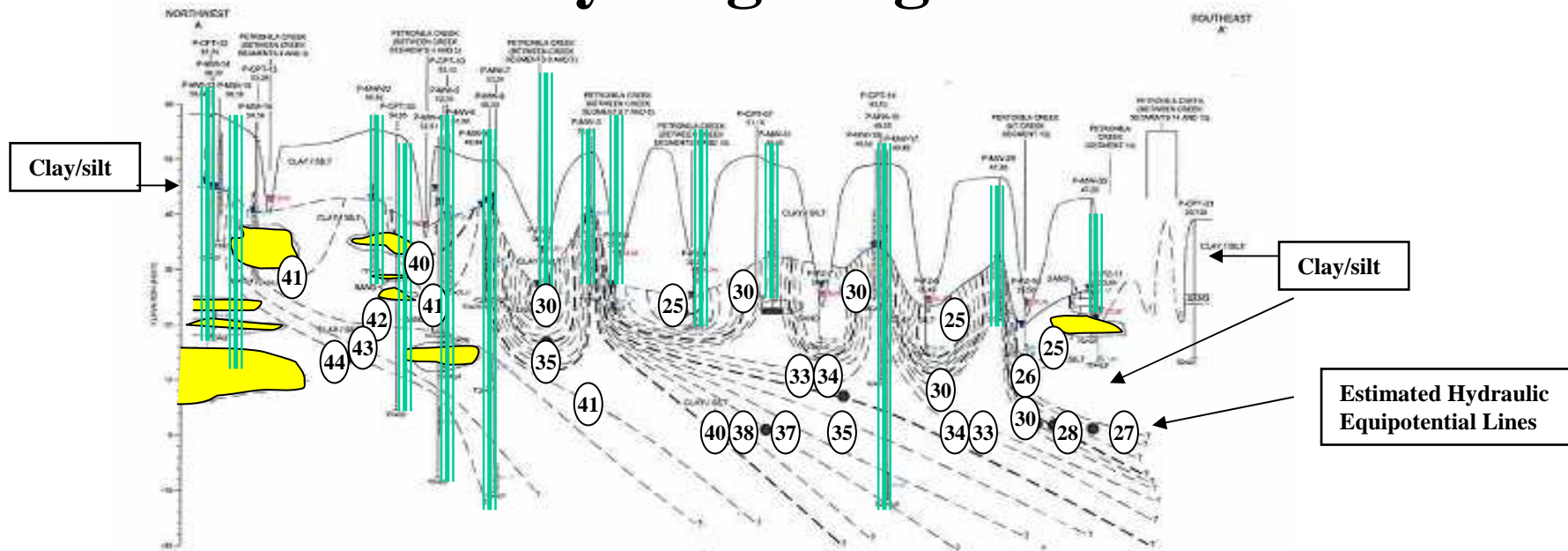
Conceptual Site Model - Groundwater Contamination

- Objectives
 - identify source areas and preferential pathways for salinity in groundwater to contaminate Petronila Creek
 - develop BMPs to mitigate the salinity contamination into the Petronila Creek
- Salinity distribution in groundwater
- Hydrogeology
- Presence and continuity of sand units as potential preferential pathways to the creek
- Hydraulic relationship between groundwater and surface water in Petronila Creek and the drainage ditches

