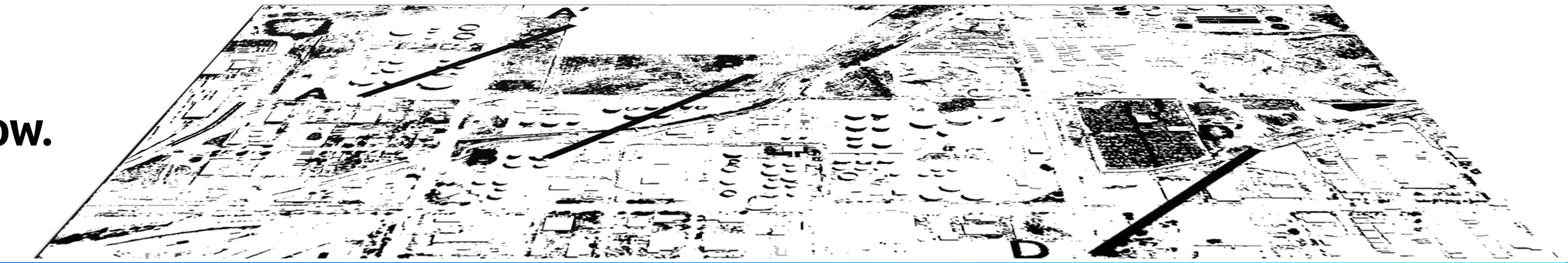

Challenging today.
Reinventing tomorrow.

Let's Connect!
Todd Kremmin, P.G.
Todd.Kremmin@Jacobs.com

Check out the other Jacobs posters:
Automated Data Analysis and Decision Making to Support Pump and Treat Shutdown Evaluation
Presenter: Jeff Ford

Session D9, Group 2

Multiple Contaminants and Aquifers: 4D Mass Flux and Volumetric Analyses

Authors
Todd Kremmin, P.G., Geologist | Jacobs
Trevre Andrews, Technologist | Jacobs
Wyatt Nolan, P.G., Hydrogeologist | Jacobs
Miles Ingraham, P.E., Environmental Engineer | Jacobs

What do static dissolved phase plume maps really tell us?

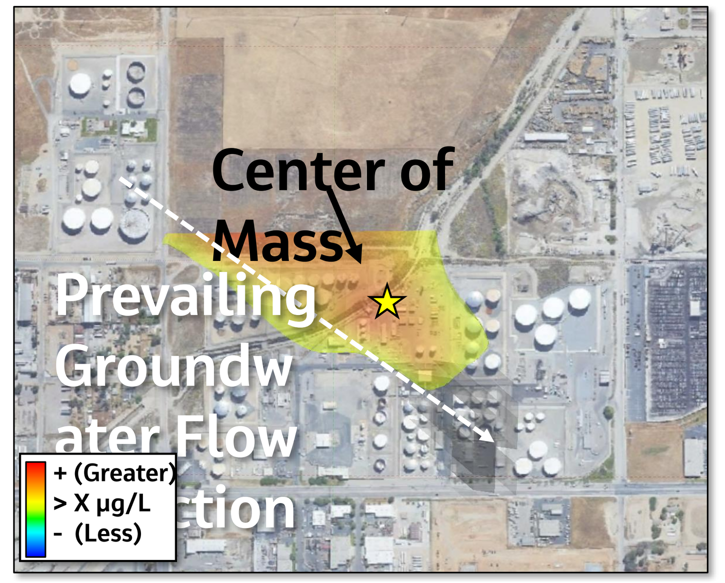

Figure 1 (Above): Contaminant of concern (COC)-A plume interpolation – 2010 @ >X µg/L iso-concentration, prevailing groundwater flow direction shown (White), approximate center of mass shown (Star).

