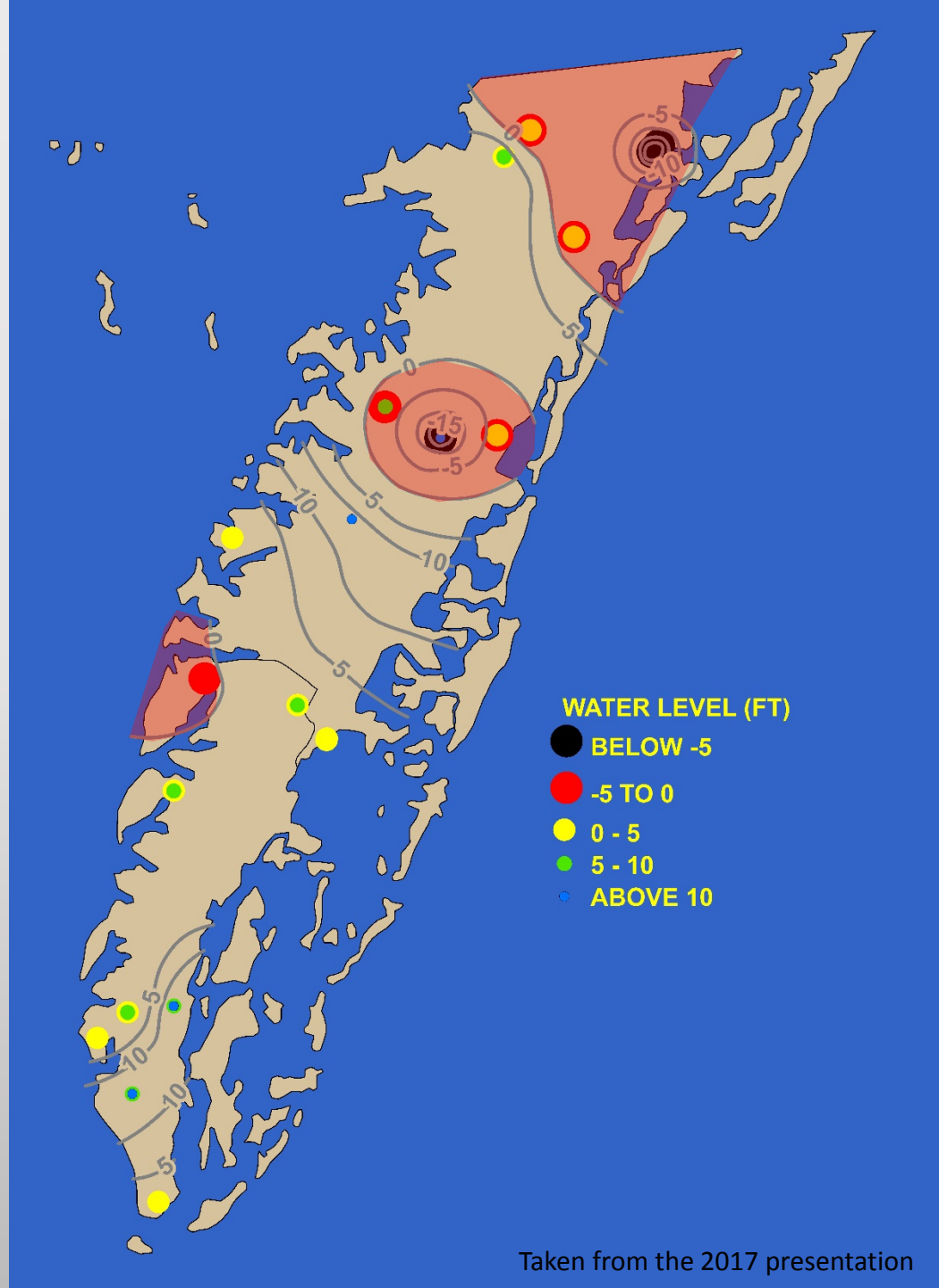
Review of Results from the 2019 EM Logging Run on the Eastern Shore

By Sam Caldwell

The State of Confined Groundwater Wells in the Eastern Shore

- Eastern Shore confined water levels are mostly above sea level
- There are three areas (shown in red) where confined water levels are at, or below sea level



Taken from the 2017 presentation

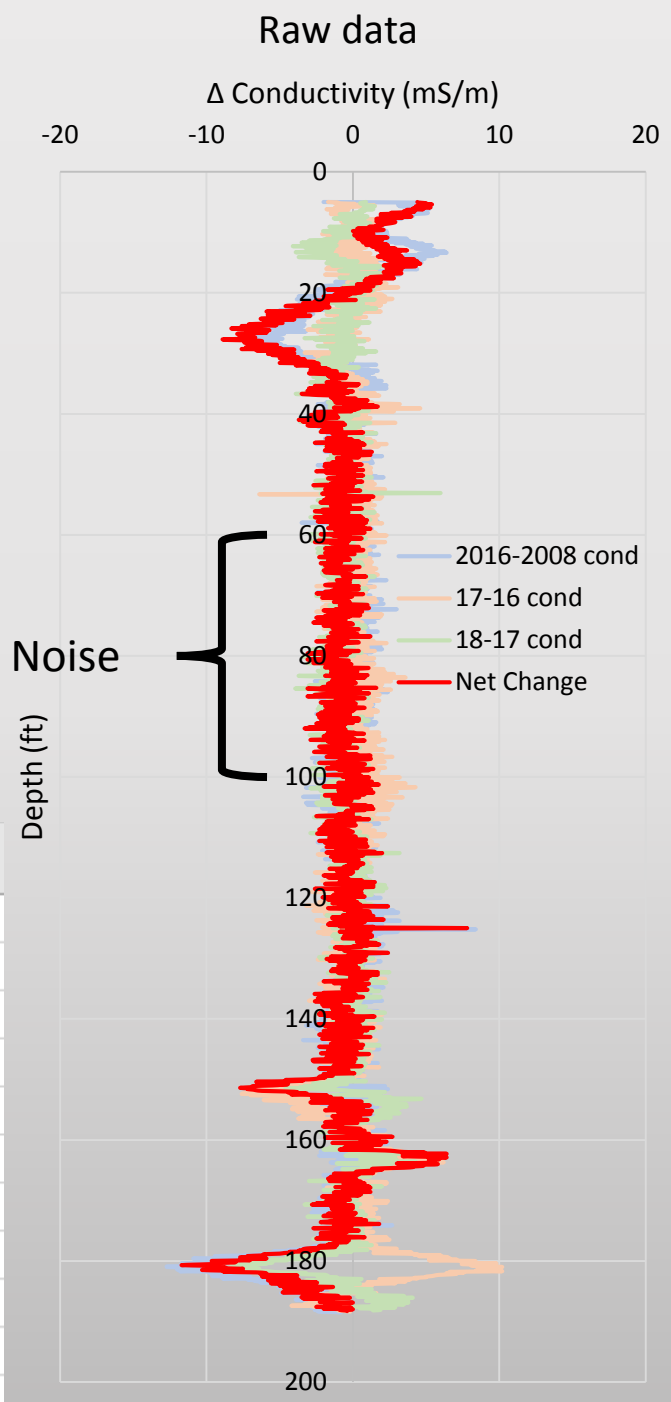
Moving Window Average (MWA):

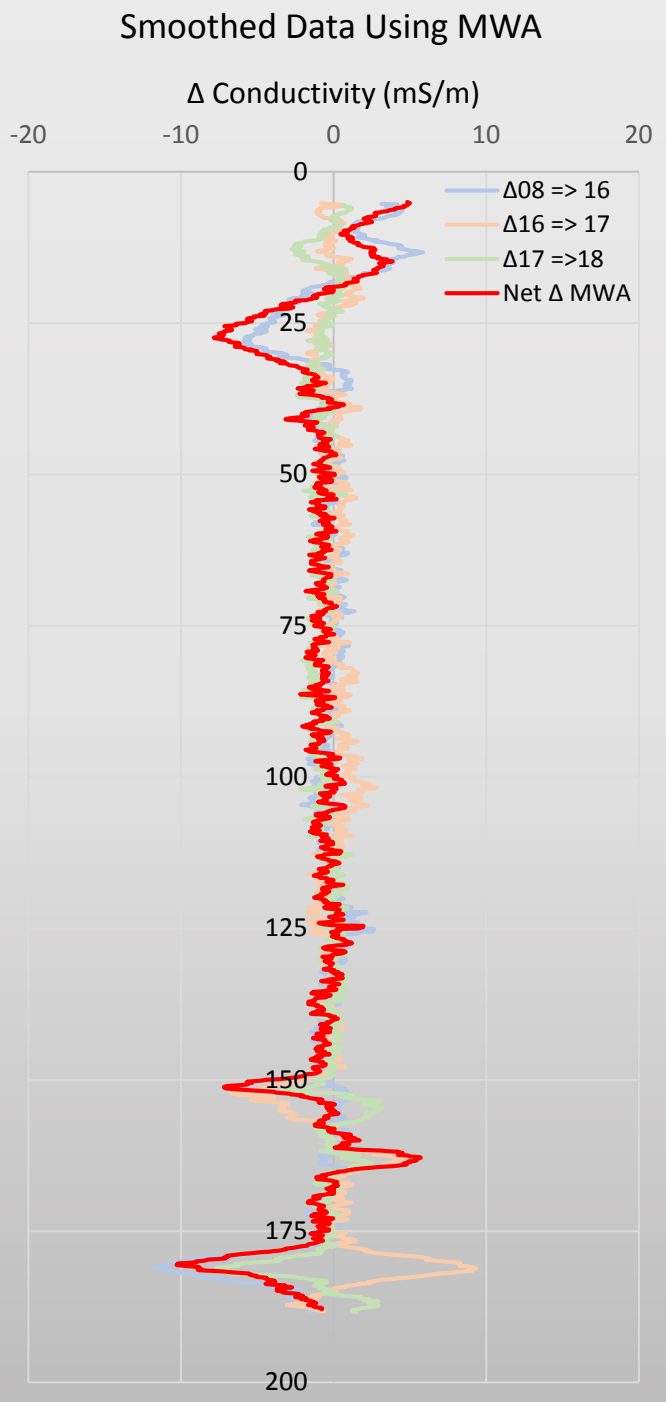
- Data smoothing technique used to reduce “noise” in data
- This is achieved by averaging a “window” of data.
- This “window” moves down the target data series cell by cell
  - Output (Smoothed data series) is centered within the window used

Window

I	M	N
2016-2008 cond	Δ08 => 16	Δ16 => 17
-2		
4.4		
4.7	=AVERAGE(I3:I7)	
3.8	4.16	-0.26
4.8	3.92	0.24
3.1	3.62	0.64
3.2	3.6	0.62
3.2	3.44	0.44
3.7	3.7	0.02

I	M	N
2016-2008 cond	Δ08 => 16	Δ16 => 17
-2		
4.4		
4.7	3.14	-0.82
3.8	=AVERAGE(I4:I8)	
4.8	3.92	0.24
3.1	3.62	0.64
3.2	3.6	0.62
3.2	3.44	0.44
3.7	3.7	0.02





