Sustainable Remediation Forum (SURF)
SURF 30: October 6-7, 2015

SURF 30 was held at Rice University in Houston, Texas on October 6 – 7, 2015 and focused on "Exploring the Energy/Water Nexus." Individuals that participated in the meeting, along with contact information, are listed in Attachment 1. Meeting minutes are posted for members at www.sustainableremediation.org. Members can log in and access the minutes by clicking "SURF Meeting Minutes" under "Member Resources."

Day 1

The meeting began with Olivia Skance (Board Member, At Large) reviewing meeting logistics, ground rules, nonconfidentiality assumptions, export control laws, and antitrust issues. She thanked current SURF sponsors for supporting the organization. (Members interested in sponsorship opportunities should contact the SURF Treasurer at treasurer@sustainableremediation.org.) Presentation slides for Day 1 are provided in Attachments 2 through 9.

Why SURF?

Maile Smith (SURF President) welcomed SURF members to SURF 30 and introduced participants unfamiliar with SURF to the organization by outlining the importance of sustainable remediation and significance of SURF's contributions to date. In addition, she said SURF will continue to:

- Be the premier network for exploring logical, holistic, and sustainable approaches in the remediation industry.
- Provide remediation professionals influence outside of their own organizations, permitting their participation in the continual improvement of their profession.
- Build and facilitate positive relationships amongst industry, regulators, academics, and consultants.
- Develop and deliver conferences and workshops of the highest technical quality.

Future activities are as follows:

- Change the standard practice of remediation to incorporate the concept of sustainability.
- Develop academic curriculum modules on the topic of sustainable remediation that focus on practical applications.
- Develop a long-term strategy for attracting and engaging members, financial sustainability, and organizational and industry growth.

- Position ourselves as the leading professional membership association for licensed and emerging remediation professionals.

Presentation slides are provided in Attachment 2.

Emerging Opportunities of Nanotechnology

Keynote Speaker Pedro Alvarez (Rice University) presented a vision of how nanotechnology can help enhance sustainability and address the challenges of the water-energy nexus. As background, Pedro provided seven “grand challenges” related to water:

1. Safe water for a growing population
2. Water infrastructure (distribution and collection)
3. Water distribution between humans and ecosystems
4. Water-induced disasters and flood protection
5. Enough food for all
6. Water to produce energy
7. Solution for water conflicts and fair water share for all

These challenges create the current competition for water and magnify the need to change the status quo. Current statistics also demonstrate the need for change. Over 20% of energy use in cities is for moving water, and over 55% of the cost of desalination and wastewater reuse is energy related. Pedro believes that nanotechnology has great potential to enable exploitation of a broader range of water sources (e.g., sea water, wastewater). Current treatment approaches that rely heavily on infrastructure, chemicals, and energy could be transformed toward catalytic and physical systems to eliminate the current tradeoffs between cost and performance and between energy consumption and treatment rate.

The general idea behind using engineered nanomaterials in water treatment and reuse is to match treated water quality to the intended use and rely more on physical and catalytic processes to lower chemical consumption and/or electrical energy requirements. Pedro described how engineered nanomaterials can be applied using a modular approach for low-energy desalination via direct solar membrane distillation, electrosorption for scaling control, photodisinfection and advanced oxidation, and select contaminant removal via multifunctional nanosorbents.

Pedro acknowledged the potential impacts that engineered nanomaterials may have on the environment. He quoted Uncle Ben in Spider Man, saying “With great power comes great responsibility.” While risk is generally addressed by focusing on the hazard or exposure, Pedro proposed focusing on safe materials (e.g., food additives) and exposure by immobilizing nanomaterials so as to prevent exposure. Specific actions were recommended to promote the safer use of engineered nanomaterials and are included in the presentation slides in Attachment 3.

After the presentation, the majority of the discussion focused on the safety and impacts of nanoparticles. Pedro responded by saying there are two principles at work: the precautionary principle and "innocent until proven guilty." He believes if we err too much on the side of being careful, we will miss an opportunity. On the other hand, if we are too permissive, we will do real harm. He encouraged participants to be cautiously optimistic and careful, but not afraid. He recommended research continue moving forward on both tracks—continuing to develop engineered nanomaterials and valuable applications and also continuing to determine the impacts of these materials through molecular analysis and modeling. As professionals, Pedro believes we need to be honest brokers by making sure decision makers are informed and then use market forces to make intelligent choices.

Green and Sustainable Remediation Meets Climate Change Adaptation

Brandt Butler (AECOM) provided an overview of the threat climate change poses to existing remedies and how climate changes could affect and influence the selection and design of future remedies. Brandt reviewed the U.S. Environmental Protection Agency's (USEPA's) climate change adaptation implementation plan. The plan considers how remediation sites may be vulnerable to climate change impacts and how adaptation strategies may be considered to eliminate the vulnerabilities. Describing mitigation and adaptation as two sides of the same coin, Brandt outlined a conceptual approach to address emissions mitigation and climate change impacts and vulnerability in remediation design and operation. By integrating green and sustainable remediation practices during remedial selection, design, construction, and operation and maintenance, remediation professionals can reduce the emissions associated with remediation. Tiered screenings can allow remediation professionals to rank facilities in terms of vulnerability. A Tier 1 screening uses existing tools, such as 100- and 500-year flood maps from Federal Emergency Management Agency (FEMA) and the National Oceanic and Atmospheric Administration's (NOAA's) sea level trend database. A Tier 2 screening involves a more detailed assessment in which items such as infrastructure vulnerabilities, localized flood patterns, and storm surge behavior are evaluated. Presentation slides are provided in Attachment 4.

At the end of his presentation, Brandt asked participants for their input about how to conduct a more detailed analysis of the most vulnerable sites. Responses are below.

- Use a sensing approach in which additional data is collected to assess a tipping point. Need to change the philosophy of how systems are engineered—we have to design for things we know may happen, but we can't go broke doing it.
- Use existing mathematical tools to determine the consequence of failure so that informed decisions can be made to prevent catastrophic financial damages to a corporation.
- Include future retrofitting as part of cost evaluation.

One participant said that a lot of information about evaluating climate change is currently available. In addition, ASTM is developing a guide related to extreme weather event preparation for communities who haven't considered these topics.

One participant asked others if they have experienced regulators reopening remedies because of climate change impacts. An individual responded that Alaska regulators have begun reopening remedies due to the projected impacts of significant erosion. Another person commented that sampling plans have changed over time because of the extreme weather related to climate change.

Tesoro's Sustainable Remediation Program

Kyle Waldron (Tesoro) presented an overview of Tesoro's current sustainable remediation program and discussed the sustainability assessment results for a former bulk fuel terminal site in Fairbanks, Alaska. Presentation slides are provided in Attachment 5.

- Sustainable Remediation Program
  Tesoro is developing a process to assess sustainability performance for its remediation sites using quantitative and qualitative measurements of key metrics that align with corporate sustainability goals. The company used LEAN-based strategic planning approaches to develop a three-year strategic plan that includes goals, action items, and metrics to track success. A key part of this plan is performing sustainable remediation pilot assessments for a subset of sites to better understand overall sustainability impacts and the interaction between different sustainability indicators (e.g., energy water) at each site. The regulatory agencies associated with the sites are providing input on the sustainable remediation elements that are going to be assessed. The results of the pilot studies are being summarized in sustainability dashboards that concisely and visually present a cost-benefit analysis, benchmarking of sustainability performance relative to Tesoro's corporate performance, and sustainability evaluations for key indicators. A standardized approach is used for the dashboard so the sites can be compared on a portfolio basis regardless of size or complexity.

- Former Tesoro Bulk Fuel Terminal Site
  As part of the pilot program, a sustainability assessment was performed for a former Tesoro bulk fuel terminal site in Fairbanks, Alaska. At this site, ongoing remediation involves a pump, treat, and reinjection system that operates only during the summer months when temperatures are favorable. This approach, as well as transporting certain materials to the site via barge instead of by airplane, reduces fuel requirements and associated emissions. Sustainability assessment results revealed the following:

  - Optimizing the air sparging system with a smaller blower will reduce electrical demand by about 531,000 kilowatts over the life of the project (as well as associated emissions) and will result in an associated cost savings of $69,000.

- Treating the soil on-site via landfarming will result in a cost savings of approximately $70,000 to $80,000 compared to the previously planned off-site thermal treatment.

In addition, Tesoro is investigating the feasibility of remote monitoring/telemetry for the system to further reduce emissions and is assessing the feasibility of installing solar panels. If solar panels are feasible, they will generate about 75% of remediation system energy requirements.

After the presentation, participants asked questions about future plans for the program and drivers for sustainable remediation.

- Future Plans for Program
  The program is a work in progress. Next steps include rolling out the program to larger internal groups with more remediation sites and eventually to facility personnel. Long-term goals include incorporating the program and its results into Tesoro's Social Responsibility Report.

- Sustainable Remediation Drivers
  Technology transfer and good public relations are additional drivers for sustainable remediation aside from cost. Kyle said that the design of the program aims to shift thinking from continuing work year to year without a cost analysis to life cycle cost analyses that can demonstrate long-term costs in achieving closure more quickly.

In Situ Activated Carbon Amendment Technology for Sediment Remediation

Yeo Myoung Cho (Stanford University) presented the sustainability of an in situ activated carbon amendment remediation strategy in a broad context, provided a technology overview and current status, and discussed an evaluation of secondary environmental impacts of this amendment compared to other remedial alternatives based on a life-cycle analysis (LCA) at a site at Hunters Point Shipyard, California. Presentation slides are provided in Attachment 6.

Yeo Myoung described the result of various laboratory and field assessments of in situ activated carbon amendment designed to answer four major questions. The questions, along with the results, are provided below (see Attachment 6 for additional details).

1. Will the activated carbon amendment remain effective over time?
   Assessment results of a five-year, post-treatment assessment at Hunters Point Shipyard show that performance has continued to improve over the last five years. Therefore, activated carbon remains effective in reducing the availability of hydrophobic organic contaminants (HOC) in the long term.

2. How will engineering and site conditions affect activated carbon amendment performance?

Based on assessment results, activated carbon amendment size and mixing heterogeneity are the key factors affecting performance.

3. How does the activated carbon amendment respond to sediment influx?
   Laboratory microcosm tests implied potential assimilation benefit of the in situ activated carbon amendment against re-contamination in the presence of bioturbation.

4. If the activated carbon amendment is accidently removed, will treatment remain effective?
   Yes, activated carbon amendment performance remains effective even after the sorbent is removed.

Secondary environmental impacts of using an in situ activated carbon amendment approach compared to other remedial alternatives (i.e., dredge-and-fill and capping and an innovative sediment treatment technique) were evaluated based on a LCA at Hunters Point Shipyard. Results show that capping generates substantially smaller impacts than dredge-and-fill and in situ amendment using coal-based virgin activated carbon; however, secondary impacts from the in situ activated carbon amendment can be reduced significantly by using recycled or bio-based sorbents. Secondary environmental impacts are highly sensitive to the dredged amount and the distance to a disposal site for dredging, the capping thickness and the distance to the cap materials for capping, and the activated carbon dose for in situ activated carbon amendment.

Discussions after the presentation focused on the confidence in LCA data because activated carbon data sets are manufacturing specific. Yeo Myoung said she searched sustainability literature for relevant information (e.g., carbon footprint) and made conservative assumptions based on the information. One participant encouraged Yeo Myoung to present this information to the USEPA.

Remediation Performance and Cost Database: Implications for Improving Sustainability

Travis McGuire (GSI) presented the work associated with developing a comprehensive remediation performance and cost database using results from 235 remediation projects. Several characteristics of remediation projects were evaluated to provide insights into factors that may affect remediation outcomes. In addition, several key focus areas were studied to provide insights on sustained treatment vs. rebound, performance of “treatment trains,” and performance at “remediation done right” sites as described in the peer-reviewed literature. Results show the following:

- Maximum contaminant levels (MCLs) were achieved at less than one in 10 sites.
- Typical performance achieved about 0.5 to two orders of magnitude reduction in groundwater concentrations.
- Costs were generally $100 to $200 per cubic yard.

- Bioremediation appears effective for long-term, sustained treatment at most sites.

Travis believes these results will help remediation professionals set expectations as part of the remedial decision-making process and help to promote the use of mass flux-based remediation criteria within the regulatory community. In addition, the dataset will help remediation professionals improve sustainability at complex sites and during regulatory five-year reviews. Presentation slides are provided in Attachment 7.

In response to a question regarding the impact of hydrogeology on remediation performance, Travis said that data from a subset of the site with sufficient detail showed that performance appeared to correlate to the number of stratigraphic layers in the treatment zone whereas sites with fewer layers exhibited better performance than sites with more layers. When asked the source of the cost data, Travis said that cost data was taken from site reports prepared by the responsible parties or their consultants. In response to a follow-up question, he acknowledged that it may be worthwhile to sort the cost data by industry (e.g., government sites, large industrial sites, dry cleaner sites) to evaluate whether unit costs are consistent.

Beneficial Reuse of Treated Groundwater for Plant Operations

Bill Butler (ERM) presented a case study at a chemical manufacturing facility in New Jersey. Although the least preferred remediation alternative was selected (i.e., groundwater pump and treat) at this site, the remediation system achieved a positive outcome in terms of achieving the remedial action objectives and meeting the plant's needs. Details are provided below and presentation slides are provided in Attachment 8.

A chemical manufacturing facility in New Jersey was required to implement a remedial action to address groundwater affected by volatile organic compounds (VOCs) and fluorocarbons. Various in situ remediation technologies were evaluated using bench-scale and pilot testing. Results indicated that these technologies would be ineffective at treating the fluorocarbons or that performance was limited by the layered soil lithology. Although not the preferred remedial approach, groundwater pump and treat was selected to hydraulically contain the VOCs and fluorocarbons on-site. The proposed groundwater pump-and-treat system consists of four recovery wells installed in the shallow, unconfined aquifer pumping groundwater at an average rate of 264 gallons per minute (gpm), which was predicted by modeling to achieve hydraulic containment. The initially proposed system also included two injection wells to return the treated groundwater to the aquifer. After evaluating the discharge and treatment options, using the treated groundwater for plant operations was selected as the most cost-effective option. This revision eliminated the need for the two injection wells and resulted in a modified, lower-cost treatment system. Water supply for the plant is provided by two on-site water supply wells installed within a deeper, confined aquifer. Groundwater from the deeper aquifer requires treatment to remove iron and other hardness minerals using ion exchange to achieve standards required for manufacturing. Ultimately, the New Jersey Department of

Environmental Protection approved a revised water allocation permit for the plant that provided the desired flexibility.

In response to a participant question after the presentation, Bill emphasized the importance of engaging operations and engineering personnel at the plant early and often in the process. At this site using this practice, remediation professionals found out that plant personnel were interested in water reuse.

Groundwater Conservation and Reuse Update and Panel Discussion

Paul Hadley (retired, California Department of Toxic Substances Control) provided a brief update on SURF's Groundwater Conservation and Reuse Initiative, followed by a panel discussion. Olivia Skance (Chevron) moderated the discussion; panelists were as follows: Matt Alexander (Leidos), Bill Butler (ERM), Laura Capper (CAP Resources), and Paul Hadley.

In Paul's update, he explained the purpose of the initiative, which is aimed at encouraging a paradigm shift and debunking myths associated with groundwater reuse. The goal is to stimulate a more holistic view of groundwater associated with remediation projects and to promote conservation and beneficial reuse of a vital natural resource. Paul explained that the potential for groundwater reuse at remediation sites has not been realized, but that the remediation industry could leverage the experience gained by longstanding water conservation and reuse practices in the municipal wastewater industry. Paul highlighted a few case studies from SURF's *Groundwater Conservation and Reuse at Remediation Sites* that demonstrate how water conservation and reuse is being applied. Presentation slides are provided in Attachment 9.

After Paul's presentation, panelists answered questions related to groundwater conservation and reuse.

1. Perception is often an obstacle to groundwater reuse. How do you identify and engage with key stakeholders to address their concerns?
   Matt highlighted a project he worked on 20 years ago involving multiple pump-and-treat systems at a military base. At the time, reuse options were rejected because of the "yuck factor." However, stakeholders allowed reuse after reinjection because of dilution. Beneficial reuses included irrigation for agricultural and golf course uses, as well as use in a cranberry bog.

2. What obstacles have you encountered (and how have you addressed them) when implementing groundwater reuse and conservation strategies?
   Laura responded that liability of reuse is the biggest barrier in reusing produced water in the oil and gas industry. She noted the existence of regulations for treated water that require reporting of a five-gallon spill, but the same water can be used to irrigate lawns. Better communication and the ability to explain details to interested stakeholders can help. In addition, ensuring that correct injection volumes are used is paramount. Laura said that, previously, specifications for fracking chemicals were the most significant

barrier to reuse. Now, in Pennsylvania, 95% of produced water is used in the next fracking job.

3. Liability and risk are often key drivers for decisions on the potential reuse of treated water. How do you approach these conversations with responsible parties?
Bill emphasized the difference between talking about reuse to remediation professionals versus the public. With remediation professionals, the discussion focuses on the quality of the product. When groundwater will be reused for drinking water, Bill emphasized the need to perform a thorough risk evaluation, including communication plans.

4. How does groundwater conservation and reuse fit into a sustainability assessment?
Matt said that, in his experience, groundwater conservation and reuse is generally not a priority when performing sustainability assessments. One participant suggested that the different "shades" of reuse be acknowledged and prioritized. For example, reusing water before reinjection should be a higher priority than other types of reuse. Paul agreed, emphasizing the need to respect the investment made to get the water out of the ground in the first place. Another participant stressed the importance of including water quantities from the pump-and-treat system in sustainability assessments to raise awareness of this issue. Laura underscored the importance of ensuring that tradeoffs of reuse are included in the assessment.

At the end of the panel discussion, one participant suggested quantifying the amount of water being discharged across the U.S. Another participant responded by saying that the USEPA would be the most appropriate organization to quantify this amount. Other participants agreed and seemed to think this would be a worthy exercise.

Melissa Harclerode (CDMSmith) mentioned that, as part of the Social Aspects Technical Initiative, she completed a survey to understand the factors and variables leading to the perceived risk of lead contamination. The project was highlighted in the SURF Report in Summer 2015 (http://www.sustainableremediation.org/library/newsletters/). The survey template, findings, and lessons learned from this research will be used to develop a comprehensive study to evaluate the public's perception of risk versus actual risk at contaminated sites where treated groundwater can be reused.

Technical Initiatives: Update

SURF members provided updates on the following two technical initiatives:

- Melissa Harclerode (Co-Chair, Social Aspects Technical Initiative) provided an update on the progress of the team's paper "Integrating the Social Dimension in Remediation Decision-Making: State of the Practice and Way Forward." The paper is scheduled to be published in the upcoming Winter issue of *Remediation*. Melissa told participants that the paper reflects input from national and international team members and contains future research needs. Based on feedback received to date, SURF members are interested in following up on two themes: (1) the perception of reusing treated groundwater and (2) the value of ecosystem services and water.

- Amanda McNally (SURF Secretary) provided a brief update on the Case Study Initiative. Twelve case studies are available on the SURF website (http://www.sustainableremediation.org/library/case-studies/case-study-initiative-database/), and 10 case studies are currently in review and will be posted when finalized. Anyone wishing to submit a sustainable remediation case study should complete the template available on the SURF website home page. Questions can be emailed to csi@sustainableremediation.org.

Day 2

The meeting began with a recap of participant's "takeaways" from Day 1. The discussion was lively; some responses are provided below. Presentation slides for Day 2 are provided in Attachments 10 through 16.

- Responsible parties and regulators are now considering climate change when planning remediation and trying to balance what is needed today with what could be needed tomorrow.
- If the past is no longer a good indication of the future, then monitoring is not going to be helpful. More modeling is needed to understand the survivability of a selected remedy.
- A different hierarchy for pump-and-treat systems is emerging; try to determine reuse options before reinjection.
- In the past, the education of remediation professionals has focused too much on risk and little on sustainability. Sustainable remediation must be promoted in education; it must become part of our professional ethics.

How Can a Green Remediation Project Benefit by Incorporating Sustainability?

Melissa Harclerode and Mike Miller (CDM Smith) presented how cost-benefit analysis methodology can be incorporated into a green remediation project, starting from its footprint analysis, to demonstrate the social and economic benefits that can be realized by monetizing environmental effects such as greenhouse gas emissions. The results support the additional value of green remediation (for cost-averse audiences) and lead the way to further project improvements (for triple bottom line-averse audiences). Presentation slides are provided in Attachment 10.

Mike began the presentation by defining green remediation and sustainable remediation. Green remediation considers all environmental effects of remedy implementation and incorporates practices to maximize the net environmental benefit of the cleanup actions.

Usually green practices are incorporated into an already-selected remedy, but can be integrated earlier in the project as well. In comparison, sustainable remediation strives to balance environmental, economic, and social concerns–the triple bottom line–throughout the life cycle of the remediation project. Mike explained that if another step is taken and the socio-economic benefits of green remediation practices are monetized, environmental indicators can be extrapolated to global-scale impacts.

The case study site presented is a manufacturing facility with chlorinated solvent contaminated groundwater beneath an active factory building. As the groundwater pump-and-treat system reached its asymptotic removal limit, it was gradually replaced with in situ anaerobic bioremediation through systematic injection of aqueous food-grade carbon substrate. The transformed treatment strategy improved contaminant removal and reduced the environmental impact of the remediation system as quantified by field logs, utility bills, invoices, and operation and maintenance records. Greenhouse gas emissions for pump and treat versus bioremediation were summed as carbon dioxide equivalents (CO2e) from activities such as drilling, transportation, and electricity use. In turn, the CO2e contributions to global climate change and projected damage to health and quality of life were quantified as costs based on the economic researches of others, including the U.S. Government. In this way, the carbon footprint of the remediation project was converted into monetized global impacts. The project's water footprint was also evaluated, but the current state of economic research limited the monetization of water depletion impacts.

Melissa explained the evaluation, which predicted costs for long-term global damages from implementing the two alternative remedial strategies. The results allowed for a direct comparison of the two remedial approaches; provided a single, universally recognized unit–cost–for disparate metrics; and demonstrated a method to quantify the more elusive socio-economic effects of a remediation project. The calculations (see Attachment 10 for equations and calculations) also revealed a possible numerical decision point for selecting one remedial approach over another: when the market cost plus environmental damages (= social cost) of the new approach become less than the social cost from making no changes. Melissa said that considering monetized socio-economic impacts allowed the triple bottom line to be incorporated without compromising the environmental cleanup. In this way, the state of practice is moved toward more sustainable remediation (vs. green) so that further positive impacts can be incorporated into remediation projects.

Participants asked clarification questions after the presentation, which led to the following suggestions and follow-up discussions:

- To strengthen the monetary argument, continue the projection of damages past 2009 in the graph and calculations. The pump-and-treat system would have been continuing to operate, thus continuously contributing to global impacts.

- Consider compiling a format or deliverable in which monetization of global impacts can easily be integrated into a footprint analysis, such as using the SiteWise tool. Melissa replied that this methodology has been published and is publically available for remediation practitioners to use and integrate into sustainability assessments.

