

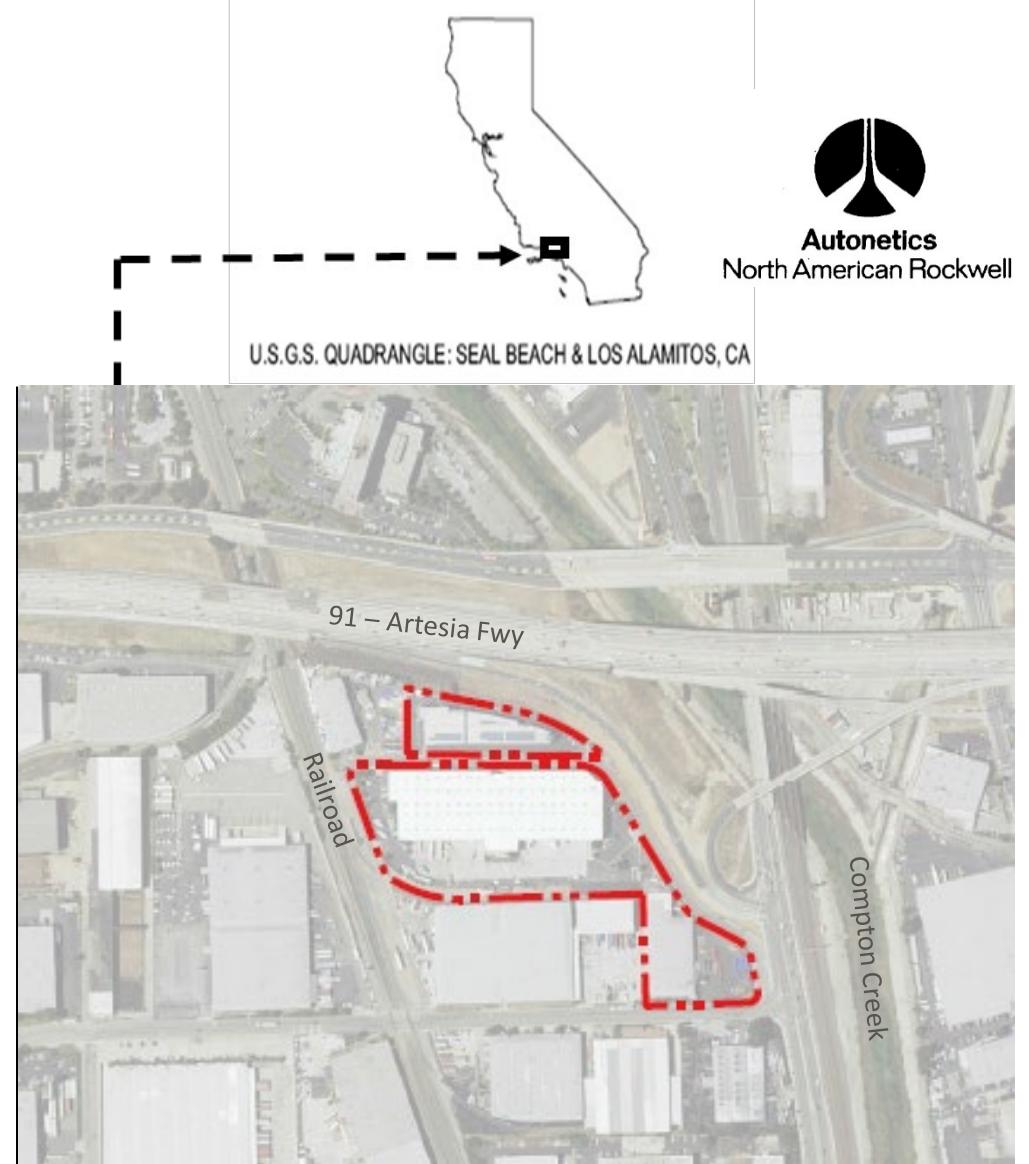
Optimization of hydraulic capture of CVOCs and management of injection well fouling for a groundwater treatment and injection system

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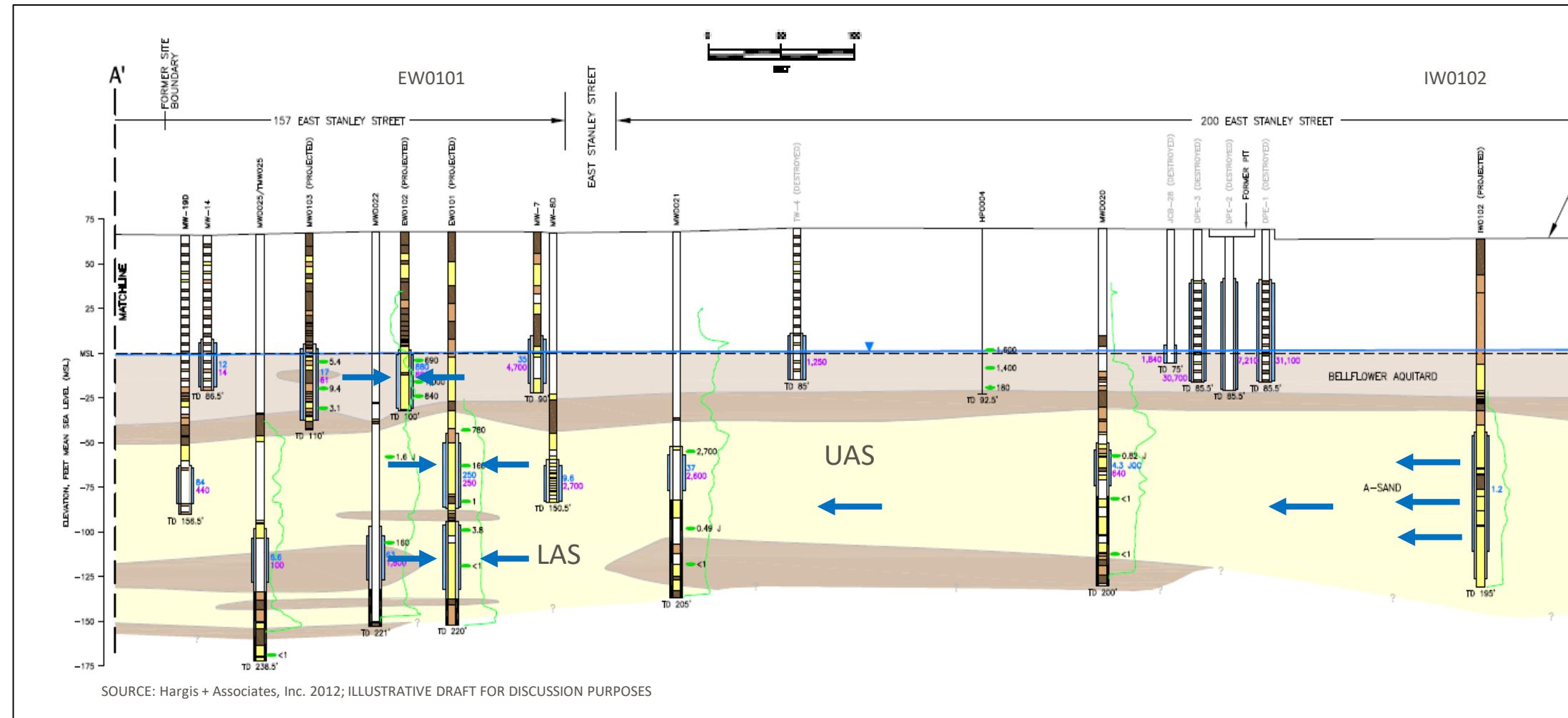