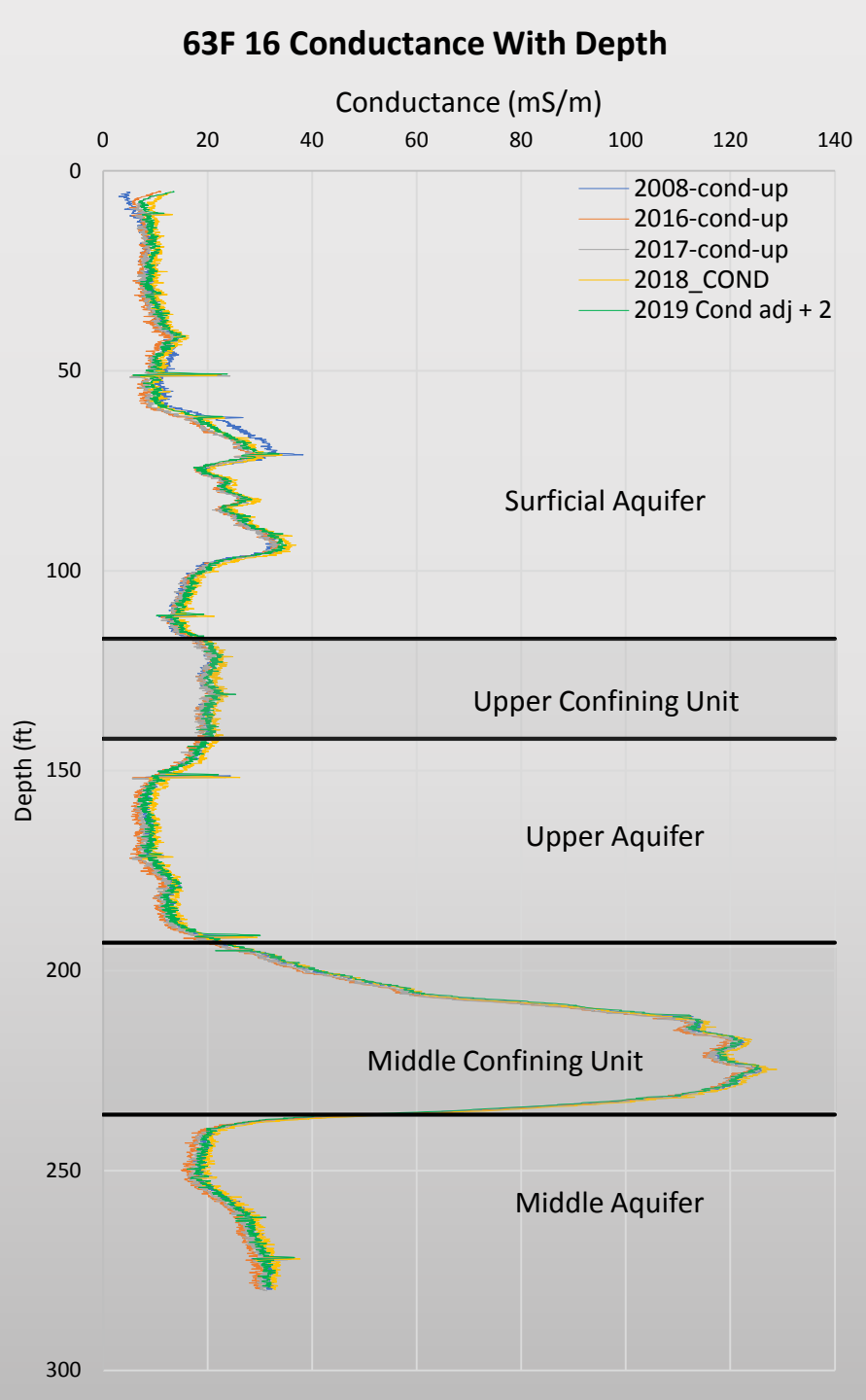
The Relatively Unchanged

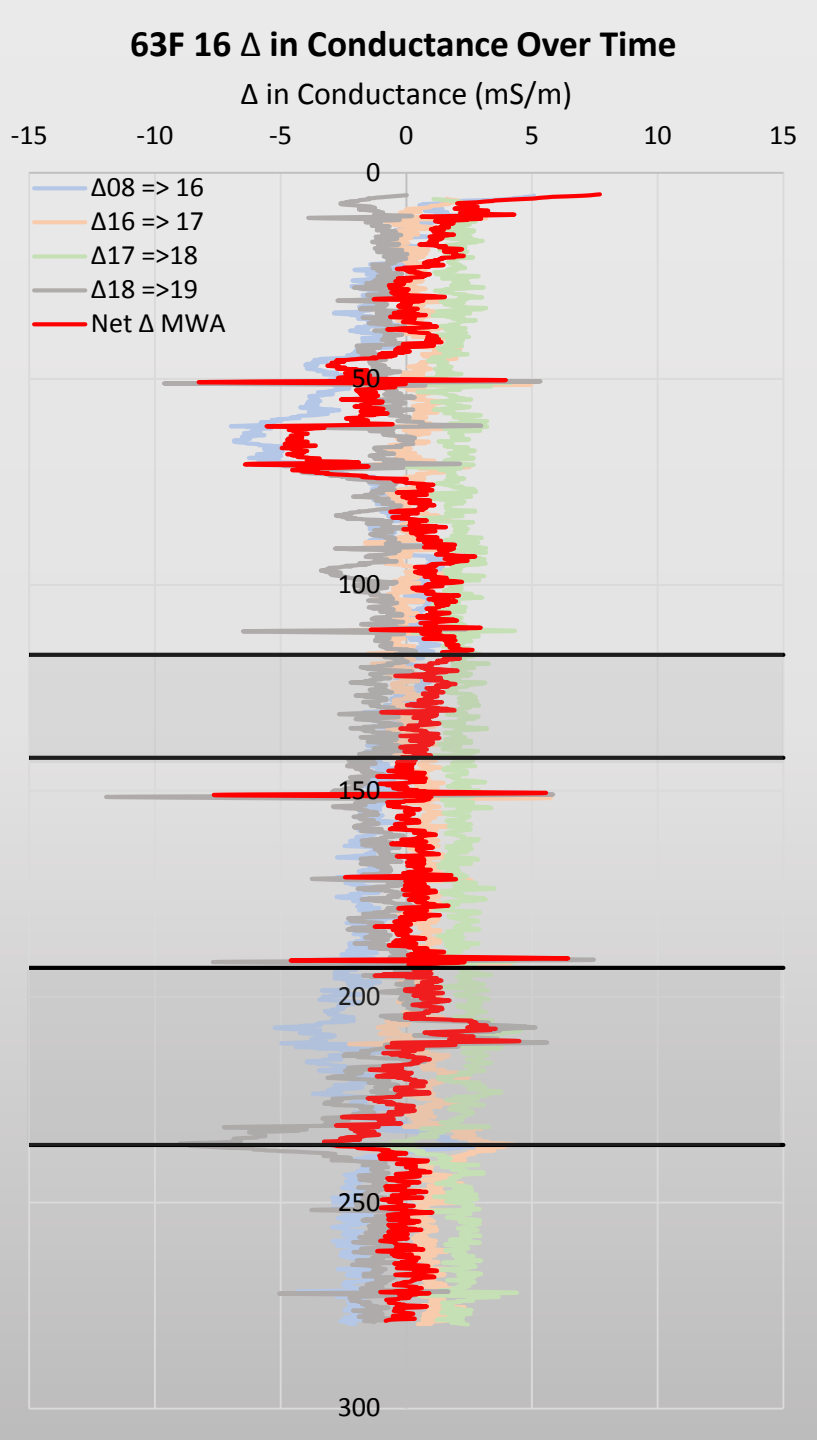
The Hydrologically Interesting

Signs and Potential for Saltwater Movement

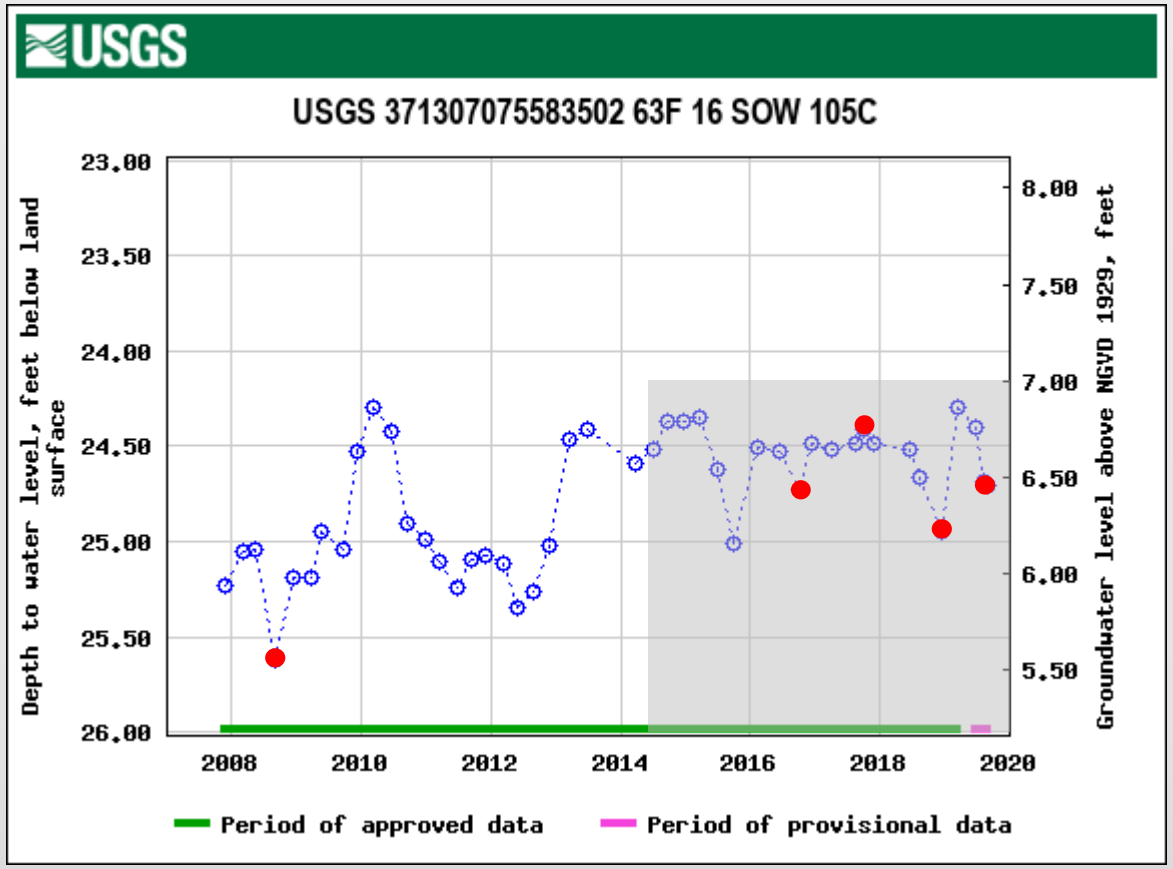
Cape Center

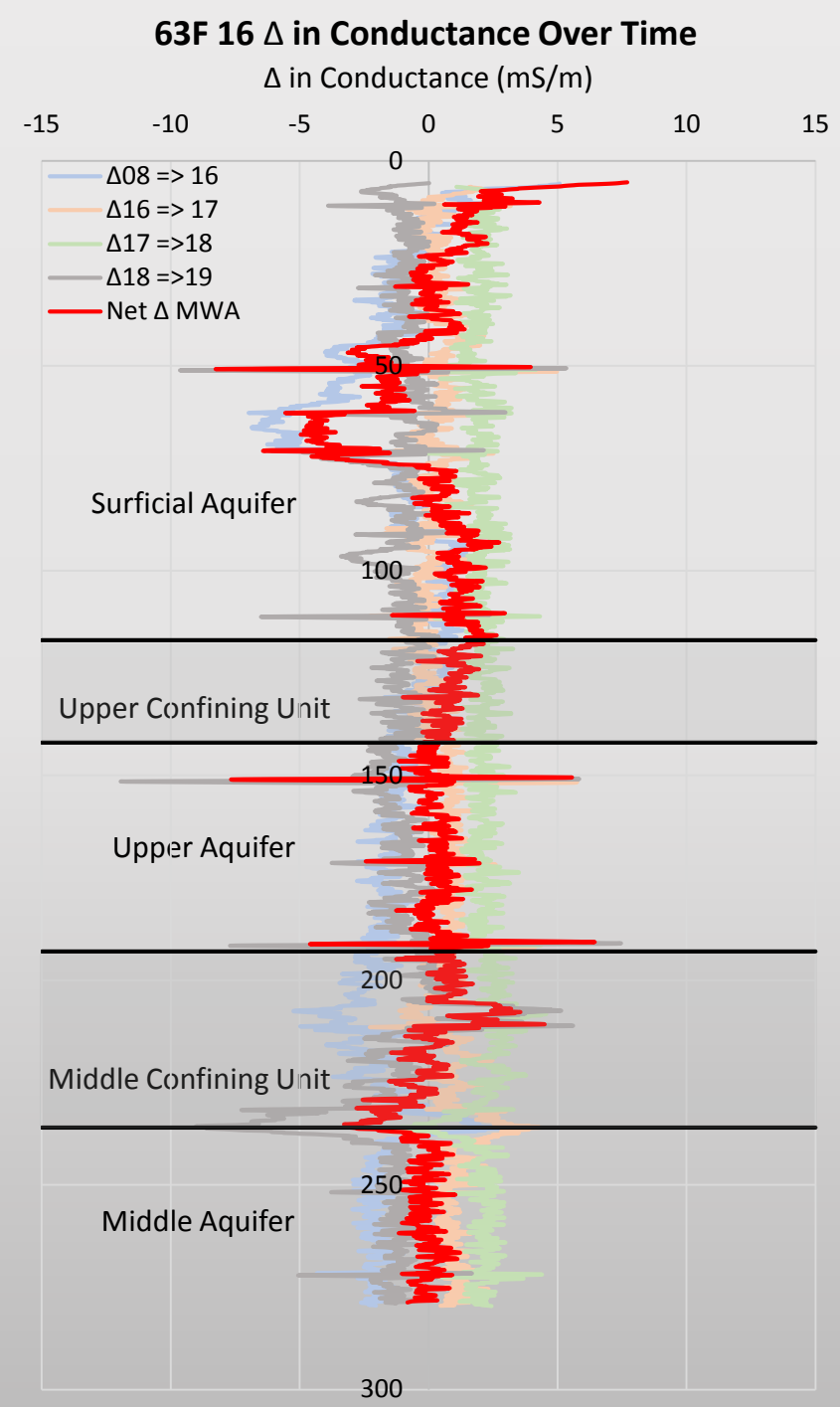
- 63F 16 shows largely slight increases in conductivity from 2008 to 2019 (<5 mS/m)
- Surficial Aquifer has seen the largest amount of change over the period of record
- Changes in Surficial Aquifer likely drilling fluids working their way out of the bore hole





Cape Center continued

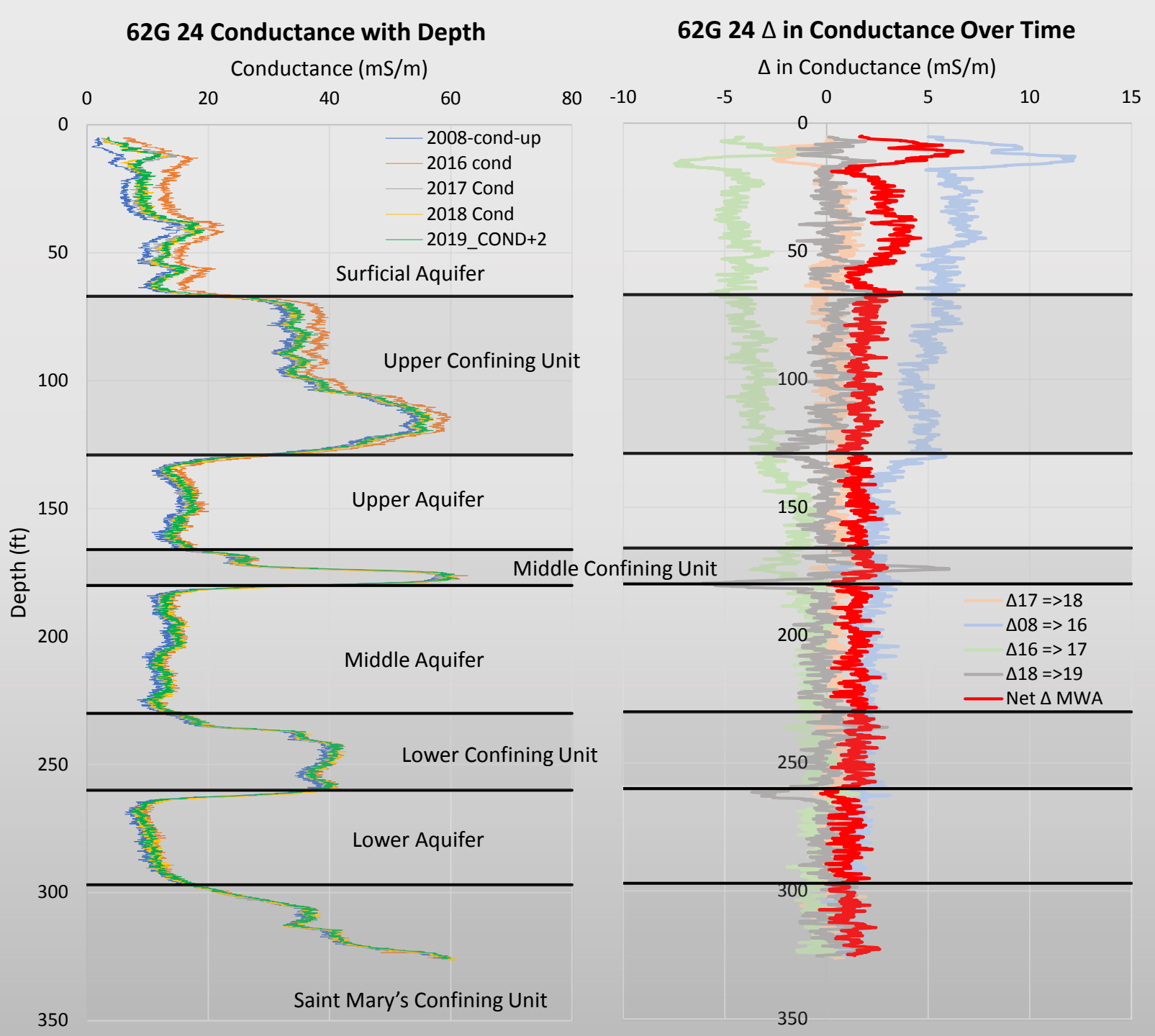




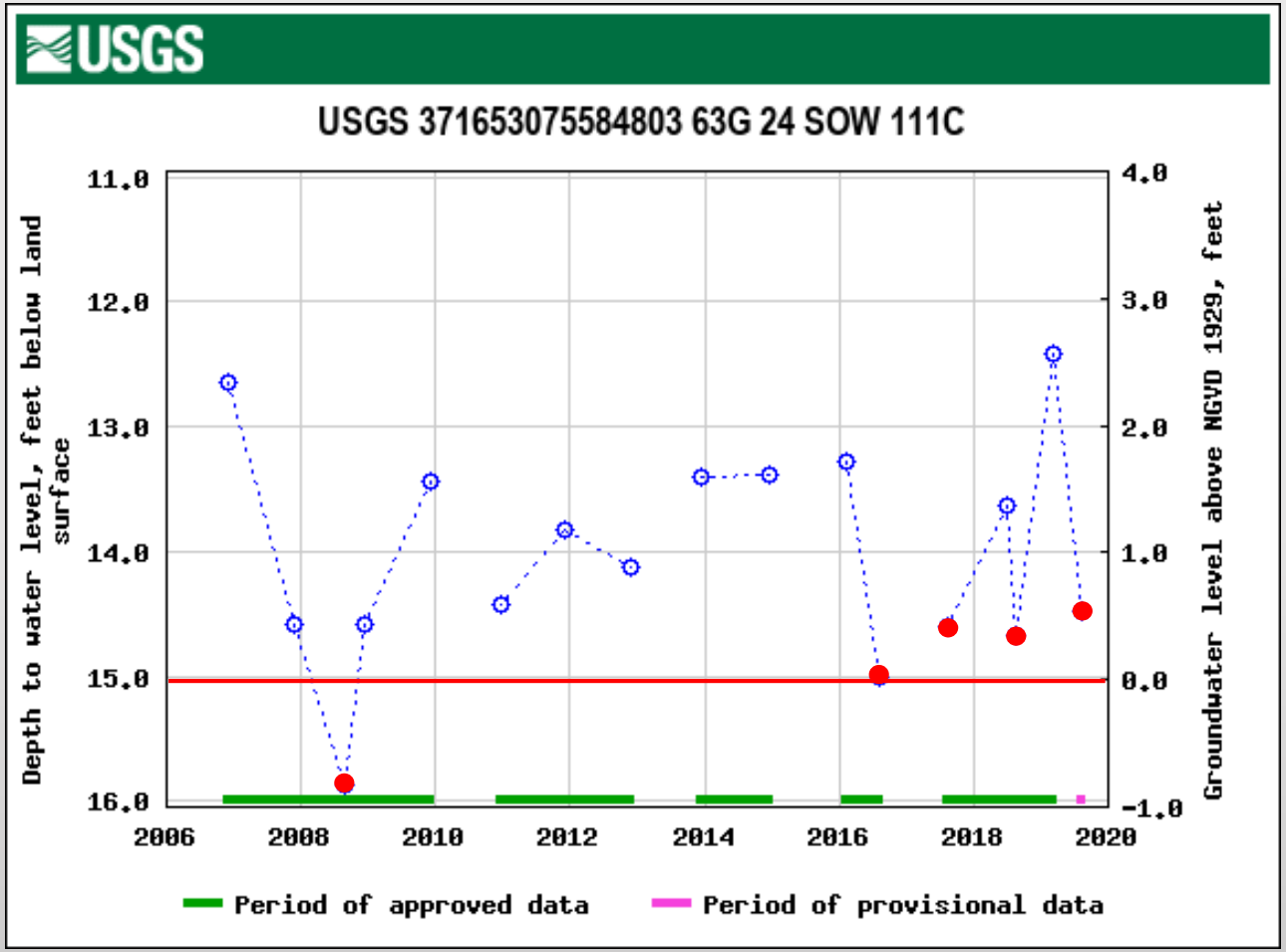
- Seasonal variation in groundwater levels appears to be muted from late 2013 onwards.
  - Results in a mean rise of water levels over time, however, does not exceed previous years' peak levels
- No clear signs of saltwater intrusion
- Surficial aquifer dynamics likely due to the stabilization of groundwater levels from 2013 onward

Cheriton

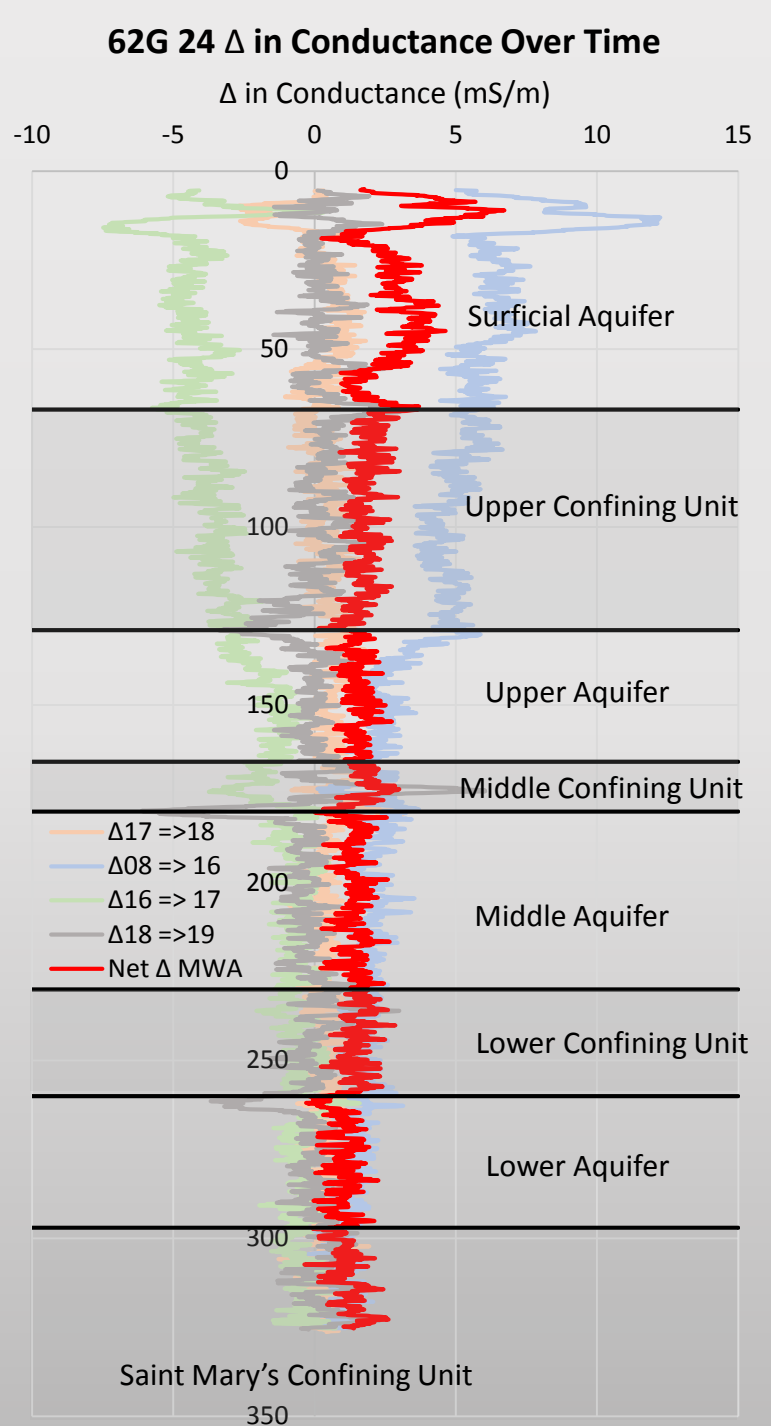
- Small increases in conductivity down the log
- Largest change in the surficial aquifers
  - Possibly due to change in land use
- Saint Mary's Confining Unit sharply increases conductivity with depth.
  - Beginning of saltwater/freshwater interface?
  - If so, no sign of change in depth of interface



Cheriton continued

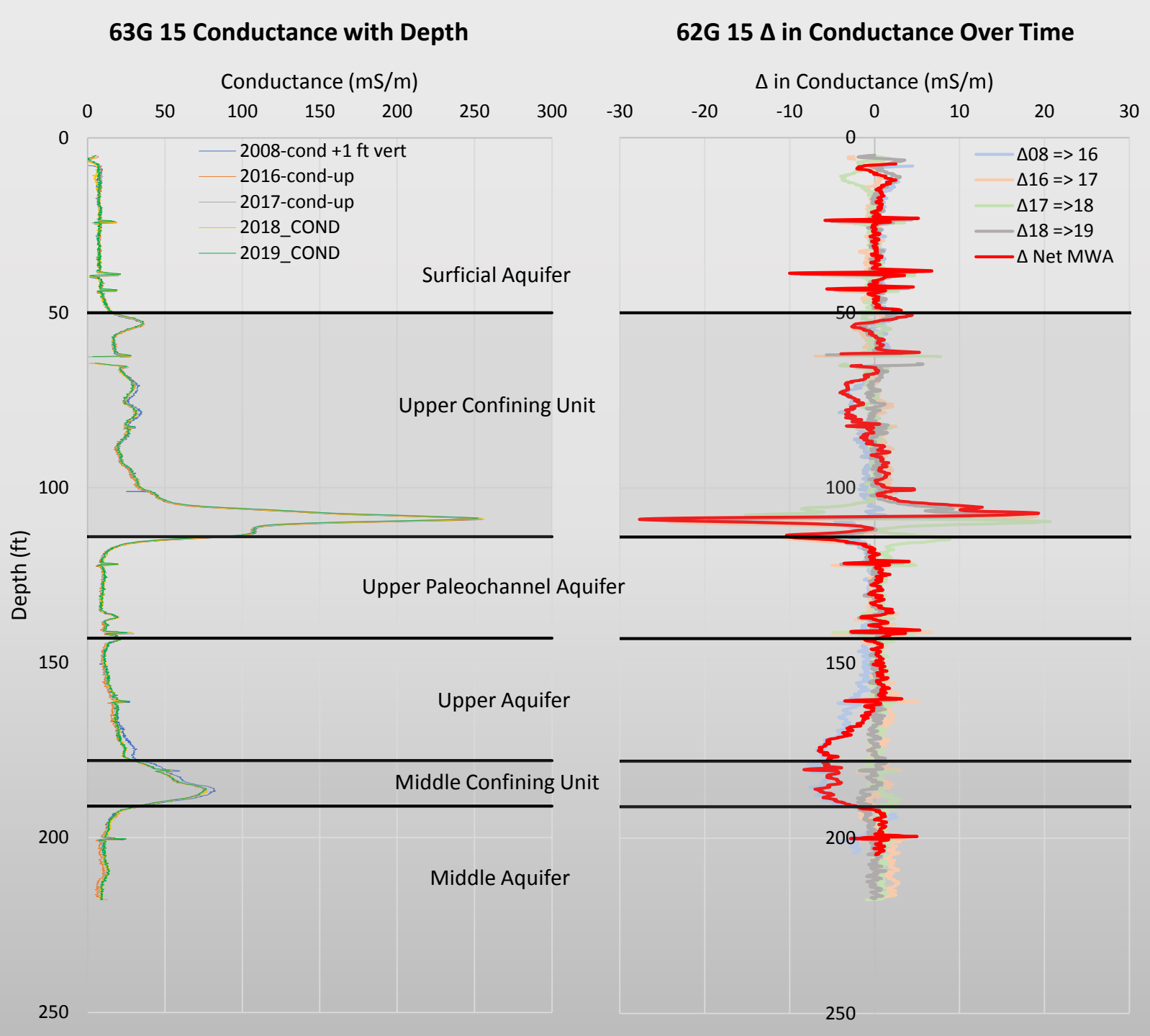


- Sparse water level data for 13-year period
  - Data suggest that water levels are holding steady, or slightly increasing. Possibly shrinking floor to water levels since 2016