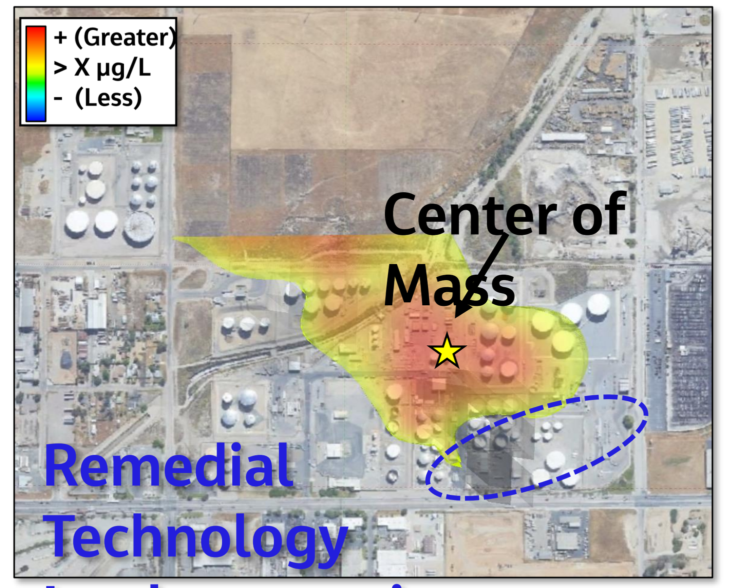

Figure 2 (Above): COC-A plume interpolation – 2020 @ >X µg/L iso-concentration, remedial technology implementation 2014 area shown (Blue), approximate center of mass shown (Star).

Conceptual site model (CSM) understanding frequently and primarily relies on recent and historical site contaminant data. These data are often qualitatively illustrated in two-dimensional (2D) contaminant concentration spatial extent figures (Figure 1 and 2), year over year. Many important and costly decisions regarding future operations and remediation at project sites are and will be based upon these illustrations, diagrams, and overall CSM interpretations, collectively. ***Some questions often asked by stakeholders:***

1. **Is this plume stable?**
2. **How is the remedial implementation improving conditions?**

Stakeholders weren't seeing the changes and improvements in dissolved phase plume distribution with traditional analysis/graphics. Using a four-dimensional (4D) mass flux/discharge analysis, quantifiable improving groundwater conditions as well as data gaps became evident and were tracked in relation to the site narrative (i.e., plume and remediation lifecycle/changes).