A participant asked if the discount rate and social cost of CO_2 emissions should be compounded every year to accurately reflect the global impacts accrued by this natural phenomenon. Upon follow-up review, the compounding effect of CO_2 emissions in the atmosphere already is taken into consideration in the climate and economic models used to quantify the social cost of CO_2. Therefore, compounding the monetized impacts accrued on yearly basis would be considered double counting and inaccurate.

Water and Waste Treatment Practices in Oil and Gas: Current Practices, Technologies, and Opportunities for Improvement

Laura Capper (CAP Resources) presented an overview of the complexity of low-cost treatment of oil and gas water, current water management and treatment practices in the industry, and trends and potential implications. Presentation slides are provided in Attachment 11.

- Complexity
  Laura described the complexities associated with the low-cost treatment of oil and gas water, including the variances in water quality, the reasons for that variance, fluctuating conditions, and technical challenges. Water basins are unique in terms of salinity, bacteria, and geologic strata. As such, mass volume efficiencies must be customized to basin requirements, which is more expensive. Additional complexities are unpredictable drought conditions and the increase of total dissolved solids levels in the first year of production.

- Current Water Management and Treatment Practices
  Laura reviewed three water management techniques (i.e., hold-by-production drilling and experimentation, exploitation and optimization, and mature field operation) and highlighted locations in the U.S. Central Rockies where current management systems are strained. Currently, treatment involves multiple technologies such as chemical precipitation, nanofiltration, and electrocoagulation.

- Trends and Implications
  When mobile versus fixed facility implementations were compared, water hauling accounted for 72% of water market spending in 2014. Attachment 11 provides details and statistics about the effect of water hauling on spend, as well as environmental, health, and safety issues. Laura discussed how mobility in field operations, such as informed mobile dispatch and real-time field data collection and connectivity with headquarters, can result in fewer trucking hours. Fewer trucking hours, in turn, results in lower costs and liability reduction as well as improved environmental, health, and safety (e.g., emissions, traffic-related risk to public).

After the presentation, participants asked questions about radioisotopes and concentrated residuals. Laura explained that the presence of Naturally Occurring Radioisotopes (NORM) is not generally an issue. However, the presence of high levels of radioisotopes become an issue when copious amounts of water are flowing through one flow line or vessel over long periods of time (i.e., years) and radioisotopes build up. Systems need to be designed to avoid this buildup because when it occurs, it is difficult and costly to remove and the waste is considered hazardous. Concentrated streams from water treatment are typically disposed of in a disposal well or a landfill. Some systems separate waste streams in the concentrate so that the concentrated residuals can be recovered and sold.

Management Strategies to Achieve Remedy Complete when Groundwater Concentrations Fluctuate with Water Table Changes and Drought Conditions

Matt Alexander (Leidos) presented management approaches to achieve remedy complete (i.e., the termination of active remediation or monitored natural attenuation) when groundwater concentrations fluctuate with water table changes and drought conditions. When concentrations have approached cleanup levels but have continued to fluctuate above and below the cleanup values for an extended period of time, the following challenges arise: the date for attainment of cleanup objective becomes unclear, the long-term monitoring period becomes much longer, and program funding becomes insufficient because of inaccurately forecasted site closure. Matt presented conceptual site model results at sample sites to demonstrate that climate variations and subsequent subsurface effects are the likely cause for these groundwater contaminant fluctuations. He believes that innovative strategies are needed to counteract the uncertainties in groundwater concentrations created by climate effects. As such, Matt presented the pros and cons of the following approaches developed to mitigate the effects of fluctuating concentrations:

- Implement in situ treatment strategically for maximum effect.
- Temporarily and artificially enhance vadose or smear zone leaching to exhaust contamination as quickly as possible.
- Modify the site regulatory approach to lessen the impact of the fluctuating concentrations.

Matt ended his presentation by describing a few of the challenges associated with implementing these approaches at applicable sites, including stakeholder understanding of the impact of concentration fluctuations, project cycles and budget limitations, and the unpredictable duration of drought and non-drought conditions. Presentation slides are provided in Attachment 12.

Questions after the presentation focused on the selection of oxidants for a particular case study presented. Matt said that longer surviving oxidants such as potassium permanganate and persulfate are selected for injection at sites located in areas where the water table remains submerged.

Green and Sustainable Sediment Remediation and Evaluating Sediment Sites Using SiteWise™ Version 3.1

Sam Moore (Battelle) provided an overview of the tool SiteWise™ and highlighted the recent revisions made to the tool to incorporate aspects associated with contaminated sediment remediation. SiteWise™ is a Microsoft® Excel-based tool that incorporates green and sustainable remediation into the remedial decision-making process by quantifying the environmental impact of remediation activities. The revised Version 3.1 tool, includes environmental footprint factors that consider primary, secondary, and even tertiary sustainability impacts. In addition, the new version includes modules that relate directly to sediment-related remediation approaches, including dredging (mechanical and hydraulic), capping, and monitored natural recovery. Off-loading operations (i.e., the movement of sediment from the scows/barges to on-shore facilities) are accounted for within the Sediment Management module, which includes various earthwork equipment and crane operations that may be required to support landside management of dredged sediment. Sam told participants about the Naval Facilities Engineering Command (NAVFAC) Engineering and Expeditionary Warfare Center's document entitled *Sustainable Sediment Remediation* (Technical Report TR-NAVFAC EXWC-EV-1515). This document is available online and provides case studies that demonstrate the application of SiteWise™ Version 3.1 at Department of Navy sediment sites.

A case study was presented in which the new version of SiteWise™ was used to re-perform a green and sustainable remediation evaluation for sediment remediation in open water sites at Bishop Point, Pearl Harbor. Although natural recovery potential was considered high, dredging was selected after the first evaluation because of the moderate risk of re-contamination during maintenance dredging and due to the instability of sediment slopes near the pier. One alternative was evaluated that included focused dredging in areas with high risk of re-contamination combined with monitored natural recovery across the remainder of the site. Evaluation results were used to highlight best management practices for various sediment remedial approaches.

Sam ended his presentation by telling participants that SiteWise™ should be used as an iterative tool to explore impacts of activities and identify where sustainable options would be most effective. Many ancillary activities are included automatically in new modules, leaving it up to the user's discretion to accept default inclusions or to edit as necessary (e.g., research vessel operation during dredging or capping). Presentation slides are provided in Attachment 13.

After the presentation, participants asked specific questions about the updated tool's functionality. During this discussion, some participants suggested the following:

- When remediation is complete at the Bishop Point site, compare post-remediation data to the model to determine the accuracy of the default assumptions included in the calculations of the tool.
- Develop a way to account for the risk of leaving the sediment contamination in place.
- Include new information for reactive caps that use generic impact categories to more accurately determine impact of materials use in advanced capping applications.

Participants discussed the lack of updating occurring with available tools (e.g., AFCEE's Sustainable Remediation Tool) and which tools regulators prefer. SiteWise™ includes worker safety and new qualitative elements for ecological and community impacts. SEFA (Spreadsheets for Environmental Footprint Analysis) estimates or quantifies environmental footprints and their associated metrics.

Integrating Sustainable Metrics into Remedial Decision Making

Erin Healy and Mark Meyers (both of Anchor QEA) provided an overview of the benefits of integrating triple bottom line elements in remediation, presented an approach and analytic framework to integrate these elements into the remedial-decision making process, and provided examples of the framework's application. Presentation slides are provided in Attachment 14.

- Sustainable Remediation Overview
  Mark provided an overview of the difference between sustainable and green remediation. He defined a sustainable remediation approach as one that integrates sustainability goals into the remedial management decision making, along with the more traditional use of risk-based remediation goals. Green remediation focuses on reducing the environmental footprint of the selected remedial alternative. Mark presented the improved outcomes resulting from remediation sustainability evaluations, such as promoting net beneficial outcomes.

- Approach and Analytic Framework
  Erin presented the approach and analytic framework, which was developed to provide an additional basis for remedial decision making. The approach does not consider the cost of the remedy, and the framework is designed to provide flexibility in how each metric is evaluated. Using the framework, metrics are developed, assessed, and scored. A set of factors are developed for each metric that can be evaluated for the potential to change during and after the remedy. The magnitude of change in each metric for each remedial alternative are assessed through professional judgment, quantitation, and monetization. The metrics are assessed in three phases (i.e., current condition, during and after the remedy) and the change between phases is evaluated.

- Ecosystem Example
  Erin demonstrated how the approach and framework were used for an example site with an impacted, modified tidal creek system. At this hypothetical site, two remedies were considered: (1) removing six feet of contaminated sediment; and (2) removing sediment in the bioavailable layer, removing culverts, and softening the shoreline. A wide range of sustainability factors were assessed, including ecosystem function, resource use (water and energy), social and cultural resources and values, climate change (carbon footprint and adaptation), and economic benefits. The second remedy was selected so that the creek could be restored as a floodplain and wetland. Details are provided in Attachment 14.

After the presentation, Erin and Mark fielded questions from participants. The presenters emphasized the importance of being creative when containing and isolating contaminants (as demonstrated by the example). Numerous established sources (e.g., rapid assessment protocol, ASTM standards, ITRC documents) were reviewed and served as the foundation of the assessment.

Assessing the Resilience and Adaptability of Phytoremediation and Enhanced In Situ Bioremediation (EISB) under Global Climate Change

Deyi Hou (Parsons) presented a study that explores the effects of sea level rise and changing hydroclimatic conditions on the life-cycle impacts of phytoremediation and enhanced in situ bioremediation systems. The objective of the study was two-fold: (1) compare the life-cycle impacts of EISB and phytoremediation in the remediation of PCE plumes, and (2) evaluate the resilience of EISB and phytoremediation to climate change. The sites were hypothetical and located in the San Francisco Bay area. Future changes related to sea level rise and local hydroclimatic change were modeled. Deyi described the inventory challenges associated with the LCA, specifically methane emissions and the carbon dioxide storage during phytoremediation. Study results emphasize the importance of both sea water intrusion and hydraulic gradient, indicate that phytoremediation is particularly vulnerable to sea level rise, and show that a constant upgradient water head nearby mitigates detrimental effects. Hydroclimatic conditions have insignificant effects because effects of increasing precipitation cancels out effects of increasing temperature. Presentation slides are provided in Attachment 15.

Sustainability of In Situ Stabilization (ISS) Projects

Paul Lear (Envirocon) presented an overview of the ISS technology, sustainable best management practices (BMPs) that can be incorporated during technology implementation, and a case study at a former gasification plant site in Florida. Presentation slides are provided in Attachment 16.

- Technology Overview
  ISS is the mixing of impacted soils with reagents (e.g., Portland cement and/or slag) to

reduce the leachability of contaminants while decreasing the permeability of the stabilized materials. ISS can be implemented using auger- or excavator-based soil mixing approaches. Paul reviewed the typical equipment and work sequence for both of these approaches.

- BMPs
  Paul discussed the following BMPs that can be incorporated while performing ISS projects: (1) minimizing total energy use by using alternate reagents instead of cement; (2) maximizing renewable energy use by using solar-powered backups for the perimeter air monitoring system; (3) minimizing air pollutants and greenhouse gas emissions by using biodegradable foam suppressants and machinery equipped with advanced emission controls; (4) minimizing water use and water resources impacts by collecting and reusing decontamination, storm water, and treated wastewater in the reagent batch grout plant; (5) reusing materials and reducing materials and waste through concrete recycling and tree/stump mulching; and (6) using local labor and supplies by hiring local skilled and general laborers and buying materials from local vendors.

- Case Study
  At a former gasification plant site and adjacent areas in Sanford, Florida, soil remediation activities included demolishing three abandoned structures; excavating 20,000 cubic yards of soil; treating 142,000 cubic yards of saturated soils using ISS; relocating utilities; installing 1,000 feet of culverts; and improving 450 feet of open channel in a creek. By substituting ground-granulated blast-furnace slag for 80% of the cement, the carbon footprint was reduced by 62%. Approximately 3.7 million gallons of decontamination, storm water, and treated wastewater was reused in the batch plant. In addition, solar-powered backups were employed for perimeter air monitoring, concrete was reused for riprap, trees and stumps were ground into mulch, 12 individuals were hired locally, and $8 million of the purchases for the project were obtained from local vendors.

Paul ended his presentation by emphasizing that sustainability BMPs are applicable for ISS projects, especially related to the substitution of alternative reagents for Portland cement.

Attachment 1

SURF 30 Participant Contact Information

SURF 30 Participant Contact Information

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SURF 30 Participant Contact Information

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Attachment 2

Why SURF?

WHY is SURF?

- Remediation projects create pollution in the process of site cleanup
  - Imperative to minimize cross-media impacts
- Cleanup goals unaligned with achievable objectives
  - Restoration is an commendable goal, but at what cost?
- Incorporate sustainability into remediation projects and practices
  - By considering environmental, economic, and social impacts, as well as benefits, find the optimal intersection of site cleanup and reuse options

What

SURF's mission it to maximize the overall environmental, societal, and economic benefits from the site cleanup process by:

- Advancing the science and application of sustainable remediation
- Developing best practices
- Exchanging professional knowledge
- Providing education and outreach

How

Remarkable portfolio of accomplishments:

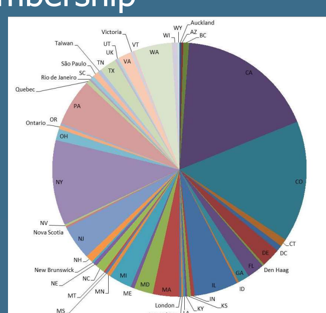
- 501(c)3 status since 2010
- Meetings and webinars (30+)
- Publications: guidance, white papers, case studies
- Technical initiatives
- GSR conference tracks
- Student chapters
- Peer mentoring
- Constructive dialogue

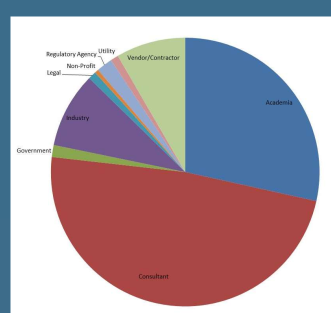
SURF
SUSTAINABLE REMEDIATION FORUM

Who

- Nine-member Board of Trustees

- Membership





- You

SURF
SUSTAINABLE REMEDIATION FORUM

What's next?

Continue to:

- be the premier network for exploring logical, holistic, and sustainable approaches in the remediation industry
- provide remediation professionals influence outside of their own organizations, permitting their participation in the continual improvement of their profession
- build and facilitate positive relationships amongst industry, regulators, academics, and consultants
- develop and deliver conferences and workshops of the highest technical quality

SURF
SUSTAINABLE REMEDIATION FORUM

What's next?

- Change the standard practice of remediation to incorporate the concept of sustainability
- Develop academic curriculum modules on the topic of sustainable remediation that focus on practical applications
- Develop a long-term strategy for:
  - attracting and engaging members
  - financial sustainability
  - organizational and industry growth
- Position ourselves as the leading professional membership association for licensed and emerging remediation professionals

SURF
SUSTAINABLE REMEDIATION FORUM

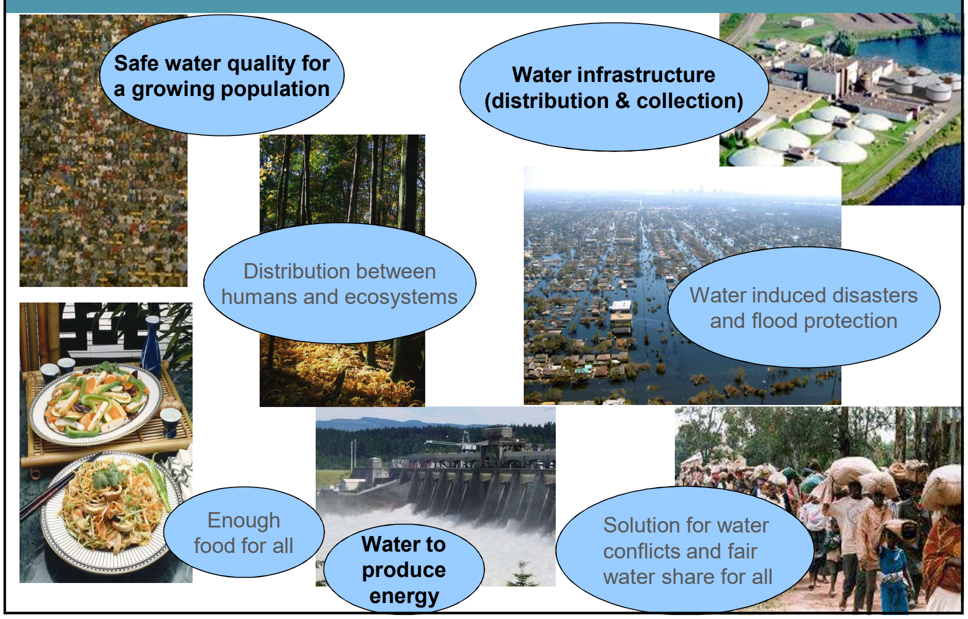
Attachment 3
Emerging Opportunities of Nanotechnology

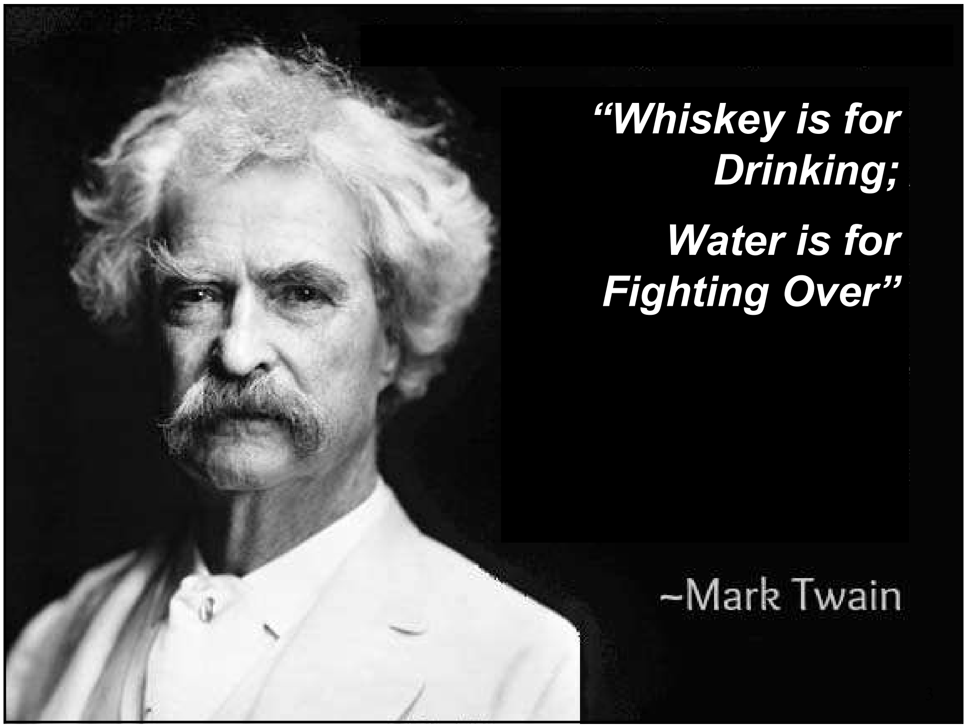
Emerging Opportunities of Nanotechnology to Address Growing Challenges of the Water-Energy Nexus

Pedro J.J. Alvarez
SURF Workshop, 6 October 2015

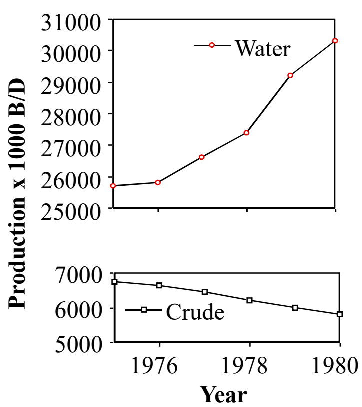
RICE
Unconventional Wisdom

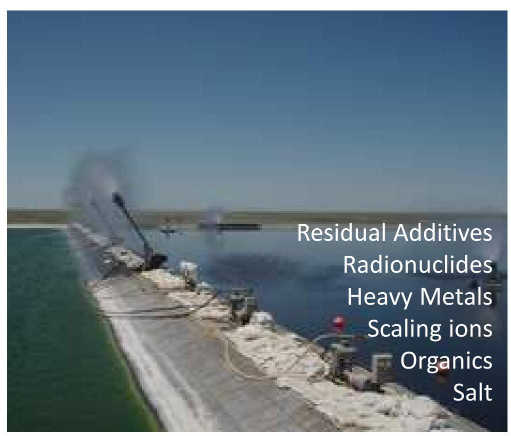
7 Grand Challenges Related to Water





Importance of Water for Energy Production

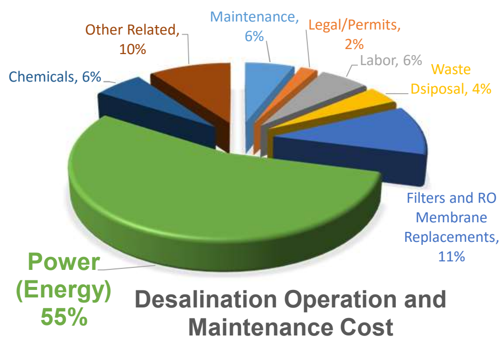




Water is by far the largest byproduct of the fossil fuel industry
Water/Oil Ratio = 10 (US), 14 (Can.) **$1 trillion/yr challenge***

*http://www.twdb.state.tx.us/Desalination/TheFutureofDesalinationinTexas-Volume2/documents/B3.pdf

Energy for Water Treatment & Distribution



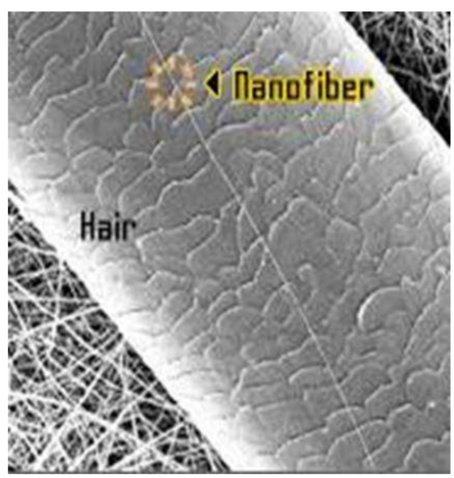
20% of energy use in cities is for moving water[1]
Desalination and wastewater reuse is very energy-intensive[2]

1. Electric Power Research Institute, Inc. Water & Sustainability (Volume 4): U.S. Electricity Consumption for Water Supply & Treatment –The Next Half Century. **2002**.
2. Water Reuse Association, Seawater desalination cost, January 2012

Nano = Dwarf (Greek) = 10^{-9}

"Nanotechnology is the understanding and control of matter at dimensions of roughly 1 to 100 nanometers, where unique phenomena enable novel applications."

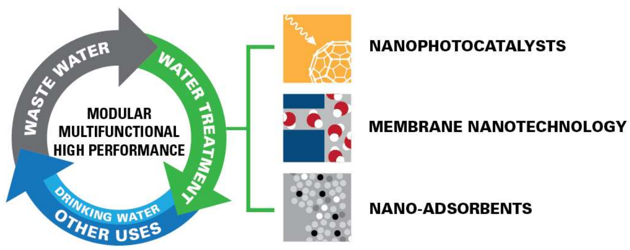
-National Nanotechnology Initiative



Why Nano?