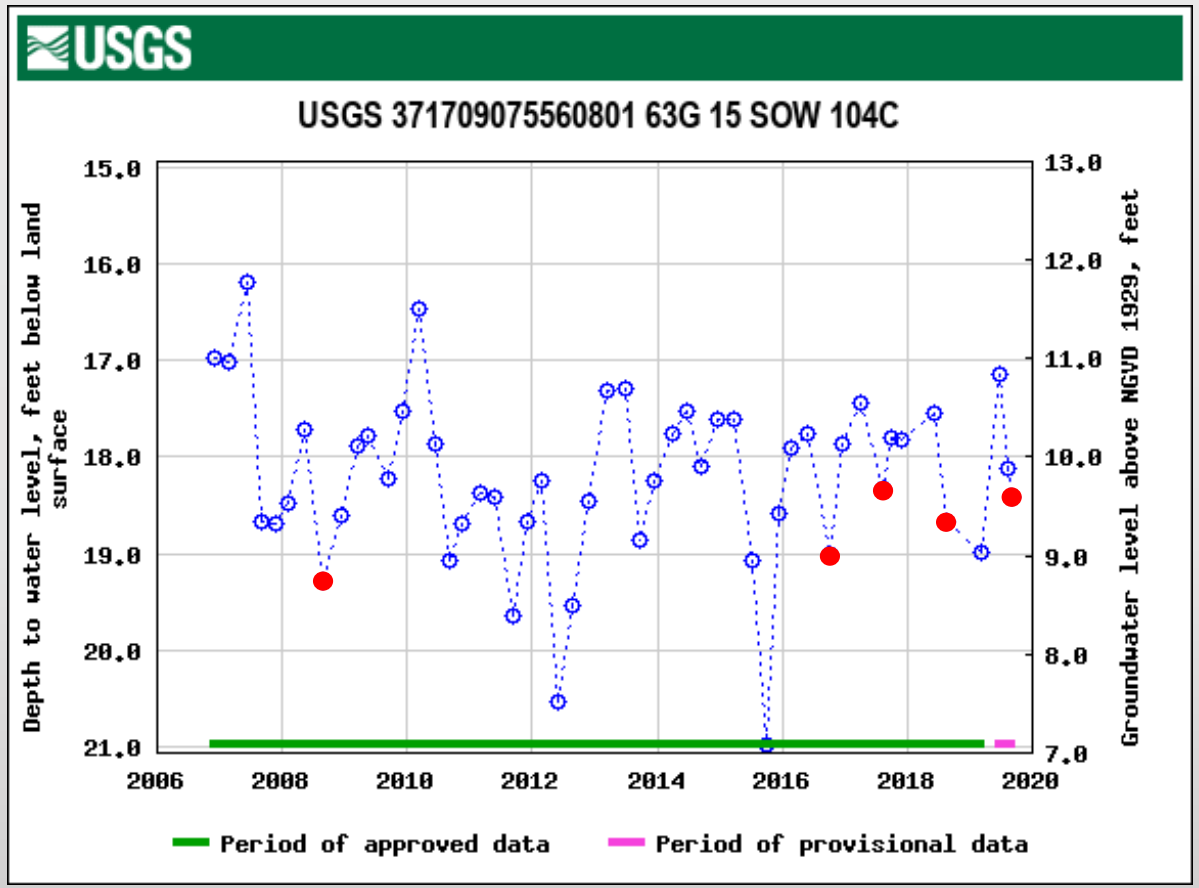


Oyster

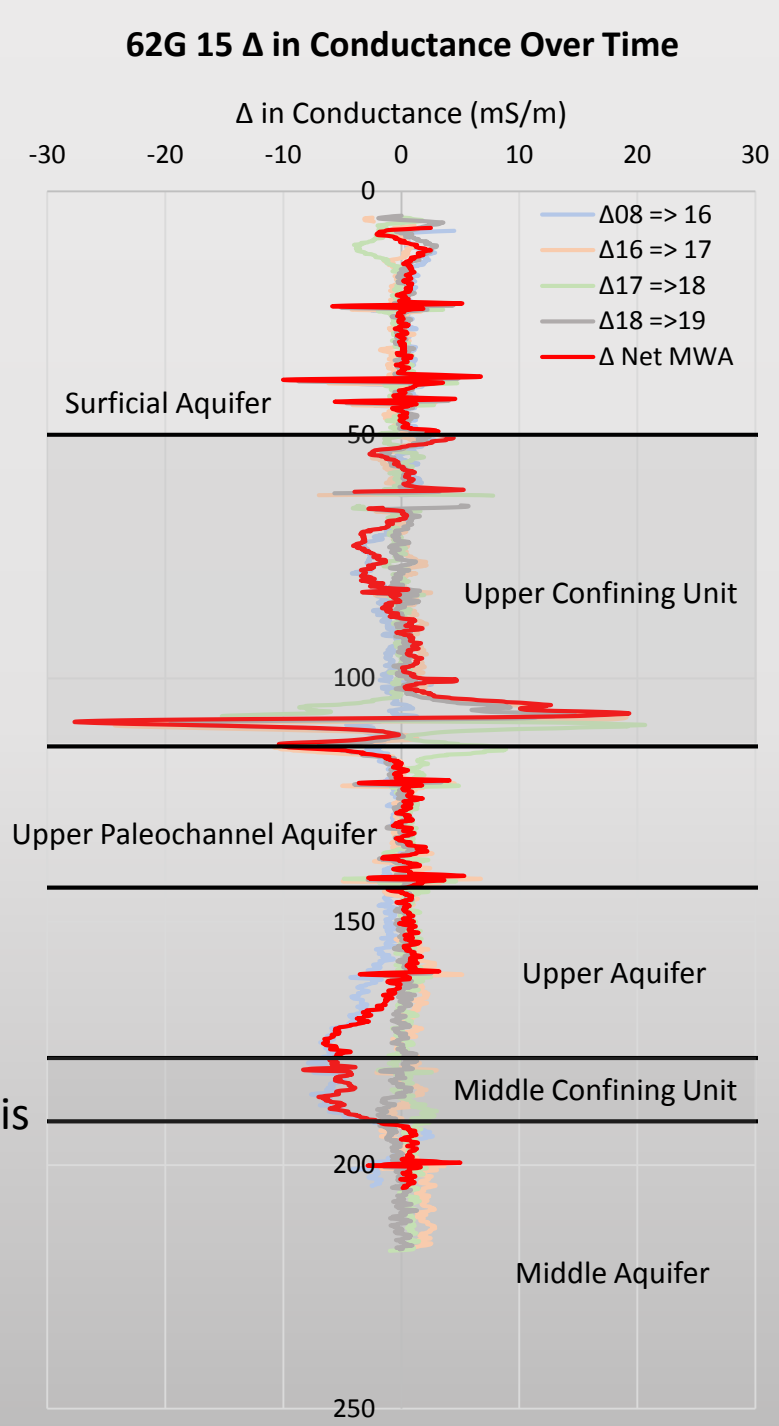
- 2008 conductivity adjusted +1 ft.
  - Necessary to establish common baseline between logs
- Almost no change to conductivity down the log
- Sharp change in top of Upper Confining Unit likely due to metal in the casing (bolt or screw)



Oyster continued

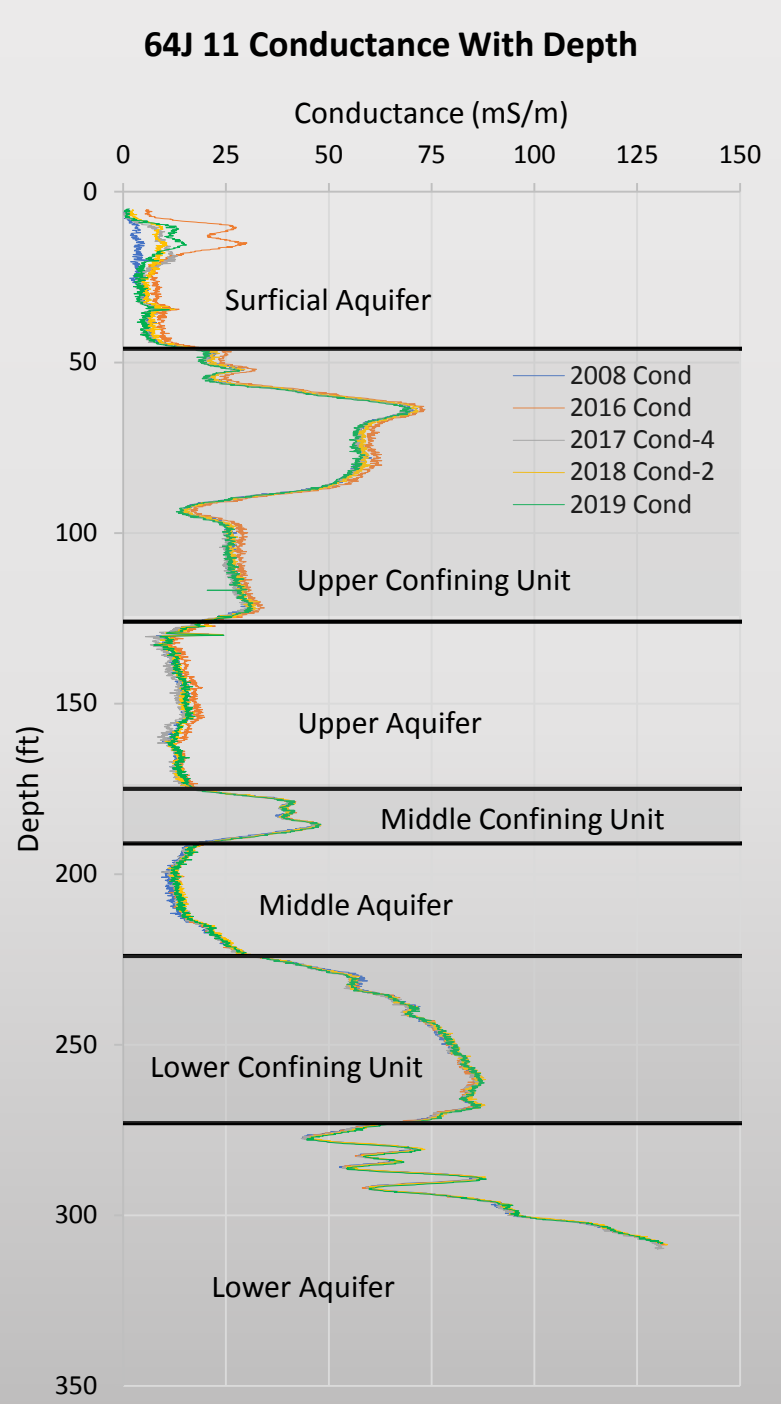


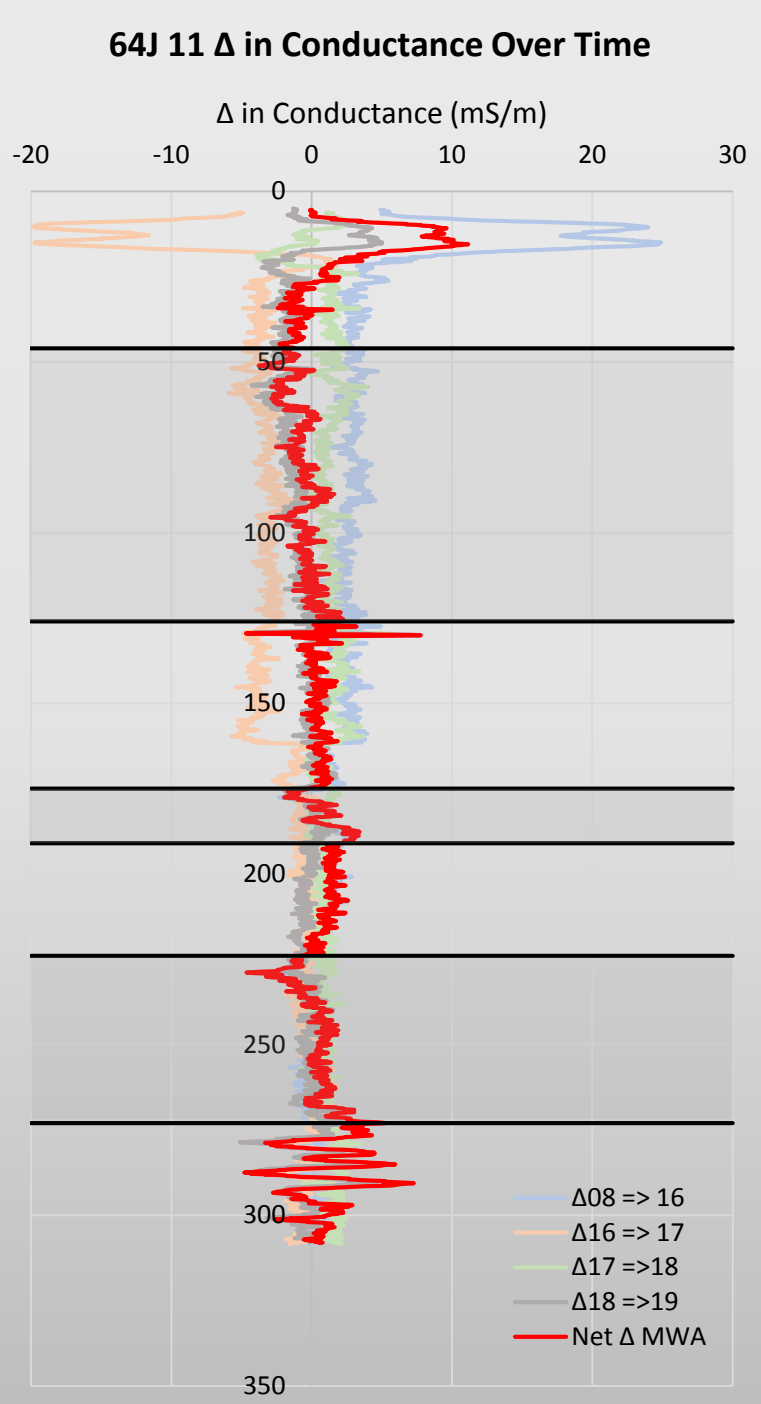
- Excluding late 2015, water levels have stabilized since 2013. This is reflected in the stabilization of conductivity in the middle confining layer
- Slight upward trend in water levels during time of logging from 2016 to present



Willis Wharf

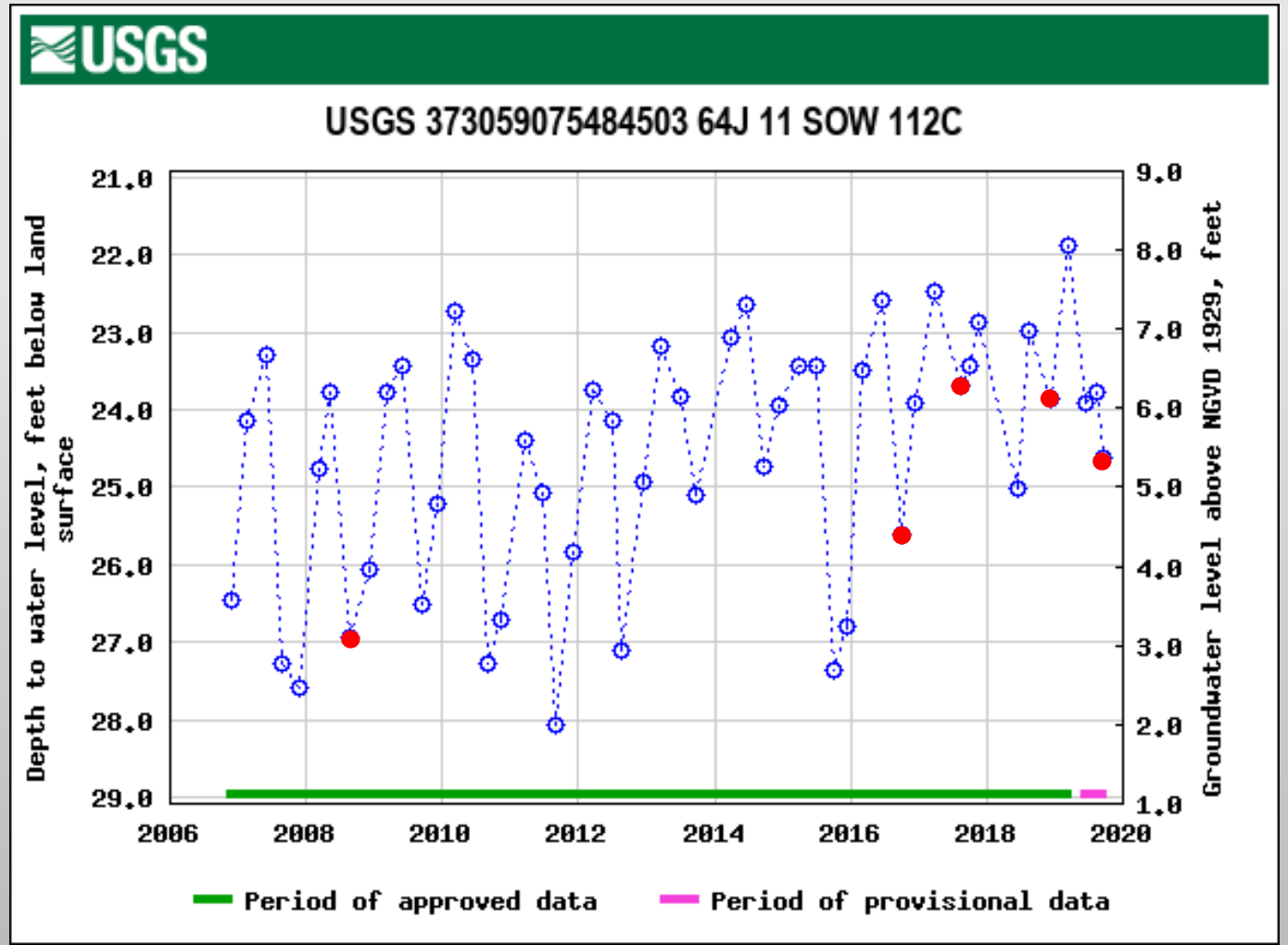
- Slight increase in conductivity from ‘08 to ’19
- Largest change in surficial aquifer
  - Likely a result of a change in solute sources
- Increasing salinity with depth in lower aquifer
  - Beginning of saltwater/freshwater interface?

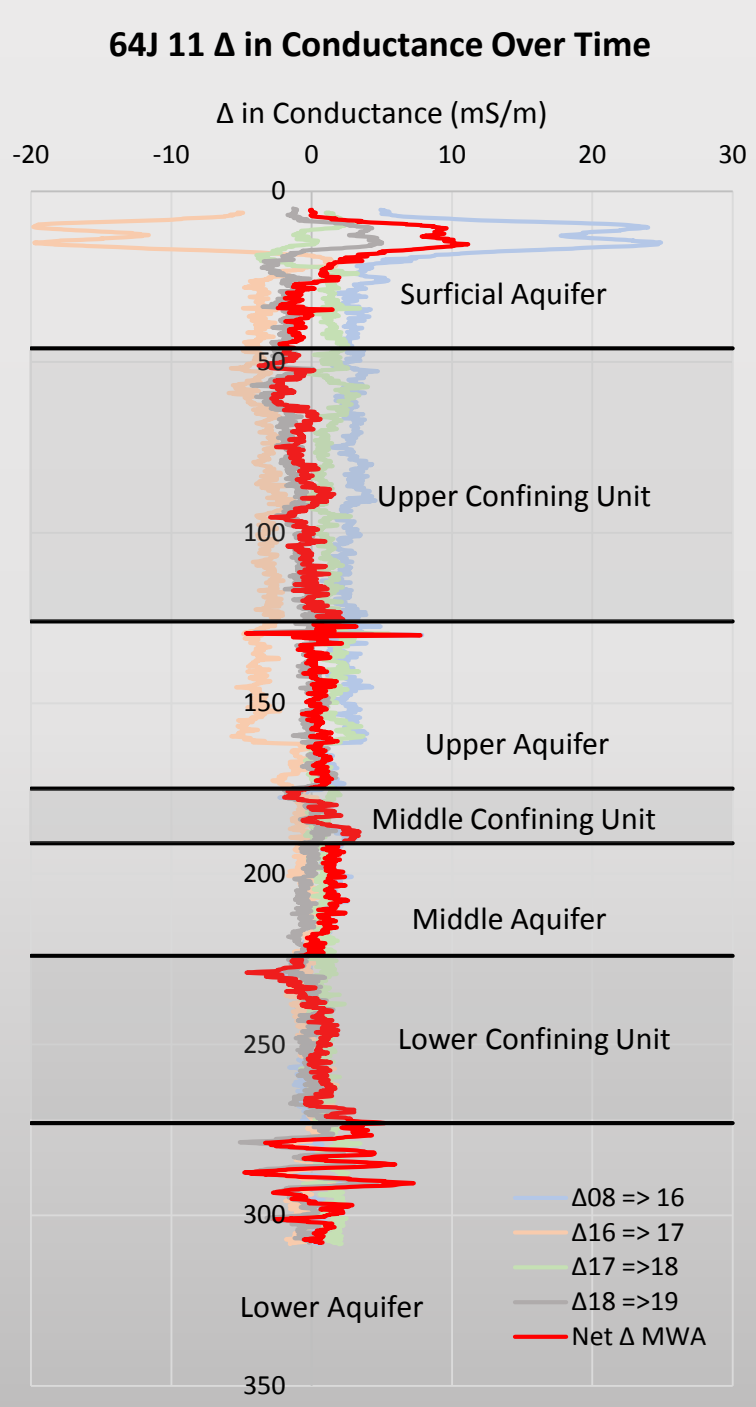




Willis Wharf continued

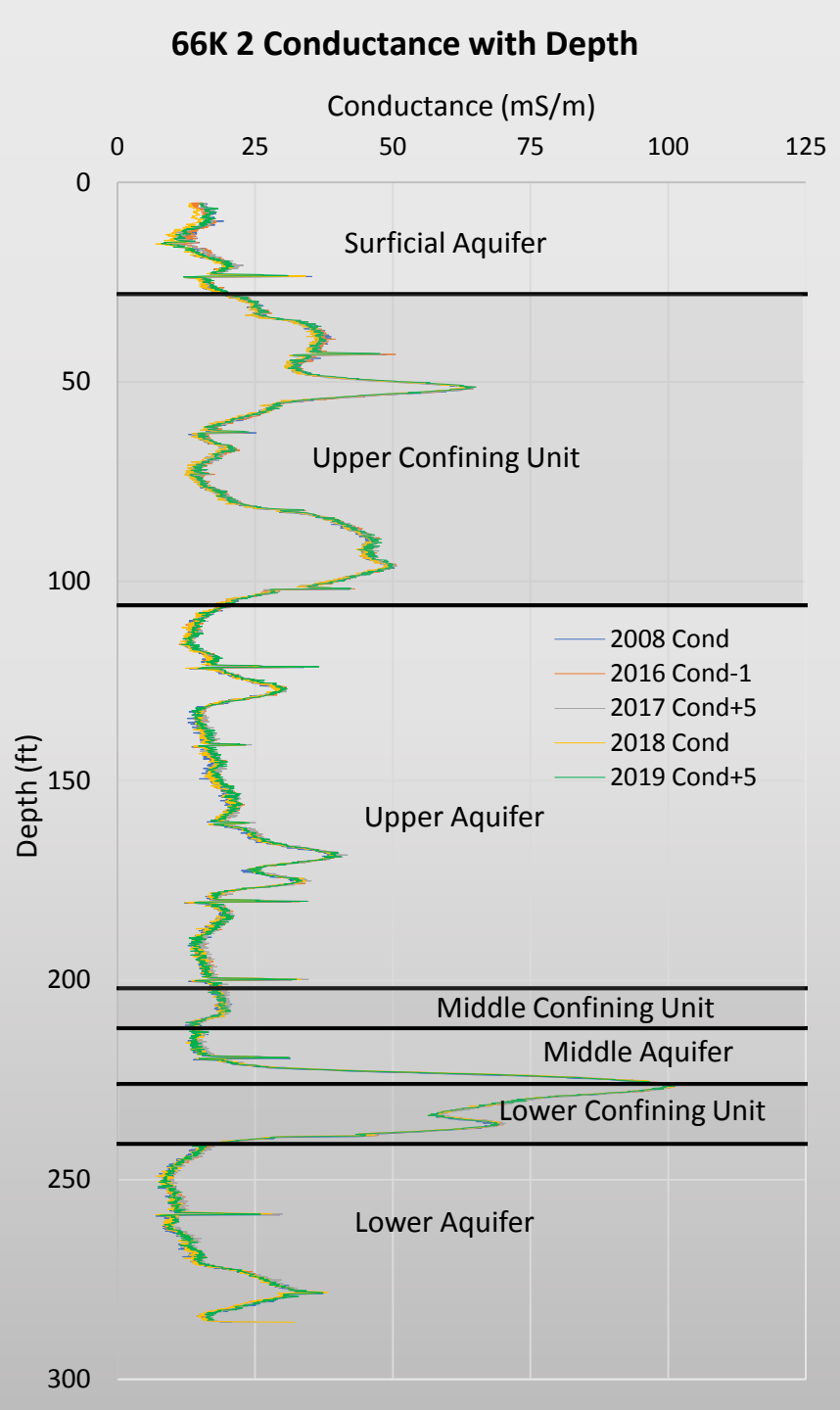
- Increasing and stabilizing water level since 2016, appears to be shrinking floor to water levels from 2016 onward