Site history

- 1955 – 1999: Rockwell International's North American Aviation, Autonetics & Space Division aerospace manufacturing
- 1999 – 2001: Automobile service, roofing, plastic molding, & manufacturing
- 2001: Purchased by Boeing
- 2003: Demolished structures & began soil remediation
- 2005: Boeing continued remedial activities, sold site for beneficial redevelopment

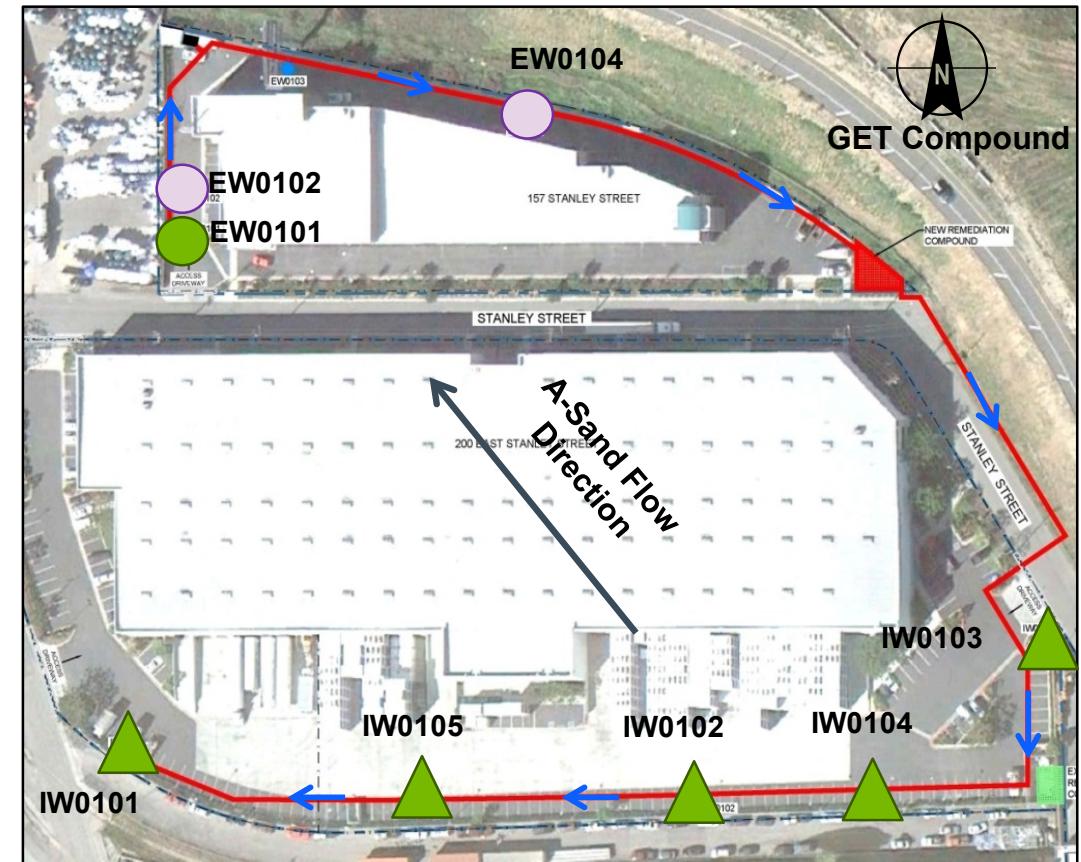


Hydrogeologic setting



Remediation

- Voluntary cleanup with Los Angeles RWQCB
- Soil closure in 2008
- Groundwater extraction & treatment system started in February 2012
- Hydraulic containment of VOCs at downgradient property boundary at 65 gpm
 - 60 gpm: A-Sand extraction well (EW)
 - 2.5 gpm: two BFA EWs
- Activated carbon filtration & injection to A-Sand via 5 upgradient injection wells (IWs)



The problem

Diminished injection performance within 2 years of startup and significant downtime to manage injection well fouling

- 3 original IWs offline (1 broken, 2 fouled with precipitate)
- 2 newer IWs showing similar signs of precipitate fouling
- 1 IW receiving 80% of discharge – no contingency; high risk of failure
- VOC concentrations varied in downgradient A-Sand monitoring wells due to system downtime

The problem (continued)

- Limited understanding of hydraulic property variations in A-Sand made it difficult to evaluate well capture zones
- EW bio-fouling complicated evaluation.
- Discharge to storm drain evaluated, not considered option due to other effluent limitations (chloride, sulfate).
- \$1M connection fee to divert discharge to sanitary sewer made taking a holistic approach to optimizing of entire system worthwhile, from extraction to injection, to continue original and more sustainable (recharge) remedy.

Approach to optimize extraction

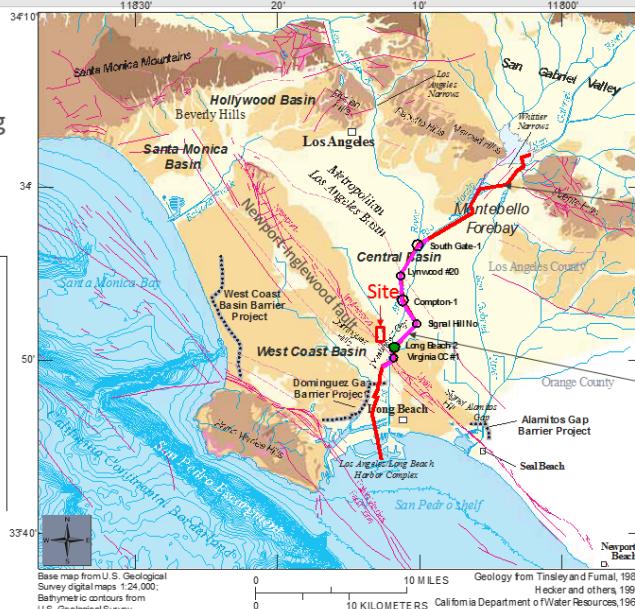
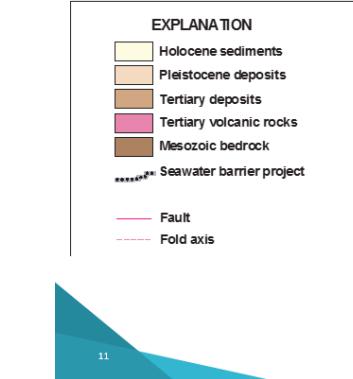
Evaluate variations in A-Sand characteristics and VOCs to support understanding & optimization of capture zones

- Environmental Sequence Stratigraphy (ESS): understand depositional characteristics and correlate laterally
- Extraction well EW0101 evaluation:
 - Video survey
 - Vertical flow log & depth-integrated groundwater samples at 30 & 60 gpm
 - Well rehabilitation & redevelopment
- Review historical pumping test data to estimate range of A-sand transmissivity & hydraulic conductivity (K_h)
- Groundwater modeling to obtain best fit for K values in UAS & LAS based on flow survey data & groundwater elevation contours during pumping from UAS & LAS.
- UAS pumping tests at 40 & 60 gpm in EW0101, to confirm best fit K value for UAS.
(10 days each with hourly data recording using pressure transducers).