Leap-frogging opportunities to:

- Develop high-performance multifunctional materials and systems that are easy to deploy, can tap unconventional water sources, and reduce the cost of remote water treatment
- Transform predominantly chemical treatment processes into modular and more efficient catalytic and physical processes that exploit the solar spectrum and generate less waste



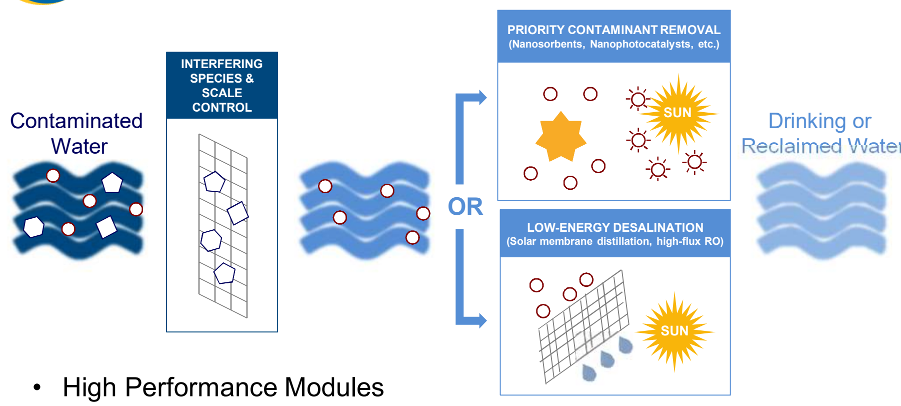
7

Opportunities for Engineered Nanomaterials (ENMs) in Water Treatment and Reuse

ENM Properties	***Examples of Enabled Technologies***
Large surface area to volume ratio	Superior **sorbents** (e.g., nanomagnetite or graphene oxides to remove heavy metals and radionuclides)
Enhanced catalytic properties	Hyper**catalysts** for advanced oxidation (TiO_2 & fullerene-based photocatalysts) & reduction processes (Pd/Au)
Antimicrobial properties	Disinfection and **biofouling control** without harmful byproducts
Multi-functionality (antibiotic, catalytic)	Fouling-resistant (self-cleaning and self-repairing) filtration **membranes** that operate with less energy
Self-assembly on surfaces	Surface structures and **nanopatterns** that decrease bacterial adhesion, biofouling, and corrosion
High conductivity	Novel **electrodes** for capacitive deionization (electro-sorption) and energy-efficient desalination
Fluorescence	Sensitive **sensors** to detect pathogens, priority pollutants

Modular Treatment Systems

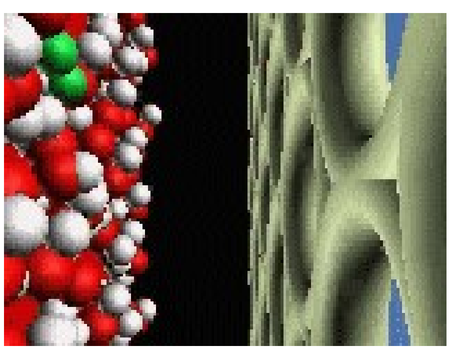
Match treated water quality to intended use

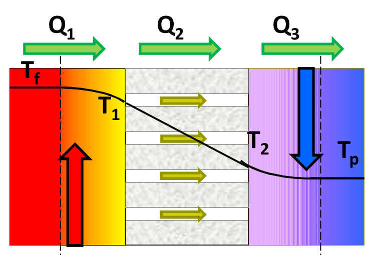


- High Performance Modules
- Lower Chemical Consumption
- Lower Electrical Energy Requirements
- Less Waste Residuals
- Flexible and Adaptive to Varying Source Waters

9

Example: Enhancing Membrane Distillation





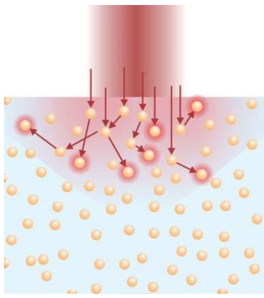
Temperature polarization:

$$\alpha = \frac{T_1 - T_2}{T_f - T_p}$$

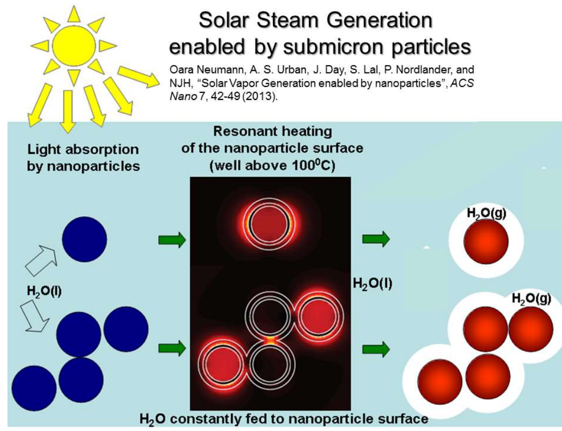
Can reduce transmembrane temperature gradient by up to 70%

www.desalination.biz

Photonics of Nanoparticles for Solar-Thermal Applications

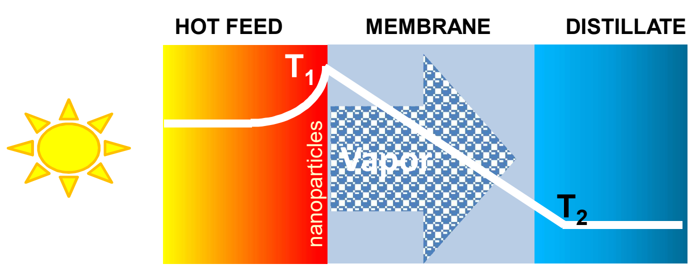


Light localization by multiple scattering confines solar energy, enabling high efficiency heat transfer
(Hogan et al., *Nano Lett.* **2014**, *14*, 4640-4645)



Enabling Technology

Direct solar membrane distillation for low-energy desalination

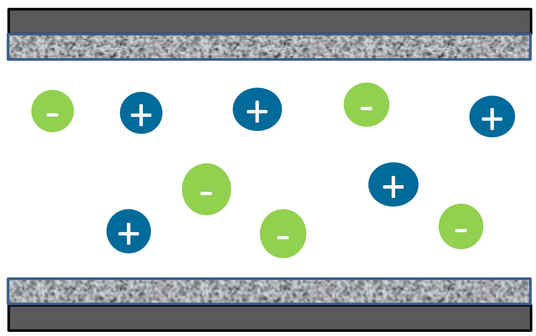


Higher T gradient = higher flux

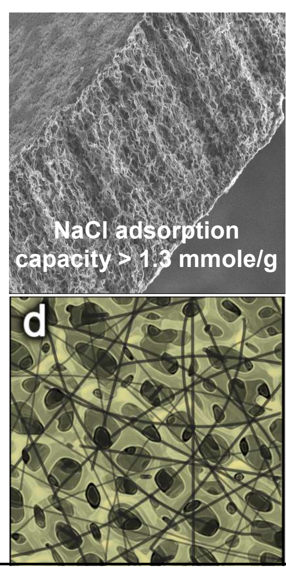
Multifunctional membranes: Fouling-resistant, High-flux Self-cleaning

Enabling Technology
Electrosorption for Scaling Control

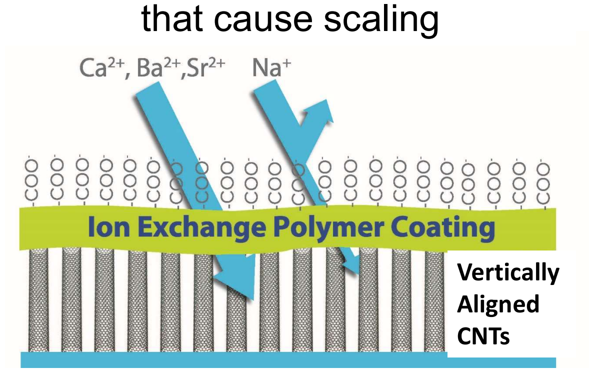
Nanocomposite electrodes to remove multivalent ions from brines, and generate smaller waste streams



Nano-Enabled CDI for Scaling Control



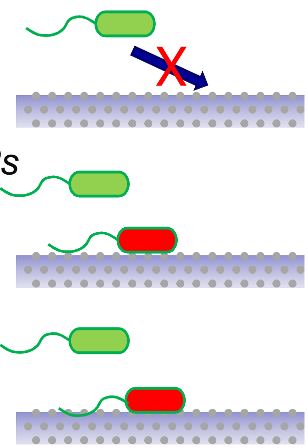
IX polymers enable preferential removal of divalent cations that cause scaling



CNTs/graphene enhance sorption capacity, kinetics, mechanical strength and electrical conductivity.

Nanotechnology for Biofouling Control

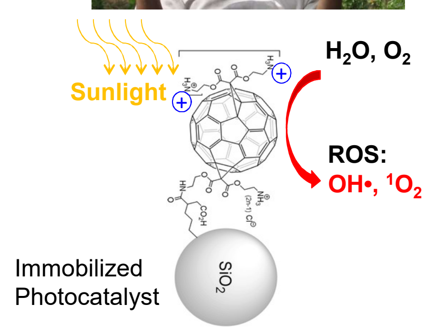
- *Discourage adhesion*
  - Nano-patterned topology
  - Surface chemistry
  - Interrupt quorum sensing
- *Incorporate antimicrobial NPs*
  - Nano silver
  - Carbon nanotubes
  - Porous nano-carriers
- *Photocatalytic ROS*
  - Semiconductors, e.g., TiO_2
  - Fullerene derivatives (self-cleaning surfaces)



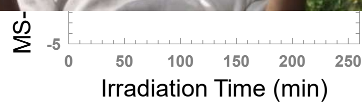
Enabling Technology

(Photo)Disinfection & Advanced Oxidation

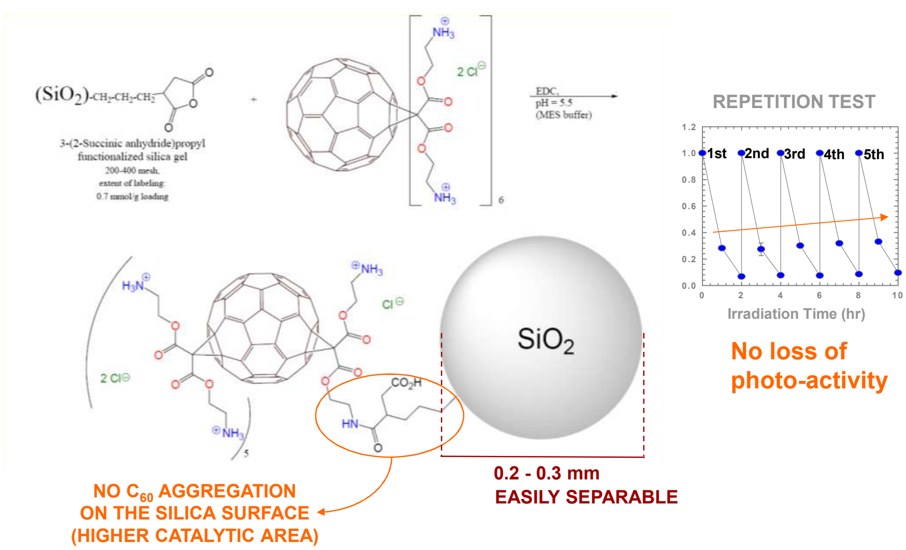
Nano(photo)catalysts that use solar radiation to generate ROS that destroy resistant microbes and recalcitrant pollutants without generating harmful disinfection byproducts



Advantages of Amino-C_{60} as Photocatalytic Disinfectant



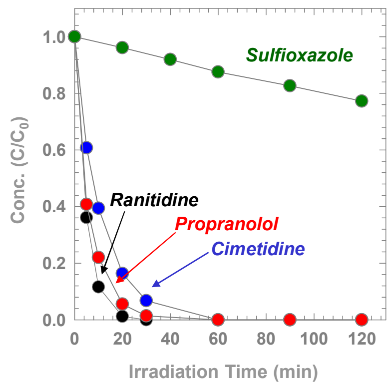
Immobilization of aminofullerene onto silica beads facilitates separation, reuse and recycling



Lee, Mackeyev, Cho, Wilson, Kim and Alvarez (2010). *Environ. Sci. Technol.*44: 9488–9495.

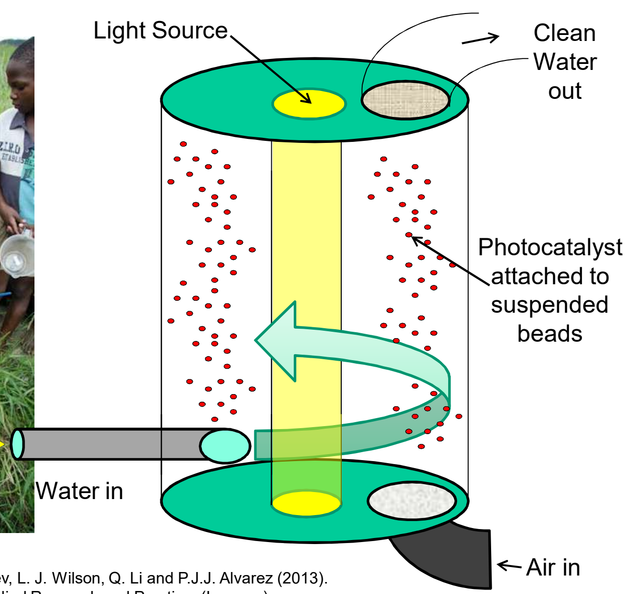
Collateral Benefit:

Photocatalytic degradation of emerging pollutants (pharmaceuticals, endocrine disruptors) to *polish* effluents from wastewater treatment plants



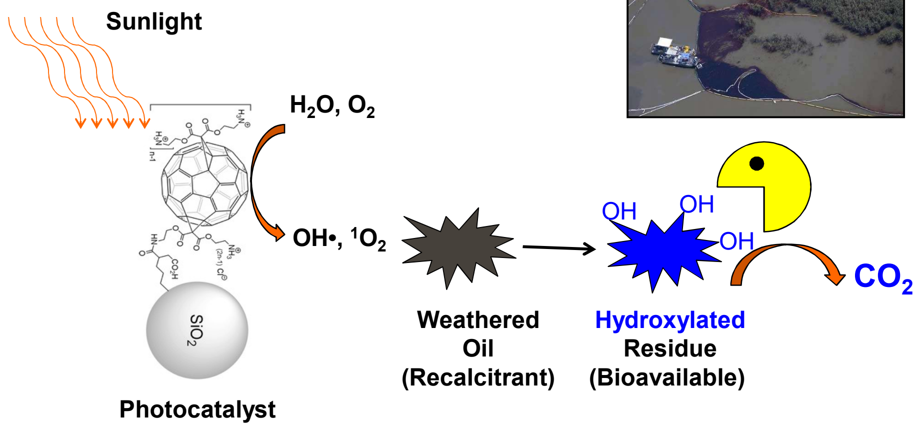
Lee J., S. Hong, Y. Mackeyev, C. Lee, L.J. Wilson, J-H Kim and P.J.J. Alvarez (2011). Environ. Sci. Technol. *45*: 10598–10604.

Fluidized Bed Photocatalytic Reactor

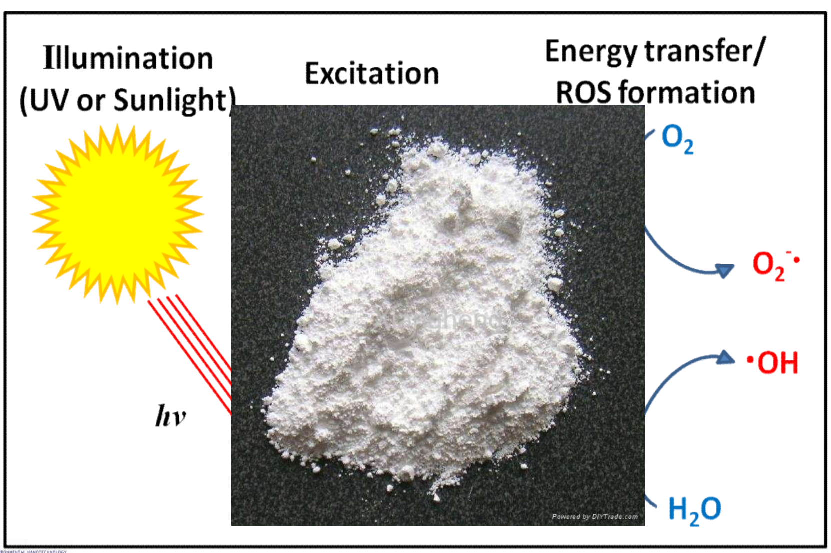


Brame J., V. Fattori, R. Clarke, Y. Mackeyev, L. J. Wilson, Q. Li and P.J.J. Alvarez (2013). Environmental Engineer and Scientist: Applied Research and Practice. (In press).

Photocatalytic *Pre-treatment* of Weathered Oil to Enhance Bioavailability and Bioremediation

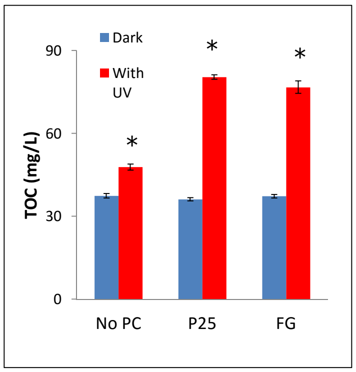


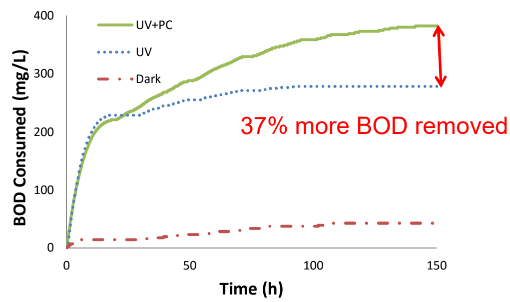
Photocatalysis with Food-Grade TiO_2



CBEN

Photocatalysis Increased Solubilization and Biodegradation of Weathered Oil



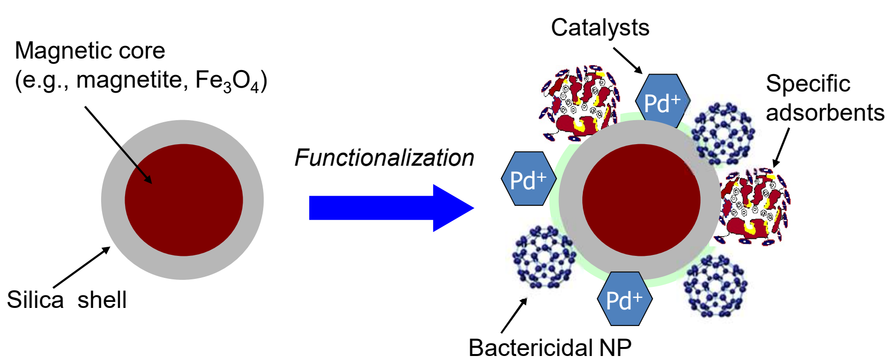


* statistically significant (p <0.05) after 1-day exposure

Brame J., S.W. Hong, J. Lee and P.J.J. Alvarez (2013). *Chemosphere* 90: 2315–2319.

Enabling Technology
Multifunctional nanosorbents

Selective removal of target contaminants by functionalized nanoparticles supported in macroscale structures or subject to (low-energy) magnetic separation for enhanced removal kinetics & reuse



Safer Use of ENMs

Risk = Hazard x Exposure

Hazard

- Prioritize use of ENMs of benign, low-cost, and earth-abundant compositions (GRAS); Green Chemistry and Green Engineering
- Experts panel to select ENMs before incorporation into products
- Interface with TSCA in the US and REACH in the EU

Exposure

- Immobilize ENMs to minimize release and exposure and enable reuse (no free NPs)
- Model & monitor treated water for leaching
- Foster safety in manufacturing by iterating with OSHA on best practices
- Independent certification for meeting health & safety stds.

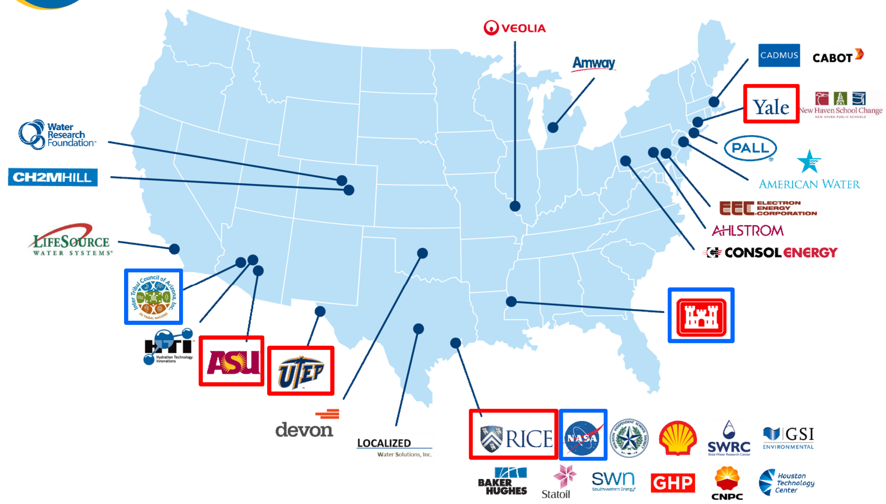
SUMMARY OF APPLICATIONS

- Low-energy desalination by nanophotonic MD or electrosorption
- DBP-free disinfection
- Advanced (photo)oxidation
- Selective nano-sorbents
- Multi-functional membranes
- Fouling- & corrosion-resistant surfaces

"People don't know what they want until you show it to them"

– Steve Jobs

Some of Our NEWT Partners

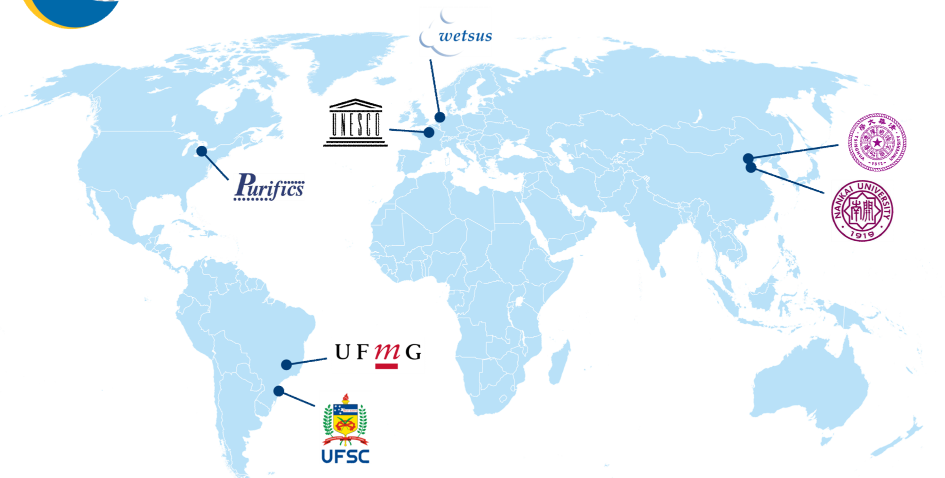


- Innovation across value chain (nanomaterial and equipment manufacturers, service providers, R&D and deployment partners, and users)

NEWT is Supported by Experienced Partners Across the Value Chain

Nanomaterial and advanced material manufacturers	EEC ELECTRON ENERGY CORPORATION, CABOT, HTI Hydration Technology Innovations, Purifics
Equipment manufacturers	AHLSTROM, Amway, LIFESOURCE WATER SYSTEMS, PALL
Research, development and deployment partners	NASA, NSF, CADMUS, GHP, Houston Technology Center, UNESCO, Water Research Foundation, wetsus
Service providers	AMERICAN WATER, BAKER HUGHES, CH2MHILL, GSI ENVIRONMENTAL, LOCALIZED Water Solutions, Inc., SWRC Shale Water Research Center, VEOLIA
End users	CNPC, CONSOL ENERGY, devon, swn Southwestern Energy, Statoil, Inter Tribal Council of Arizona, Inc.