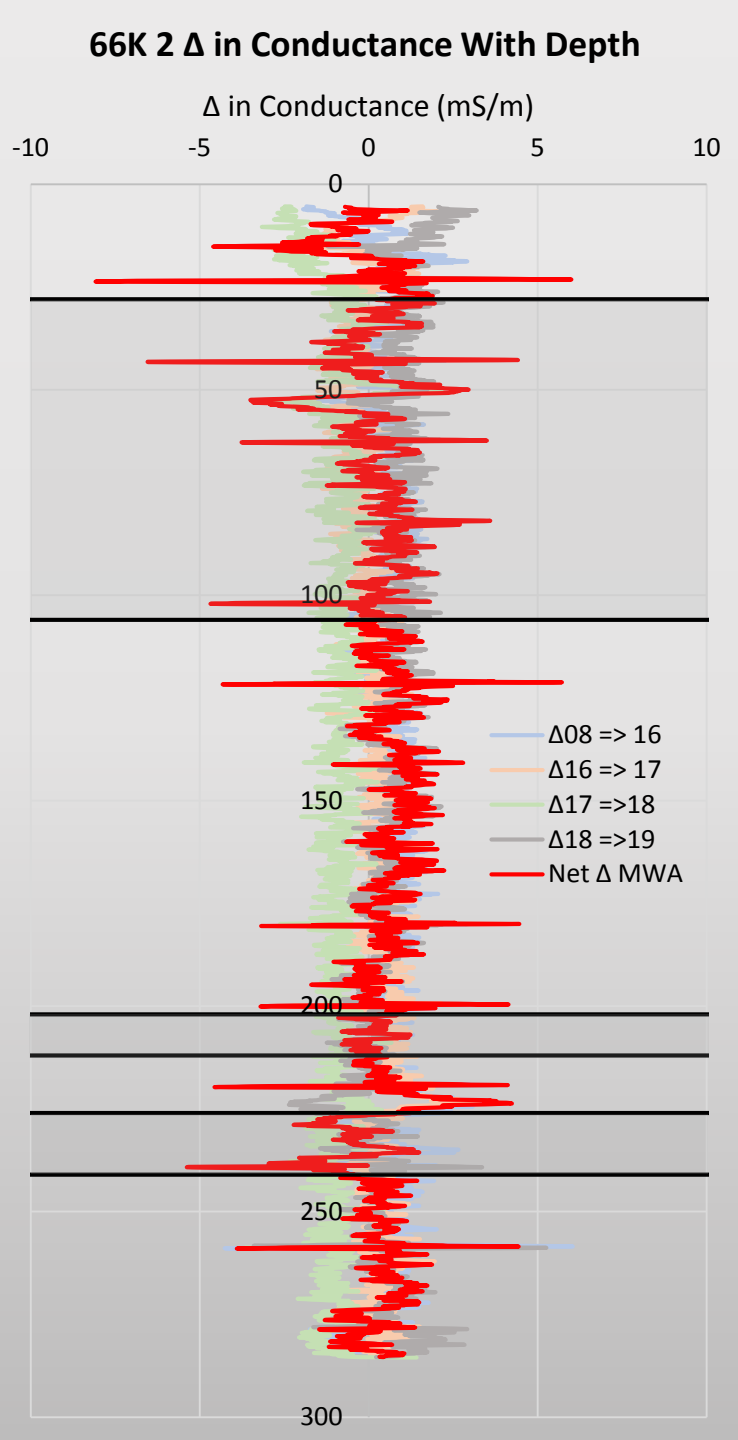




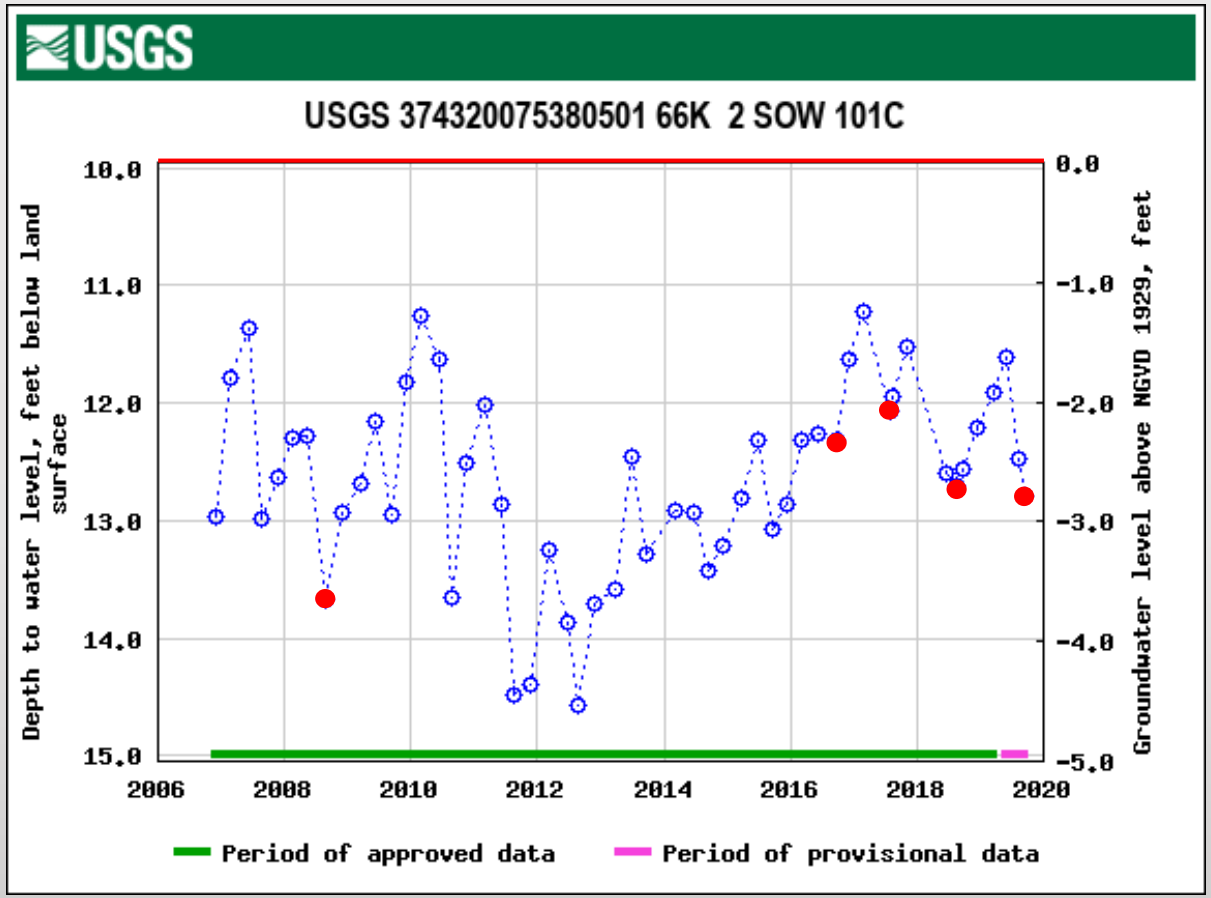
Bayly's Neck

- 2017 conductivity adjusted +5 µS/cm
  - Necessary to establish common baseline between logs
- Near no net change in conductivity
  - Very small decrease in conductivity from 2008 to 2019
- Spikes in raw data correspond to metal in the well casing: screws, bolts

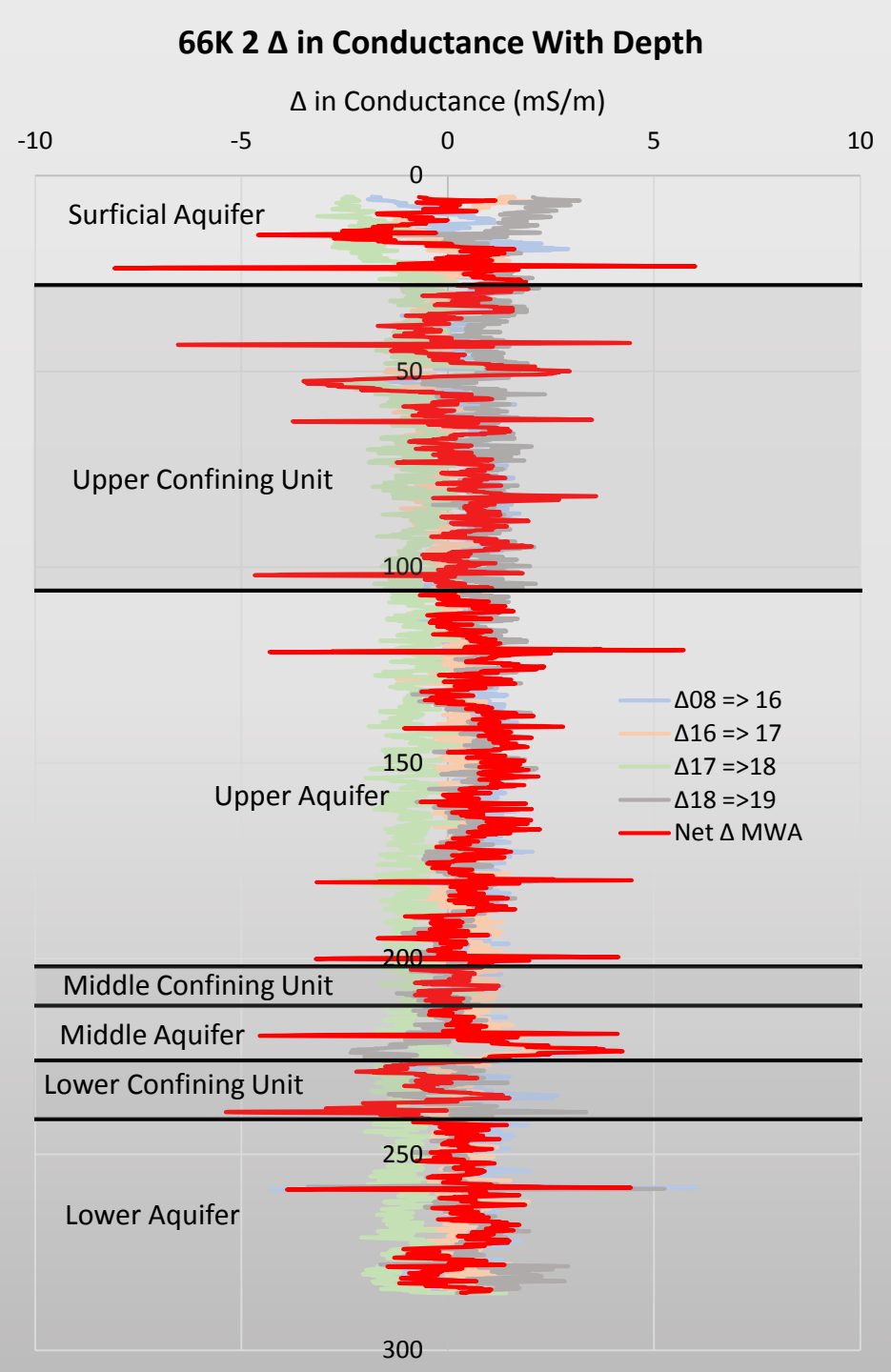




Bayly's Neck continued



- Water levels are below sea level
- Potential downward trend since 2017



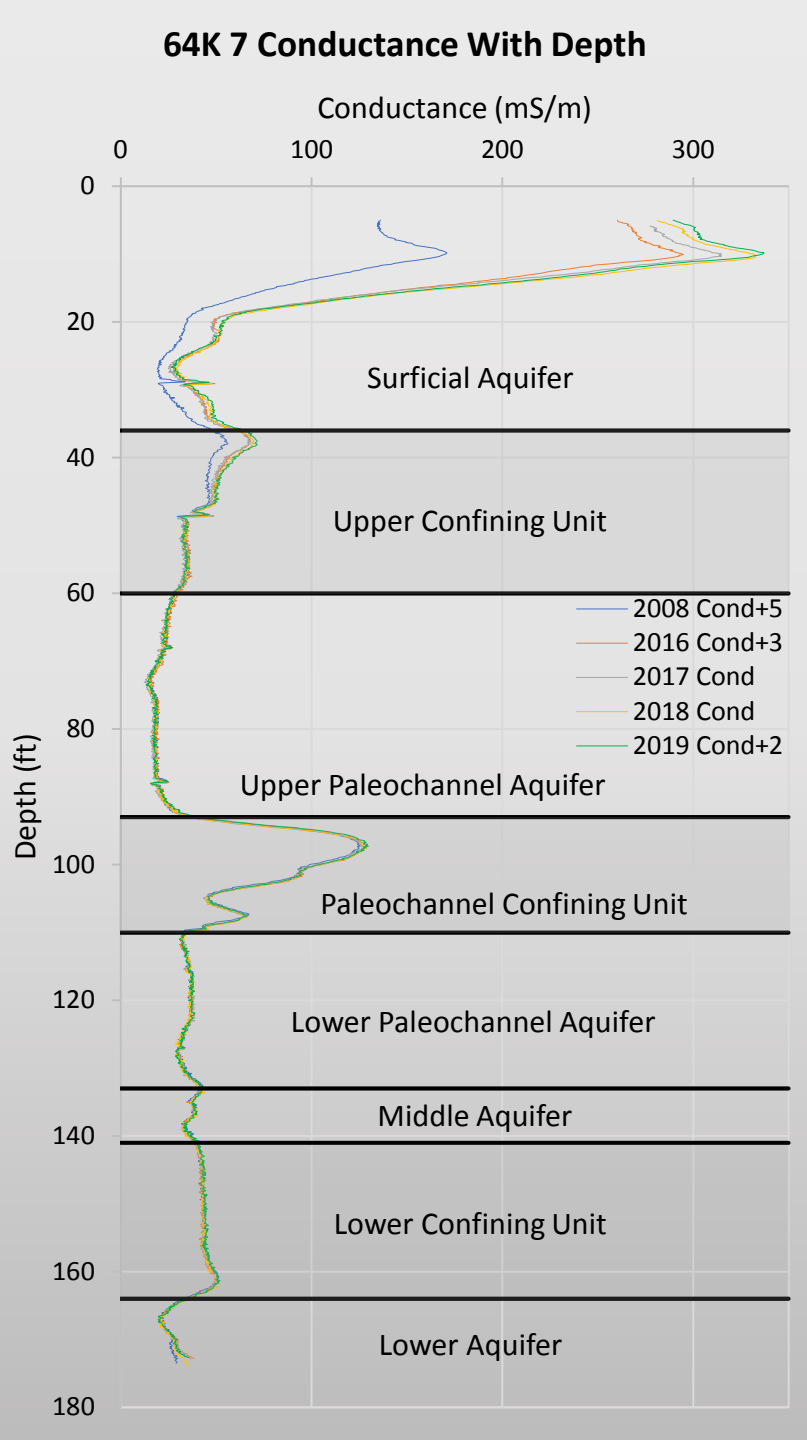
The Relatively Unchanged

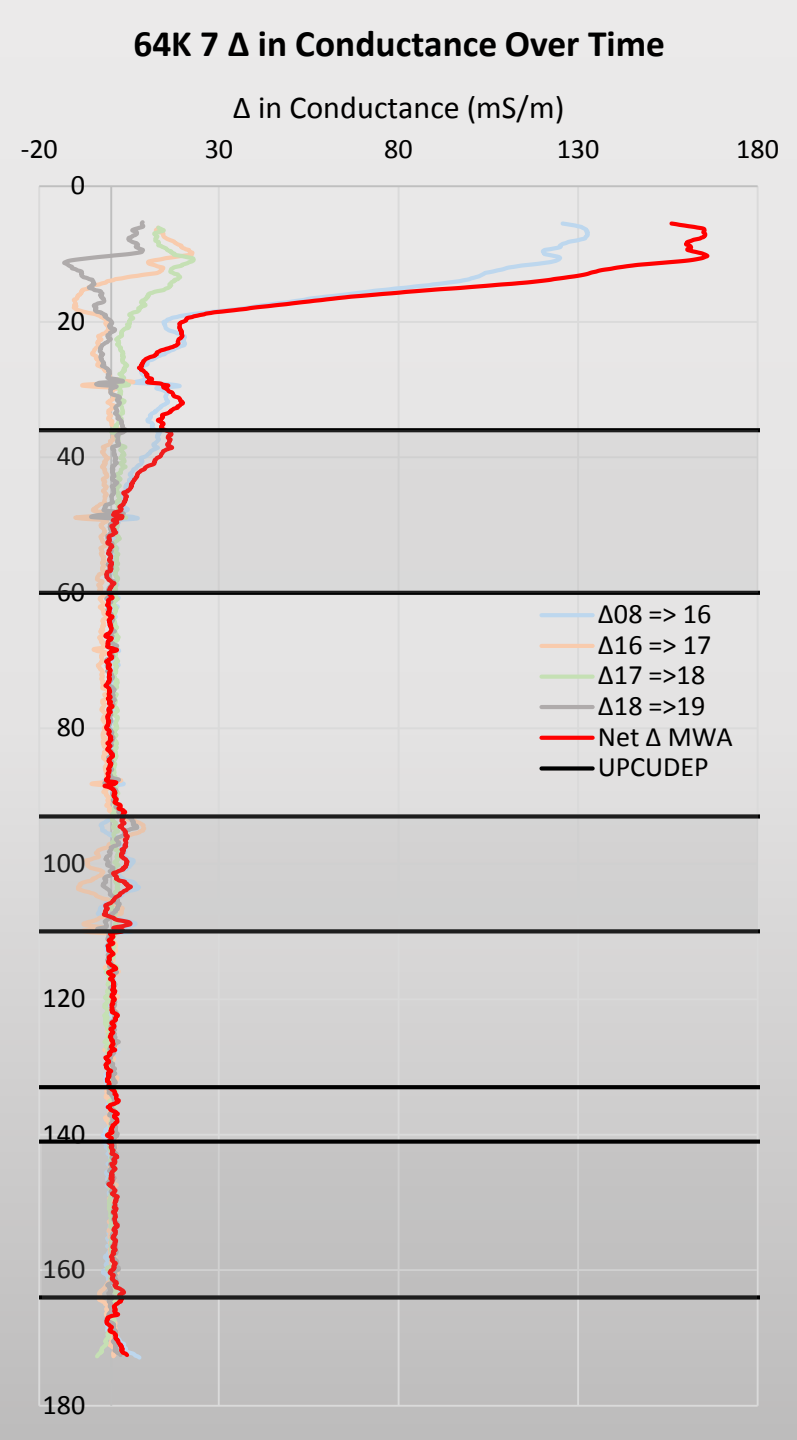
The Hydrologically Interesting

Signs and Potential for Saltwater Movement

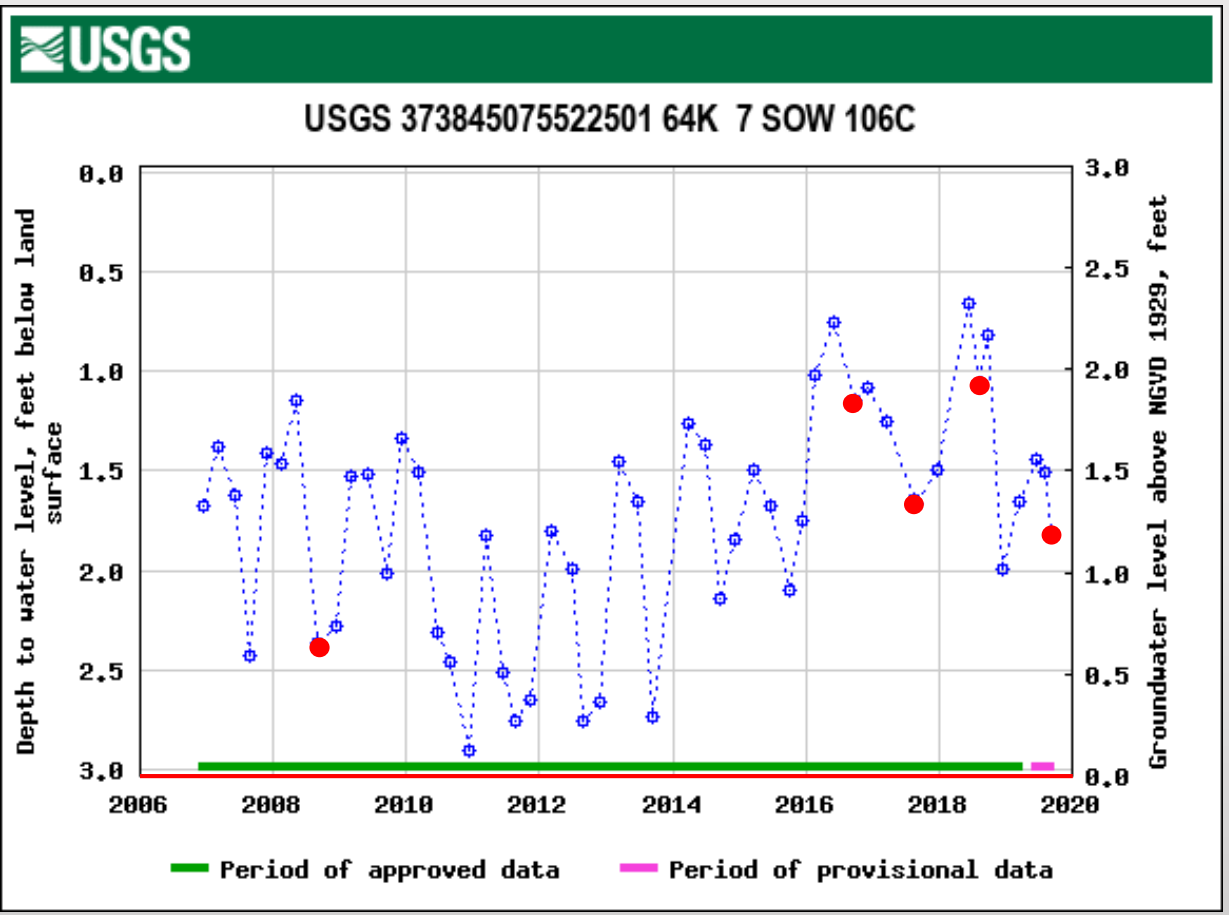
Hacks Neck

- Most of the log shows a small increase in conductivity over the observation period.
- Exception in the top of the surficial aquifer.
  - consistent increases in conductivity from year to year
- Given the shallow location of the increase, saltwater intrusion is likely not the cause
  - Conductivity changes are likely combination of:
    - Solute change and change of use
    - Sea level rise (given proximity to the Bay shore)