Environmental Sequence Stratigraphy (ESS)

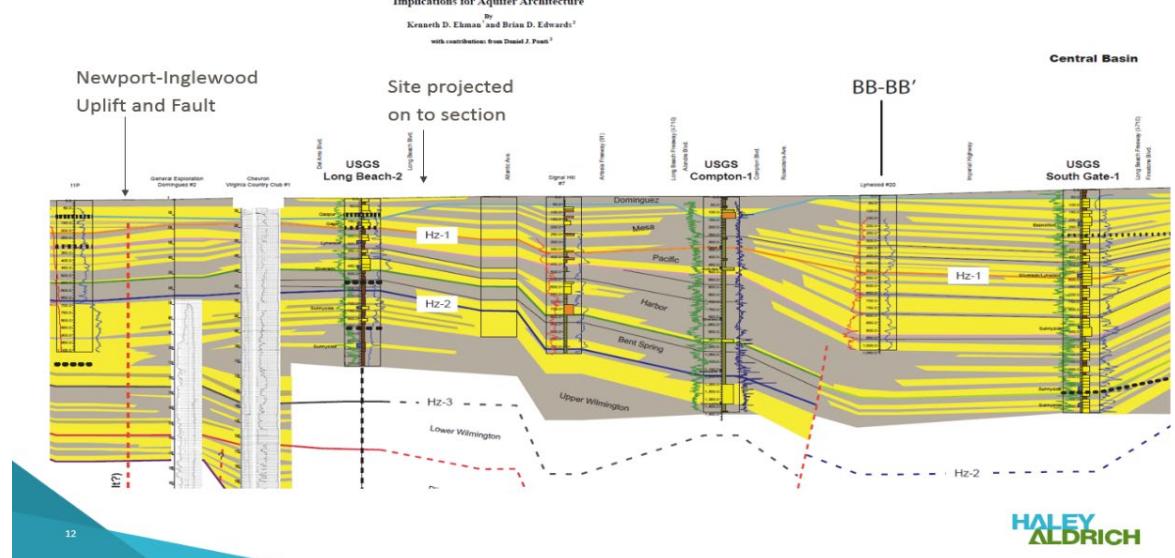
- **BFA = Holocene Dominguez unit**
 - Channel-fill and flood plain deposits
 - Formed due to climatic changes at end of last glacial period
 - Complex sand/silt deposits with low permeability
- **A-Sand = Pleistocene Mesa unit**
 - Shallow water marine to marginal marine as well as non-marine fluvial and alluvial fan deposits
 - Formed due to shoreline progradation
 - Homogeneous sand units with variable transmissivity:
 - Upper A-Sand – on-Site
 - Middle A-Sand – primary pathway for off-Site plume
 - Lower A-Sand – shallow marine with shell marker beds

Surface Geologic map from Ehman and Edwards (2014) showing the location of the Newport-Inglewood fault to the west of the site



Ehman
and
Edwards'
(2014)
Cross
section
AA-AA'

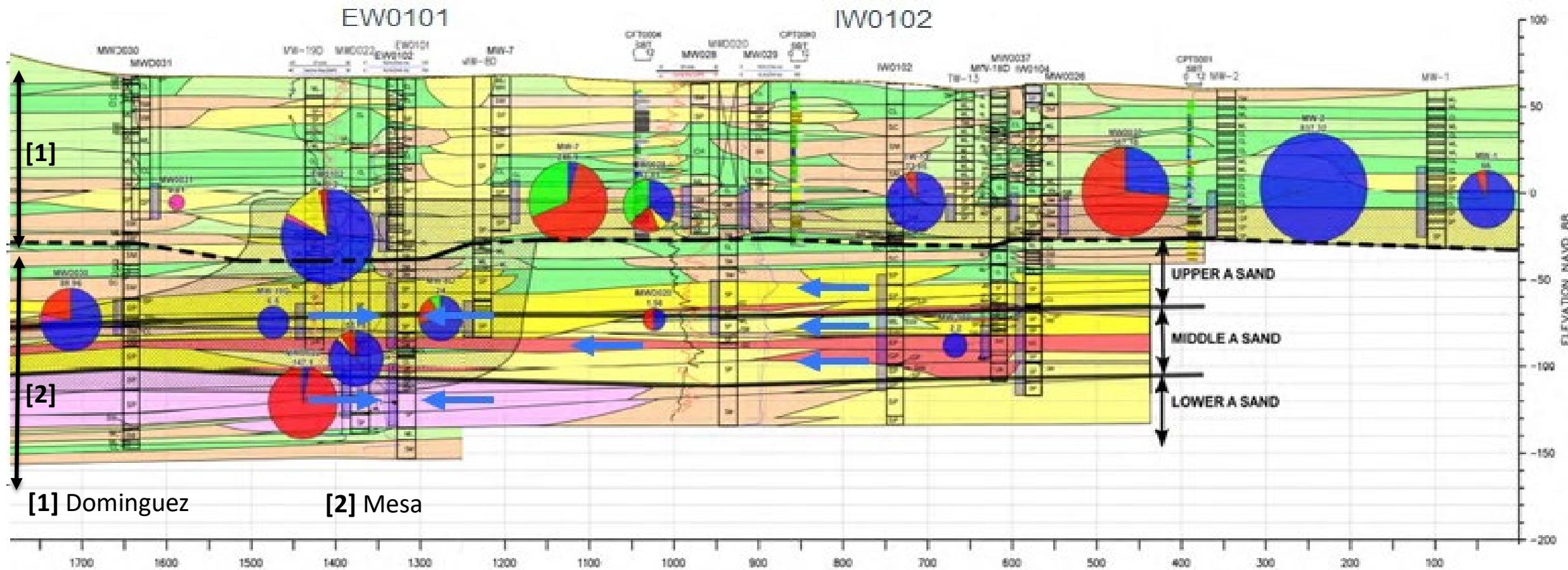
Subsection
shown on
next slide



Central Basin

HALEY
ALDRICH

Environmental sequence stratigraphy (ESS)

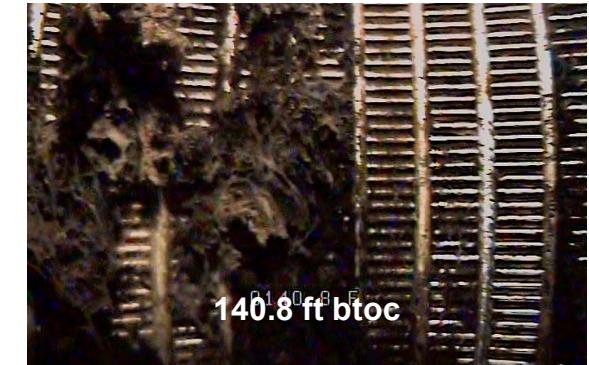


EW0101 video log, flow survey, & redevelopment - February 2017

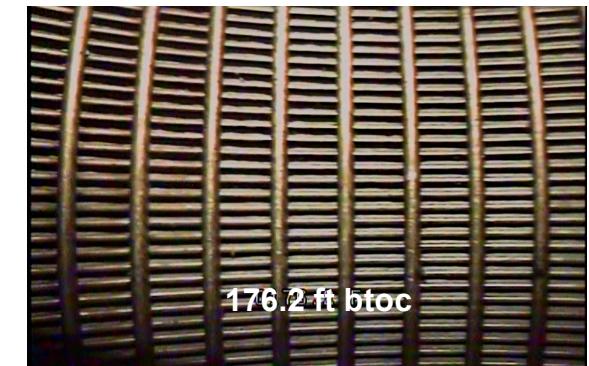
- **UAS** is **aerobic** – significantly affected by bio-chemical fouling; redevelopment increased discharge by 13%
- **LAS** is **anaerobic** – bio-chemical fouling not observed, redevelopment did not change discharge
- Following rehabilitation, UAS accounts for 89% & LAS 11% of total well discharge.
- Specific capacity increased from 1 gpm/ft to 2 gpm/ft and water level sustained above top of UAS screen