International Partners



- Co-development and production of advanced multifunctional materials
- Globally-relevant research and education experiences for students
- Testbed sites for applications in fast-growing water markets

Nanosystems Engineering Research Center for

Nanotechnology-Enabled Water Treatment

NEWT

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www.newtcenter.org

NSF RICE ASU UTEP Yale

CONCLUSIONS

- Nanotechnology has a great potential for enabling exploitation of a broader range of water sources (e.g., sea water, flowback-water, wastewater)
- Could help transform some infrastructure-, chemical- and energy-intensive treatment approaches towards catalytic & physical systems that obviate current tradeoffs between cost & performance, and between energy consumption & treatment rate

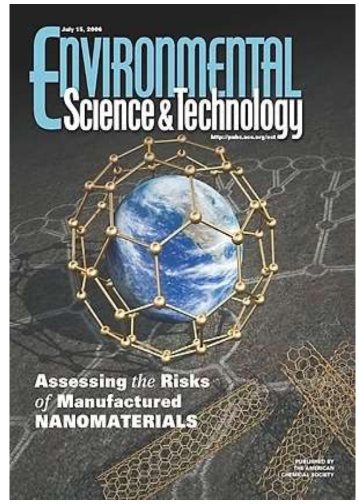


Plate-and-Frame Configuration

Thin, patterned transparent poly(methyl methacrylate) sheet serves simultaneously as the top plate of the module, the optical window and the spacer that forms the feed flow channels. Mount it on a solar tracker to maximize sunlight collection.

http://www.wassertech.net/content/view/34/29/lang,thai/

1) Need for Low-Energy Desalination

- High TDS represents a beneficial disposition challenge (discharge regulations)
- Multivalent cations (Ca^{2+}, Ba^{2+}, Sr^{2+}, Fe^{2+}/Fe^{3+}) interfere with performance of friction reducing polymers and also form scale (flow assurance)
- Naturally occurring radioactive materials
- Toxic inorganic contaminants (e.g., Zn^{2+})

Vision: Nano-Enabled Water Treatment & Reuse

"Nano" particles:

- High surface areas
- Hyper-catalytic functions
- Tunable physical properties
- Multifunctional membranes
- Faster kinetics

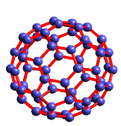
Transformative Technologies to

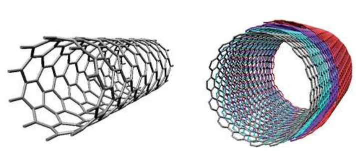
clean water, enhance water infrastructure, & enable integrated water management & reuse

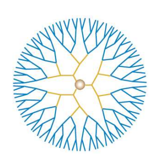
Enable high-performance water treatment and remediation systems with
(1) Less infrastructure,
(2) Less materials/reagents (selective targeting)
(3) Lower costs & energy

Unique Properties of Nanoscale Materials

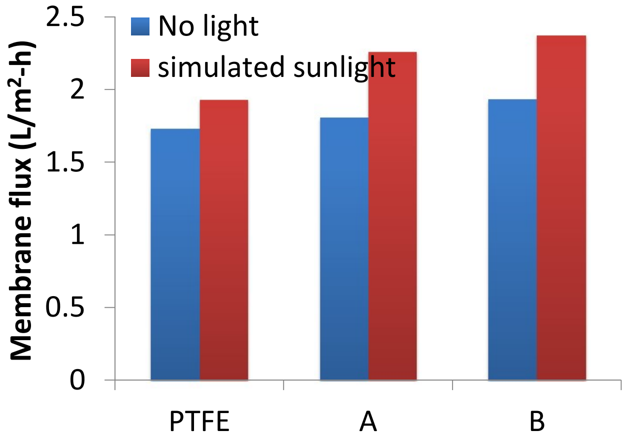
- Chemical reactivity greatly different from macroscopic forms; e.g., inert gold becomes catalytic, C changes from insulator to conductor
- High surface area per unit mass (>100 m^2/g)
- Quantum effects (dual behavior, wave- and particle-like) resulting in unique mechanical, electronic, photonic, and magnetic properties





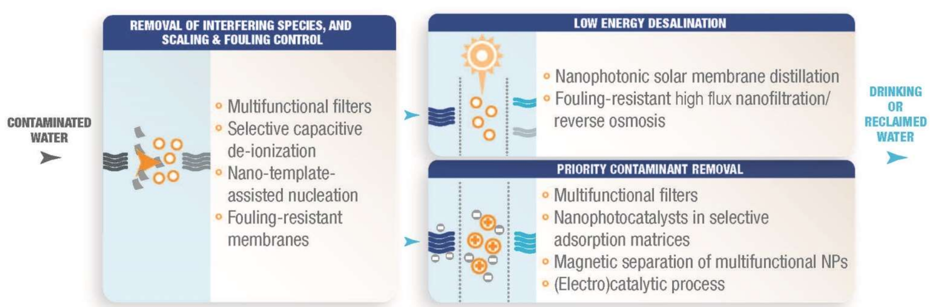


T_f = 30 °C, T_p = 20 ° C 10 g/L NaCl
1 sun unit

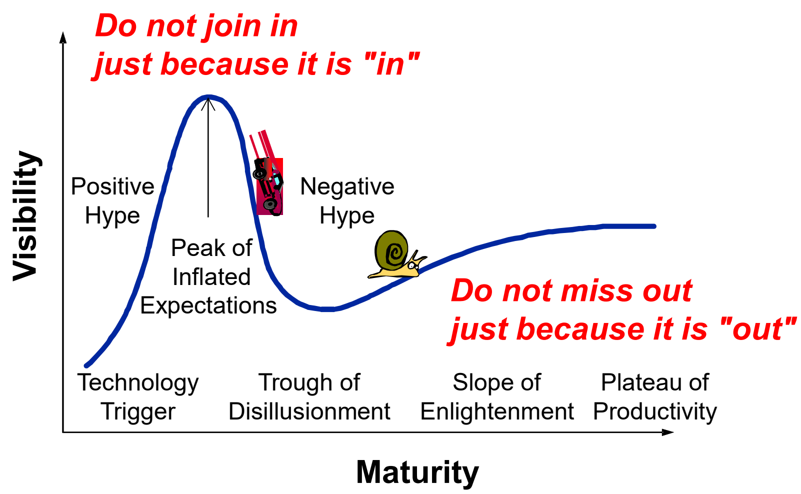


Advantages:
- Localized heating
- Reverse temperature polarization
- T_1 independent of module length

Portable Off-Grid Treatment Trains with Multiple Modular Options for Varying Source Water Quality and Treatment Goals

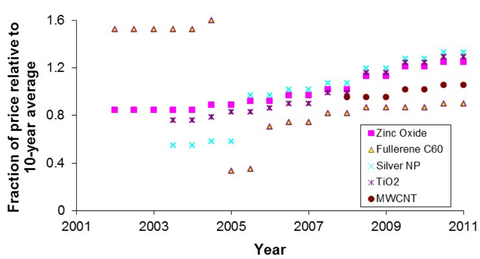


Beware of Technology Hypes

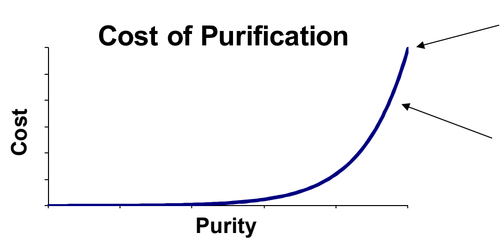


"Nanohype" - Berube

Need market-driven decrease ENM price



Few commercial applications
= low supply
→ prices stay high

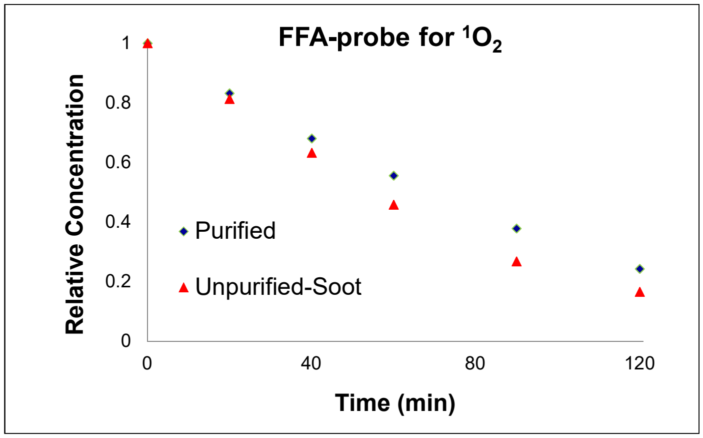


Most production is done for research (small quantities of highly purified material)

High purity requirements increase **separation cost** due to higher energy, solvent, & process time requirements

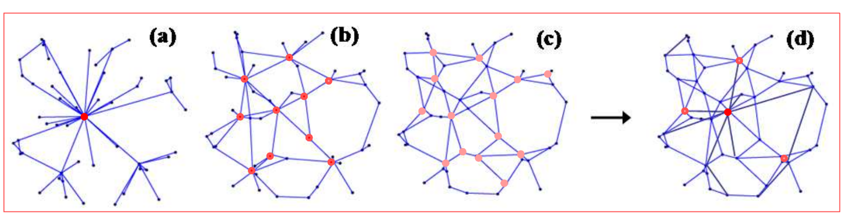
Avoid the diminishing returns of ultra high purity

Less pure amino-C_{60} cost less (20x) without significantly sacrificing reactivity



LOWER ENERGY FOOTPRINT OF WATER

- Innovative energy-efficient water treatment technologies
- Integration of novel materials to decrease headloss
- Alternatives to water for heat dissipation
- Decentralized water network topologies
  (HPC systems modeling)



RICE

Nano-Enabled Water Treatment & Reuse

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Transformative Technologies to

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Enable high-performance water treatment and remediation systems with
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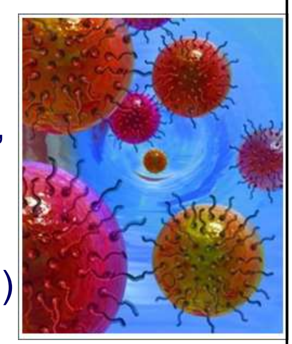
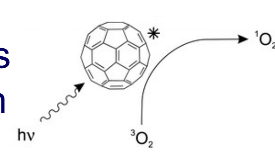
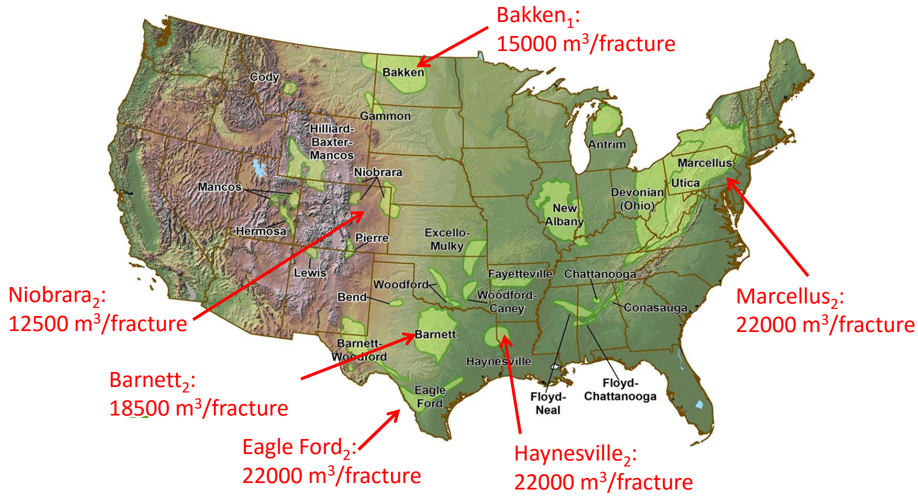
Nano-Enabled Water Treatment @ Rice



- Sand filter coated with nano-magnetite to remove As (pilot in Mexico, reported by BBC, NY Times, Forbes and CBC).
- Fouling-resistant membranes that also inactivate virus (nAg, nano-TiO_2)
- Pd/Au hypercatalysts to treat TCE (Pilot at Dupont site)
- Novel amino-fullerene photocatalysts to enhance UV and solar disinfection and advanced oxidation processes



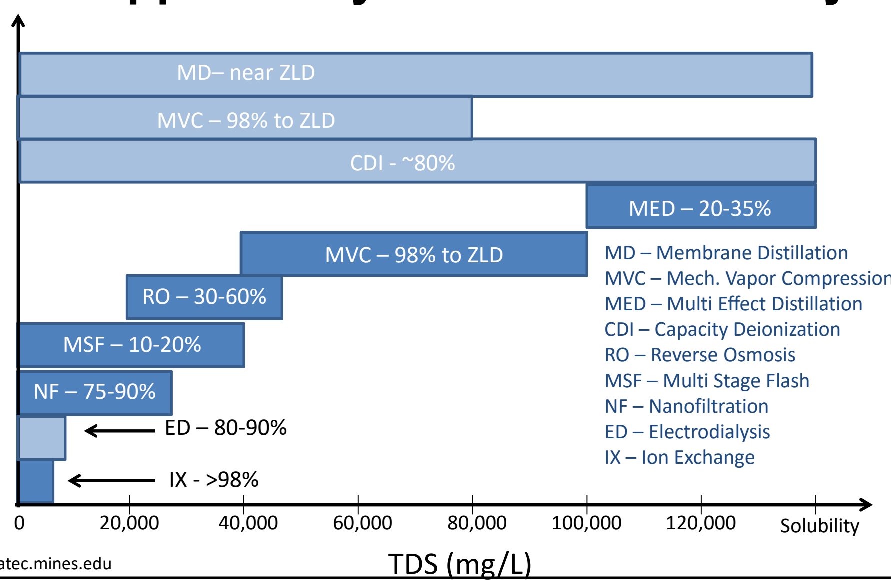
Hydraulic Fracturing Water Use



1: National Energy Technology Laboratory Winter 2011 Newsletter
2: EPA Hydraulic Fracturing Study Technical Workshop #4: Water Resource Management, March 2011

All-llc.com

Desalination Technologies: Applicability and Water Recovery



aqwatec.mines.edu

Responsible Nanotechnology

"With Great Power, Comes Great Responsibility"
Uncle Ben to Peter Parker in Spider Man

Paul Hermann Muller
Thomas Midgley

Attachment 4

Green and Sustainable Remediation Meets Climate Change Adaptation

AECOM

Green and Sustainable Remediation Meets Climate Change Adaptation

Or, "Nothing is sustainable, if it doesn't work … " D. Woodward

SURF 30 – Houston, Texas

(Paul) Brandt Butler, PhD PE
Director – Global Green and Sustainable Remediation Practice

Create. Enhance. Sustain.

October 6, 2015

Order of Presentation

- State of the Practice - Green and Sustainable Remediation
- Current Trends in Climate Change and Adaptation Strategy
- EPA Climate Change Adaptation Implementation Plan
- Path Forward

https://www.youtube.com/watch?feature=player_embedded&v=DJLDF6qZUX0

State of the Practice - Green and Sustainable Remediation (GSR)

Battelle 2015

- Tiered Frameworks are established employing Best Management Practices (BMPs) and Footprint Tools
  - ASTM – Greener Cleanups
  - ITRC – Green and Sustainable Remediation
- BMPs have been documented by many
- Footprint Tools are known and regularly updated
  - SRT 2.3 (November 2012)
  - SiteWise 3.1 added sediment remediation (May 2015)

Battelle 2015

- Provider-Developed Qualitative Tools
  - Environmental, Social and Economic outcomes
  - AqSRT
    - Multi-variable analysis
    - Local impacts, community value, redevelopment options
- Sustainable Return on Investment (SROI)

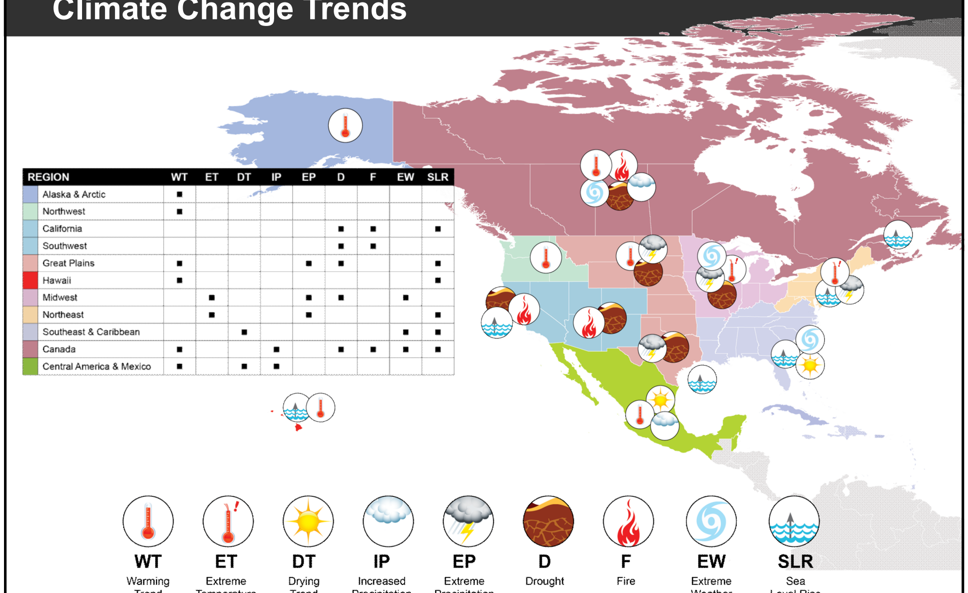
Sustainable Return on Investment – Green Roof

- Economic Benefits
  - Electricity savings
  - Natural gas savings
  - Avoided roof replacement cost

- Social and Environmental Benefits
  - Avoided water treatment costs (stormwater runoff)
  - Reduced GHG and CAP emissions (SO_2, NO_x, O_3 and PM_{10})

Summary		sROI	FROI
Life-cycle costs	$137,809	21%	10%

Climate Change Trends



REGION	WT	ET	DT	IP	EP	D	F	EW	SLR
Alaska & Arctic	■								
Northwest	■								
California						■	■		■
Southwest						■	■		
Great Plains	■				■	■			■
Hawaii	■								■
Midwest		■			■	■		■	
Northeast		■			■				■
Southeast & Caribbean			■					■	■
Canada	■			■		■	■	■	■
Central America & Mexico	■		■	■					

Information adapted from NCA (2013) and IPCC AR5 (2014)

Impacts, Affects and Drivers

Climate Impacts

Extreme Events

- Extreme storms, rainfall, wind and fires

Degradation of Materials

- Reduce asset life from change in ground movement, corrosion rates, structural fatigue and chemistry

Resource Availability and Demand

- Water (drought), energy (heatwaves) and viable agricultural (climate)

Longer Term Loss

- Sea level rise and coastal erosion

Affects and Drivers

Infrastructure

- Facilities
- Transportation
- Pipelines
- Long-term Remedial Actions

Operations

- Supply Chain
- Schedule

Employees

- Safety
- Access

Is climate adaptation relevant?

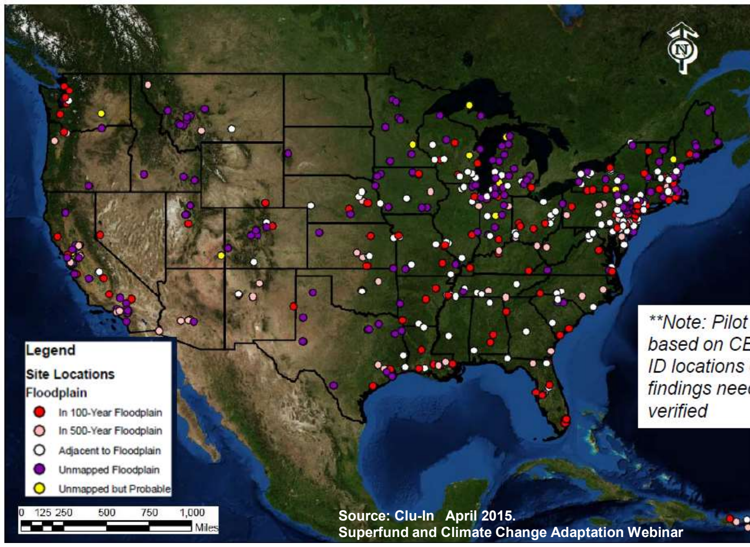
Consider:

- Risks of current and future extreme events on operations and physical assets
- Vulnerability of long life-span facilities (e.g. major infrastructure, remediation or investment projects)
- Effect of long-term changes in the climate (e.g. rainfall or temperature) on operations or assets?
- Extreme events and conditions are becoming more frequent – past doesn't predict future

EPA Climate Change Adaptation Plans

- Draft EPA Climate Change Adaptation Plan – June 2012
- OSWER CCA Implementation Plan – June 2014
  … while pursuing reductions in GHG emissions (mitigation),
  adapt to climate change that is already happening …
  - Vulnerability Assessment - focus on specific vulnerabilities
  - 26 priority actions for RCRA and Superfund
- Themes
  – How can we reduce GHG emissions?
  – How will climate change likely affect remedy protectiveness and what should be done about it?”