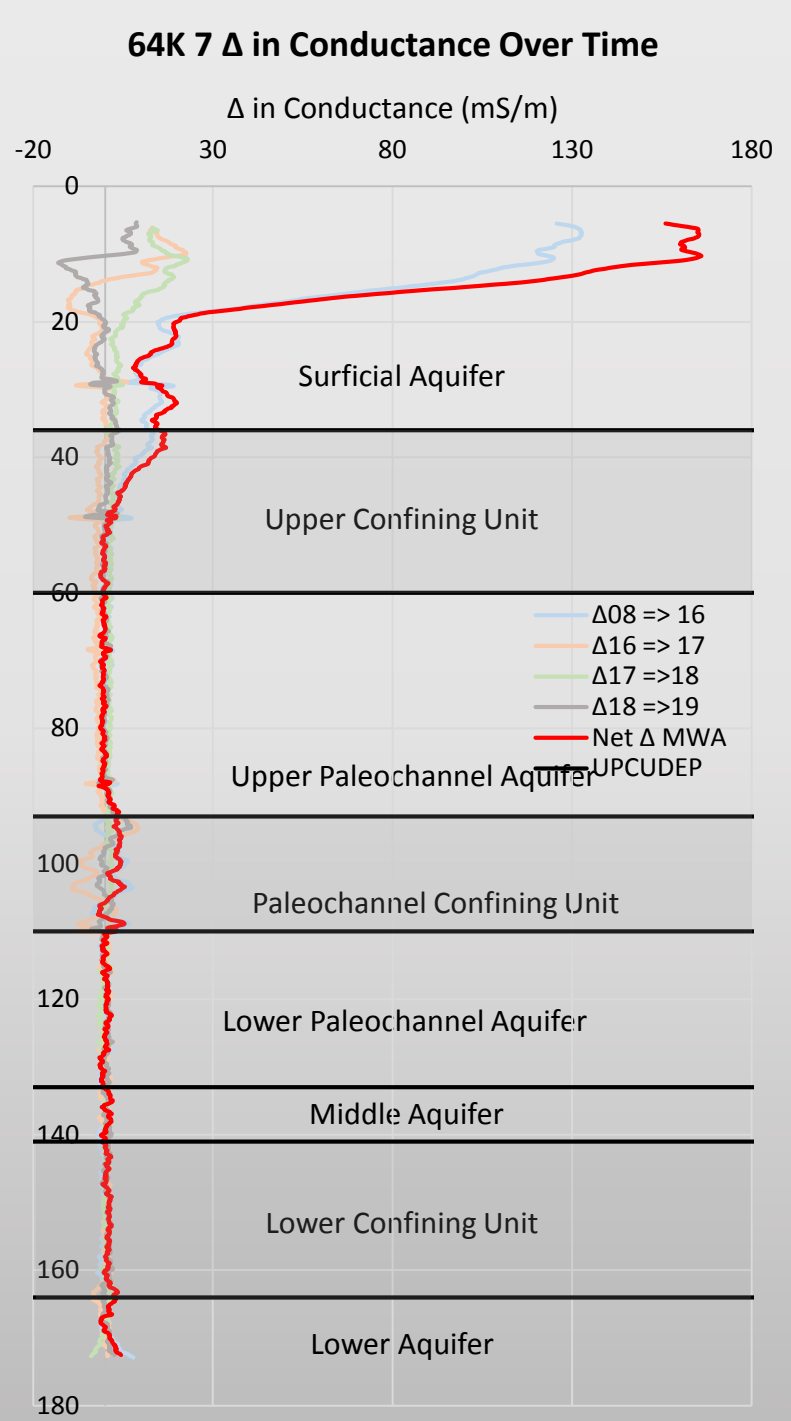




Hacks Neck continued

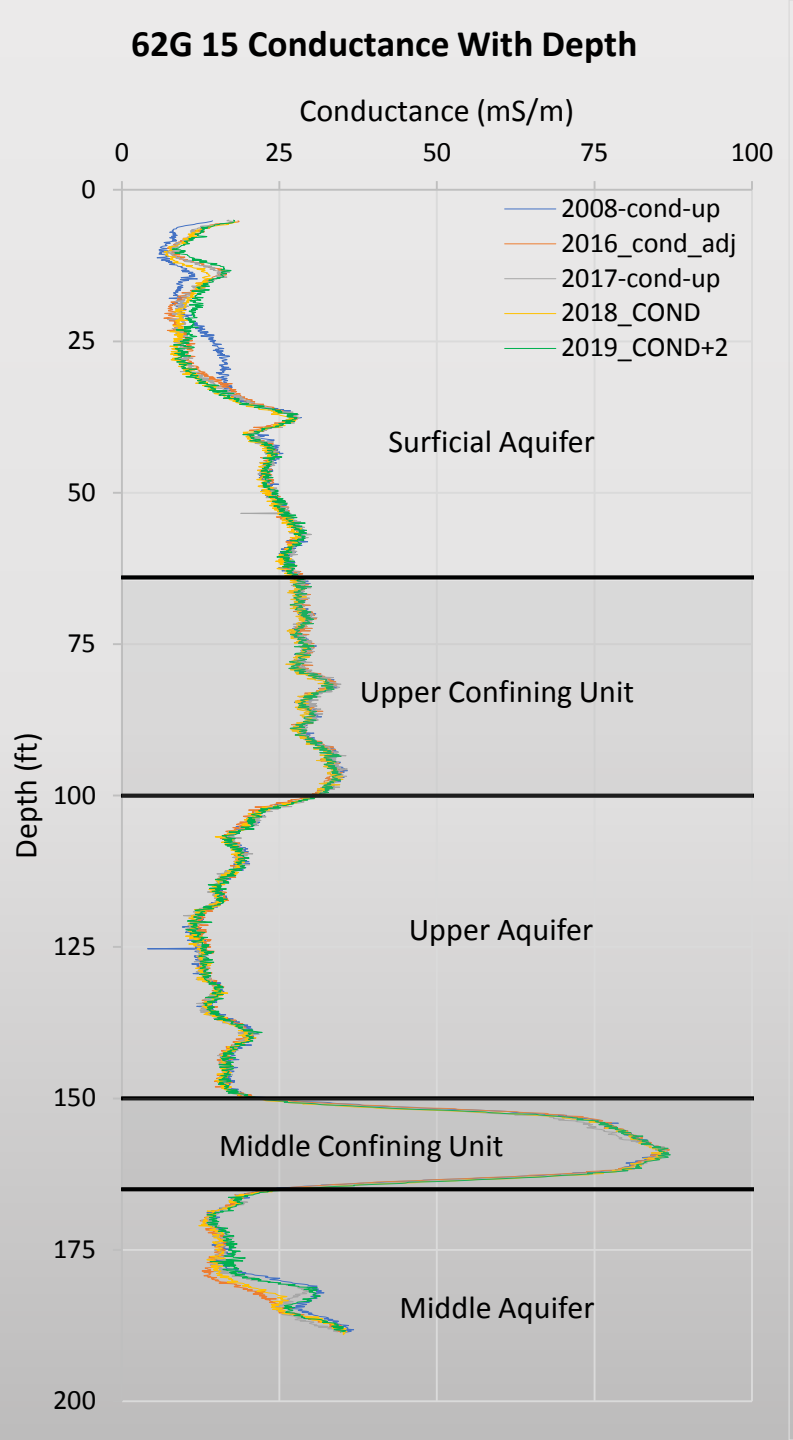


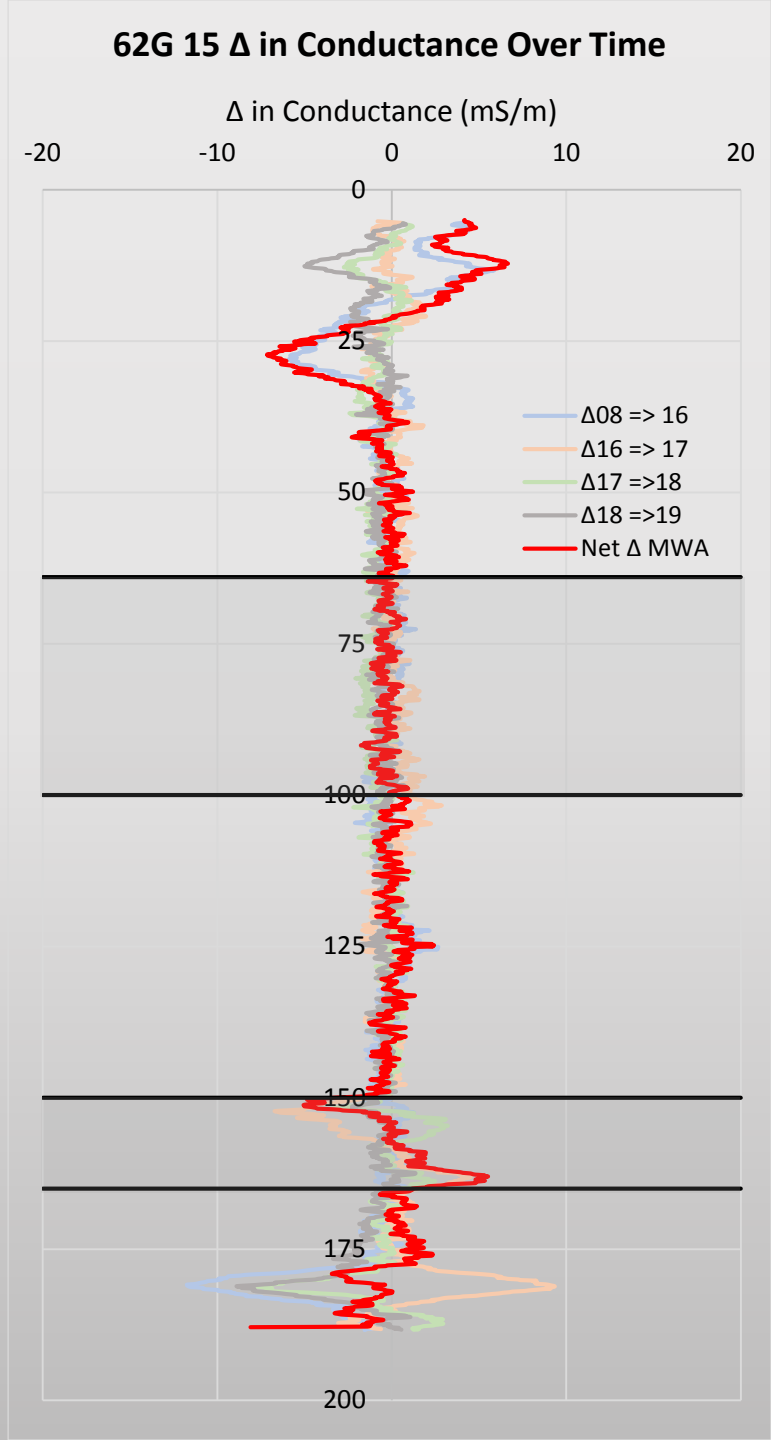
- Water levels have increased over time and are above sea level.
  - Reflected in homogeneity of middle and lower portions of the log.
  - Possible decrease in water levels sine 2016



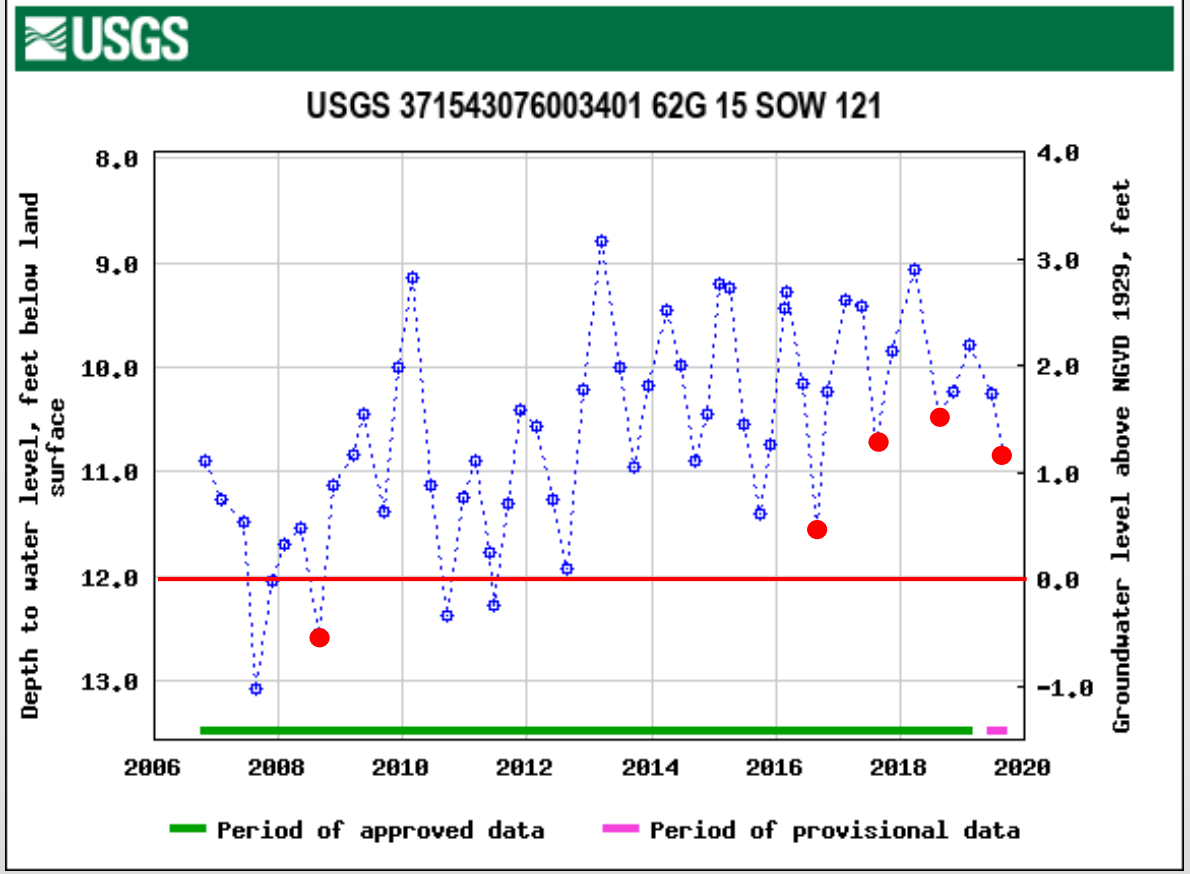
Bay Creek Resort

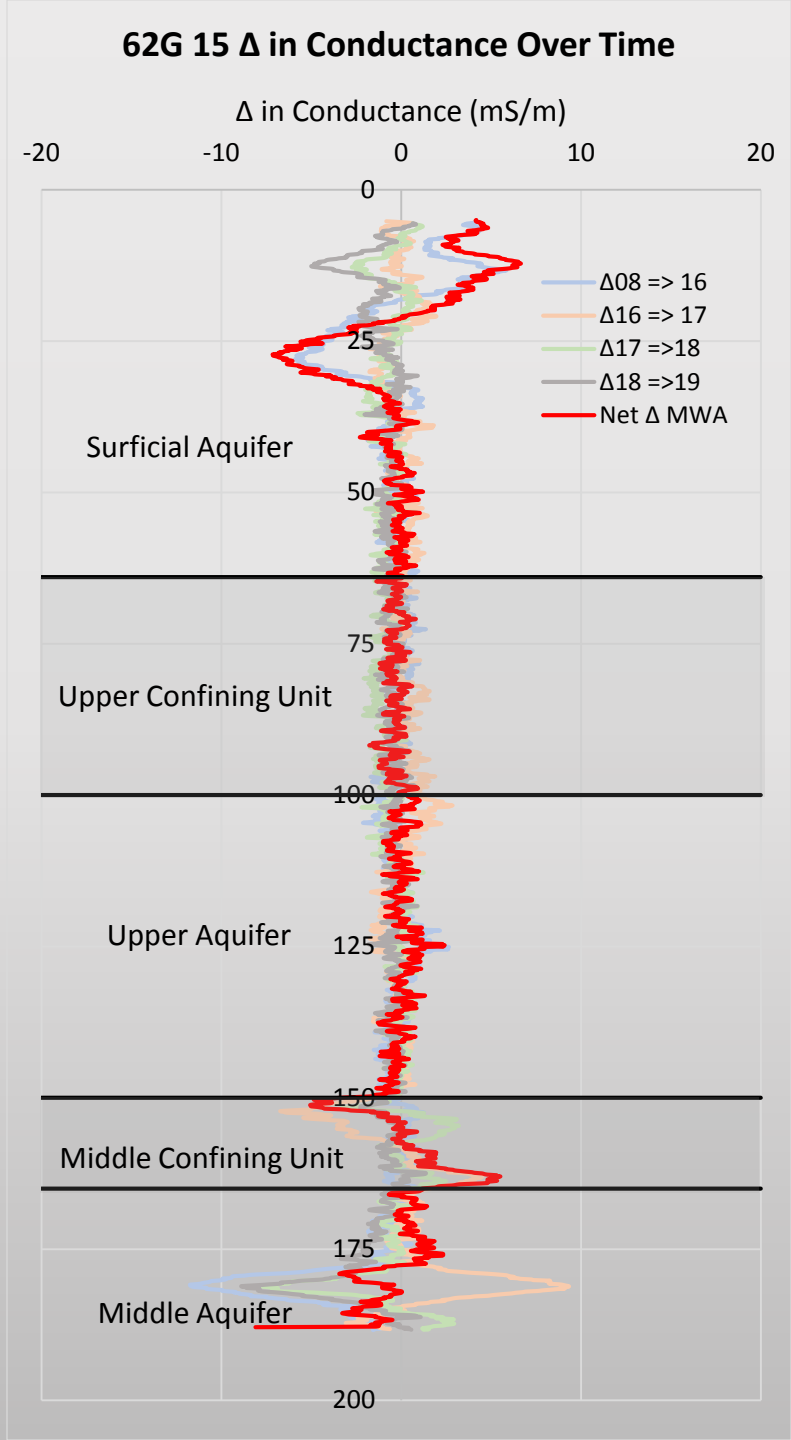
- 2016 conductivity adjusted +6 mS/m.
  - Necessary to establish common baseline between logs
- overall, slight changes in conductivity if any at all, none of which exceed more than 11 mS/m from 2008 to 2019
- Surficial and Middle Aquifers, Middle Confining Unit show small changes to conductivity





Bay Creek Resort continued





- Overall increase in water level over time.
- Surficial aquifer dynamics are likely a result of higher water levels and less seasonal variation in water levels
- Oscillations in lower end of log need continued monitoring to tease out likely causes
- No clear signs of saltwater intrusion