Conceptual Site Model - Groundwater Contamination

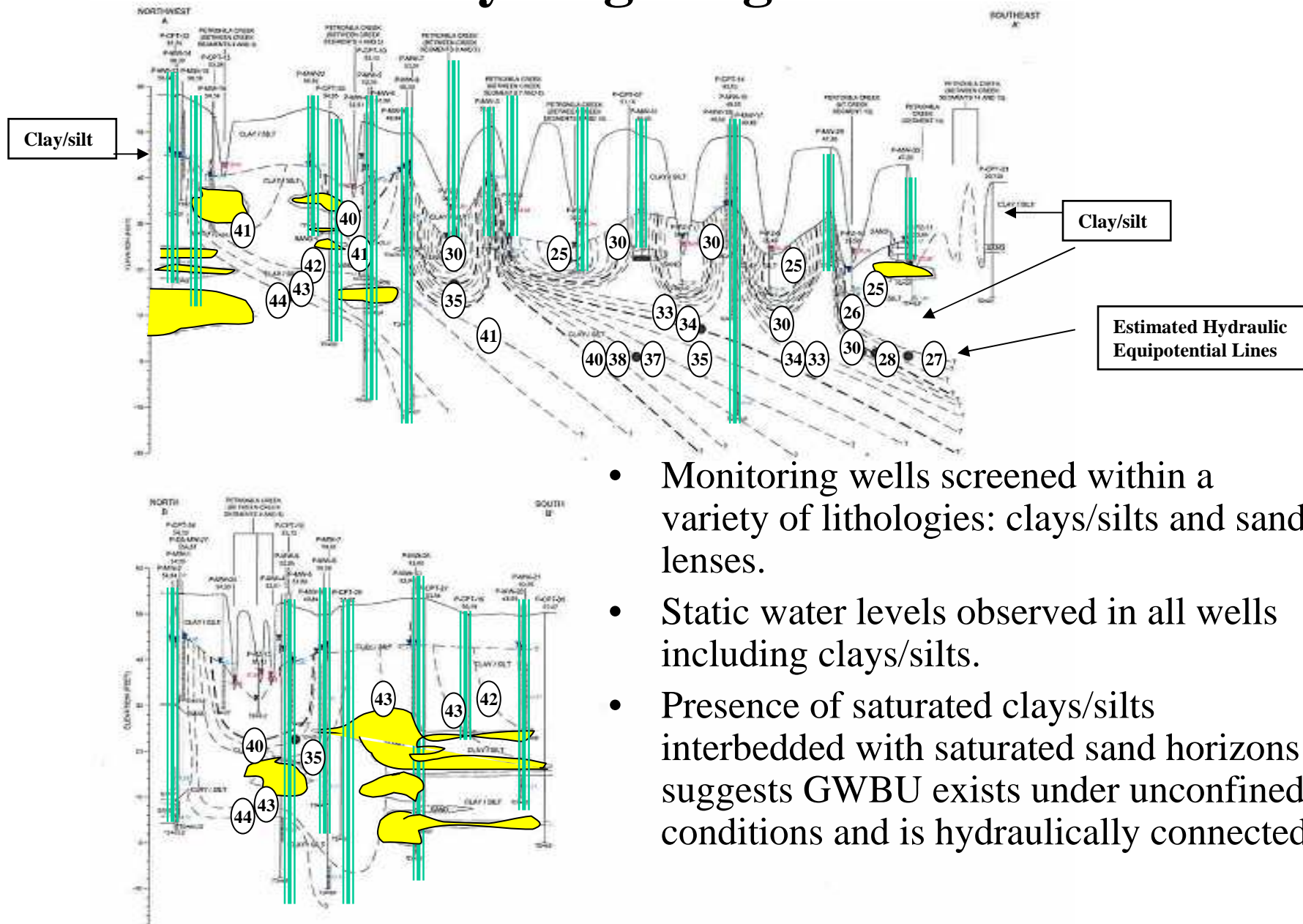
- Widespread salinity contamination – highest contamination is shallow GWBU.
- Shallow and deep groundwater flow systems
- Shallow GWBU appears to be localized, upward gradient (discharge zone), intersects the creek.
- Deep GWBU appears to be regional, downward gradient (recharge zone) to the south/southeast, and does not intersect the creek.