Superfund Sites Near or Within 100 & 500 year Floodplains



Anticipated Vulnerabilities

	Climate Change Scenarios							
Common Remedy Types*	**Flooding (Event)**	**Inundation (Chronic)**	**Extreme Storms**	**Large Snowfall**	**Wild Fires**	**Drought**	**Extreme Heat**	**Landslide (Precip)**
Source In Situ								
SVE								
Solidification/Stabilization*								
In Situ Thermal Treatment								
Multi-phase Extraction								
Bioremediation								
Source Ex Situ								
Solidification/Stabilization*								
Physical Separation								
Recycling								
Surface Water Treatment								
Unspecified Off Site Treatment								
On-site Containment								
Groundwater In Situ								
Bioremediation								
Chemical Treatment								
Air Sparging								
Permeable Reactive Barrier								
Groundwater Ex Situ								
P&T								
Vertical Engineered Barrier								
Monitored Natural Attenuation								

Source: Clu-In April 2015. Superfund and Climate Change Adaptation Webinar

Remedy Types and Zones of Susceptibility

Remedy Types	Combined Zones of Susceptibility				
	100-year FLP and 1 m SLR	100-year FLP and 1 – 1.5 m SLR	500- year FLP and 1 m SLR	500-year FLP and 1 – 1.5 m SLR	Total
On-Site Disposal Only	0	0	2	0	2
On-Site Containment Only	4	0	3	1	8
GW P&T	0	1	0	0	1
On-Site Disposal and GW P&T	0	1	0	0	1
Landfill and On-Site Containment	3	0	0	0	3
GW P&T and On-Site Containment	4	0	2	0	6
On-Site Disposal, GW P&T, and On-Site Containment	1	0	2	0	3
TOTAL	12	2	9	1	24

Source: Clu-In April 2015. Superfund and Climate Change Adaptation Webinar

5 Site Desktop Review

- No sites have no-low vulnerabilities to climate change scenarios
- Vulnerabilities are often identified early and factored into the remedy selection, design and operations
- Some sites considered vulnerable (by the project team) had O&M plans, for example to address flooding
- Sites used historic flood data for future analyses
- For long term remedial actions, five year reviews offer an opportunity to consider potential CCA needs

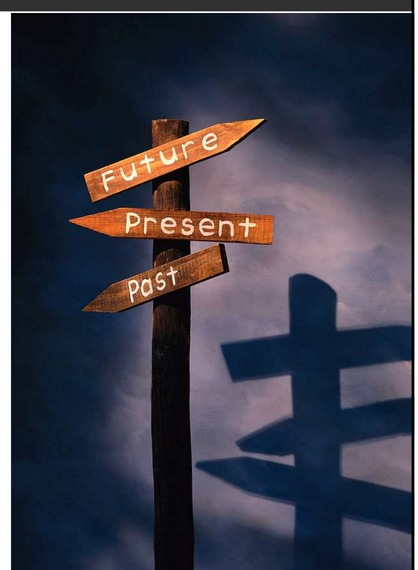
OSWER Framework for CCA Implementation Plans

1. Screen remedies for vulnerabilities
2. Conduct sensitivity analysis to screen out low probability/low impact vulnerabilities
3. Evaluate adaptation measures available and applicable to address vulnerabilities and improve resilience
4. Implement adaptation measures

Risks to Site Remediation

50 years will be here before we know it …

- Landfills - High number of remedies and contaminants remaining on site could be mobilized. Berm stability.
- Groundwater treatment systems - High infrastructure cost, presence of physical plant, long operating life and high number of remedies. Loss of containment.
- Wetlands – Replacement or restorative value lost

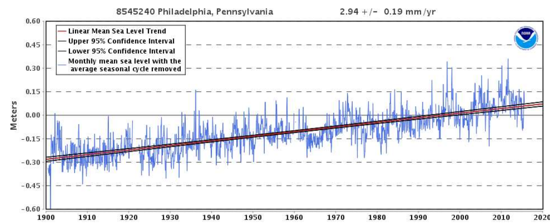


Opportunities for Mitigation and Adaptation in Remediation

- Mitigation for Reduced Emissions
  - GSR during remedial selection, design and construction
  - GSR during O&M
    - Baseline emissions assessment
    - Remedial Process Optimization (RPO)
- Adaptation for Increased Resiliency
  - Tiered screening of facilities for vulnerability ranking
  - Detailed assessment of a highly-vulnerable facilities

Climate Change Adaptation – Tier 1: Existing Tools

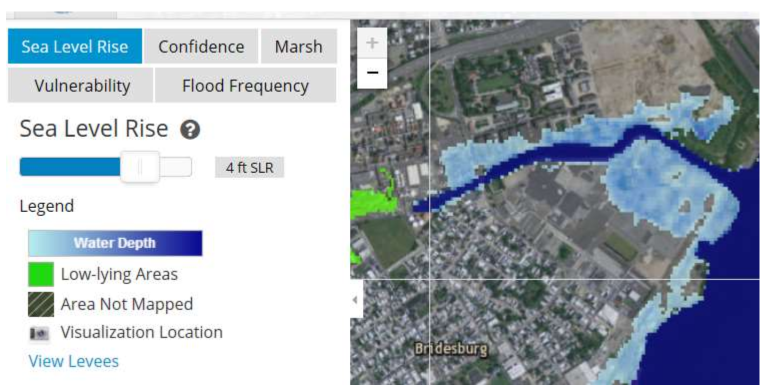
- NOAA – Sea Level Trends
  - http://tidesandcurrents.noaa.gov/sltrends



- FEMA - 100 and 500 year Flood Maps

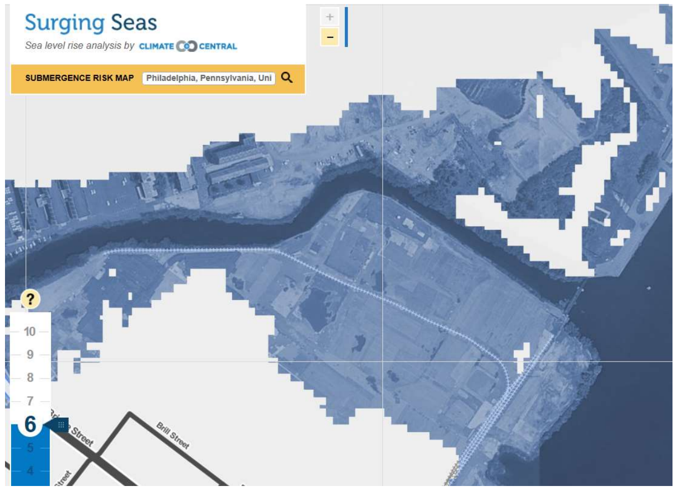
Climate Change Adaptation – Tier 1: Existing Tools

- NOAA - Sea Level Rise
  http://coast.noaa.gov/slr/



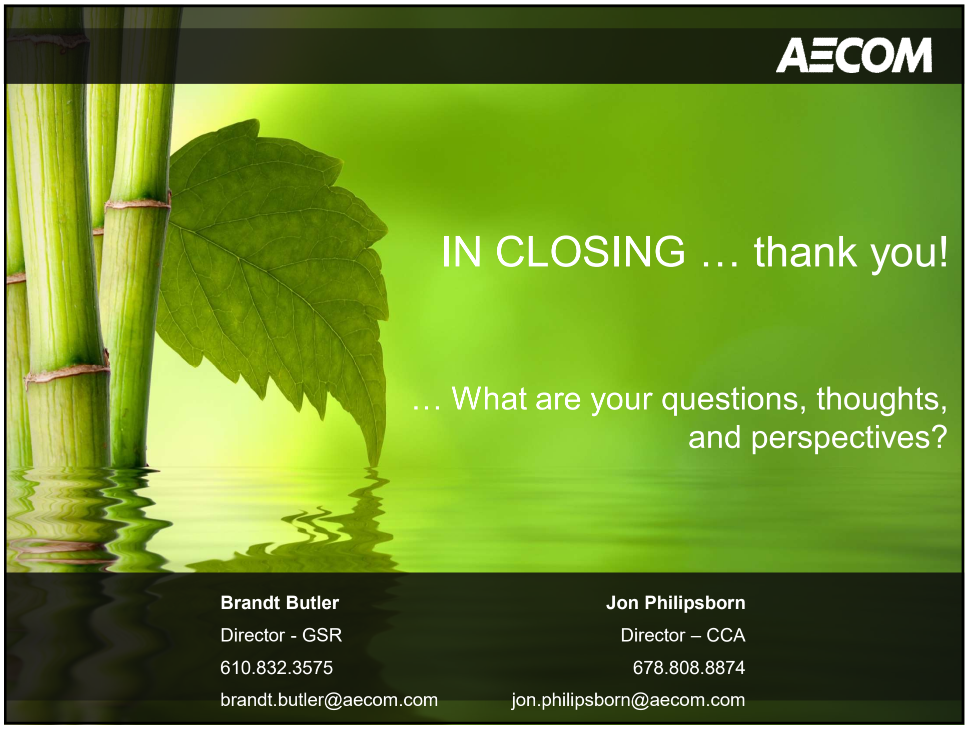
Climate Change Adaptation – Tier 1: Existing Tools

- Sea Level Rise + http://ss2.climatecentral.org/
  - Social Vulnerability
  - Ethnicity
  - Population



Tier 2 – Detailed Assessment of Vulnerable Sites

- Details matter
  - Infrastructure on-site and off-site
  - Localized flood patterns
  - Storm surge behavior
- And more …


AECOM
IN CLOSING … thank you!
… What are your questions, thoughts, and perspectives?
Brandt Butler
Director - GSR
610.832.3575
brandt.butler@aecom.com
Jon Philipsborn
Director – CCA
678.808.8874
jon.philipsborn@aecom.com

Attachment 5
Tesoro's Sustainable Remediation Program

TESORO'S SUSTAINABLE REMEDIATION PROGRAM: CURRENT AND FUTURE SUSTAINABILITY CONSIDERATIONS AND INTERPLAYS

October 6, 2015

Kyle Waldron, Tesoro
Karin Holland, Haley & Aldrich
Bethany Zinni, Haley & Aldrich

HISTORY

Personal experiences shaped my views on sustainability

1. Waste

2. Multiple characterization/ remediation efforts

3. Footprint vs Benefit

IMPLEMENTING SUSTAINABILITY

- Why sustainability?
  - Target a net environmental gain
  - Drives better decision making
  - Continuous improvement

- How to obtain acceptance?
  - It's good for business
  - Company reports sustainability performance

IMPLEMENTING SUSTAINABILITY

- What is important?
  - Building a standard process
  - Measurable metrics
  - Reporting

- Where do we go?
  - Establish a team
    - Experts (H&A experience)
    - Tesoro predecessors
  - Brainstorming session

TESORO'S SUSTAINABILITY FOCUS

TESORO

Excerpt from Tesoro's Sustainability Report

PERFORMANCE: These data reflect a significant change in the Company's profile in 2013, with the acquisition of the Southern California assets and the divestiture of the Hawaii refinery and related assets.

DIRECT GREENHOUSE GAS EMISSIONS

In 2013, direct GHG emissions increased by 5%, from 32.72 tons of carbon dioxide equivalent (CO_2e) per thousand barrels of throughput in 2012 to 34.42 tons in 2013. The slight increase is primarily a result of the Hawaii refinery divestiture.

INDIRECT GREENHOUSE GAS EMISSIONS

Total indirect GHG emissions from our refineries decreased slightly in 2013 to 1.57 tons of carbon dioxide equivalent (CO_2e) per one thousand barrels of throughput from 1.77 tons in 2012.

ENERGY USE

Our energy use decreased 2% from 2012 to 2013. In 2013, our total energy use from all sources was 490.12 million BTUs per one thousand barrels of throughput, compared to 498.09 million BTUs in 2012.

AIR EMISSIONS

We continued to successfully reduce total air emissions in 2013. In 2013, we produced 64.97 tons of emissions per million barrels of throughput, a 14% reduction from 2012. Even with the inclusion of the combined Los Angeles refinery we have seen a significant improvement in air emissions over the years, approximately a 50% reduction since 2007.

WASTE

In 2013, our refineries produced 86.48 thousand tons of waste. This increase over 2012 was largely due to nonhazardous waste generated from expansion activities at our operating sites. Of the 86.48 thousand tons of waste, only 4% was hazardous waste.

WASTEWATER

We successfully reduced our wastewater discharge from 2012 to 2013. In 2013, we discharged 86.62 cubic meters per thousand barrels of throughput versus 86.97 cubic meters per thousand barrels of throughput in 2012.

WATER WITHDRAWAL

Water consumption at our refineries decreased in 2013. We used 150.31 cubic meters per thousand barrels of throughput in 2013 as compared to 150.81 cubic meters per thousand barrels of throughput in 2012.

SPILLS

Spills (greater than one barrel to a permeable surface) were 22 in 2013, compared with 16 in 2012. We continue to perform well by keeping significant quantities of product out of our waterways. Over the last three years, we have not had any significant spills to water.

LEAN-BASED STRATEGIC PLANNING

TESORO

DESIRED OUTCOMES OVER TIME

2015 goals
- determine metrics
- do alternatives assessments vs. absolute *'s
- assess 2 sites in 2015
- determine how to report this

1-3 years
- Env't'l group is presenting @ conferences etc.
- good stories
- include sustain in 2015 FB Annual Rpt

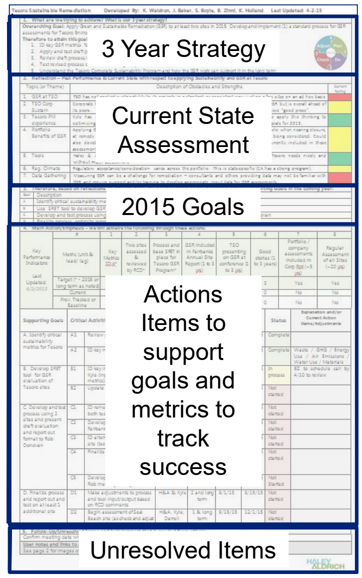
Long Term
- by 20 years regular assessments of all sites
- (~3 yrs...) ? long term possible portfolio/company assessments

ID KEY METRICS TO MEASURE FOR TESORO

Metrics
- GHG
- Energy Use
- Air Emissions
- Waste
- ~~Wastewater~~ Water Use
- Materials

LEAN-BASED STRATEGIC PLANNING

- Used A3 (Lean tool) to develop/capture strategic plan:
  - Goals
  - Action items
  - Status



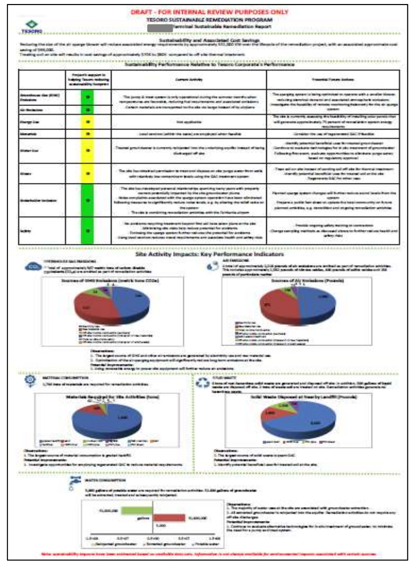
LEAN-BASED STRATEGIC PLANNING

- Site selection
- Scoring system

DASHBOARD COMPONENTS

TESORO

- Cost impacts
- Sustainable activities
- Key performance indicators



SITE SUSTAINABILITY EVALUATION

TESORO

FORMER TESORO BULK FUEL TERMINAL

- Ongoing remediation
  - Groundwater remediation systems
    - Air sparge
    - Recirculation
    - Pilot test bioremediation
  - Groundwater monitoring
- Decision point
  - Facility demolition
  - Remedial system requires upgrade
  - Remedial Option matrix

DASHBOARD REPORTING

TESORO

TESORO

Sustainability and Associated Cost Savings

Reducing the size of the air sparge blower will reduce associated energy requirements by approximately 531,000 KW over the lifecycle of the remediation project, with an associated approximate cost saving of $69,000.
Treating soil on-site will results in cost savings of approximately $70K to $80K compared to off-site thermal treatment.

Sustainability Performance Relative to Tesoro Corporate's Performance

	Project's support in helping Tesoro reducing sustainability footprint	Current Activity	Potential Future Actions
Greenhouse Gas (GHG) Emissions	☺	- The pump & treat system is only operational during the summer months when temperatures are favorable, reducing fuel requirements and associated emissions - Certain materials are transported to the site via barge instead of by airplane	- The sparging system is being optimized to operate with a smaller blower, reducing electrical demand and associated atmospheric emissions - Investigate the feasbility of remote monitoring/telemetry for the air sparge system
Air Emissions	☺		
Energy Use	😐	Not applicable	- The site is currently assessing the feasibility of installing solar panels that will generate approximately 75 percent of remediation system energy requirements

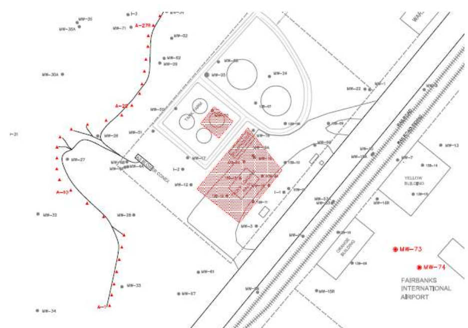
Business Case for sustainable options – Cost savings & lifecycle assessment

Identify current activities and potential future activities to promote

Standardized approach for each dashboard

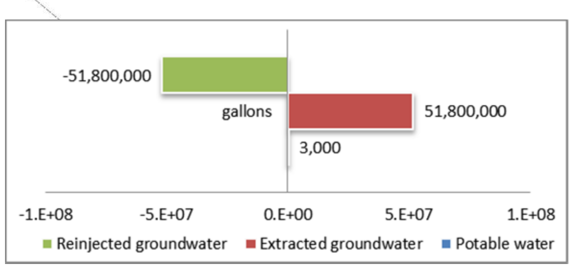
WATER CONSUMPTION ISSUES

TESORO



- Air sparging system (plume control)

- Groundwater recovery and reinjection system (capture zone for fuel additive – EDC)



OPPORTUNITIES FROM ASSESSMENT

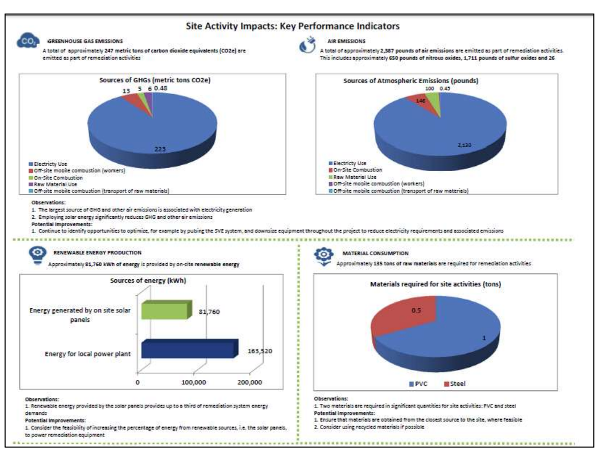
TESORO

Previously planned activities	Sustainable Alternative
Offsite soil contamination at rail track – Soil excavation and offsite disposal	Onsite treatment using a landfarm (Work Plan in review/revision)
EDC soil contamination – Traditional investigation with drill rig	Use of passive sampling • Passive soil gas survey conducted
Stakeholder engagement – FAI airport preparing to send soil to TSDF	Combine landfarm efforts
Remediation system upgrades	*Air sparge system –* • replace with smaller blower to reduce energy consumption • Assess use of solar supplement *Groundwater Recovery/Injection –* • Bio amendment (sulfate)

OTHER SITES CURRENTLY IN THE PROGRAM

TESORO

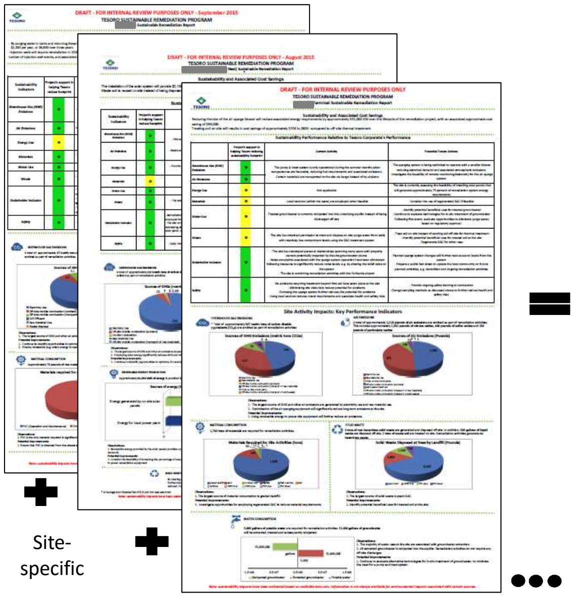
- Site in Mountain West: SVE system to use solar/grid hybrid
- Site in Western USA: LNAPL recovery and oxygen injection systems
- Site in Western USA: Oxygen injection and SVE systems

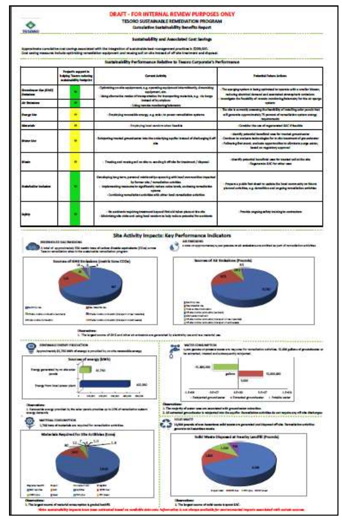


Each site's sustainability performance evaluated

CUMULATIVE SUSTAINABILITY IMPACTS

Cumulative





Portfolio sustainability performance summarized on single page

LESSONS LEARNED FROM PROGRAM

- Where to start? …. **corporate metrics**

- Develop a plan… using **lean thinking/tools**
- **Standardized approach** enables:
  - Streamline
  - Benchmarking

- **Cost benefits**
- **Buy in**

QUESTIONS

Kyle Waldron
253-896-8731
Kyle.A.Waldron@tsocorp.com

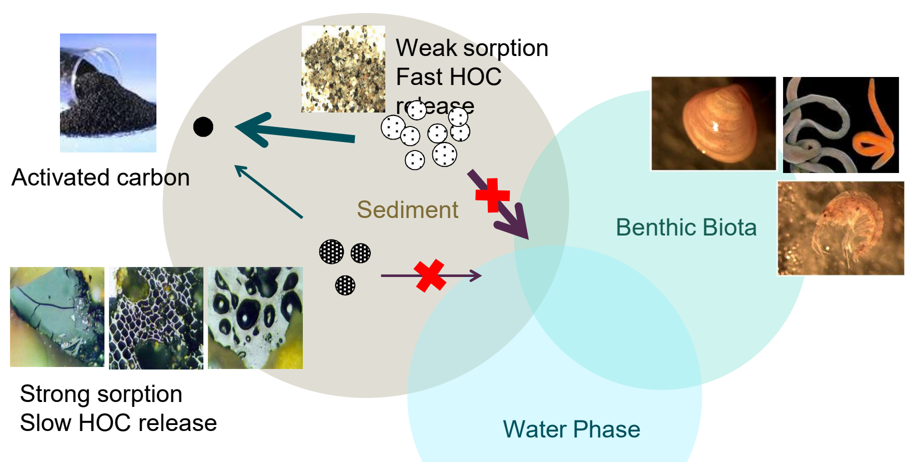
Attachment 6
In Situ Activated Carbon Amendment Technology for Sediment Remediation

IN-SITU ACTIVATED CARBON AMENDMENT TECHNOLOGY FOR SEDIMENT REMEDIATION: STATUS UPDATE AND SUSTAINABILITY ASPECT

YEO MYOUNG CHO, PHD
DEPT. OF CIVIL AND ENVIRONMENTAL ENGINEERING
STANFORD UNIVERSITY

Oct 6, 2015
SURF 30 at Rice University, TX

IN-SITU AC REMEDIATION: FACILITATING NATURAL ATTENUATION

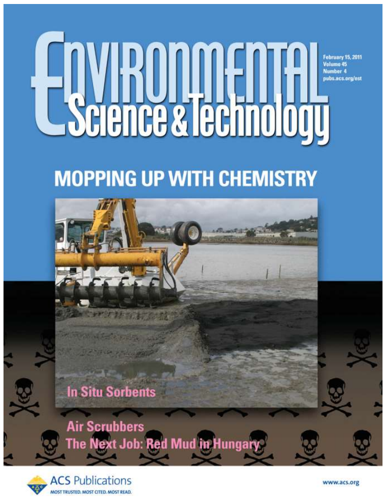


Geochemical natural attenuation process
: **HOC repartition to be less bioavailable**