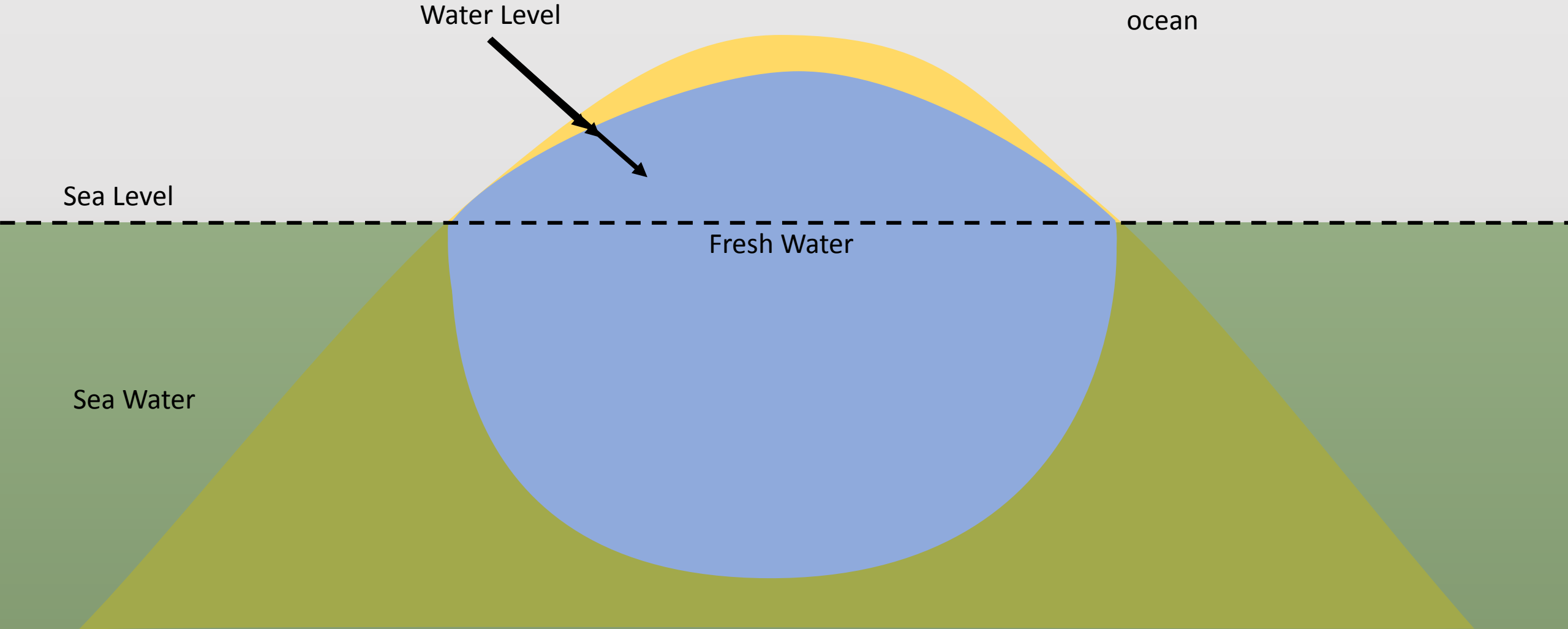
The Relatively Unchanged

The Hydrologically Interesting

Signs and Potential for Saltwater Movement

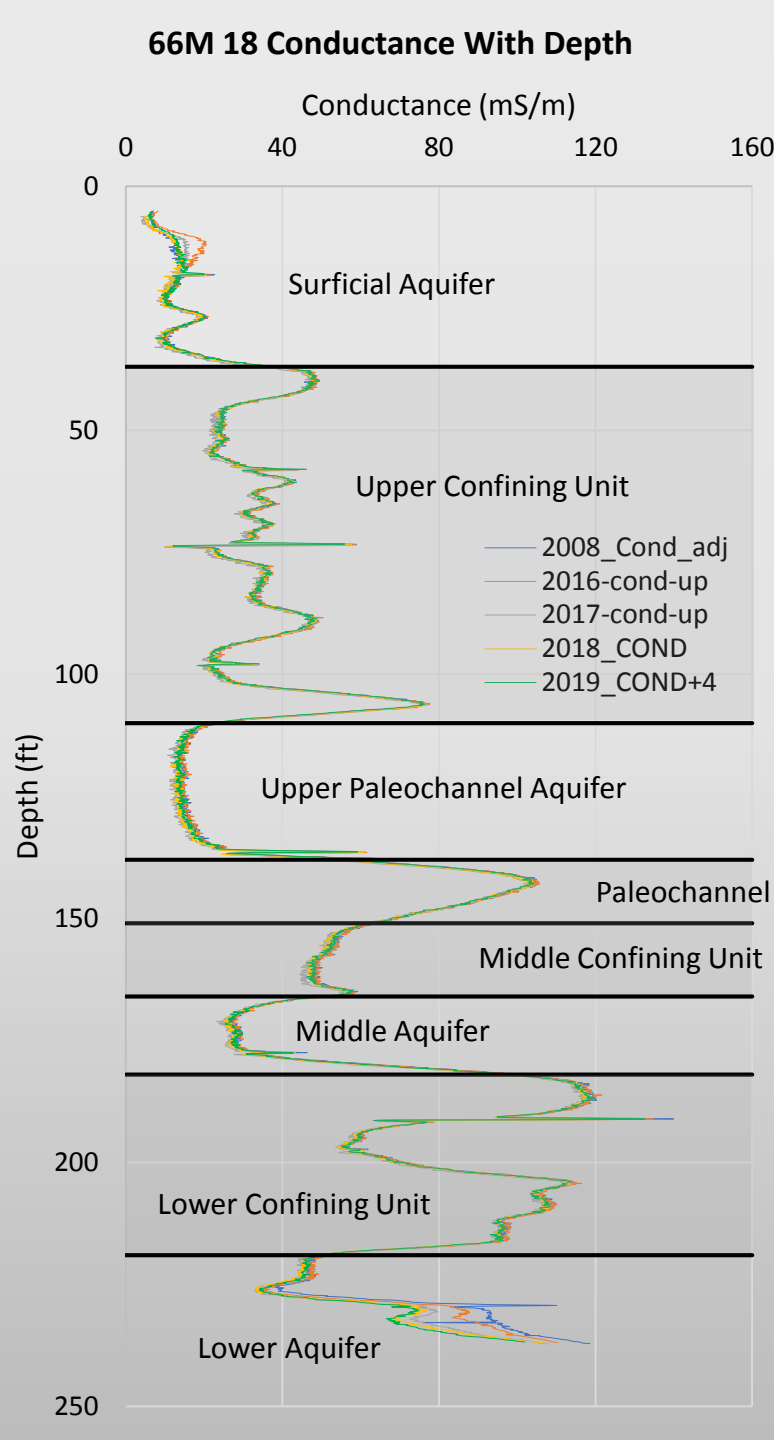
Freshwater and Saltwater Dynamics

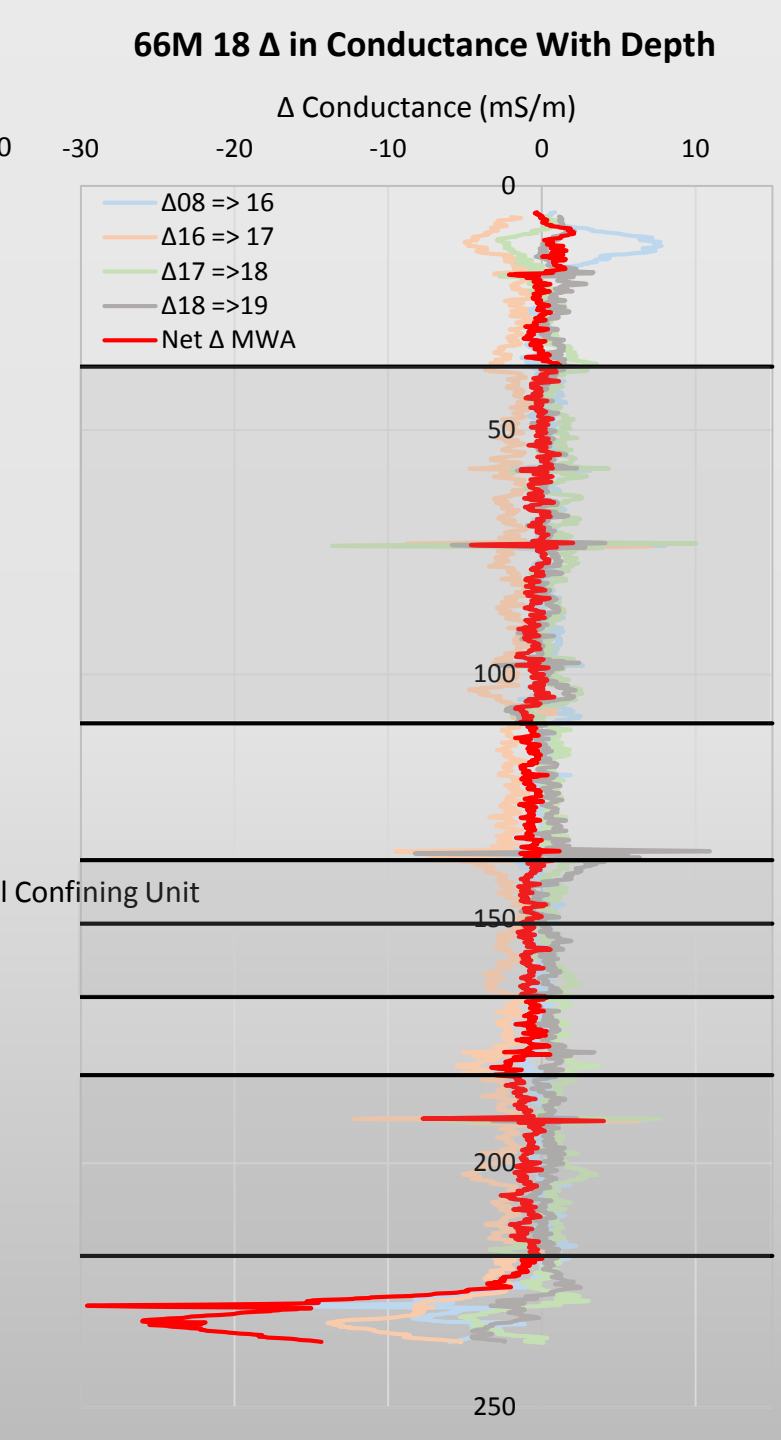
- Just like an iceberg, much of the mass of water sits below sea level
- Due to this difference in density, the less dense freshwater "floats" on top of the saltwater
- This happens until the water levels are in the same way that an iceberg floats in the ocean



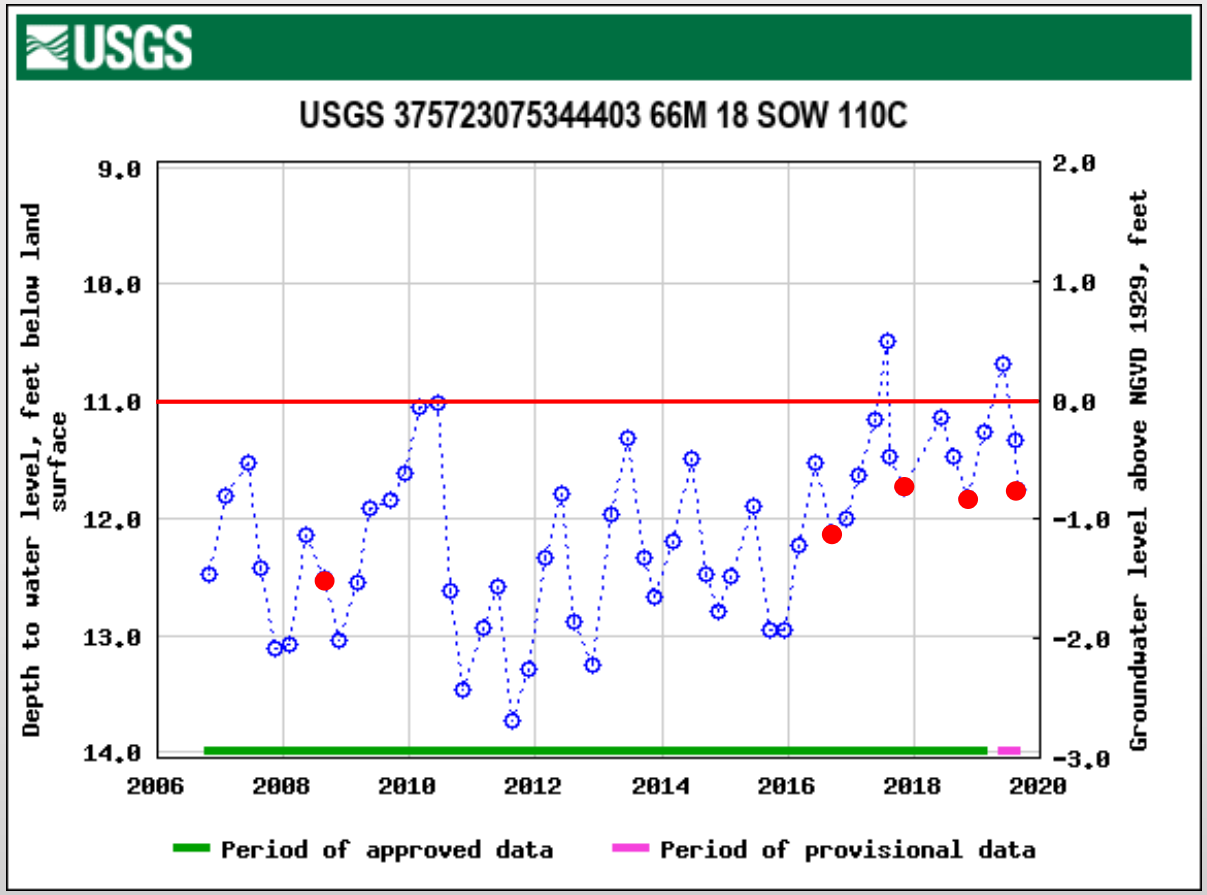
Withams

- 2008 conductivity adjusted +4 mS/m.
  - Necessary to establish common baseline between logs
- Zero to small decreases in conductivity down the log
- Conductivity increase from 2008-2016 in surficial aquifer largely offset by decreases from 2016-2018
- Lower aquifer shows consistent decreases in conductivity likely due to an increasing water level

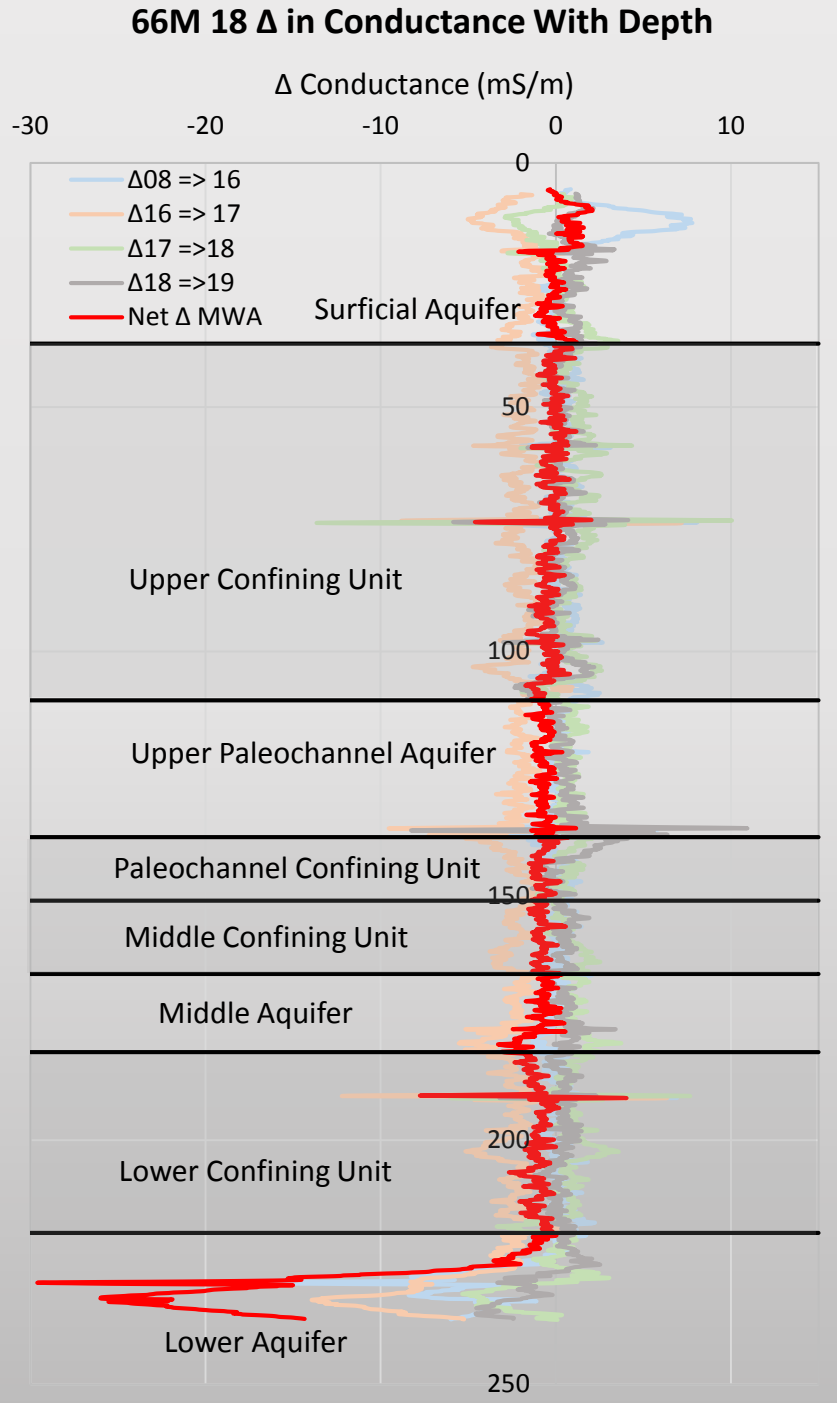




Withams continued

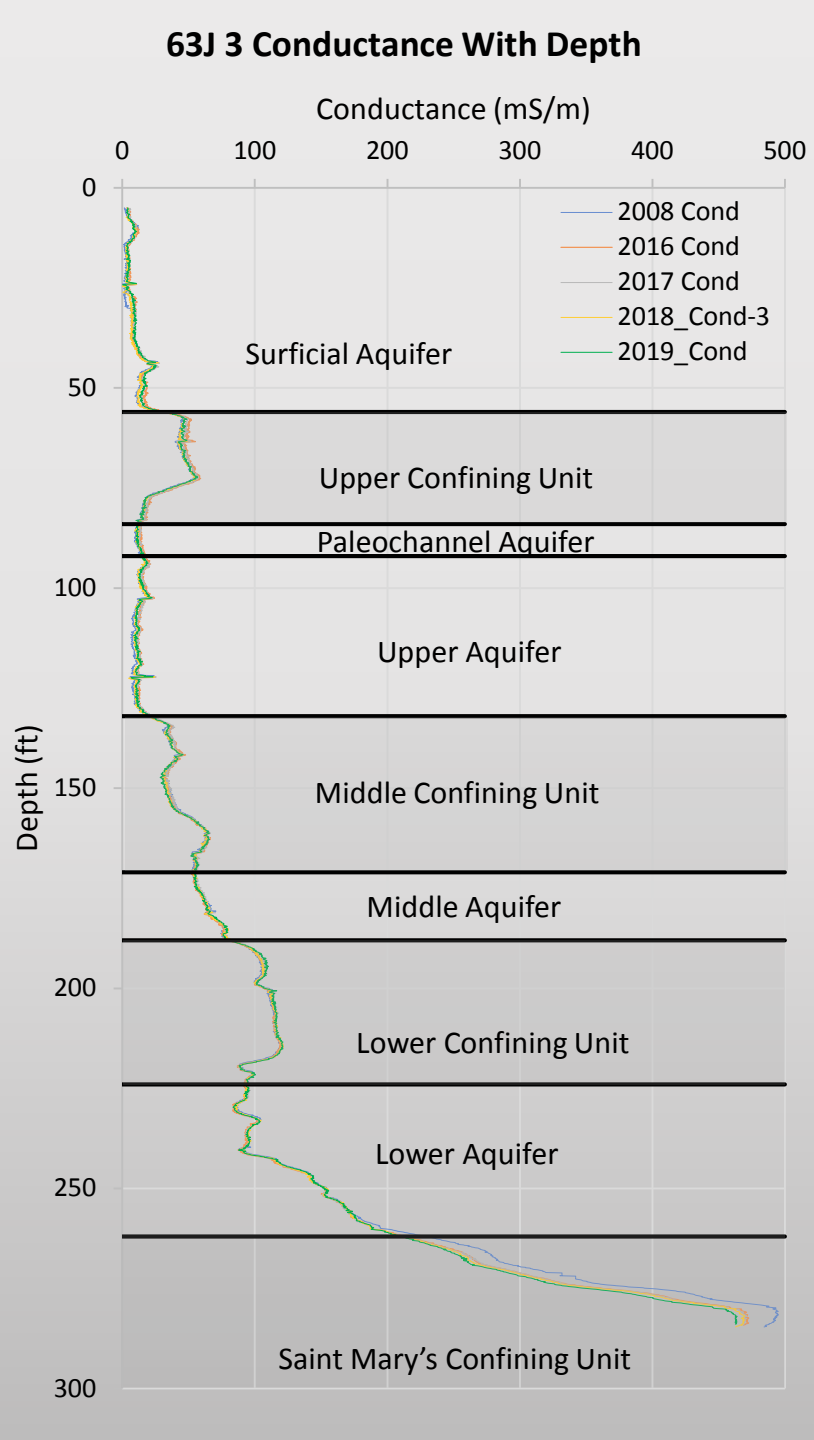


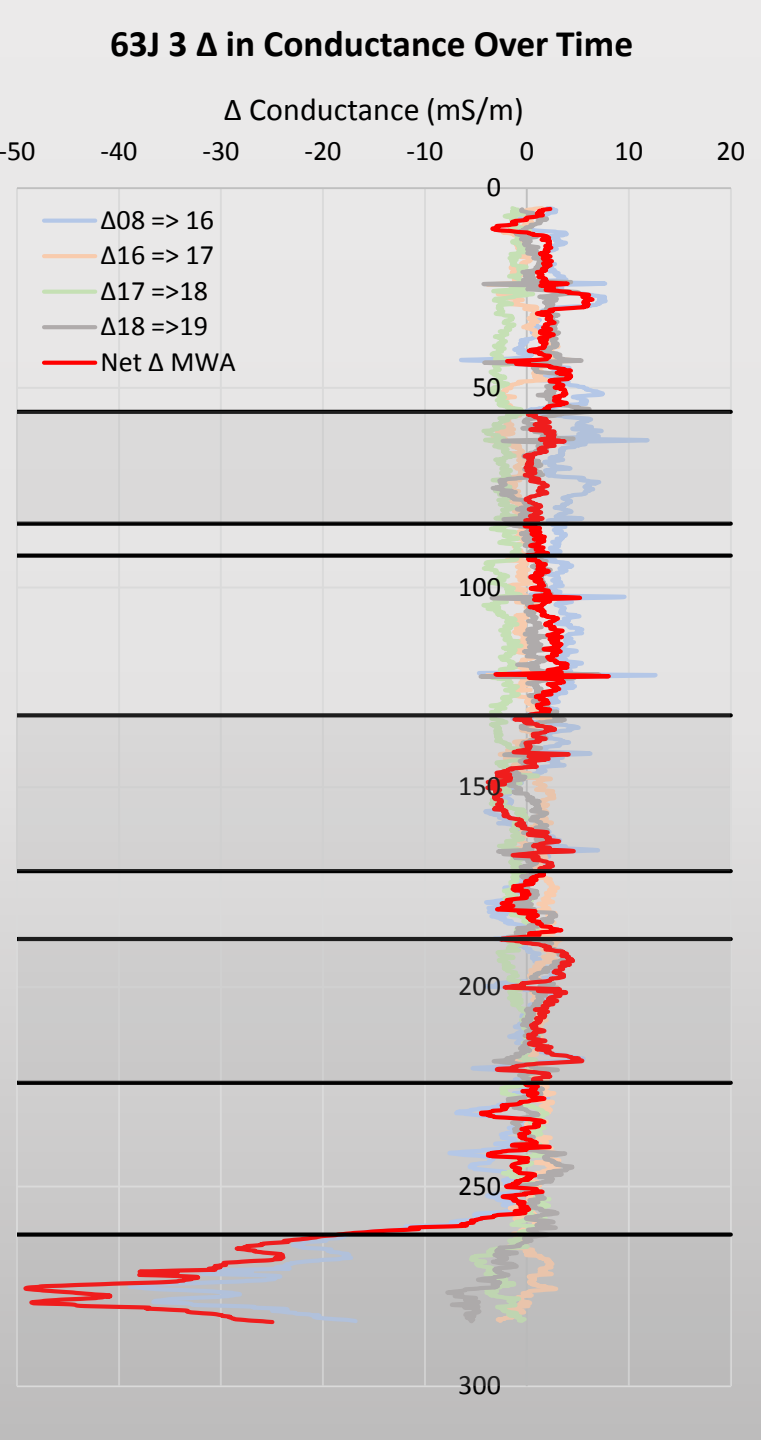
- Water levels are below sea level, but increasing since about 2011.
- Affects of this are seen in the base of the log in the consistent decrease in conductivity



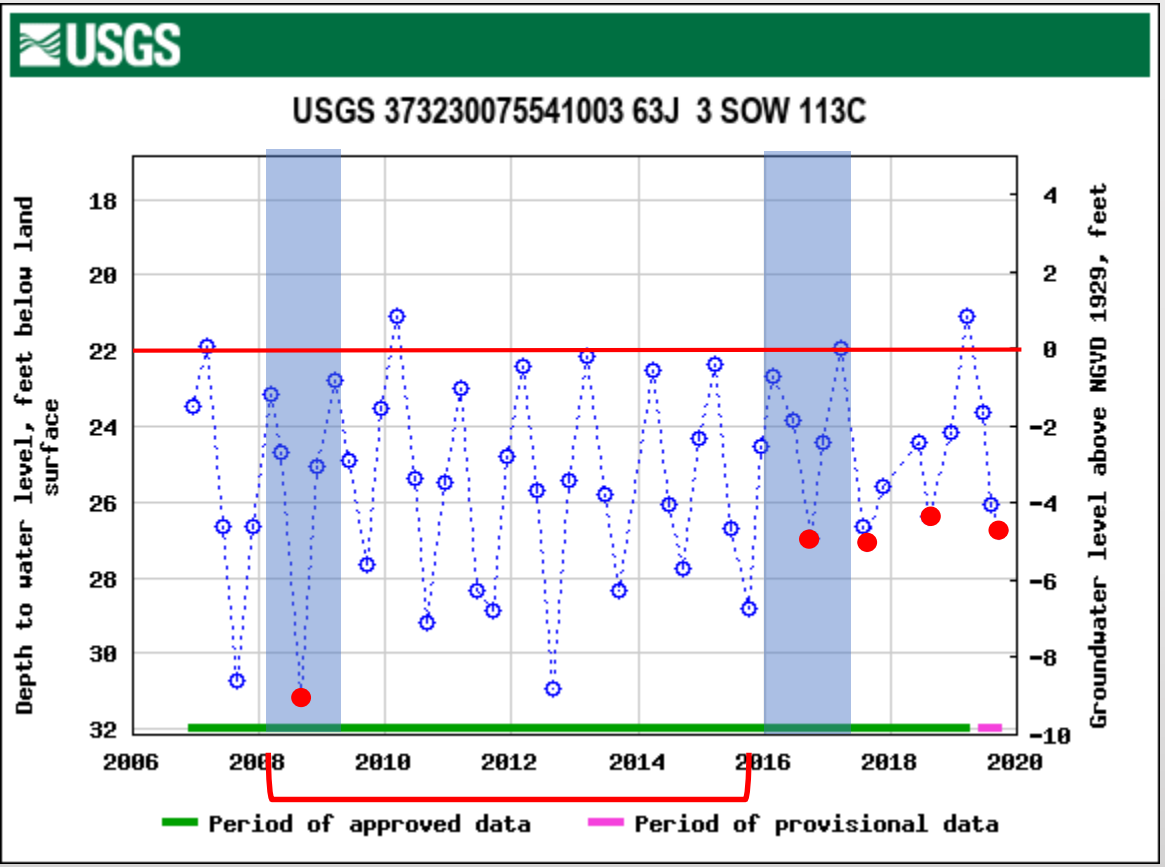
Concord Wharf

- Slight increase in conductivity down log from 2008 to 2018
- Major changes in St. Mary's Confining Unit
  - Decrease from 2008-2016
  - Stabilized 2016-2018
- Excellent example reflecting saltwater movement as a result of a rise in groundwater level.