Generalized Hydrogeologic Cross-Sections



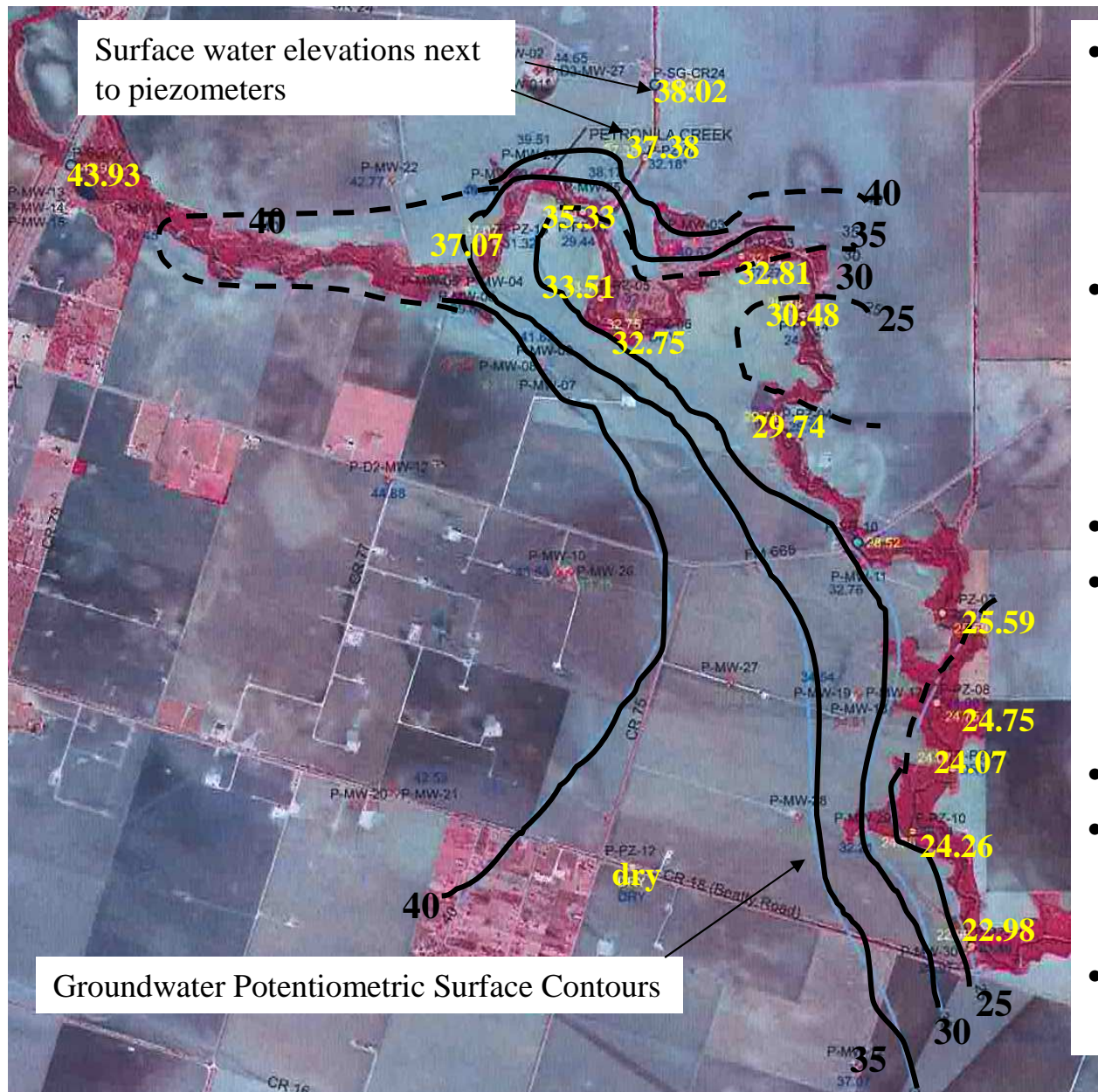
- Upper 60 feet of Beaumont Formation:
- 10-15 feet bgs consists of clays/silts
- >10-15 feet bgs laterally continuous and discontinuous sand horizons that reside within clays/silts.
- Sand horizons appear to be 5 to 15 feet thick
- Lithologic data consistent with a fluvial depositional environment and representative of the Beaumont Formation.