AC picture source: PollutionOnline
Benthic biota pictures: US Army ERDC

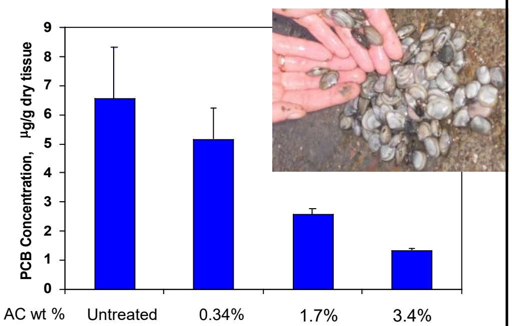
2 Intro

TECHNOLOGY DEVELOPMENT



Ghosh, Luthy et al. ES&T, Feb 15, 2011

Proofs of concept:
- Laboratory physicochemical, biological evidences (since 2000)



McLeod et al. ET&C, 2007, 26, 980-987

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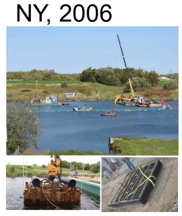
3 Intro

First Pilot
Hunters Point
San Francisco Bay
CA, 2004 & 2006

ROTOTILLER OR SLURRY INJECTION

Grasse River
NY, 2006



SLURRY INJ AND COVERED ROTOTILLER

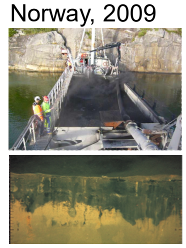
Bailey Crk VA, 2009
Canal Crk MD, 2010

PELLETIZED AC (SEDIMITE)

Trondheim Harbor
Norway, 2006

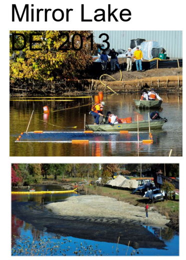
SLURRY INJ W/ AND W/O CLAY

Greenlands Fjords
Norway, 2009



ACTIVE CAP CLAY+AC MIX

First Full-Scale
Mirror Lake
DE, 2013



SEDMITE

Source: Greene, R.W.
DNREC
AAEES website

Source: Ghosh, Luthy et al. *ES&T,* Feb 15, 2011

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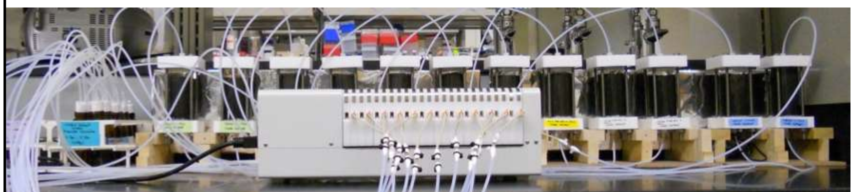
I. TECHNOLOGY STATUS



- Cho, Y.-M.; Werner, D.; Choi, Y.; Luthy, R. G., Long-term Monitoring and Modeling of the Mass Transfer of Polychlorinated Biphenyls in Sediment Following Pilot-Scale after Field Application of Activated Carbon Amendment in Marine Sediment. *Journal of Contaminant Hydrology*, **2012**, 129130(15), 25-37.
- Choi, Y.; Cho, Y.-M.; Luthy, R. G., In-Situ Sequestration of Hydrophobic Organic Contaminants in Sediments under Stagnant Contact with Activated Carbon: 2. Mass Transfer Modeling. *Environ. Sci. Technol.*, **2014**, 48(3), 1843-1850.
- Lin, D.; Cho, Y.-M.; Werner, D.; Luthy, R. G., Bioturbation Delays Attenuation of DDT by Clean Sediment Cap but Promotes Sequestration by Thin-Layered Activated Carbon. *Environ. Sci. Technol.*, **2014**, 48(2), 1175-1183.
- Luthy, R.G.; Cho, Y.-M.; Choi, Y.; Wu, W. ER-1552 Long-term risk reduction from activated carbon treatment of sediment. Phase III Final Report, **2015**
- Lin, D.; Cho, Y.-M.; Tommerdahl, J.; Werner, D.; Luthy, R. G. Bioturbation Facilitates DDT Sequestration by Activated Carbon with Deposition of Contaminated Sediment **In Review** *Water Research*

5-YEAR POST-TREATMENT ASSESSMENT AT HUNTERS POINT SHIPYARD

Q1: Will AC amendment remain effective over time?

AC dose

SPMD 28d

PE 28d

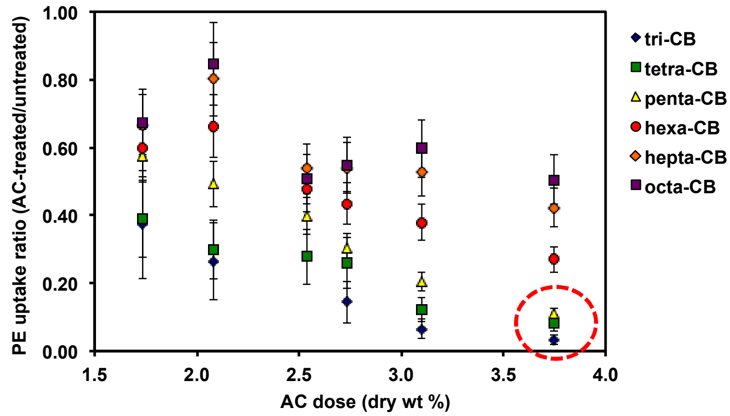
14d Equilibrium Aq.

Stability

Remediation effectiveness

AC sorption kinetics

LONG TERM EFFECTIVENESS



- **Performance continues to improve**
- **Dose-response relationship** between the local AC dose and the reduction in PE
- For a **4%** local AC dose, the reduction in PE increased up to 97% and 50% for tri-CBs and octa-CBs respectively. **73% for total PCBs**

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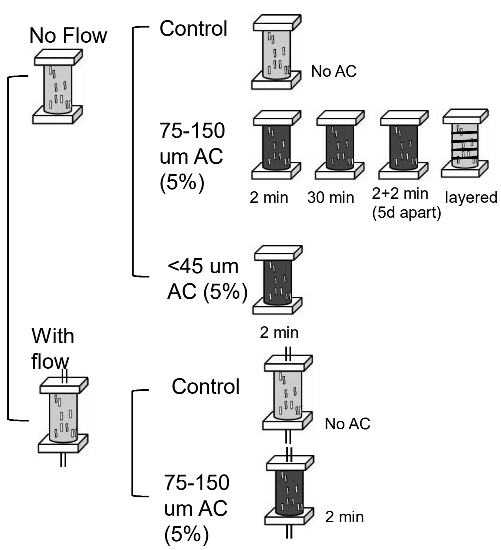
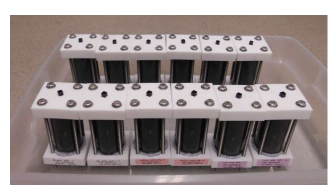
IMPROVE MECHANISTIC UNDERSTANDING: COLUMN STUDY & MODELIN

Q2: How engineering & site conditions affect AC performance?

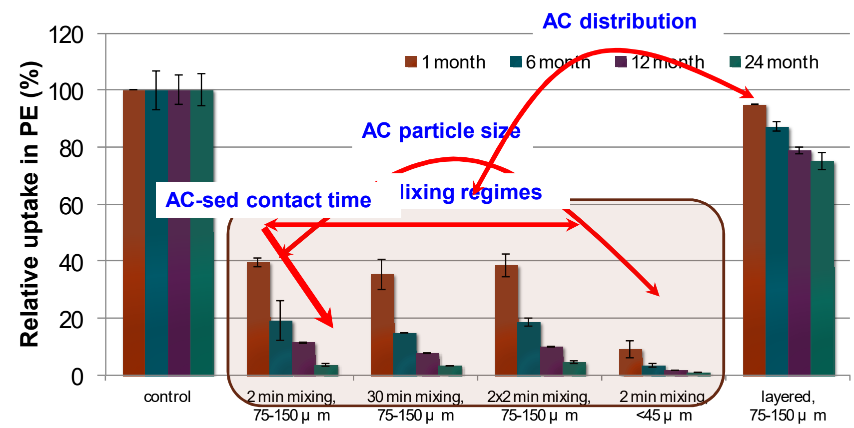


- BENEFIT OF AC AMENDMENT
- MIXING REGIME
- AC PARTICLE SIZE
- AC DISTRIBUTION
- PORE-WATER MOVEMENT



Sediment Column Studies

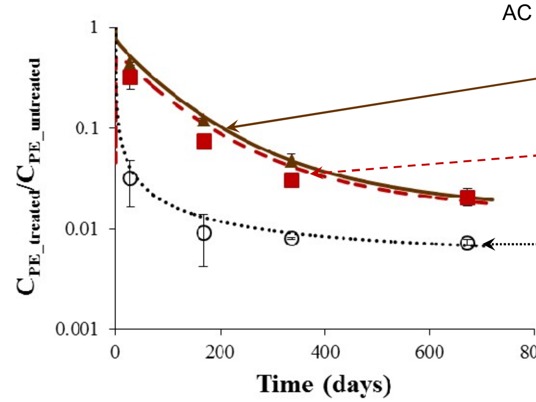
For PAH-impacted sediment, AC dose: 5% sed. dry wt.



- **96-99%** reduction in PE uptake after 2 years of stagnant contact
- Significant variables: **AC particle size** and **mixing heterogeneity**

HOC Mass Transfer Model

Test compound: benz[a]anthracene
AC dose = 5 dry wt%

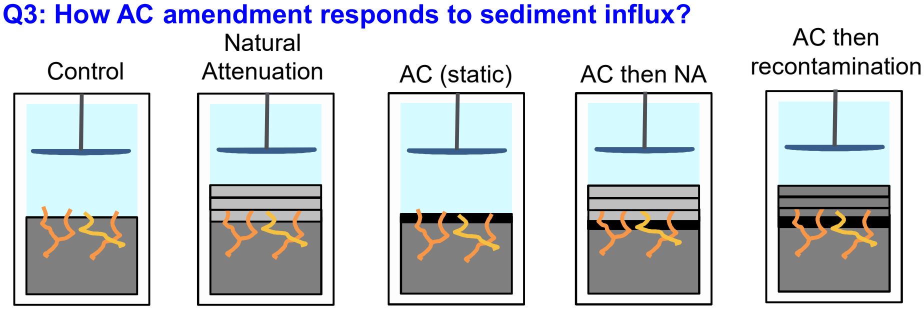


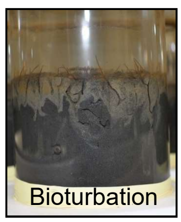
- **Quantitative reproduction of the column study results for various AC application scenarios**

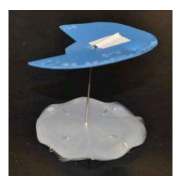
10 Status Update

Simulating AC-Amendment with Sediment Influx

Q3: How AC amendment responds to sediment influx?







Sed-Water DDT Flux

Lumbriculus variegatus

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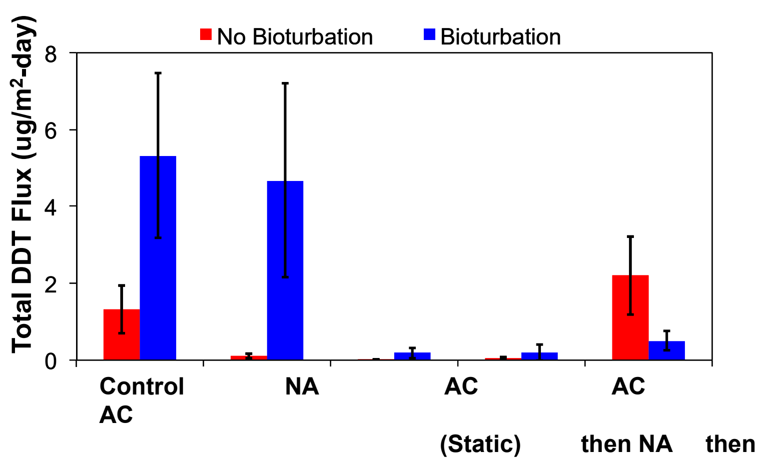
11 Status Update

Assimilation Efficiency of AC Amendment



- **AC amendment facilitated by bioturbation showed treatment effect on recontamination.**

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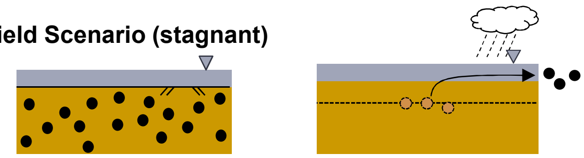
HOC REPARTITIONING

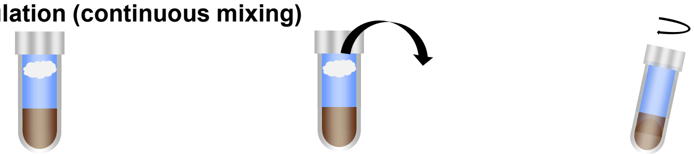
Q4: If AC accidently removed, will treatment remain effective?

Field Scenario (stagnant)



I. AC treatment (yrs) II. AC winnowing event III. Treated sed. w/o AC (yrs)

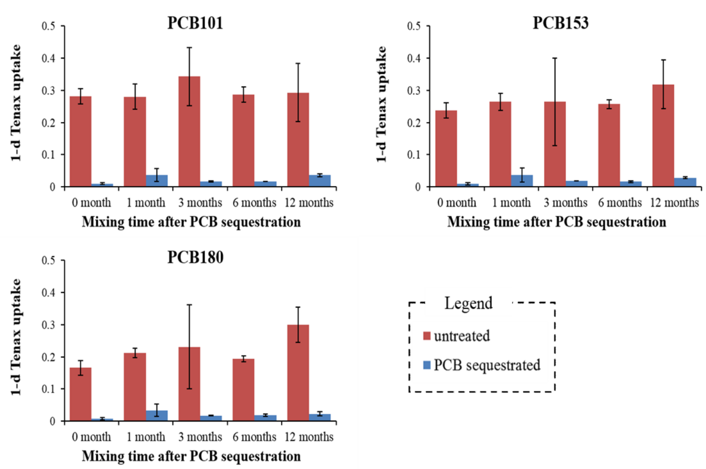
Lab simulation (continuous mixing)



I. Sorbent treatment (month) II. Sorbent removal III. Treated sed. w/o sorbent (0,1,3,6, and 12 months)

HOC REPARTITIONING

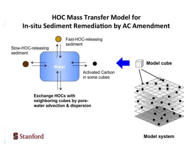
1-day Tenax bead uptake as **available PCB fraction**

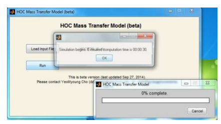


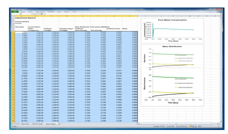
- **Sorbent treatment remains effective**

Take Home Messages

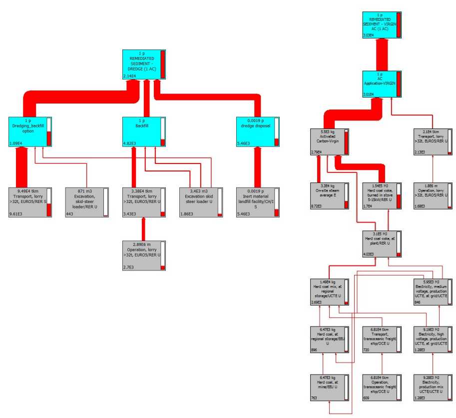
- AC remains effective in reducing HOC availability in the long term
- AC particle size and mixing homogeneity are two key factors for performance
- AC shows assimilation benefit against recontamination
- HOC mass transfer model successfully predicts AC performance with various system conditions







II. Sustainability Aspect



Choi, Y.; Thompson, J.M.; Lin, D.,; Cho, Y.-M.; Ismail, N.S.; Hsieh, C.-H.; Luthy, R.G., Secondary environmental impacts of remedial alternatives for sediment contaminated with hydrophobic organic contaminants. *Journal of Hazardous Materials*, **Accepted**.

16 Sustainability

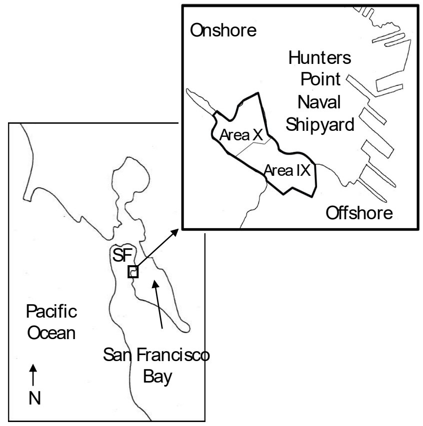
Life Cycle Analysis Study for Remedial Alternatives

Quantify and compare:
Secondary environmental impacts of
1. Dredge and fill
2. Capping
3. AC amendment

for PCB remediation of Hunters Point Shipyard

Scope

Raw material acquisition & manufacture
On-site activities
Disposal
Long term monitoring (30 years)



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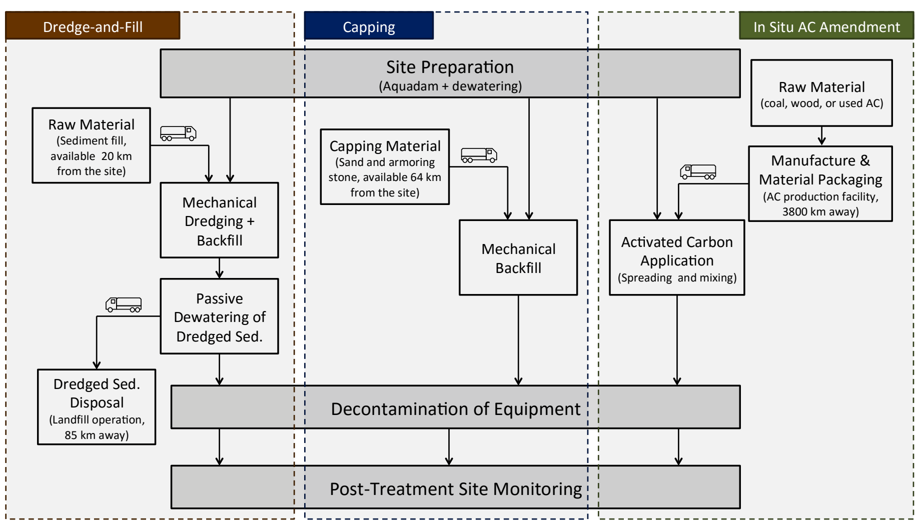
17 Sustainability

Process Flow



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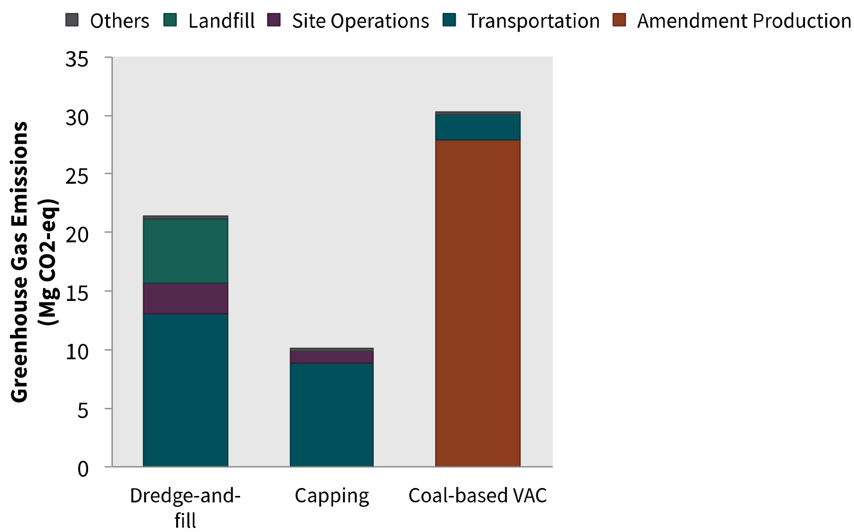
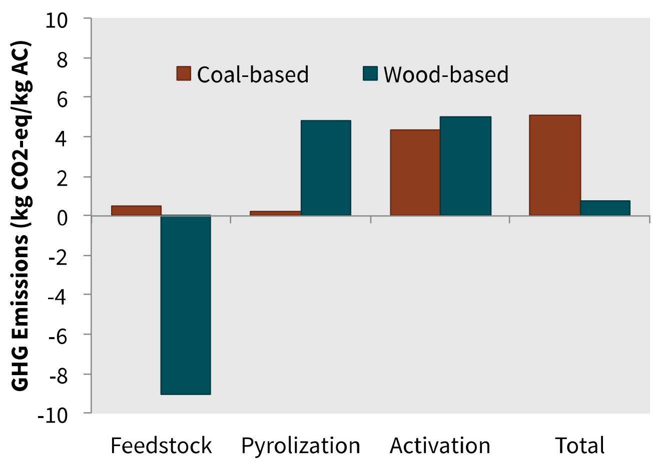
SECONDARY ENVIRONMENTAL IMPACT

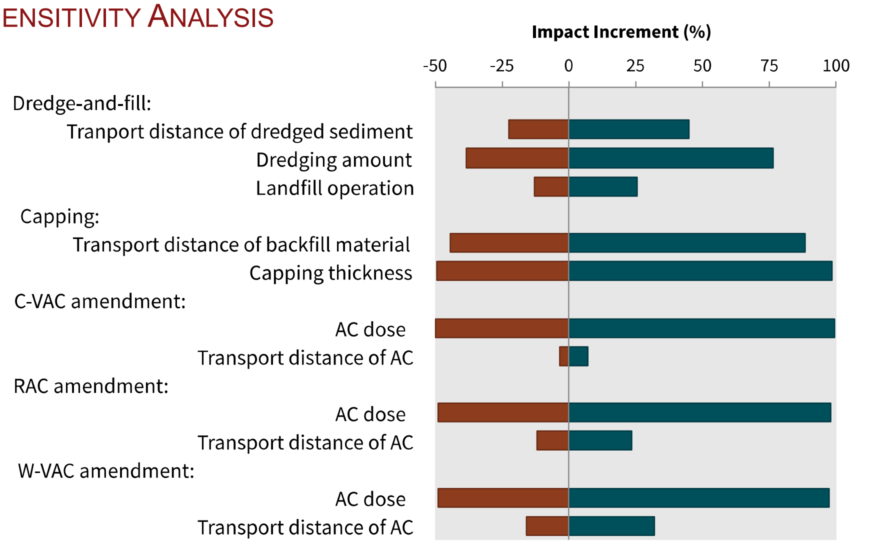


FEEDSTOCK EFFECT



- **Feedstock selection is the most important design choice with respect to GHG emissions by in-situ AC amendment.**

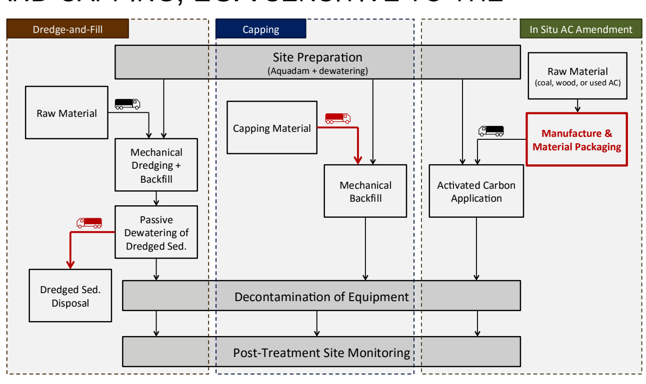
Sensitivity Analysis



GHG emissions. By 50%, 200% change.