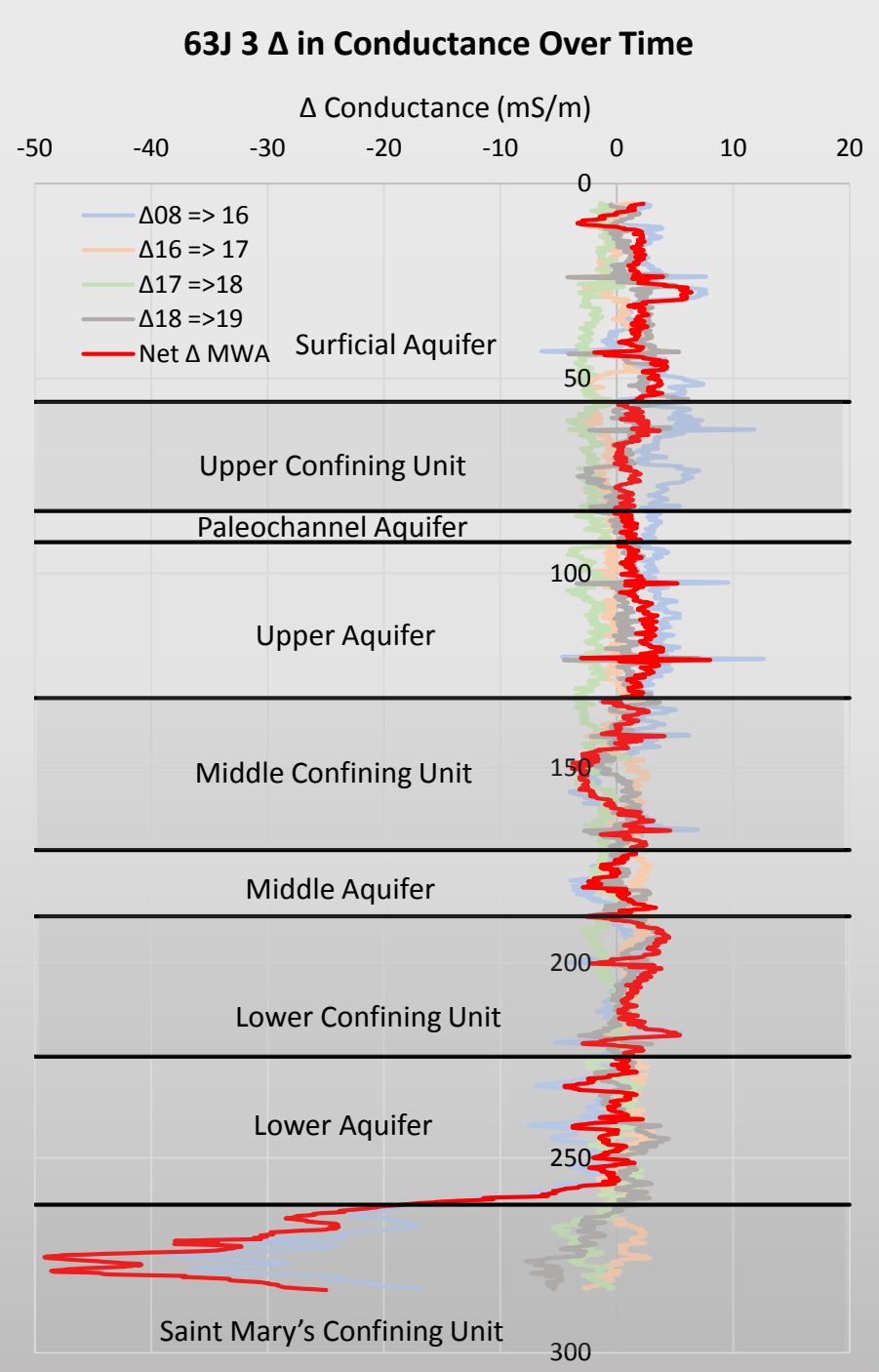




Concord Wharf continued

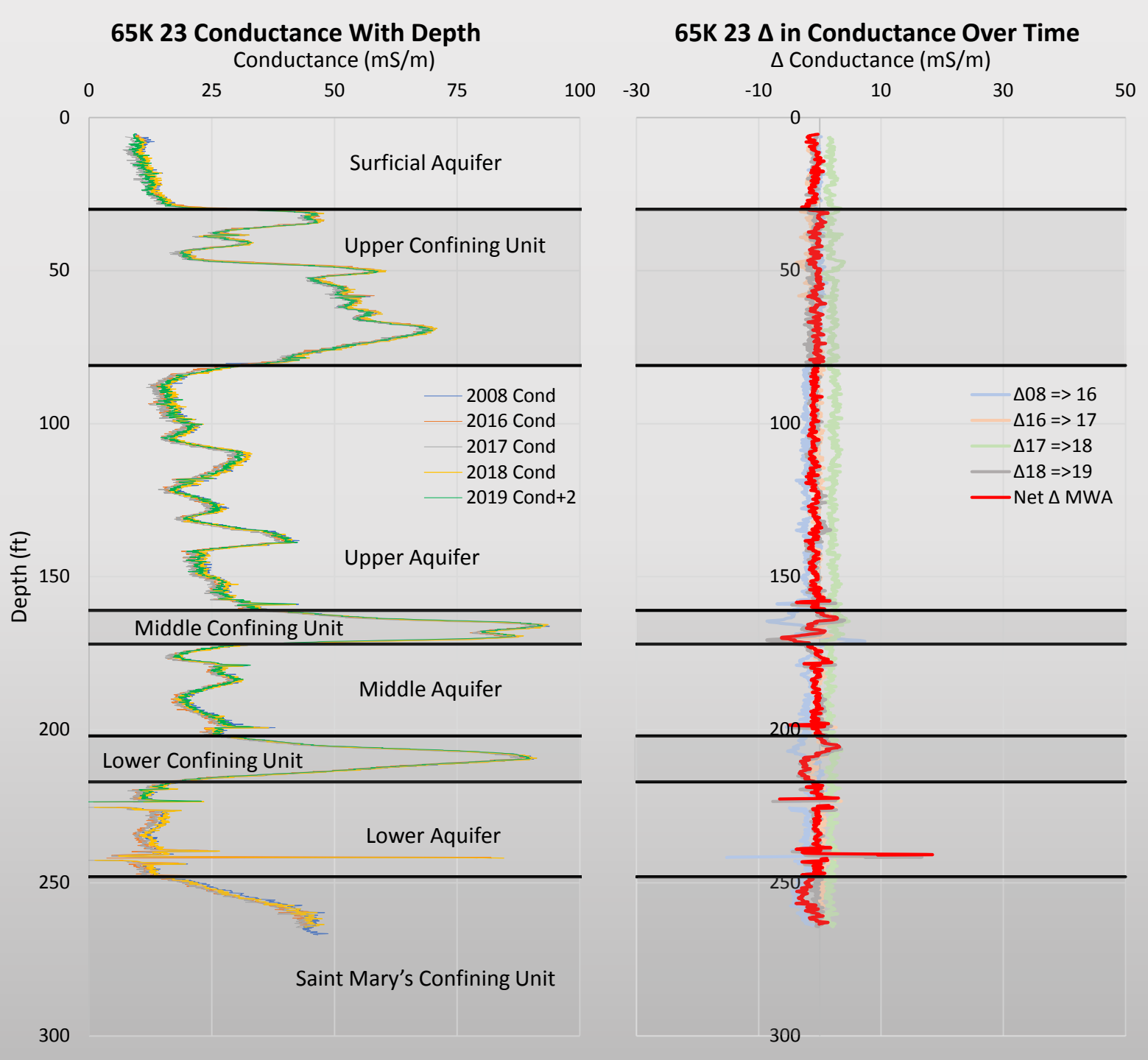


- Shows a significant decrease in conductivity from 2008-2016
- Lower water levels in 2008 than 2016 might explain this:
  - Higher water levels means more fresh water pushing down on the saltwater interface
  - Water levels largely stable during logging since 2016

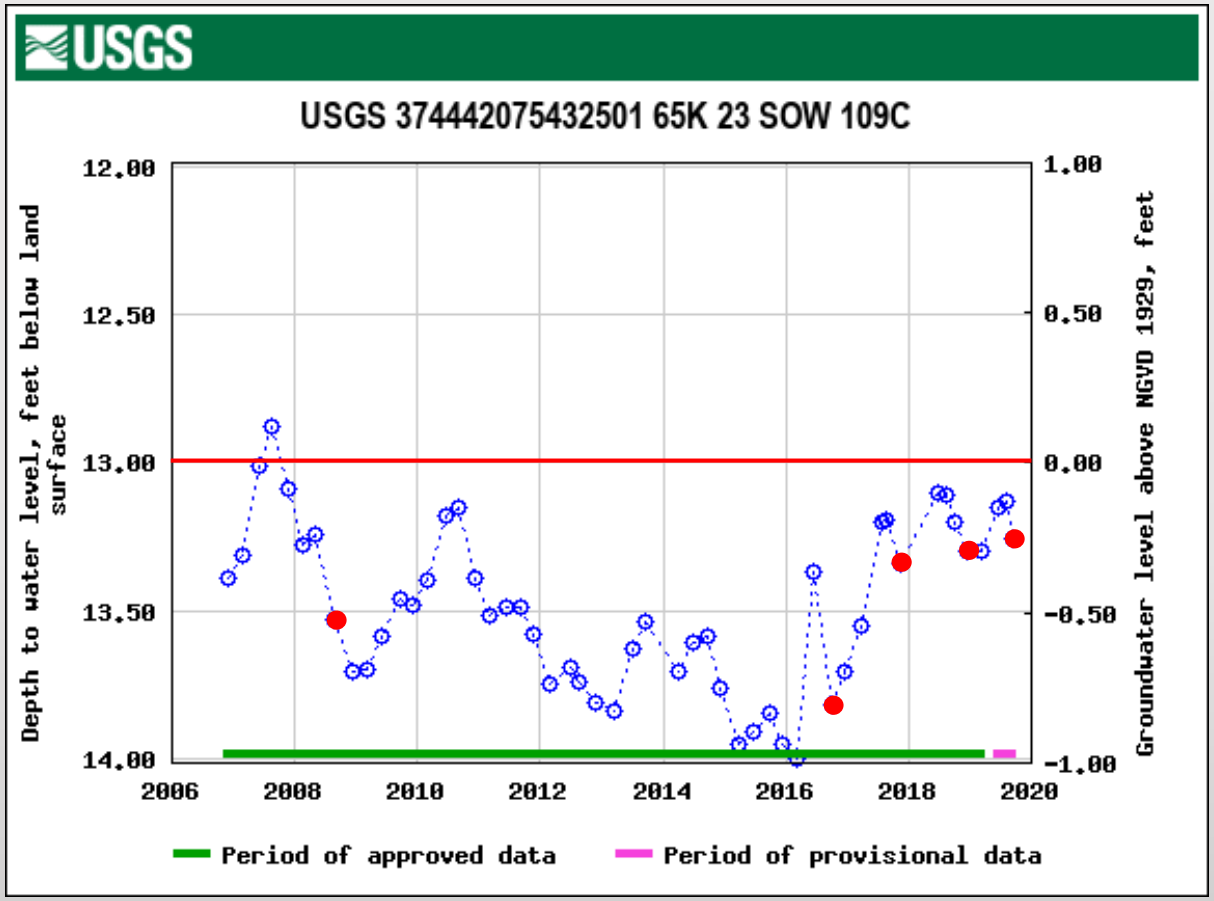


Bayside

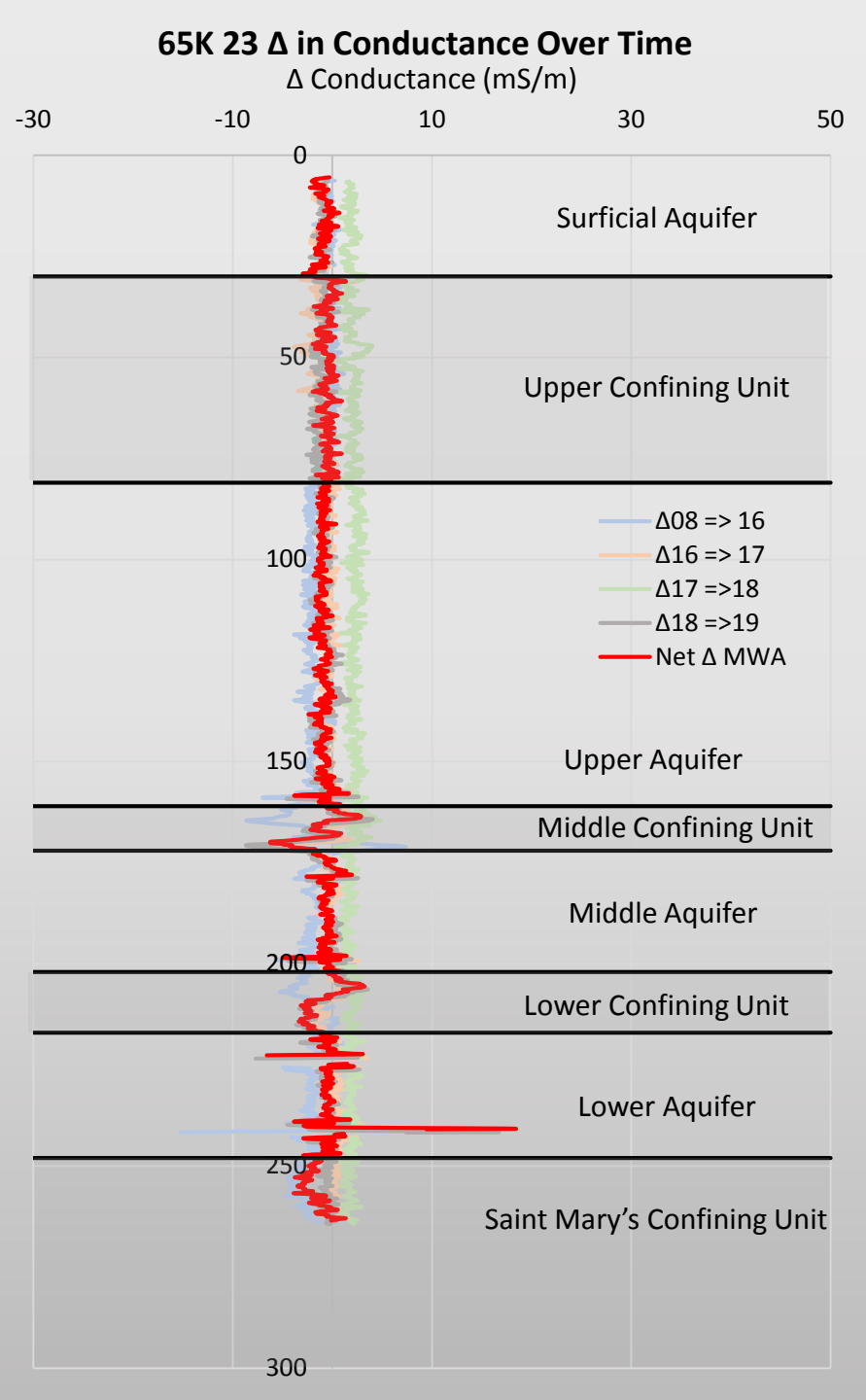
- 2016 Conductivity adjusted -0.3 ft
  - Necessary to establish common baseline between logs
- Increases in conductivity corresponding to confining units
- Two spikes in conductivity in lower aquifer almost certainly due to metal in the well (likely casing centralizers)



Bayside continued

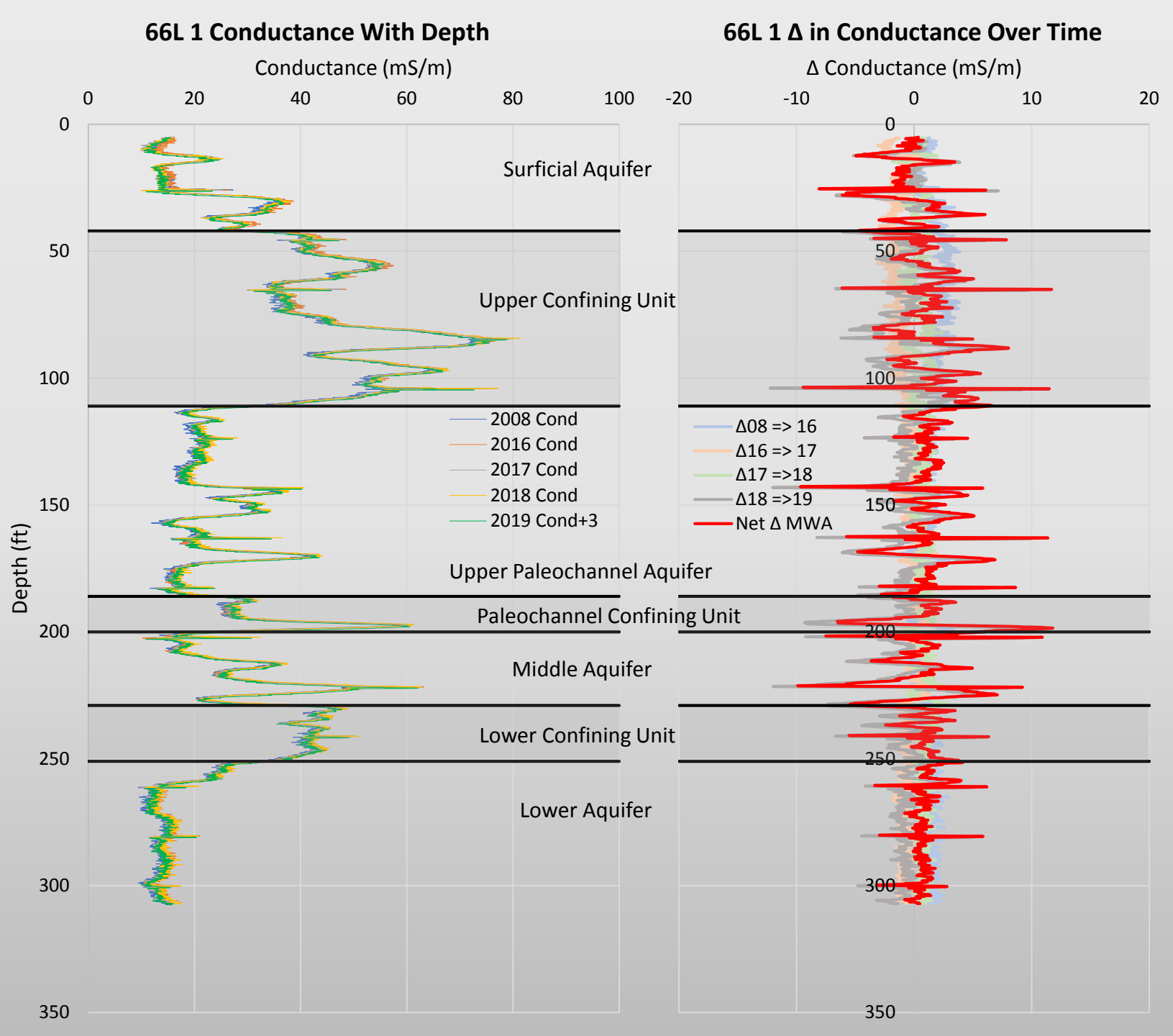


- Groundwater is below sea level, but has been recovering since 2016
- Well is on the edge of a large cone of depression making continued monitoring of conductivity in this well very important