Bio-growth on EW0101 pump

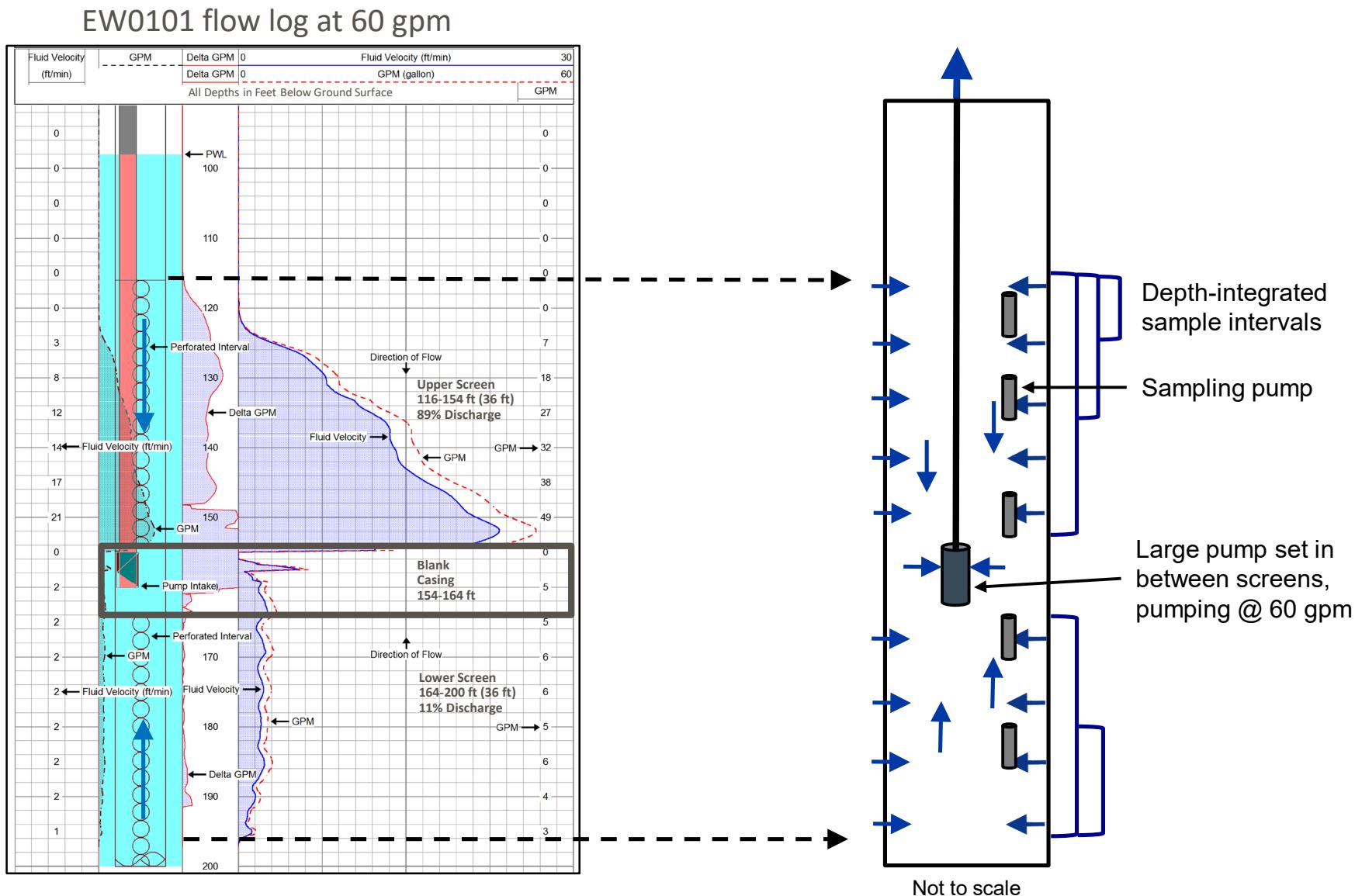


Upper A-Sand
One side of screen bio-fouled



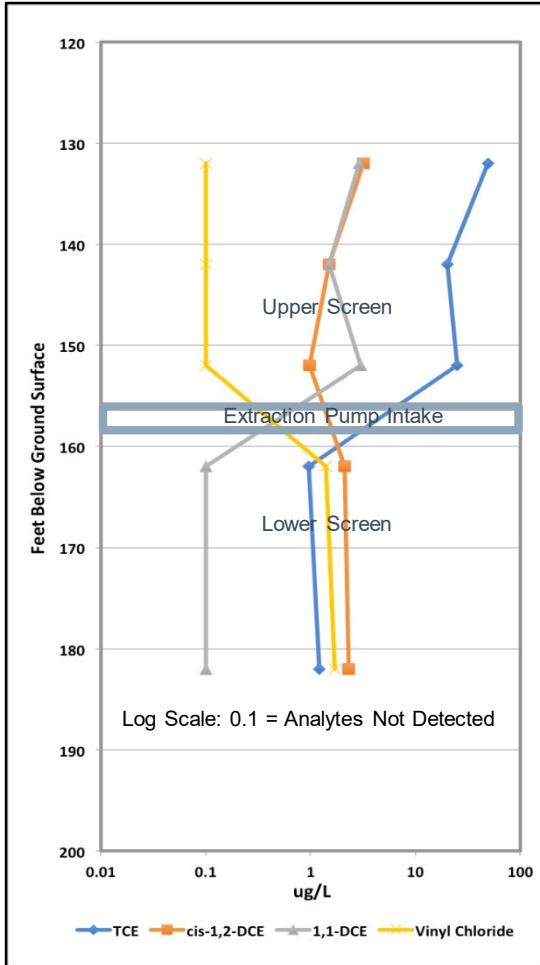
Lower A-Sand
Screen mostly clean & open

EW0101 vertical evaluation – Depth integrated sampling



EW0101 vertical evaluation – Depth integrated sampling

Depth-integrated samples April 2017



UAS
TCE concentrations > MCL
(Max = 49 $\mu\text{g/L}$).
Concentrations decrease with depth.

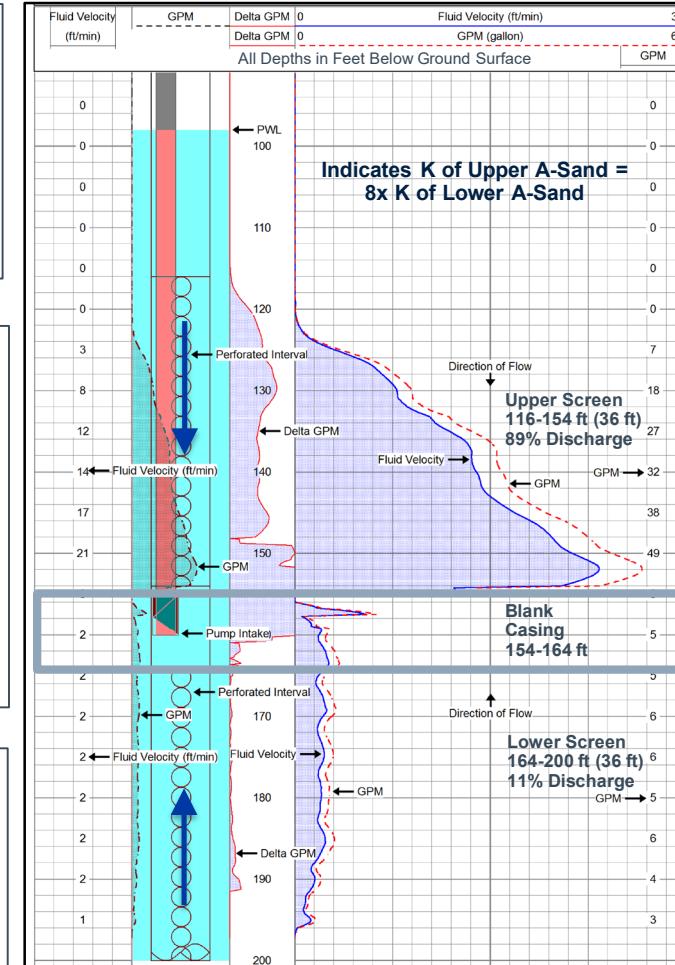
Aerobic groundwater in shallow UAS,
increasingly anaerobic with depth.