Take Home Messages

- For in-situ AC amendment, sorbent production is a major impact contributor
- Minimize impacts of in-situ amendment by using recycled or bio-based sorbents
- For dredging and capping, LCA sensitive to the transport dist



ACKNOWLEDGEMENT

PI, ADVISOR,
RICHARD G. LUTHY, STANFORD UNIVERSITY

Project support

SERDP DOD • EPA • DOE

Chevron

STANFORD SURF STUDENT CHAPTER, 2012-2014

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(ADVISOR)

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DR. NIVEEN ISMAIL

SURF
SUSTAINABLE REMEDIATION FORUM

Stanford University

Attachment 7
Remediation Performance and Cost Database: Implications for Improving Sustainability

REMEDIATION PERFORMANCE AND COST DATABASE:

Implications for Improving Sustainability

6 October 2015

Travis M. McGuire, P.E.
David T. Adamson, Ph.D., P.E.
Charles J. Newell, Ph.D., P.E.

BACKGROUND

ESTCP Project ER-201120:

- Evaluate performance of in-situ technologies at chlorinated solvent sites

Technical Approach:

- Data mining to compile concentration versus time data from before and after treatment
- Limited field investigation at 3 sites

Focus Areas:

- Change in groundwater concentrations
- Performance correlations
- Rebound vs. sustained treatment
- Technology unit costs

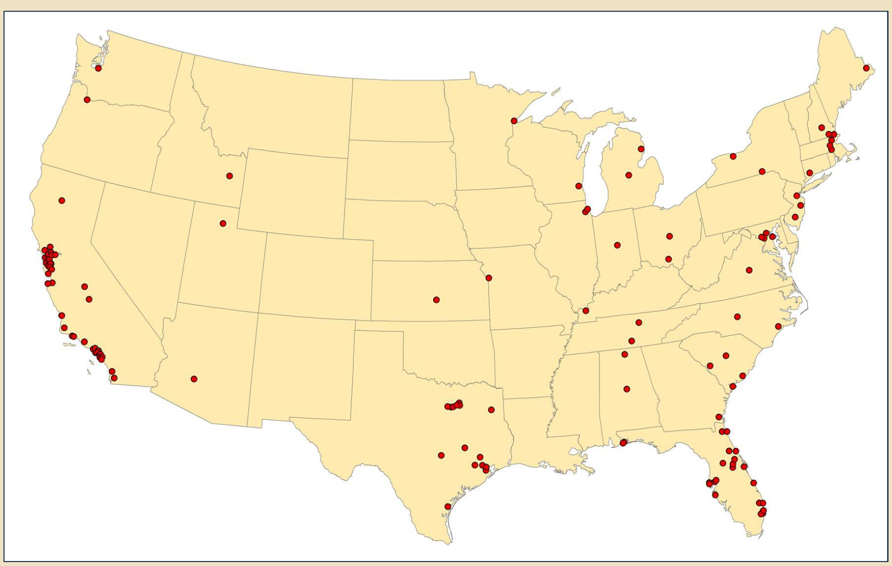
2

DATABASE BY THE NUMBERS

- **Database by the Numbers**
  - ⇨ 280 Chlorinated Solvent Groundwater Sites
    - ⇨ 235 In-Situ Remediation Sites
    - ⇨ 45 Untreated (MNA) Sites
  - ⇨ 796 Wells
  - ⇨ 11,965 Sampling Events
  - ⇨ 48,594 Chlorinated Compound Concentrations
  - ⇨ ~ $120,000,000 at $10,000 per event

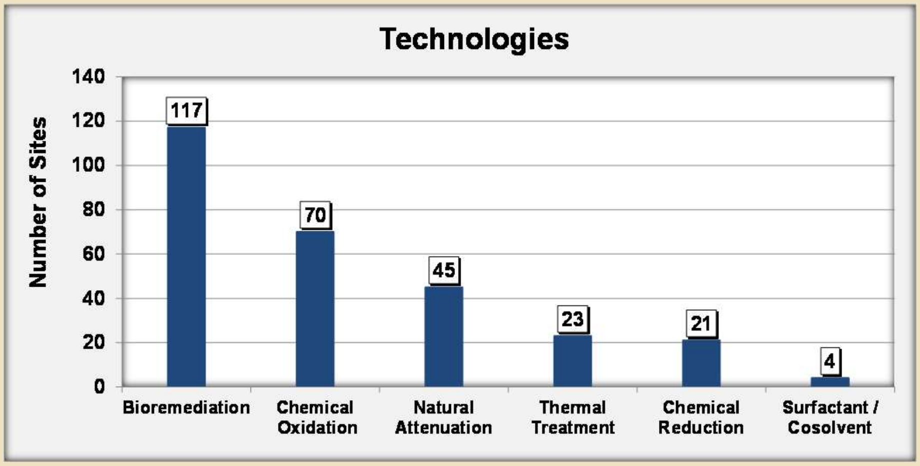
3

SITE LOCATIONS



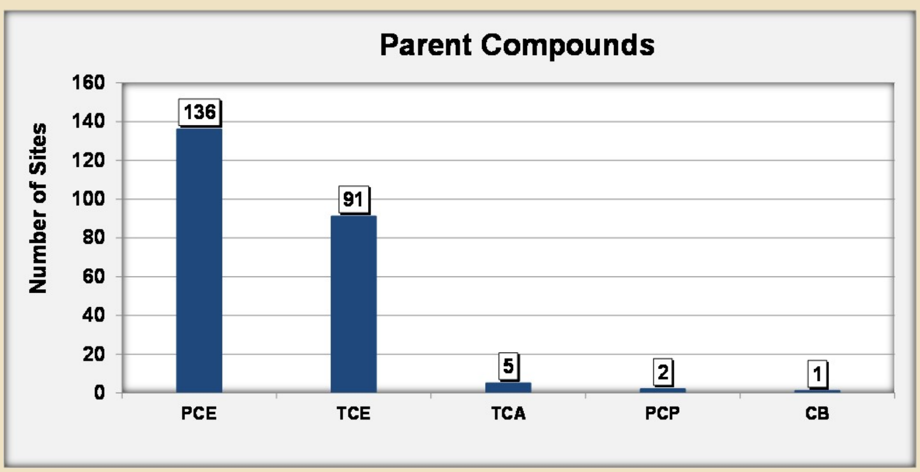
4

TECHNOLOGY DISTRIBUTION



5

PARENT COMPOUND DISTRIBUTION



6

DATA MINING PROCESS

- Data mining Project example

- 4.5 Stars on Yelp!

Remedial Action Plan Modification

Herman Jackson Cleaners

1981 San Marco Boulevard
Jacksonville, Florida

February 21, 2011

FDEP Facility Identification 169502441
FDEP Task Assignment D14L
LFR Project 004-06004-19

Prepared for
Florida Department of Environmental Protection
Bob Martinez Center
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Prepared by
LFR Inc.
3382 Capital Circle N.E.
Tallahassee, Florida 32308-1568

LFR

DATA MINING PROCESS

- Data mining Project example

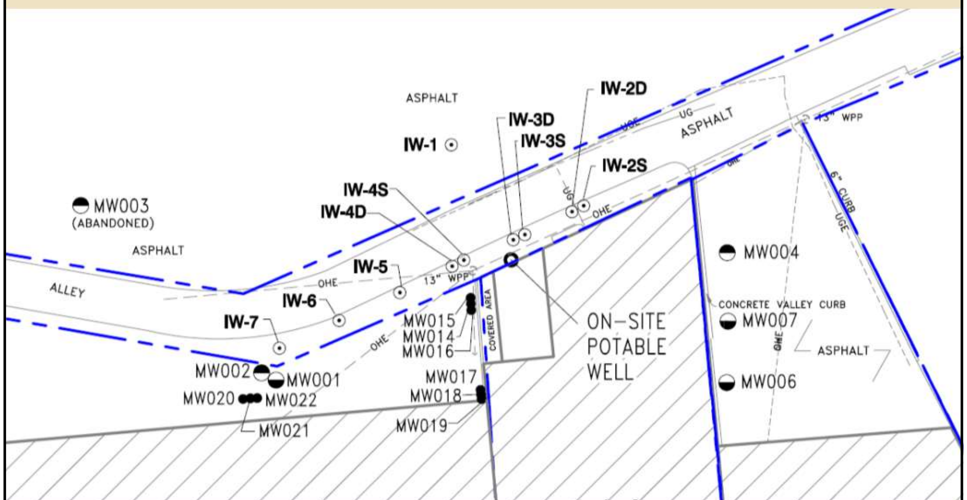
The remediation system was originally started on August 25, 2004. The remediation system includes the following components:

- Ten 2-inch-diameter injection wells ranging in depth from 12 to 38 feet bgs. The injection-well piping is routed from each injection well and stubbed up on the northern side of the equipment building. A trailer-mounted injection system was mobilized to the Site to inject ethyl lactate into the subsurface through the injection wells.

The last ethyl-lactate injection event was completed in August 2007, and the SVE system was shut down on November 7, 2007, as documented in the data submittal deliverable submitted to FDEP on December 19, 2007.

DATA MINING PROCESS

- **Data mining Project example**



DATA MINING PROCESS

- **Data mining Project example**

LFR ENVIRONMENTAL MANAGEMENT & CONSULTING ENGINEERING

September 14, 2010

TL006004.0020

Ms. Miranda Bartlett
Bureau of Waste Cleanup
Division of Waste Management
Florida Department of Environmental Protection
2600 Blair Stone Road, M.S. 4520
Tallahassee, Florida 32399-2400

Subject: Groundwater Monitoring Report, Herman Jackson Cleaners, 1981 San Marco Boulevard, Jacksonville, Florida; FDEP Facility Identification 169502441

Dear Ms. Bartlett:

This letter report summarizes the July 2010 groundwater-monitoring event completed for Herman Jackson Cleaners ("the Site") and is intended to meet the deliverable requirements of Florida Department of Environmental Protection (FDEP) Task Assignment D14M. The previous groundwater-monitoring event was conducted in July 2009. The last ethyl-lactate injection event was completed in August 2007, and the in situ air-sparging (IAS) and soil-vapor extraction (SVE) remediation system was shut down on November 7, 2007. The scope of work is outlined in a letter to the FDEP, dated January 21, 2010.

Groundwater Monitoring Activities

DATA MINING PROCESS

- **Data mining Project example**

Table 4 LFR Inc.
Groundwater Analytical Data Summary
Herman Jackson Cleaners
Jacksonville, Florida

Location	Date	PCE (ug/l)	TCE (ug/l)	cis-1,2-DCE (ug/l)	trans-1,2-DCE (ug/l)	1,1-DCE (ug/l)	Vinyl Chloride (ug/l)	Total Chlorinated Ethenes (ug/l)	Ethanol (mg/l)
MW001	2/28/97	28.4	9.7	<1	<1	<1	6.4	44.5	NA
	4/27/01	<1	<1	<1	<1	<1	<1	BDL	NA
	10/1/03	<1	<1	<1	<1	<1	<1	BDL	NA
	12/21/04	<1	<1	<1	<1	<1	<1	BDL	<1.0
	3/16/05	<1	<1	<1	<1	<1	<1	BDL	<1.0
MW002	2/28/97	1,880	5,070	16,300	<100	<100	8,000	31,250	NA
	2/28/97dup	1,300	4,950	<100	<100	<100	6,660	12,910	NA
	4/27/01	285	1,740	10,850	<50	<50	5,850	18,725	NA
	4/27/01dup	260	1,750	9,350	<50	<50	5,200	16,560	NA
	9/30/03	<1	3	680	12	5.9	870	1,571	NA
	12/20/04	4.4	8.7	330	1.8	2.5	190	537	<1.0
	3/16/05	47	64	940E	<20	<20	100	1,151	<1.0
	3/16/05‡	41D	64D	860D	<40	<40	84D	1,049D	NA
	6/29/05	25	49	270	1.6	3.0	19	368	NA
	9/15/05	4.2	13	140V	<1	1.8	58	217	NA
	1/23/06	2.4	6.4	12	<1	<1	1.9	23	NA
	7/15/09	<200	<200	2,300	<200	<200	2,100	4,400	NA
	7/22/10	<200	<200	1,800	<200	<200	3,600	5,400	NA
MW004	2/28/97	20.9	2.6	<1	<1	<1	205	229	NA
	4/27/01	<1	<1	5.8	<1	<1	2.4	8.2	NA

DATA REDUCTION

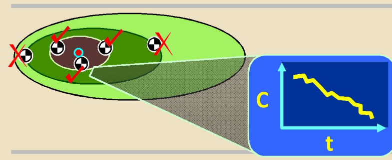
PERFORMANCE CALCULATIONS:

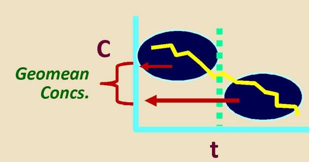
A) Compile conc. vs. time data for wells within treatment zone

B) Calculate geometric mean and maximum concentrations of before and after treatment periods

C) For geomean, calculate median before and after treatment concentrations of multiple wells as final performance metric for the site

= Injection pt = Monitoring well



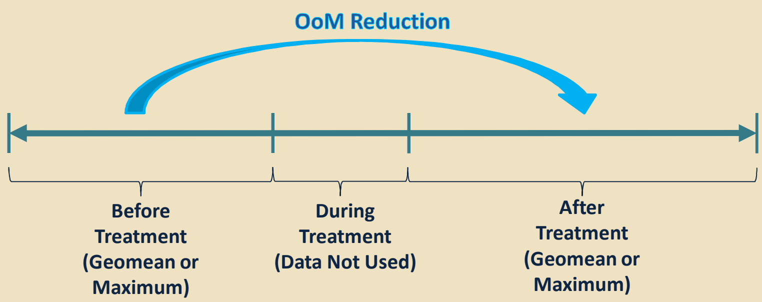


	Geomean	Median
Well # 1	50	7.5
Well # 2	10	
Well # 3	5	
Well # 4	0.05	

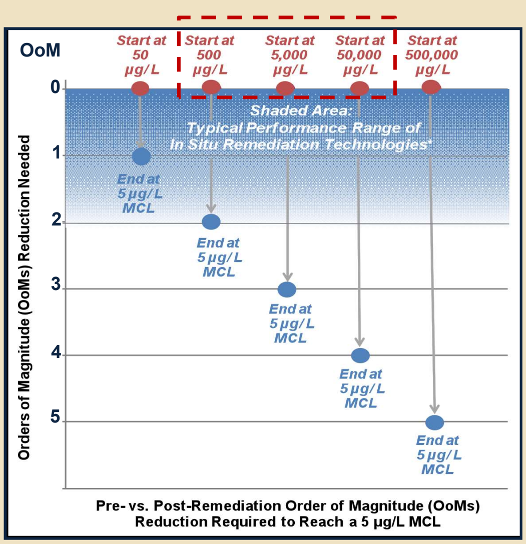
DATA REDUCTION

- **Order of Magnitude (OoM) Concentration Reduction**

$$OoM\ Reduction = -\log\left(\frac{C_{Post}}{C_{Pre}}\right)$$



WHY *OoMs*?



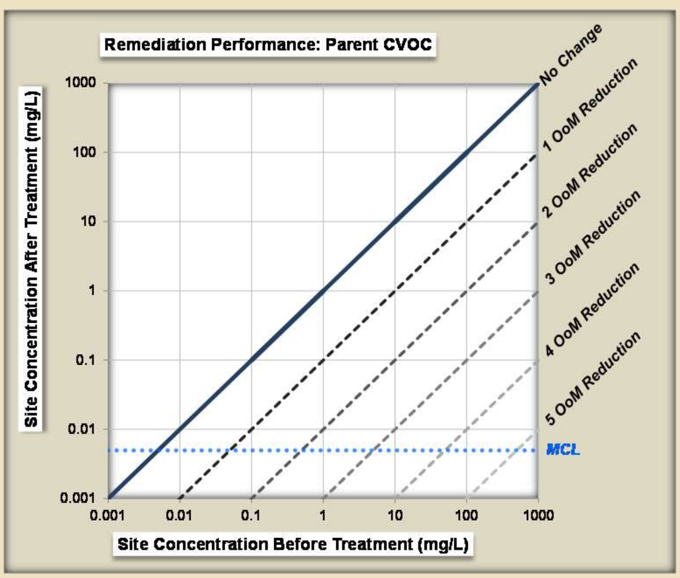
ITRC, 2012. Integrated DNAPL Site Strategy Guidance

KEY POINT:

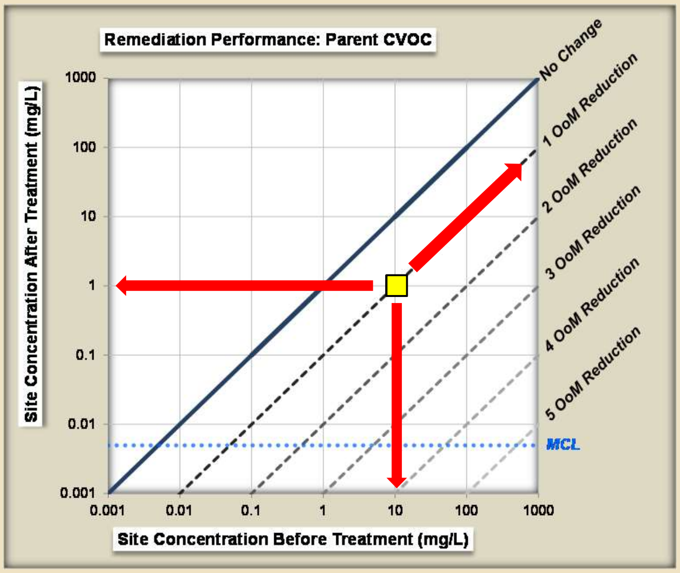
Most CVOC sources zones need >2 to 4 OoM reduction to reach MCLs

PERFORMANCE RESULTS

PERFORMANCE RESULTS

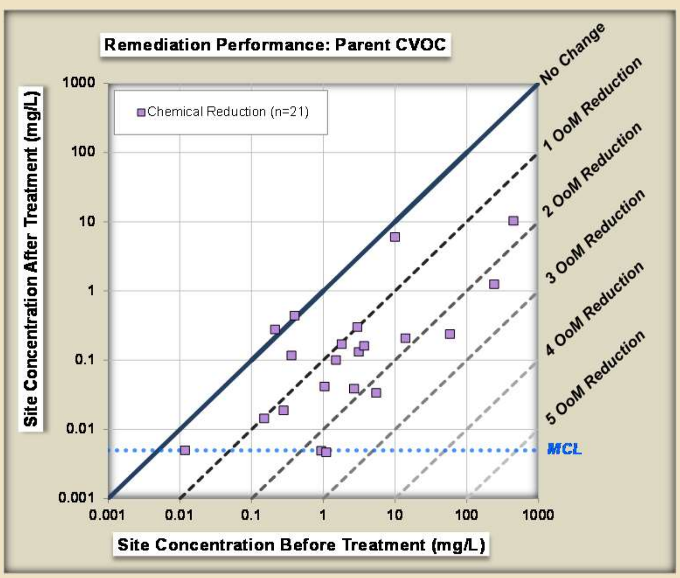


PERFORMANCE RESULTS



17

PERFORMANCE – Geomean Conc. by Site



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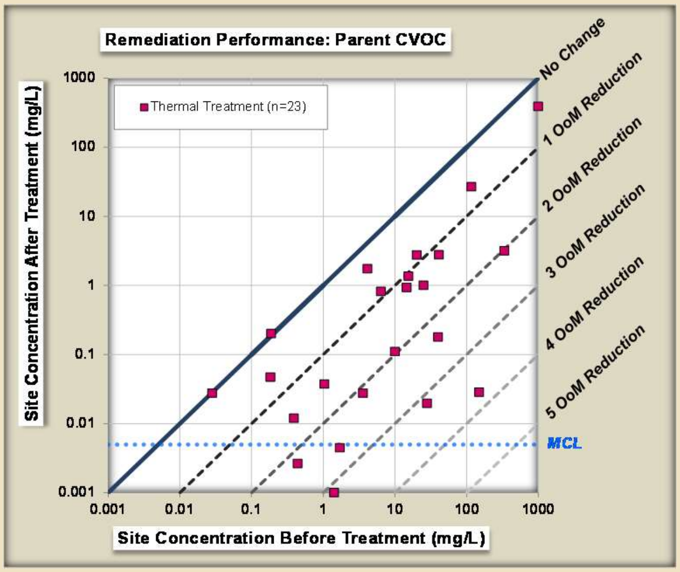
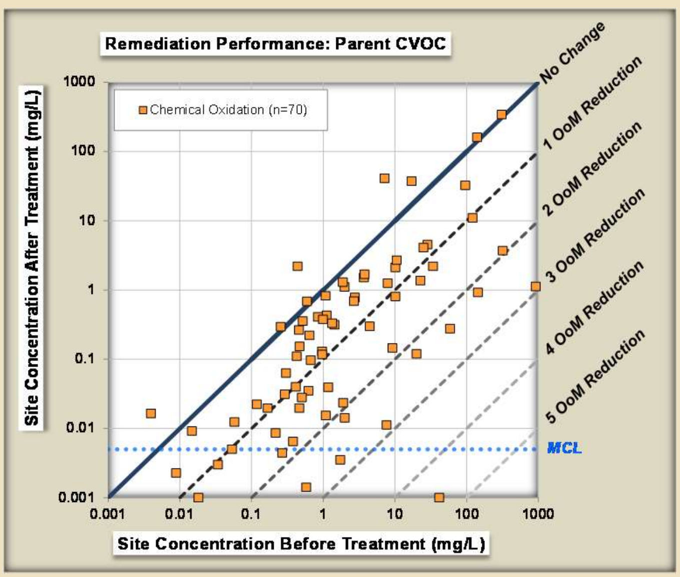
PERFORMANCE – Geomean Conc. by Site



19

PERFORMANCE – Geomean Conc. by Site



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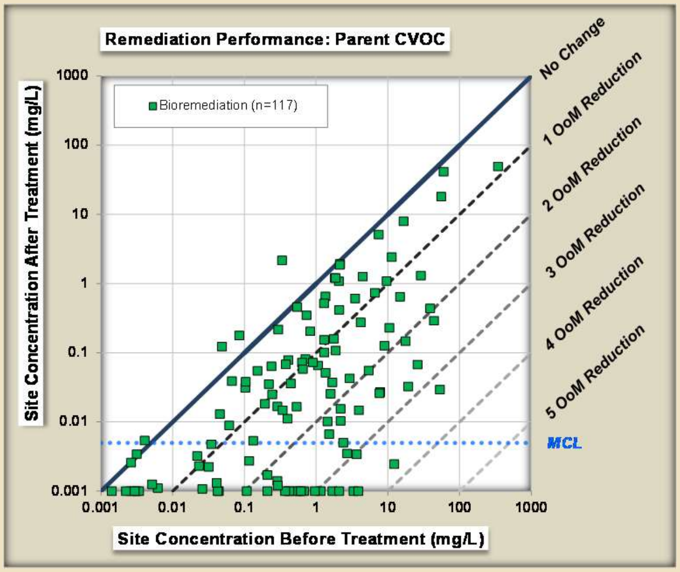
PERFORMANCE – Geomean Conc. by Site