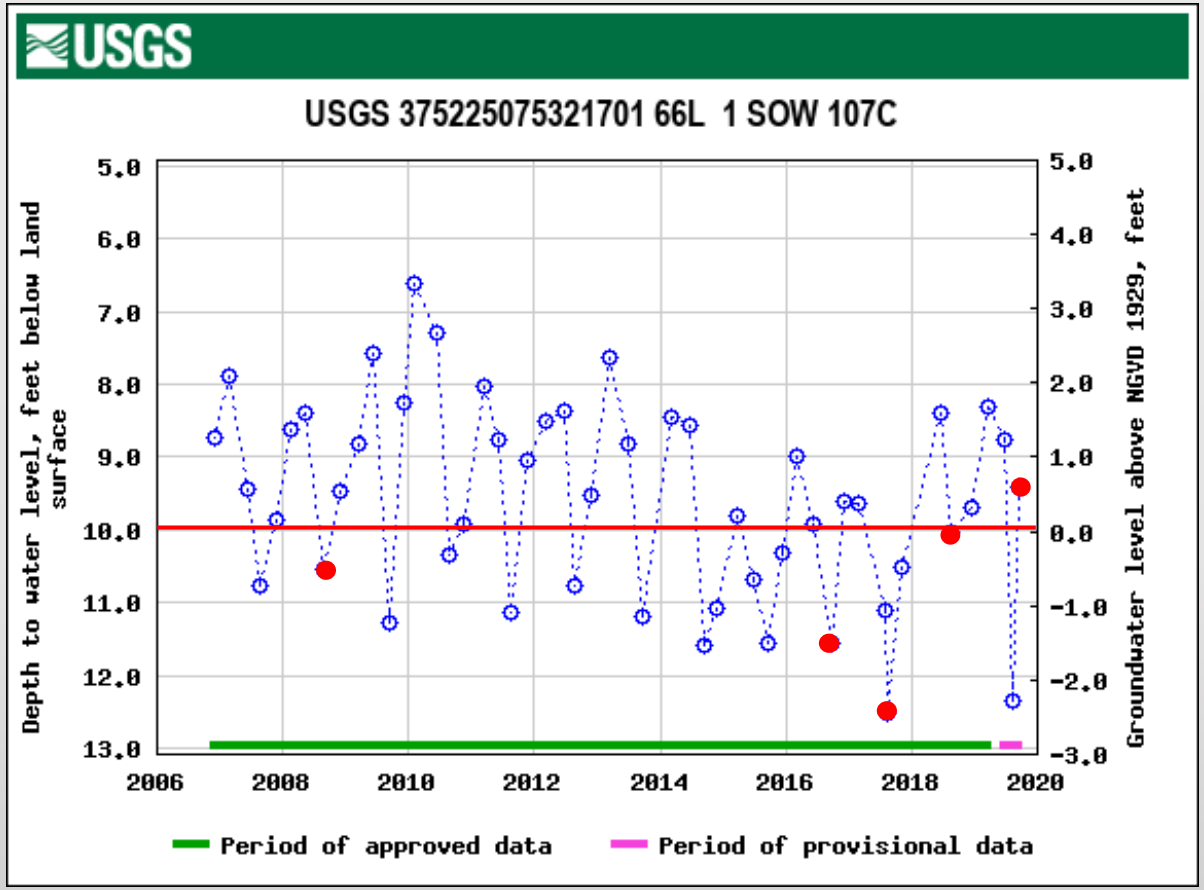


Chesser Road

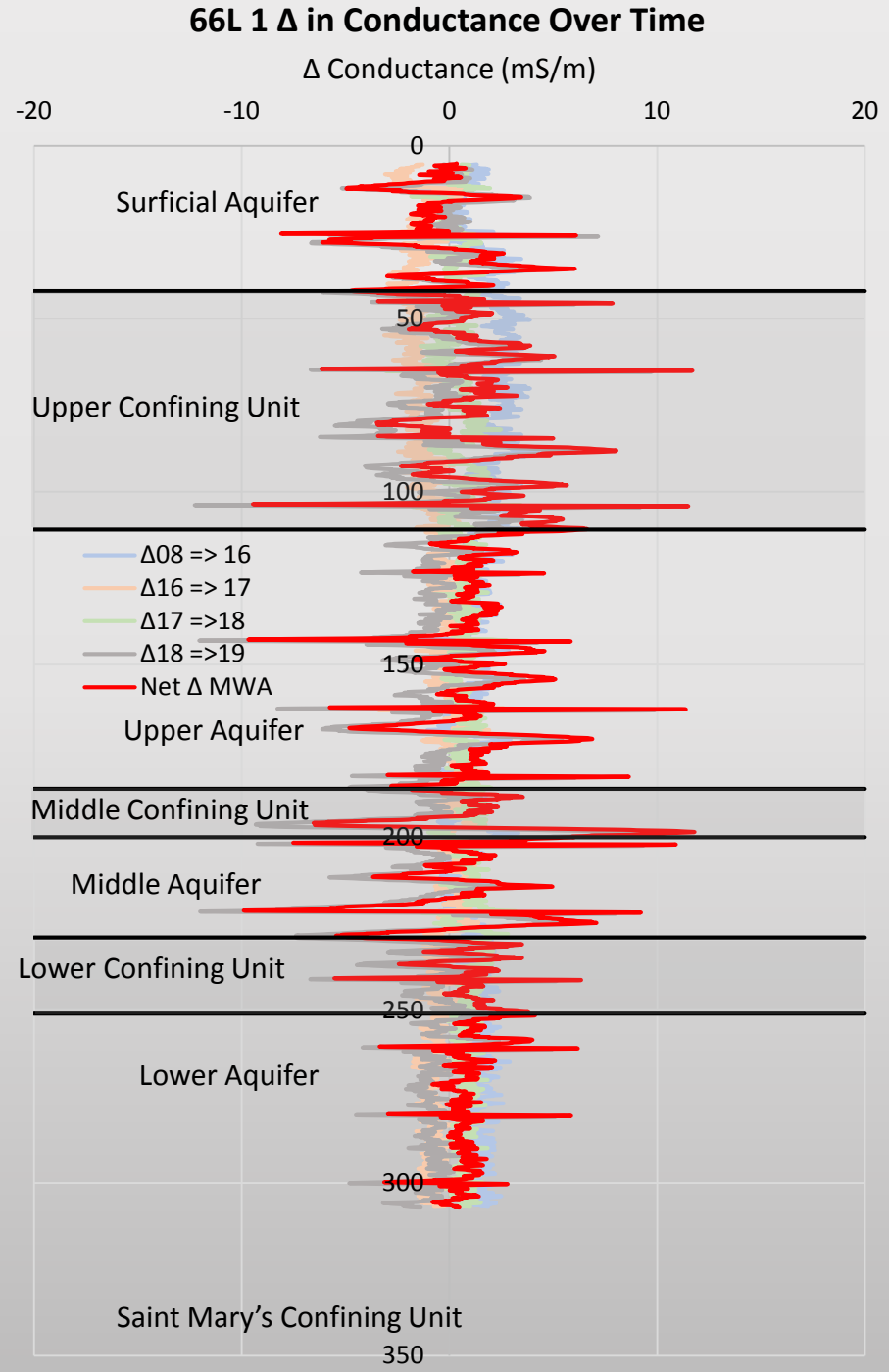
- Slight increase in conductivity from 2008 to 2018
- Exception in the top section of the surface aquifer
- Interference from screws or other metal objects in the well casing throughout the log



Chesser Road continued

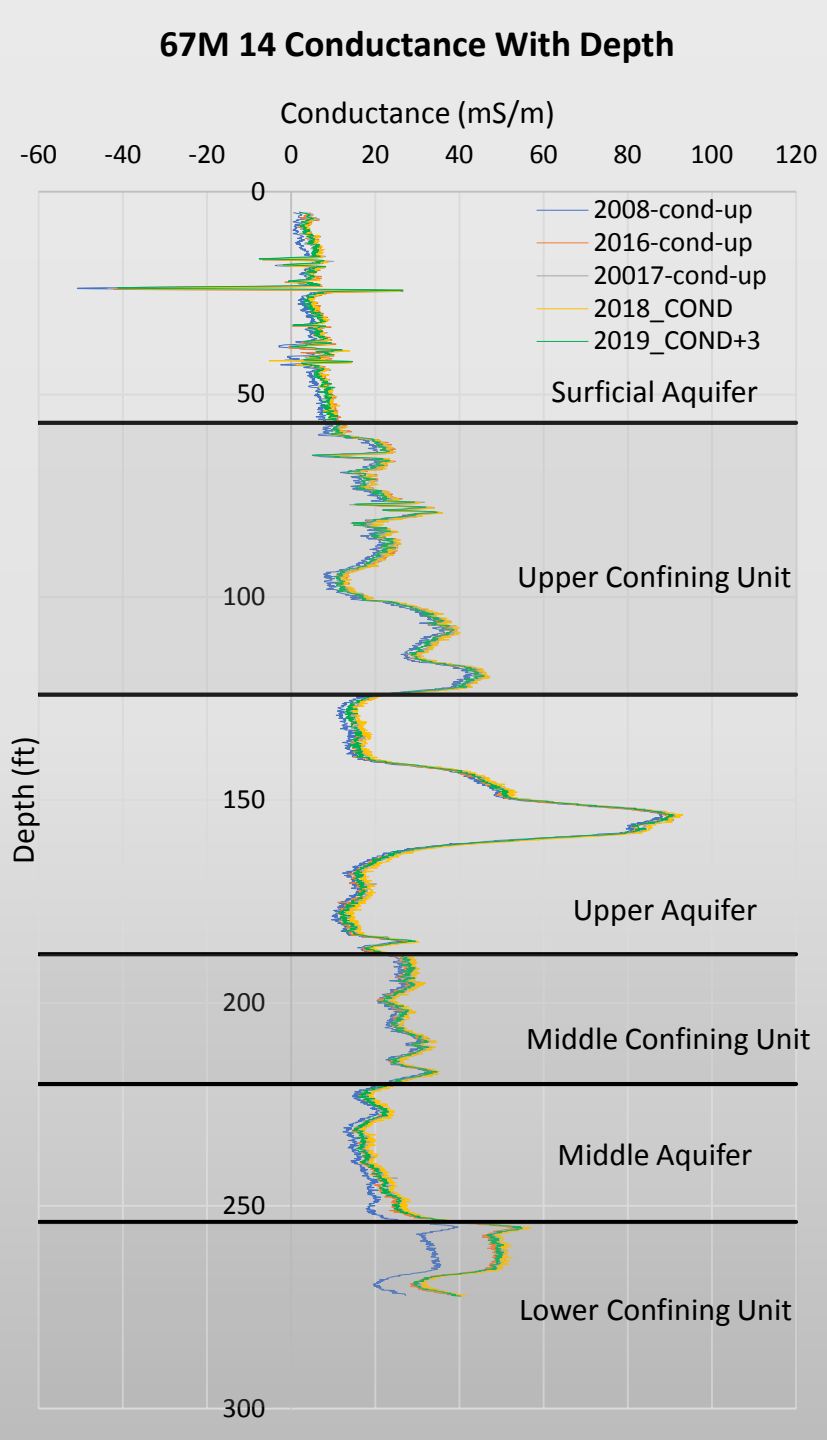


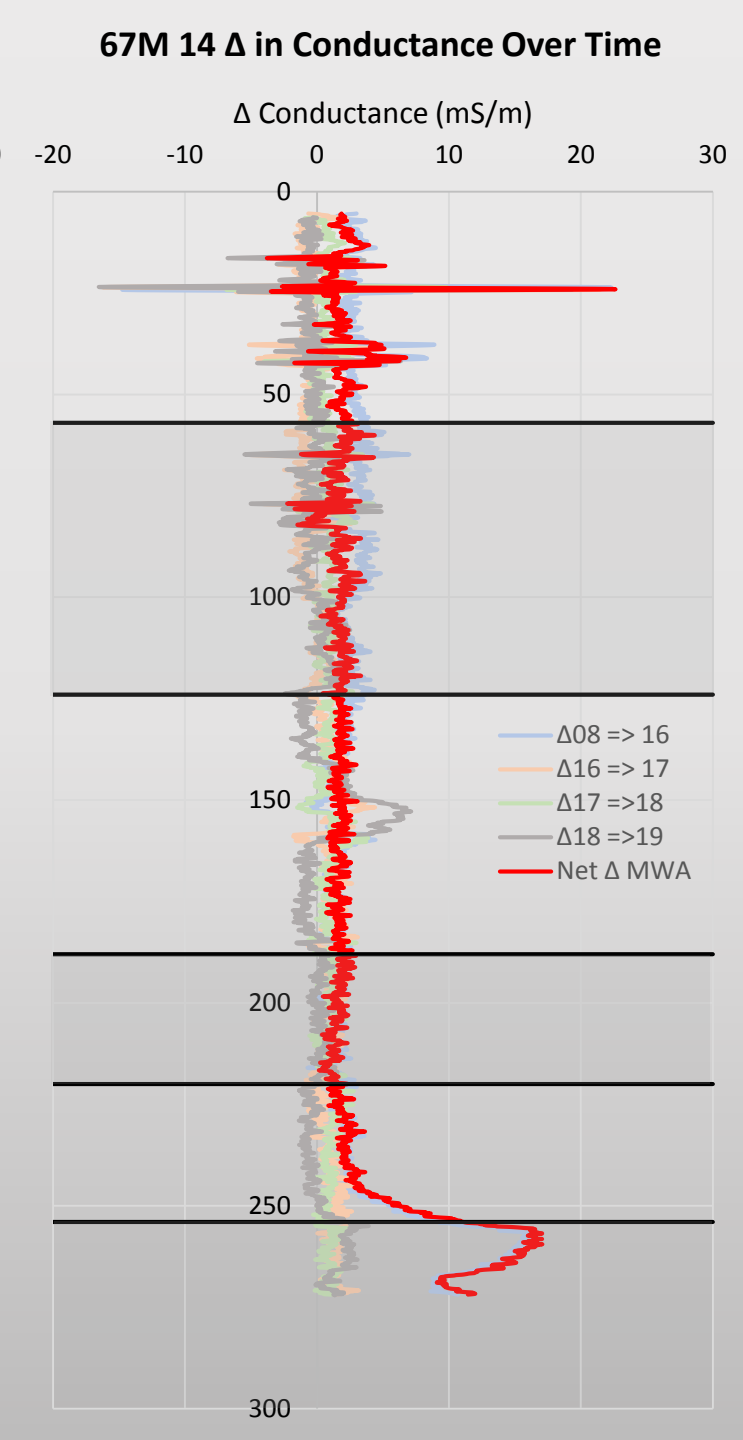
- Water level is close to sea level and decreasing over time
- Signs of increasing water lever from 2015-Present
- Low spots probably coincident with active pumping



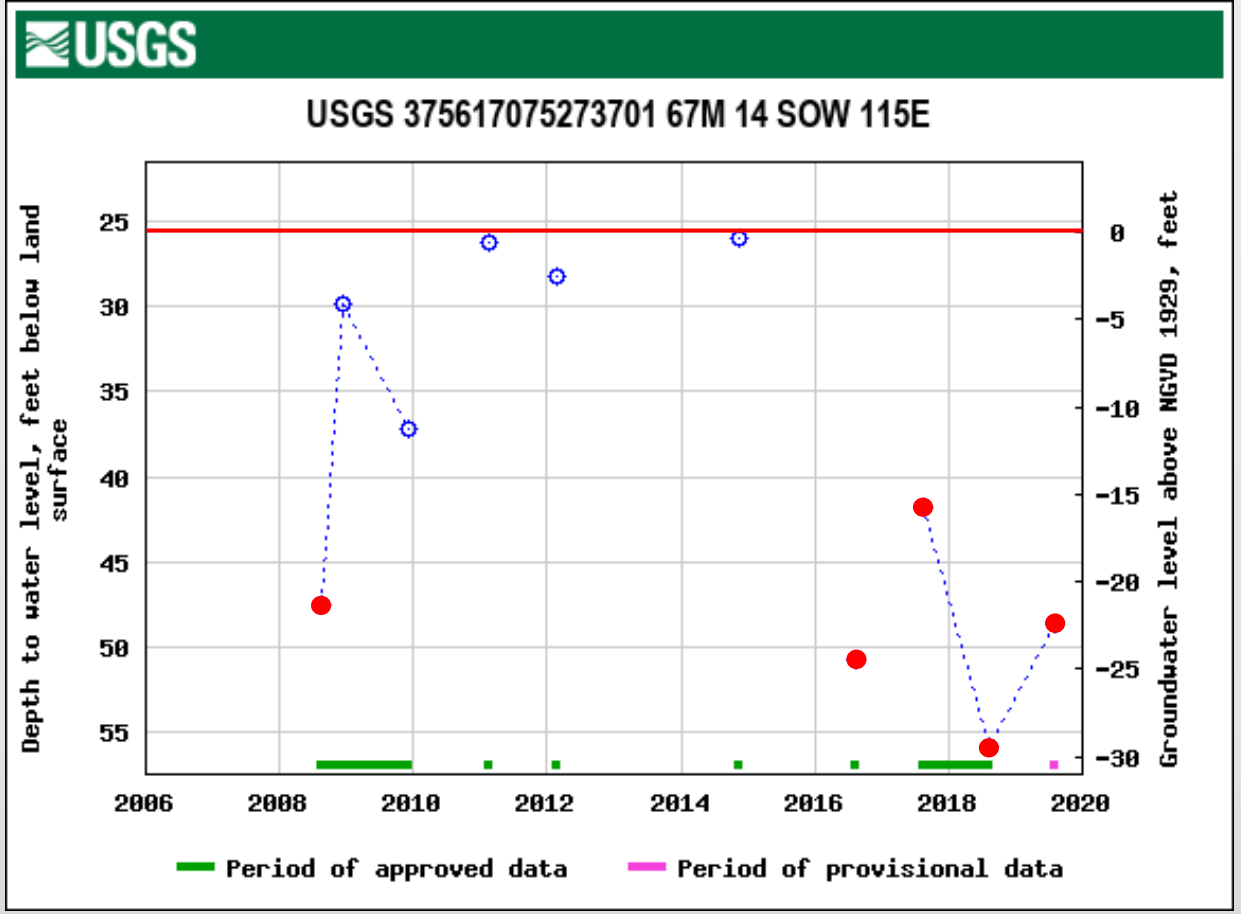
NASA WFF

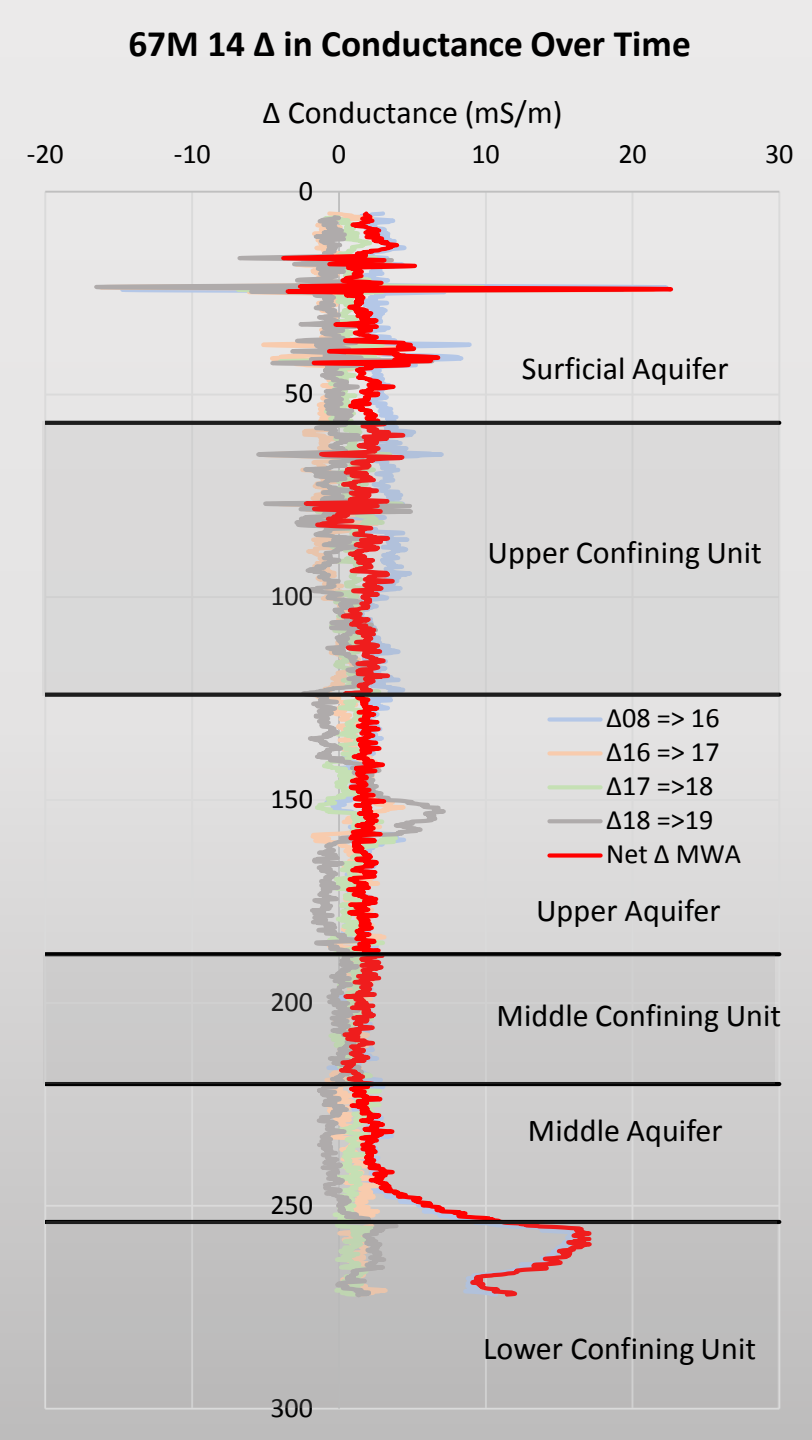
- Small increase in conductivity throughout the log
- Lack of change in lower confining unit since 2016
  - Likely drilling fluids working their way out of bore hole





NASA WFF continued





- Sparse data, and frequent gaps make interpretation of water levels difficult
- Water levels are very much below sea level and show no signs of recovery. This is because the well is within the Chincoteague cone of depression
- High potential for reversal of flow in the flow-system
- Appears to be a sharp drop in water level from 2014 onwards
  - This would help to explain the increasing conductivity in the base of the logs

Conclusions

- Most of the Eastern Shore has water levels that are:
  - above sea level
  - Stable, or recovering
  - Show no signs of saltwater movement, or potential signs of downward movement
- Parts of the northern half of the Eastern Shore show:
  - Water levels below sea level
  - Potential signs of upward saltwater movement
- Sparse or incomplete historic groundwater data limits ability to fully analyze EM Logs
- Logging has not been going on long enough to establish a baseline for each well to normalize data from each year…but we are starting to get there
- Continued monitoring is necessary to confirm the possible signs of saltwater movement, and monitor for movement elsewhere