Total well discharge
Except for vinyl chloride (VC), VOC
concentrations in total well discharge
exceed concentrations from all depth-
integrated samples.
Maximum VOCs in total discharge:
TCE = 70 $\mu\text{g/L}$
cis-1,2-DCE = 9.4 $\mu\text{g/L}$
1,1-DCE = 1.6 $\mu\text{g/L}$
VC = 0.72 $\mu\text{g/L}$

LAS
VC only detected in groundwater from
LAS (Max = 1.7 $\mu\text{g/L}$).
Other VOCs < MCLs in lower screen.

Anaerobic groundwater in LAS.

EW0101 flow log at 60 gpm



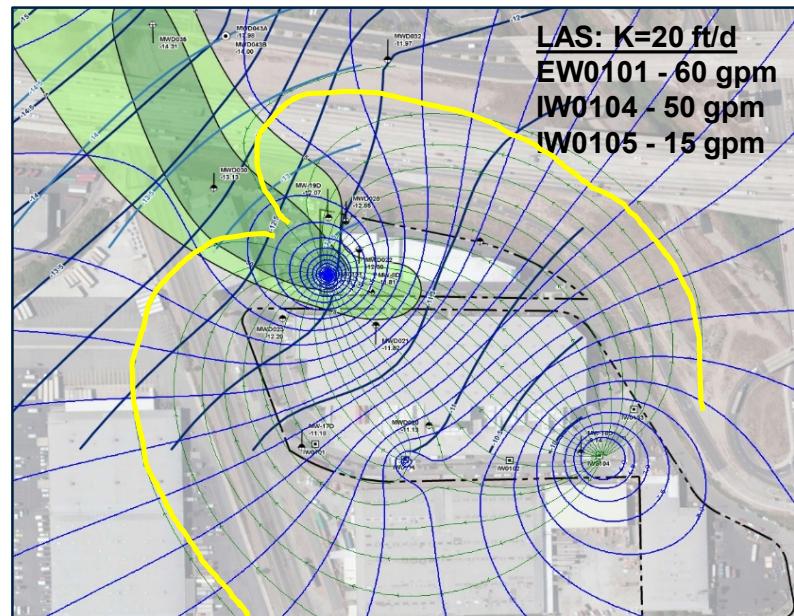
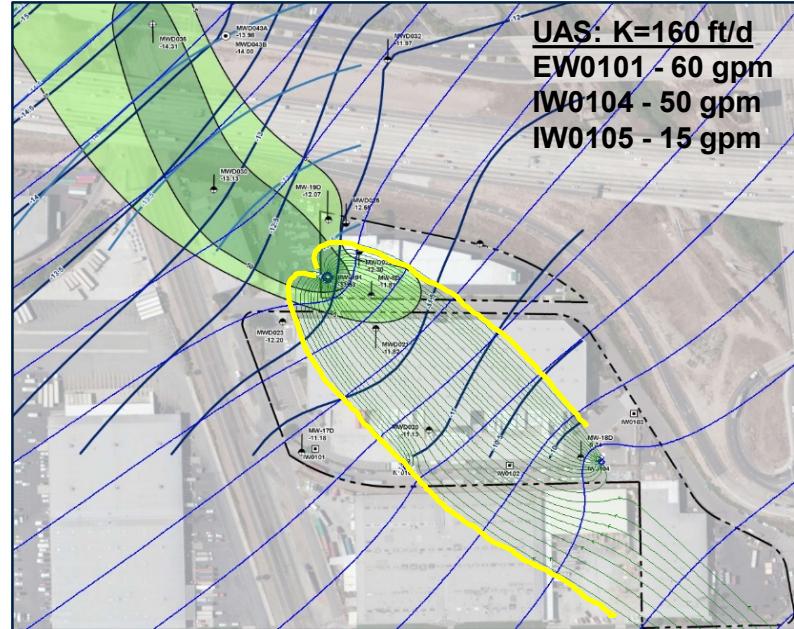
Historical pumping test data & modeling

- Modeling used to estimate best-fit for hydraulic conductivity (K_h)
- Estimated historical K_h values for UAS range from 6.6 to 160 ft/day. Data not available for LAS.
- Best fit to observed groundwater elevation contours indicated $K_h \sim 140$ ft/day for UAS & 17.5 ft/day for LAS

Well	Hydraulic Conductivity (K) (ft/day)
EW0101-Upper*	17.8
EW0101-Lower*	2.2
IW0101*	6.6
IW0102*	27.6
IW0103*	27.7
MW-19D**	126.0
MW-19D Obs Wells**	160

* Data from Avocet, 2010: Field Implementation Report GET System Well installations, August 4, 2010. Data analyzed by HaleyAldrich, 2017.

** Tait Environmental Management, Inc. 2003: April 2003 Aquifer Test Field Data Report, May 9, 2003. Data analyzed by HaleyAldrich, 2017. & Hargis + Associates, Inc., 2003: Groundwater Flow & Contaminant Transport Modeling, September 19.



Extraction optimization summary

- **Findings**
 - Sequence stratigraphy, flow logging, depth-integrated sampling & modeling revealed vertical variation in K & VOC concentrations
- **Optimization opportunity**
 - Most VOC mass in UAS; pumping from LAS induces drawdown & downward vertical gradient; pumping from LAS has little benefit



Extraction optimization summary (continued)