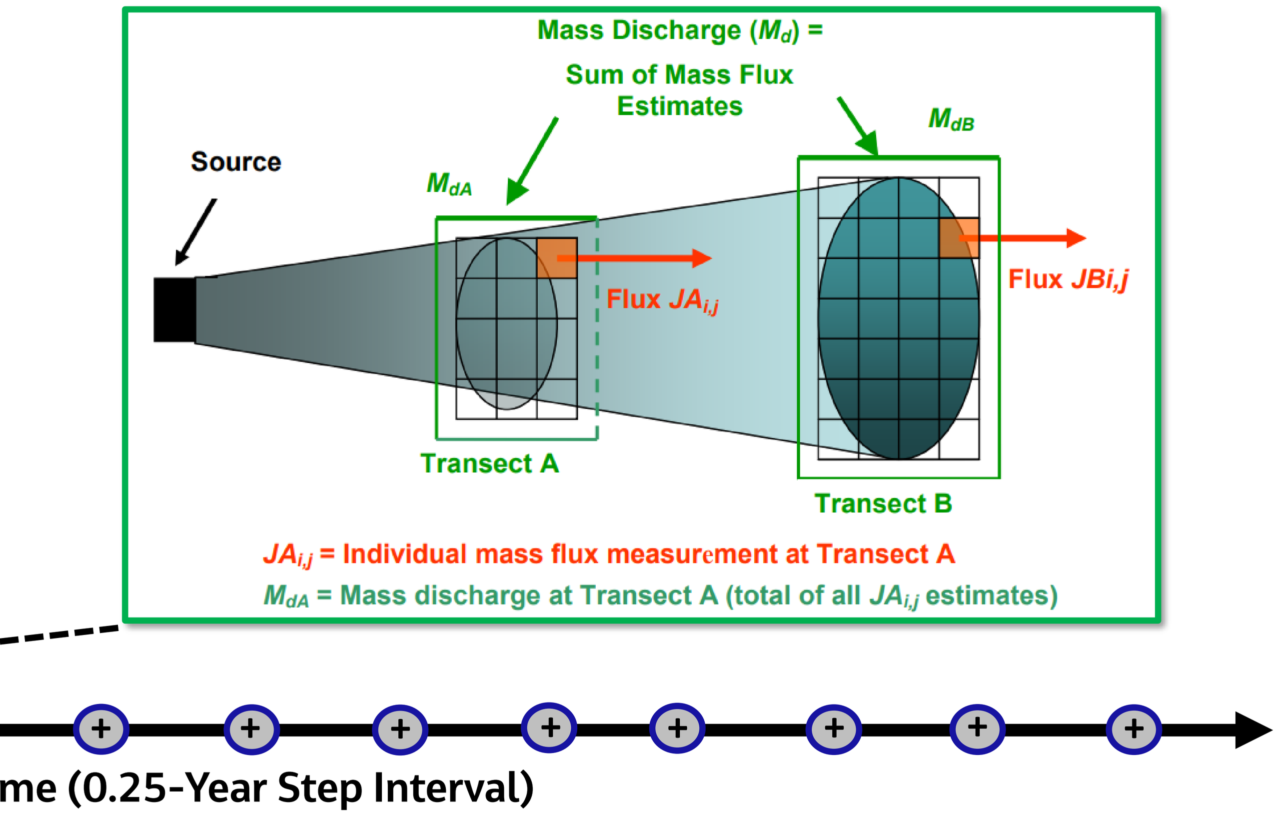

Figure 3 (Above-Right): Interstate Technology & Regulatory Council (ITRC) – *Use and Measurement of Mass Flux and Mass Discharge* (ITRC, 2010) conceptual figure (p. 23) illustrating transects in three-dimensional (3D) space which demonstrates the quantification of mass flux and discharge across a slice of a given area downgradient from a contaminant source. Flux being the mass moving past a plane of given area per unit time. Discharge being the total mass flux integrated across the entire transect. This concept of flux/discharge was iterated over time at a 0.25-year step interval, creating a 4D analysis.

4D Mass Flux Quantifies Site Progress to Optimize Remediation

Site decision-making, remediation efficiencies, and improved closure forecasting can be enhanced with the incorporation and use of 4D mass flux/discharge and volumetric analyses for CSM's. Mass flux/discharge and volumetrics can be isolated to custom transects and integrated to all CSM project site data (Figure 4 and 5). In addition, multiple contaminants can be analyzed using this technique to comprehend and assess biodegradation patterns/trends across multiple aquifers (Figure 6).