Generalized Hydrogeologic Cross-Sections



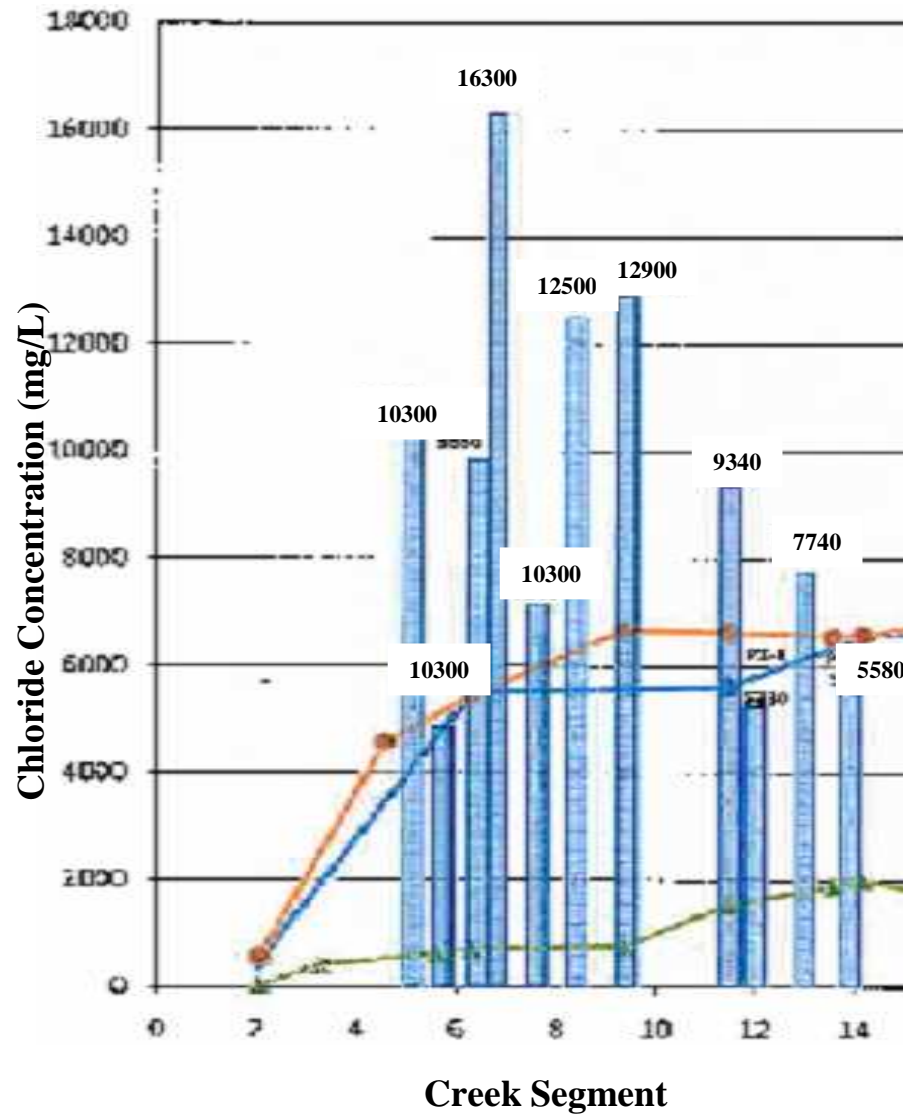
- Monitoring wells screened within a variety of lithologies: clays/silts and sand lenses.
- Static water levels observed in all wells including clays/silts.
- Presence of saturated clays/silts interbedded with saturated sand horizons suggests GWBU exists under unconfined conditions and is hydraulically connected.

Comparison of Groundwater Elevations and Surface Water



- Surface elevations between groundwater and surface water more similar in downstream segments than upstream.
- Suggests that groundwater may intersect creek in the downstream portions more regularly than upstream portions.
- One time sampling event.
- Fluctuations in water levels near the creek suggest communication between creek and groundwater
- Not a static system
- Shallow groundwater on a local scale flows towards the creek
- The elevation of creek bed was not determined.

Comparison of Groundwater Chloride and Adjacent Surface Water Chloride



- Data suggest that groundwater base flow upstream of segment 10 has greater potential to contaminate the creek than downstream segments.
- Limiting factor is that groundwater intersection with the creek is sporadic upstream of segment 10.
- Data suggest that groundwater base flow is a long-term contributor to saline contamination at Petronila Creek.

Conceptual Site Model Results

- Hydrogeologic and salinity results suggest that soil, groundwater and surface water are connected.
- Potentiometric groundwater surface indicates that base flow into creek is more prevalent in downstream portions of the creek than upstream portions.
- While chloride is more likely to intersect the creek in downstream portions, the concentrations are not high enough for BMP implementation in this area.
- Groundwater-surface water relationship is dynamic and a function of seasonal precipitation.
- Likely that the primary loading mechanism to portions of the creek is base flow, which is influenced by precipitation events.

Preliminary Groundwater BMPs

- Widespread salinity contamination in groundwater
- Focus on portions of the chloride plume with highest concentrations and highest potential to contaminate the creek
- Groundwater sampling results show highest chloride contamination in an area west of North Clara Drainage Ditch and north of the creek (area 5).
- Not cost or time effective to implement BMP (recovery/disposal) that directly addresses contaminated groundwater.
- Alternative to groundwater BMP is to address primary source area (area 5) contaminating groundwater by remediating contaminated saline soils.

Aerial photographs of Petronila Creek Area



Nueces County, ASCS 1961



Nueces County, TXDOT, 1979

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[http://ww.rrc.state.tx.us/environmental/environsupport/nps/
petronila/index.php](http://ww.rrc.state.tx.us/environmental/environsupport/nps/petronila/index.php)

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