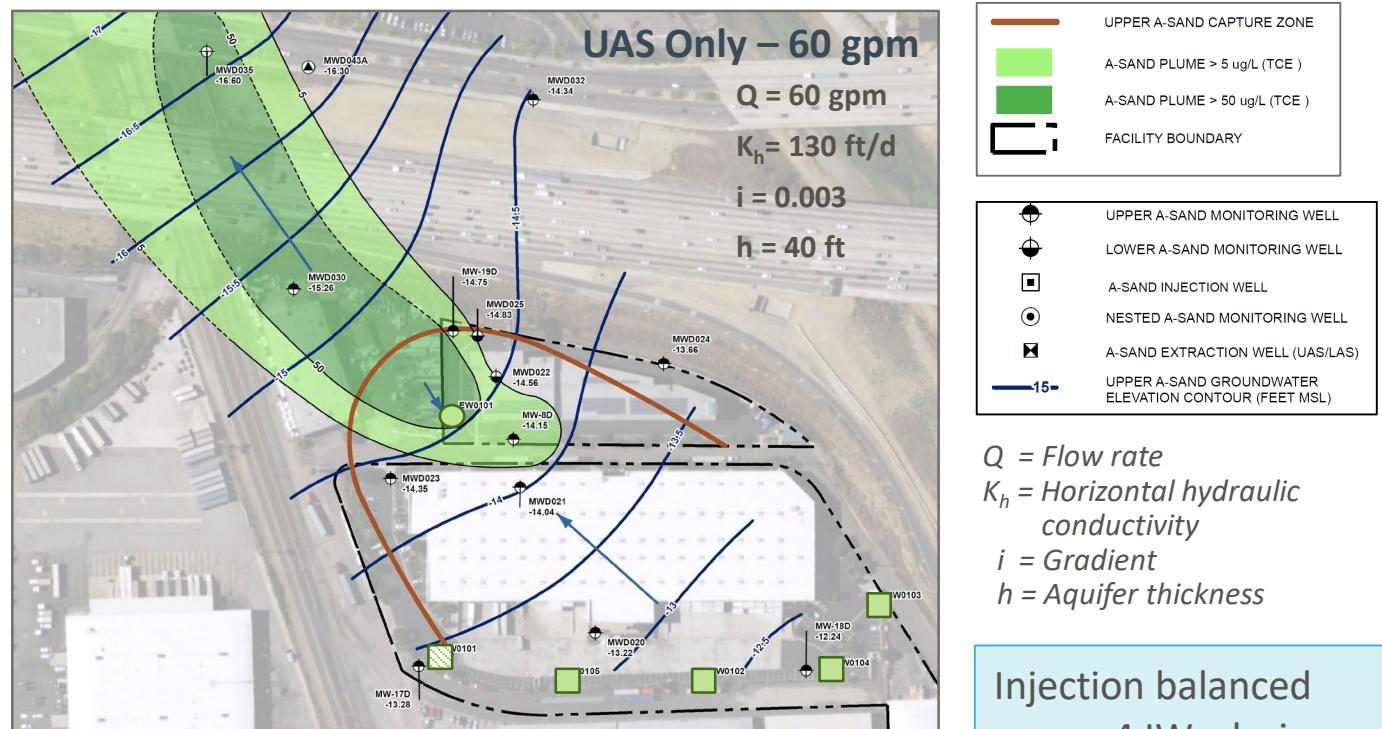
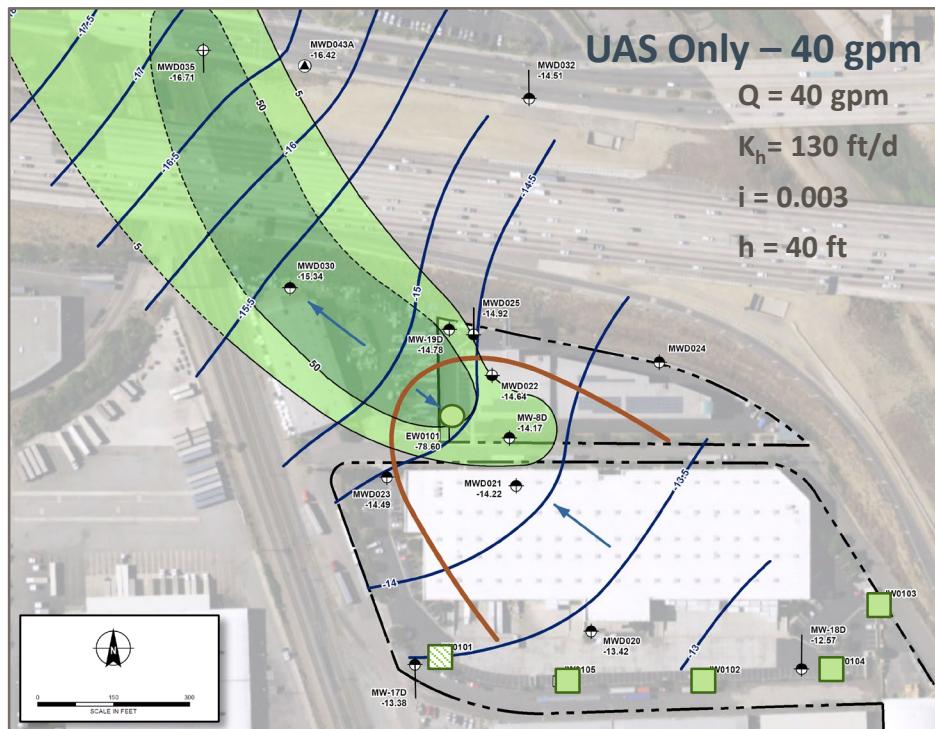
- **Extraction optimization**

- Packer installed in EW0101 to isolate UAS from LAS
- Pumping tests in UAS at 40 & 60 gpm for 10 days each
 - 40 gpm: best fit mean K_h of 130 ft/day
 - 60 gpm: best fit mean K_h of 126 ft/day
- 40 gpm from UAS provides similar CZ as 60 gpm for combined UAS/LAS, saving 20 gpm extraction & treatment



Extraction optimization verification

- As expected, 60 gpm capture zone (CZ) larger than 40 gpm CZ in UAS, however....
- UAS 40 gpm CZ similar in size to 60 gpm UAS/LAS combined CZ at 60 gpm (not shown)