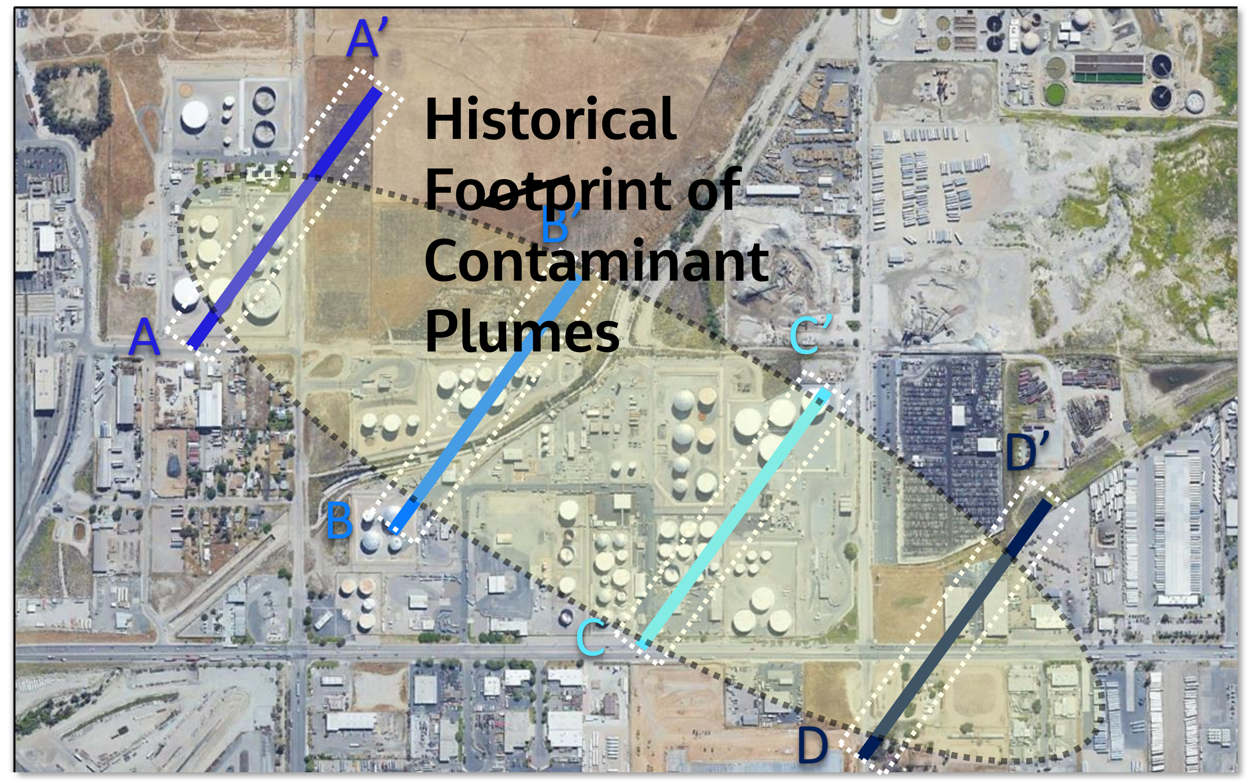

Figure 4 (Right): A 3D data visualization was developed using C Tech's Earth Volumetric Studio (EVS) for the project site. Four fixed transects (A-D), were implemented across the site, approximately perpendicular to the prevailing groundwater flow direction and the historical footprint of contaminant plumes. Each transect captured the site-wide quantitative interpolated COC-A plume data @ >X µg/L iso-concentration over time (utilizing a quarterly step iteration). These data were integrated to other known CSM data, metrics, and information, including (but not limited to); 1. thickness of aquifers, 2. groundwater elevation changes, 3. hydraulic conductivities, and 4. calculated groundwater gradients, to aid in determining the relative flux/discharge, volumetrics, and concentrations at each transect from 2001 to 2020. In addition, the same analysis was performed for multiple COC's/aquifers, allowing for comparative ratio analyses.