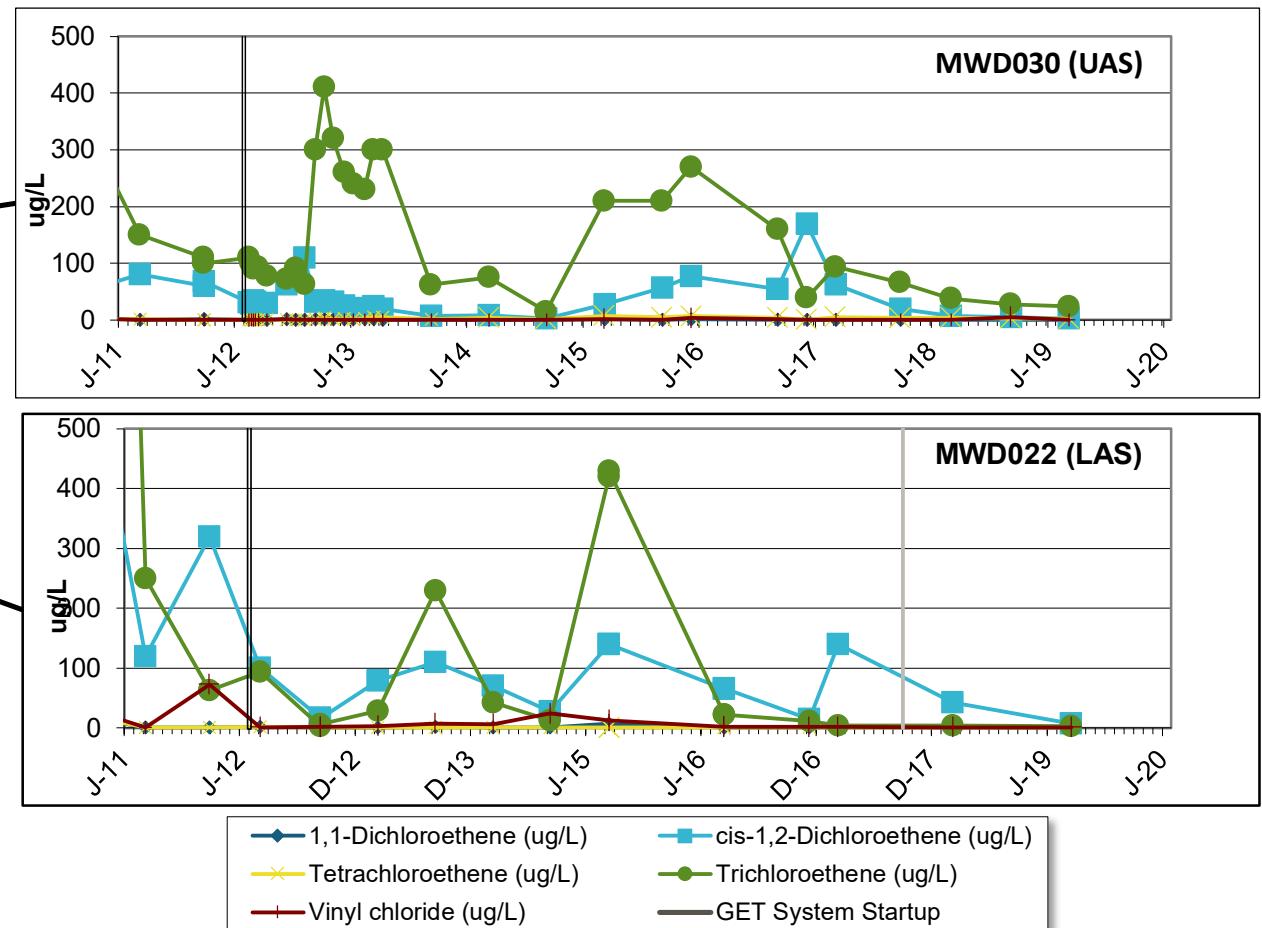
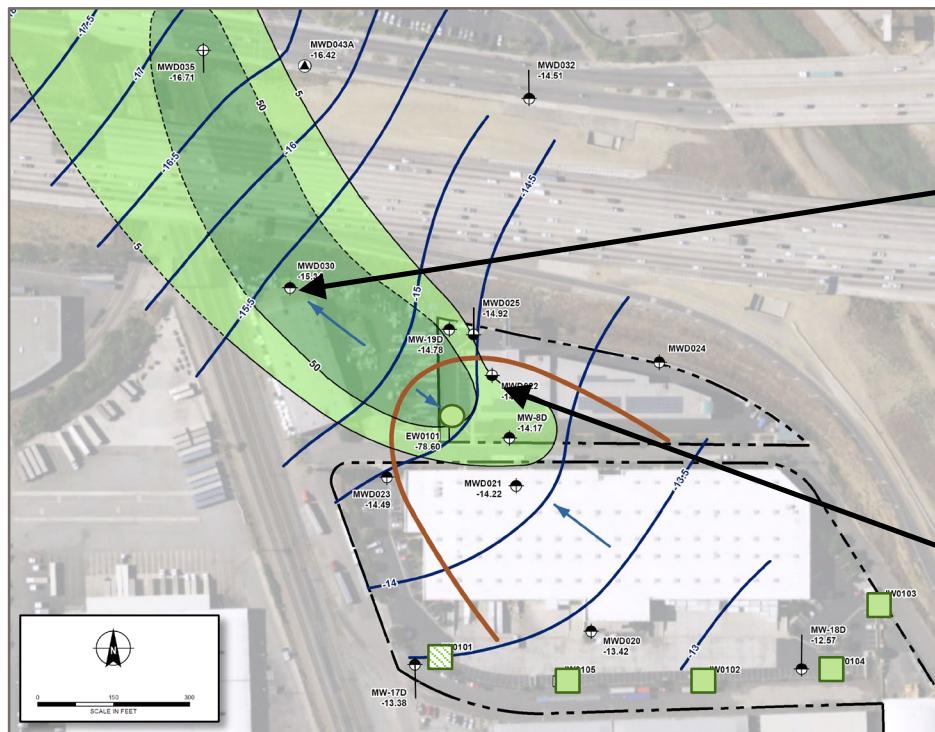


Q = Flow rate
 K_h = Horizontal hydraulic conductivity
 i = Gradient
 h = Aquifer thickness

Injection balanced across 4 IWs during pumping test

Extraction monitoring

- Downgradient COC concentrations decreasing in Upper A-Sand
- On-Site COC concentrations decreasing in Lower A-Sand after extraction isolation to UAS



Approach to optimize injection

Is injection a viable discharge method? Our approach included the following...

- Review previous investigations of injection well fouling
- Collect samples of precipitate from injection wells
- Research and test additional well rehabilitation methods
- Collect water samples at influent, midpoint, & effluent of treatment system
- Install effluent particulate filter
- Test effect of aeration to encourage precipitation within treatment system surge tank
- Evaluate additional oxide mitigation measures
- Conduct cost-benefit analysis of long-term well rehabilitation & replacement versus one-time cost of sewer connection (\$1M)

Injection well fouling



Black sediment in IW0105



Suspended Solids in IW0103
(2013 video)



Scaling on IW0105 Infrastructure
Blackish-Red / Brittle

- Sediment samples collected from IW0104 contained 29% (dry weight) manganese. Additional sampling confirmed presence of manganese & iron oxides
- Based on these results, effluent particulate filter unit installed on treatment system & further evaluation of manganese performed to identify locations of potential manganese precipitation in treatment system

Rehabilitation methods

- Acid treatment with NuWell 120 & 310 for 36 hours – acid removed prior to next step
- Backflush >4,500 gallons at 70+ gpm – removes particles from within screen openings
- Sonar jetting – high-pressure pulse to break up oxide scale
- Water jetting
- Mechanical development – removes heavy particles & brushes screen
- Video survey before/after for confirmation of condition