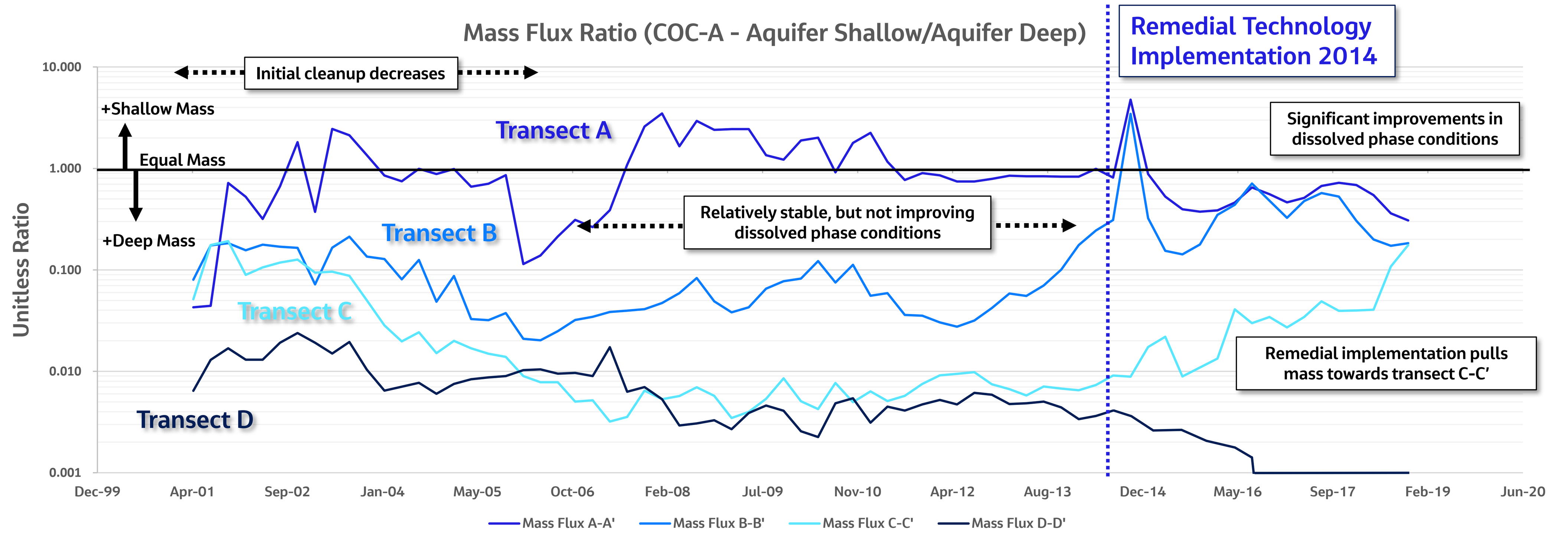

Figure 5 (Above): Output graph of relative flux ratio of COC-A interpolated over time, from approximately 2001 to 2020, utilizing a quarterly step iteration and integrated data (see figure 4 notes). Remedial technology implementation in 2014 highlights the point at which significant changes occur in respective transects, allowing for enhanced understanding of project data, aquifers, and remedial efficiencies. Transect D-D' illustrates an area offsite from the project area, showcasing the near immediate effectiveness of the remedial technology implemented. The convergence of the flux ratio of COC-A at transect C with transects A/B, demonstrates the apex of total mass across the site, and declining trends should be expected in all remaining transects going forward, which can be projected.

Taking it to the next (fifth) dimension?

A mass flux/discharge and volumetric analysis case study from a fuel terminal in the western U.S. is provided, built from recent and historical site data employing C Tech's EVS (Figure 5 and 6). The case study illustrates both qualitatively and quantitatively the dynamic mass flux/discharge and volumetric changes that have occurred since site data collection began, approximately 30 years ago (pre-2001 data not shown). The analyses at the site indicate among many other things, that the interpolated plume of COC-A (parent) has biodegraded significantly to COC-B (daughter) due to the remediation technologies implemented in 2014.