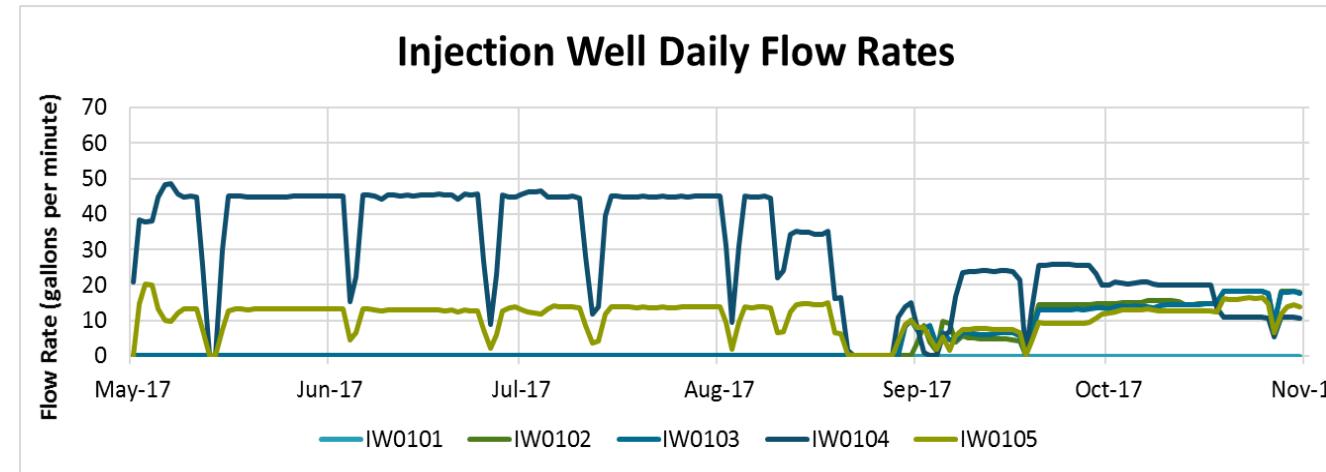
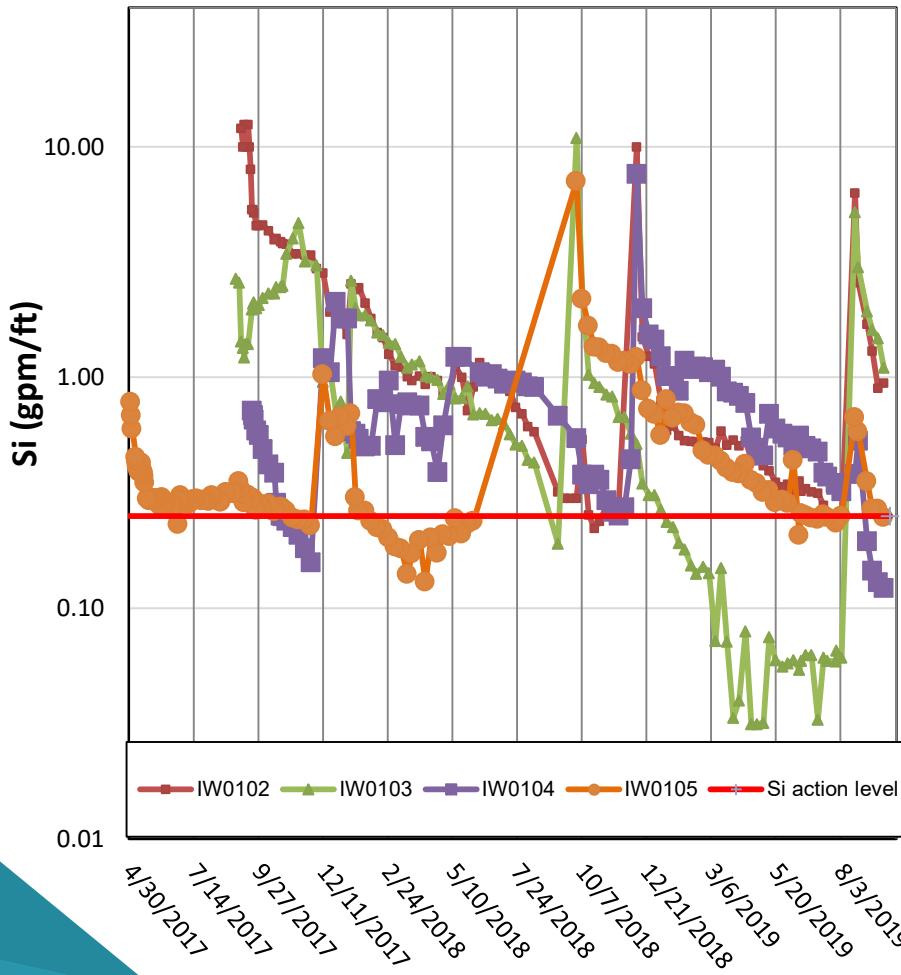
Before & after rehabilitation photos of IW0102



IW0102 water before & after back-flushing

Performance results / Specific injection rate (S_i)

Specific injection over time (2017 – 2019)

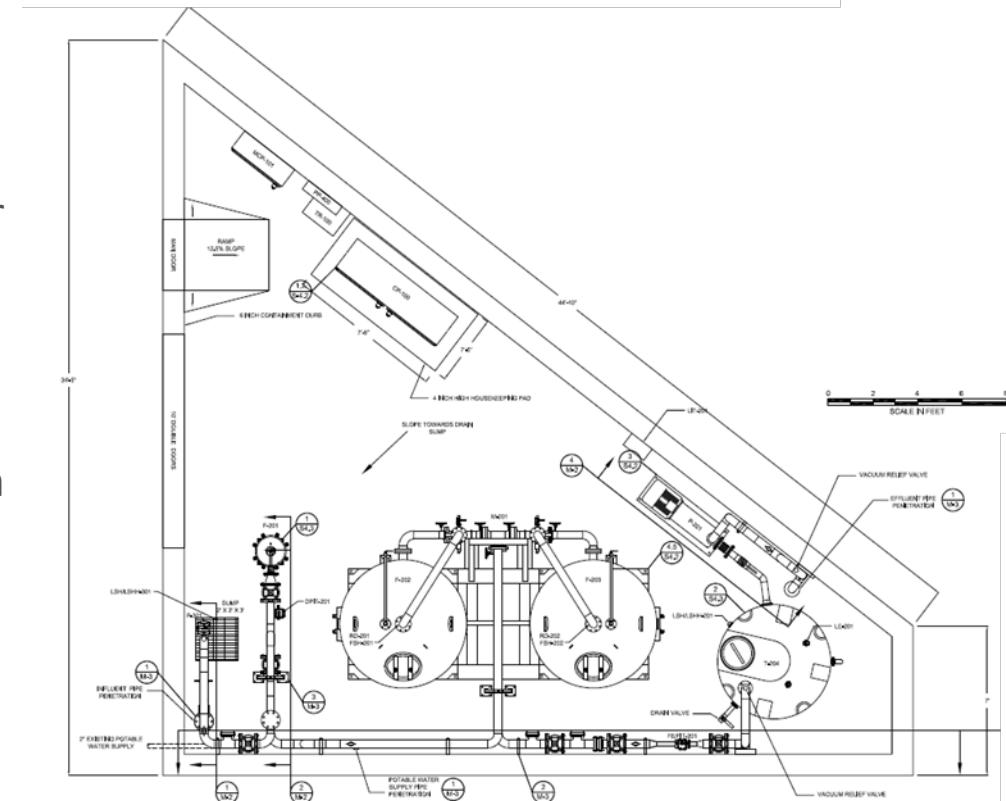


	Backflushing Only	Sonar with Backflushing	Water Jetting with Backflushing	Acid with Backflushing	Acid & Sonar with Backflushing	Acid with Water Jetting with Backflushing
IW0102	O	O	O	8 Months (3500)	14 Months (4700)	2+ Months* (6900)
IW0103	O	12 Months (4700)	O	5 Months (2600)	O	2+ Months* (6600)
IW0104	3 Months (4700)	O	< 1 Month (4500)	8 Months (5200)	12 Months (4200)	O
IW0105	6 Months (4000)	O	1 Month (5000)	9 Months (5900)	6 Months (4000)	O

■ ≤ 6 months ■ 6 to 11 months ■ ≥ 12 Months
○ Method has not been tried on well
* = Performance evaluation in progress
(3500) = Volume in gallons of water purged during backflushing

Aeration effectiveness

- Bubbler system within the surge tank not effective enough
 - 14% dissolved Mn reduction
 - Effluent filter does not require frequent replacement
 - Injection wells exhibit fouling and require rehabilitation <1 year
 - Modifications...
 - Microbubbler for greater surface area
 - Maintain water level in surge tank between extraction/injection
 - Ozone recirculation unit
 - Additional or finer effluent filters



Summary & conclusion

- **Hydraulic capture zone optimized, reducing flow rate & level of effort**
 - Sequence stratigraphy, video, flow survey, and depth-discrete sampling within extraction well resulted in valuable vertical characterization
 - Isolation of UAS & pumping tests to obtain hydraulic properties & define capture zones
 - Groundwater modeling helped to refine understanding of K_h in UAS & LAS
- **Injection system optimized, balancing injection & capacity**
 - Identified cause of injection well fouling
 - Tried new & more aggressive rehabilitation methods
 - Implemented preventative measures, continuing to check and adjust
- **Optimized, sustainable injection resulted in lower energy use, reduced carbon footprint, and cost savings compared to sanitary sewer discharge**
 - Reduced treatment volume by 11M gallons per year
 - Meeting system objectives - system uptime >90% and COC concentrations are decreasing

Thank You!
Questions?