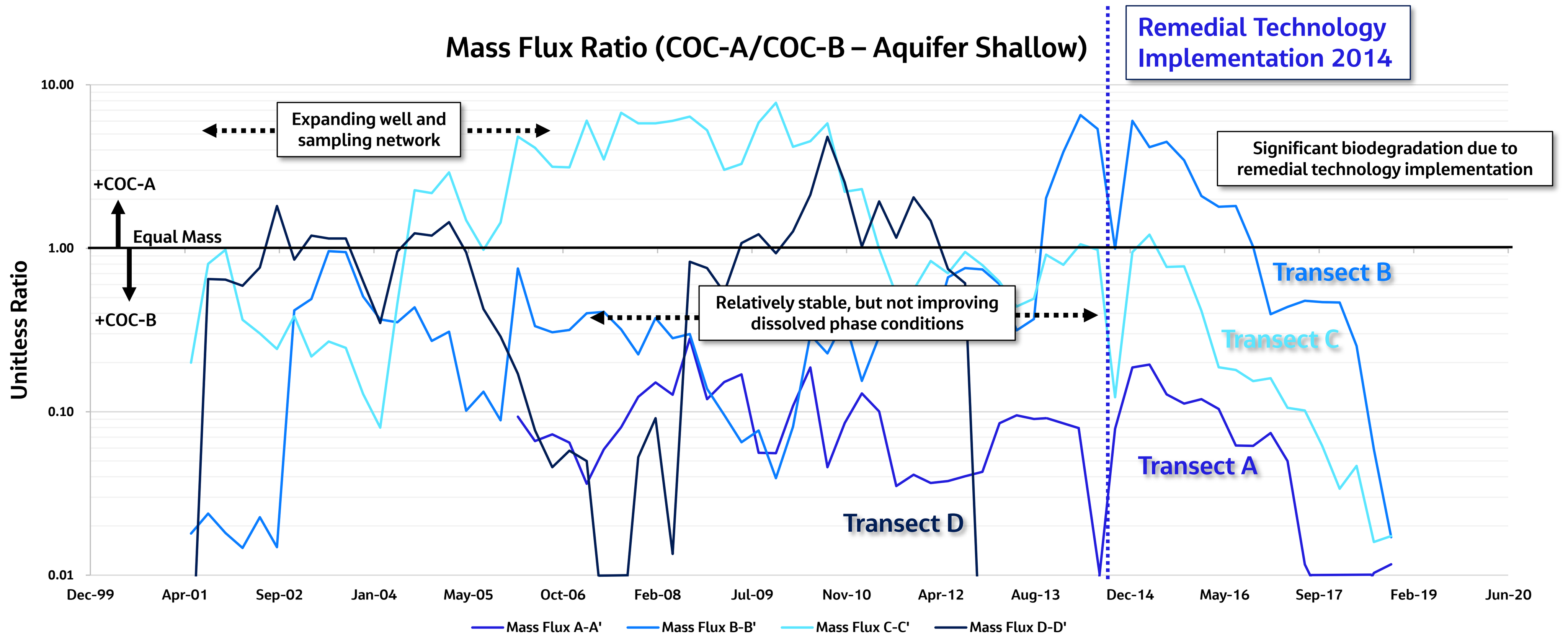

Figure 6 (Above): Output graph of flux ratio of COC-A/COC-B (COC-B is a degradation product of COC-A) interpolated over time, from approximately 2001 to 2020, utilizing a quarterly step iteration and integrated data (see figure 4 notes). Remedial technology implementation in 2014 highlights the point at which significant changes occur in respective transects, allowing for enhanced understanding of project data, aquifers, and remedial efficiencies at a wholistic site-wide scale. The rapid decline of the flux ratio of COC-A/COC-B across all transects, demonstrates the remedial technology is effectively degrading COC-A, which can be quantitatively defined with a simple trendline evaluation of the data from 2014 to present. Data that has not yet declined to near zero can be projected for evaluation into the future, helping guide remedial endpoints and future decision-making.

Acknowledgements/References

Thanks to all mentors, collaborators, and colleagues at Jacobs! Additional thanks to the 3D Data Visualization Community of Practice (CoP) and Environmental Data Analysis and Management (EDMA) group!. Additional acknowledgements/references:

1. Interstate Technology & Regulatory Council (ITRC), 2010. *Use and Measurement of Mass Flux and Mass Discharge.* August.
2. C Tech Earth Volumetric Studio (EVS) version 2022.10.2
3. Jacobs Engineering Group, Inc. and Confidential Client