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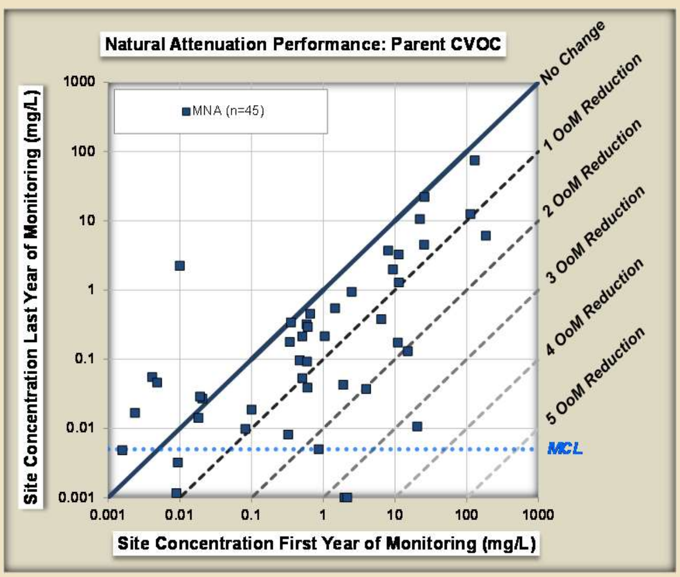
PERFORMANCE – Geomean Conc. by Site



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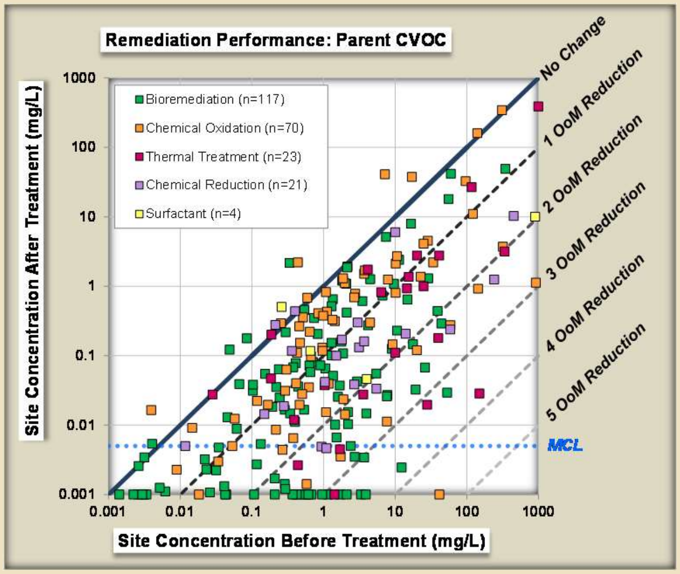
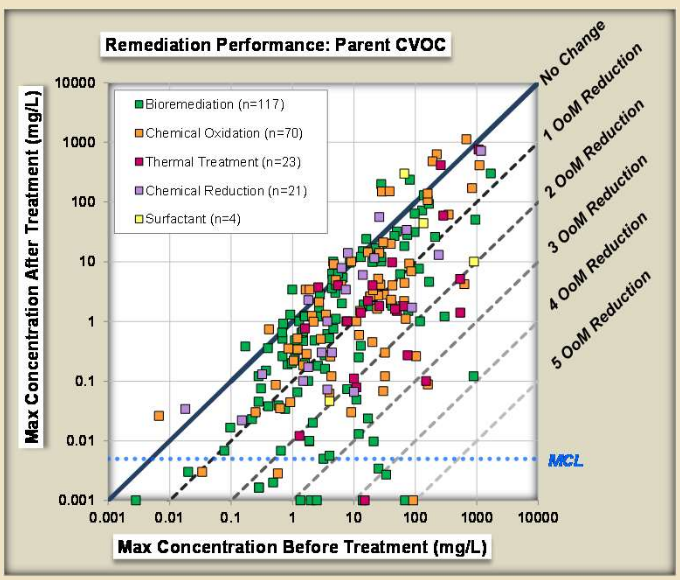
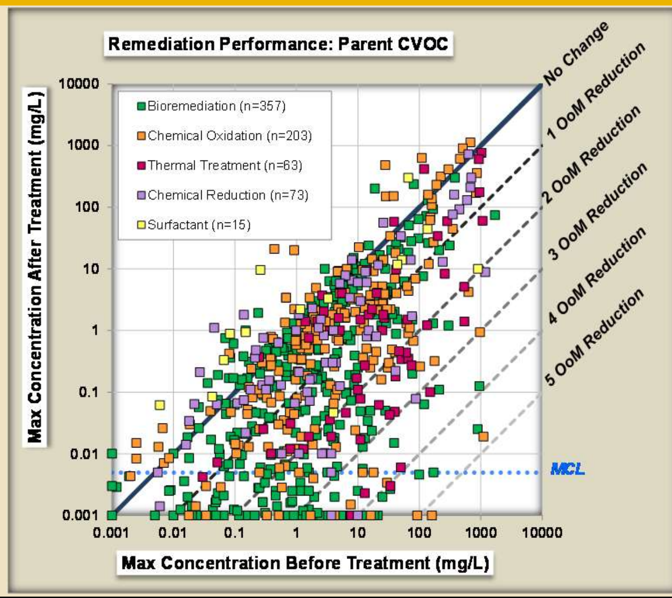
PERFORMANCE – Geomean Conc. by Site



PERFORMANCE – Max Conc. by Site



PERFORMANCE – Max Conc. by Well



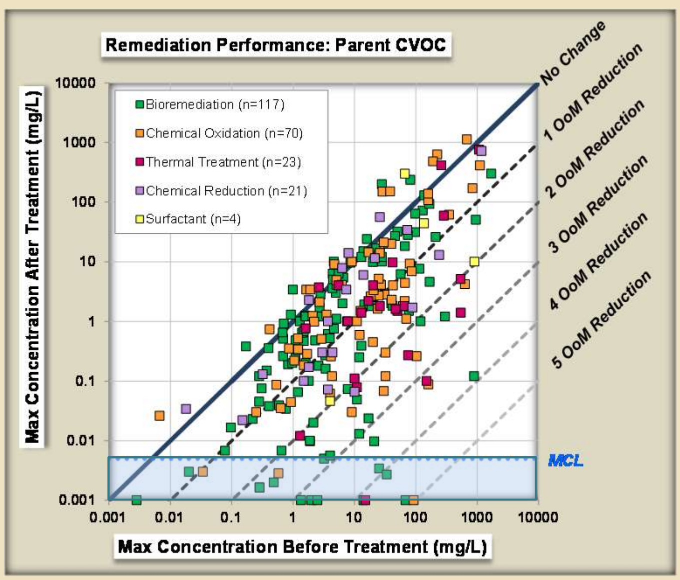
25

PERFORMANCE – A Closer Look

Max. Concs.
(Regulatory Drivers)

Achieved MCLs

8 %
of sites



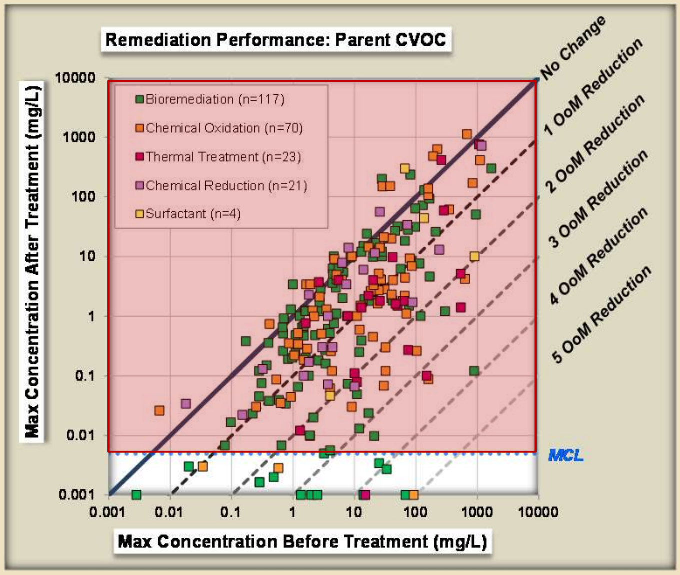
26

PERFORMANCE – A Closer Look

Max. Concs.
(Regulatory Drivers)

Failed to
Achieve MCLs

92 %
of sites



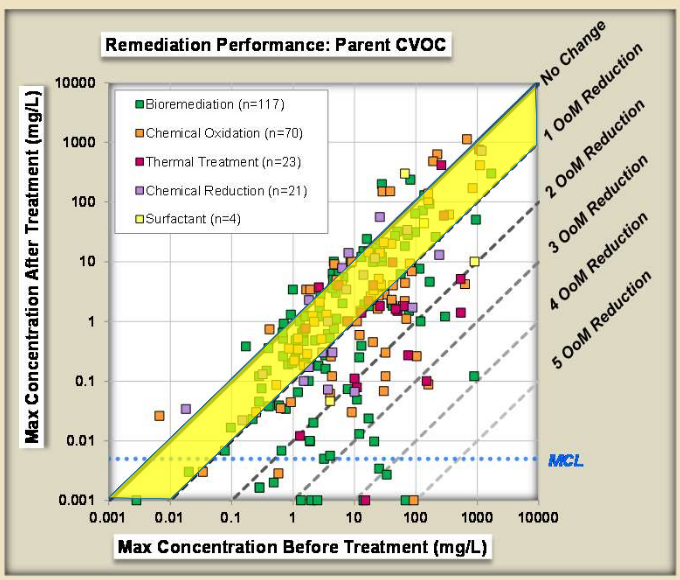
27

PERFORMANCE – A Closer Look

Max. Concs.
(Regulatory Drivers)

Achieved
0 to 1 OoM
Reduction

47 %
of sites



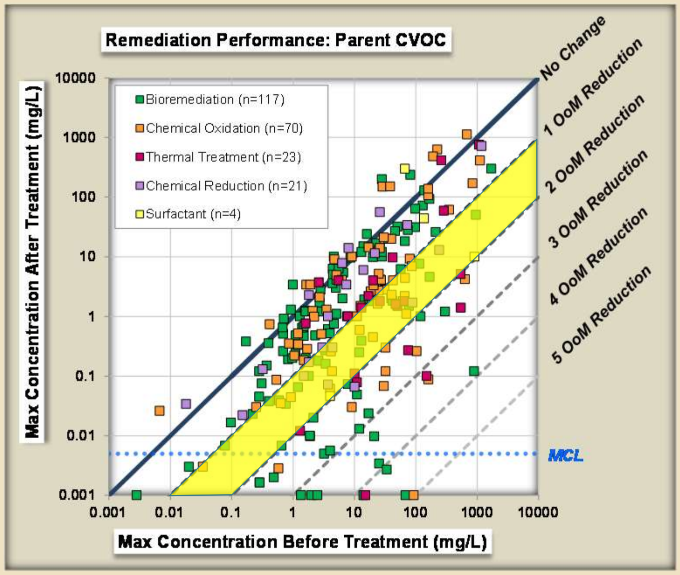
28

PERFORMANCE – A Closer Look

Max. Concs. (Regulatory Drivers)

Achieved 1 to 2 OoM Reduction

22 % of sites



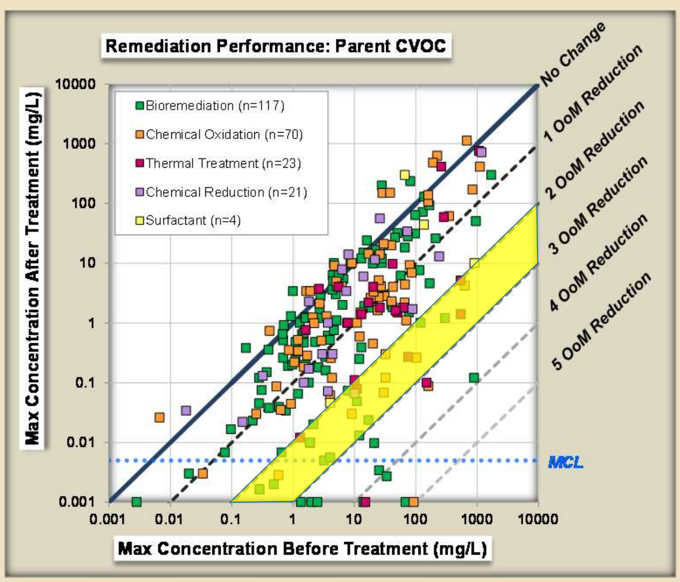
29

PERFORMANCE – A Closer Look

Max. Concs. (Regulatory Drivers)

Achieved 2 to 3 OoM Reduction

11 % of sites

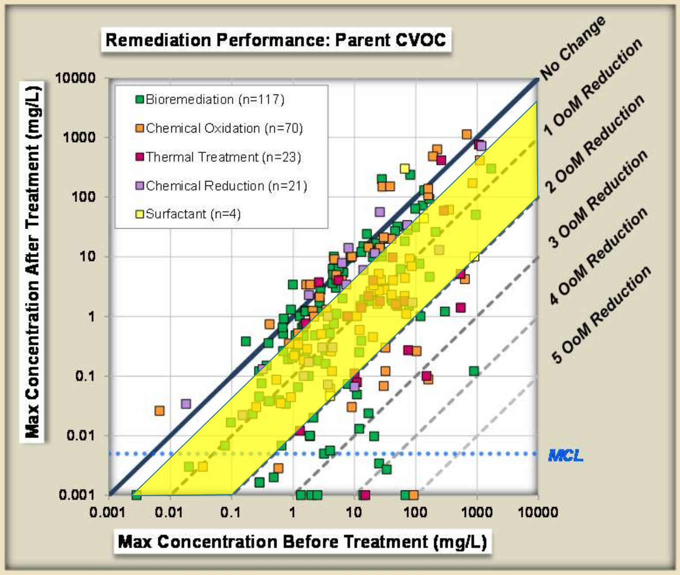


30

PERFORMANCE – Rule of Thumb

Max. Concs. (Regulatory Drivers)

Middle 50% of Sites Achieved ~ 0.4 to 2 OoM Reduction



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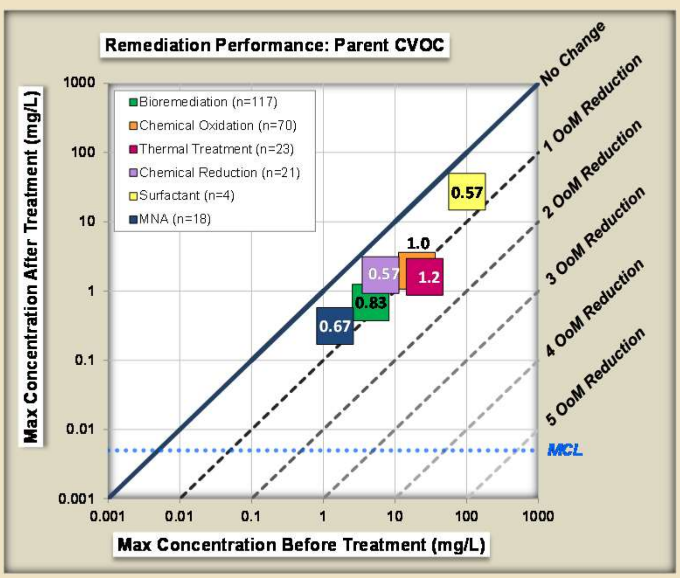
PERFORMANCE – Rule of Thumb

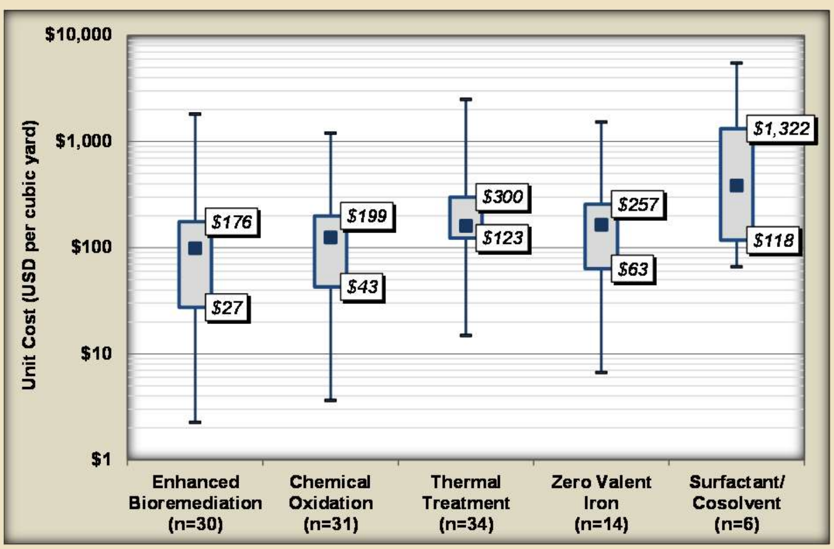


32

AT WHAT COST?

33

AT WHAT COST?



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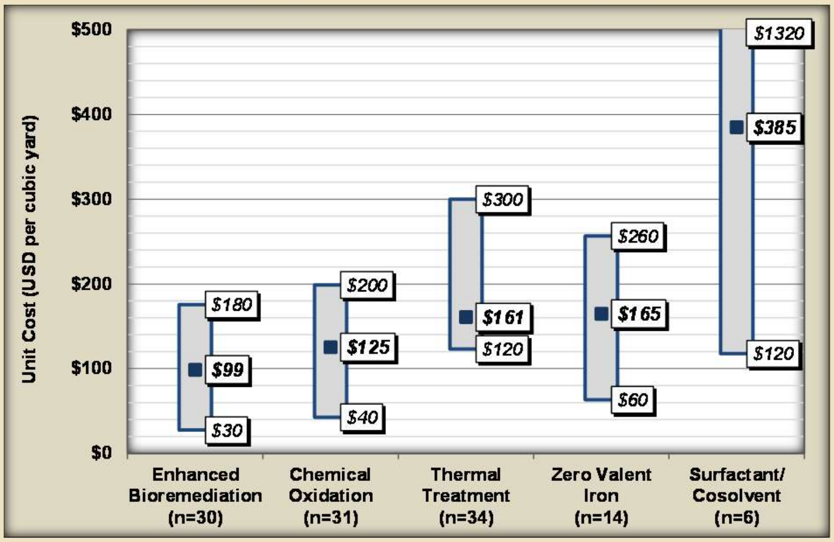
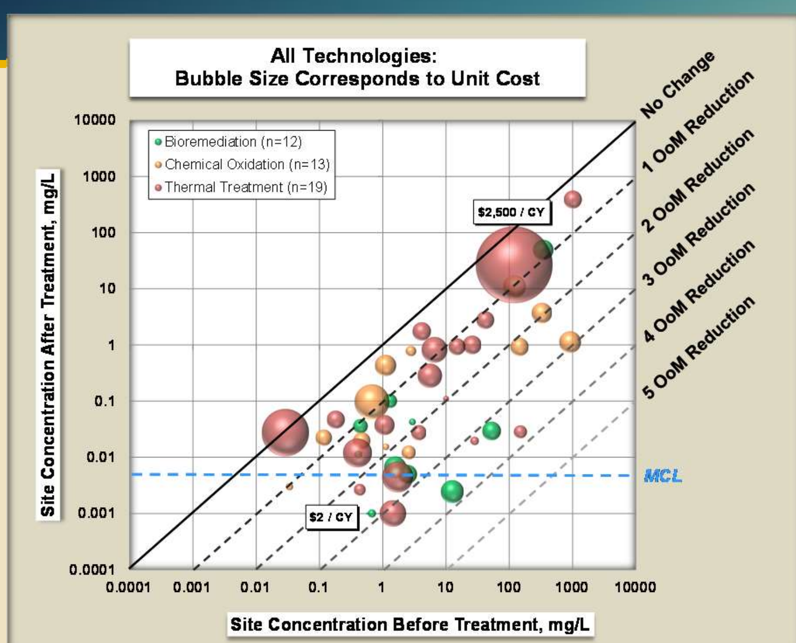
AT WHAT COST?



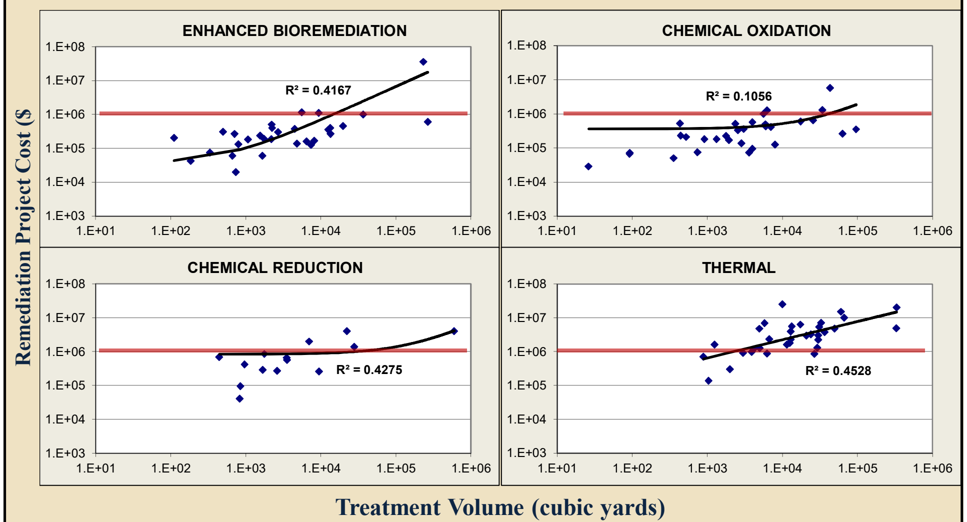
35

AT WHAT COST?



36

AT WHAT COST?

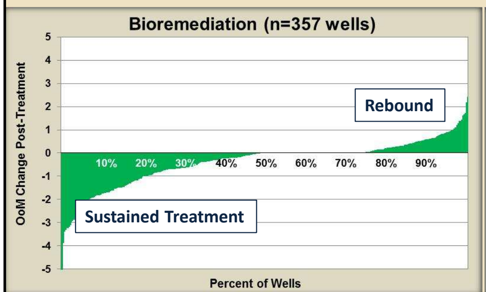


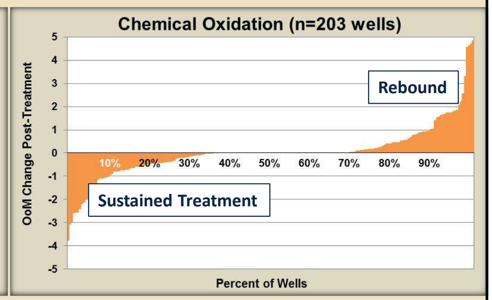
IMPLICATIONS FOR SUSTAINABILITY

1. Sustained Treatment vs. Rebound
2. Transitions Assessments
3. Mass Discharge
4. Aquifer Management

IMPLICATIONS FOR SUSTAINABILITY

Sustained Treatment vs. Rebound for 2 Most Common Technologies





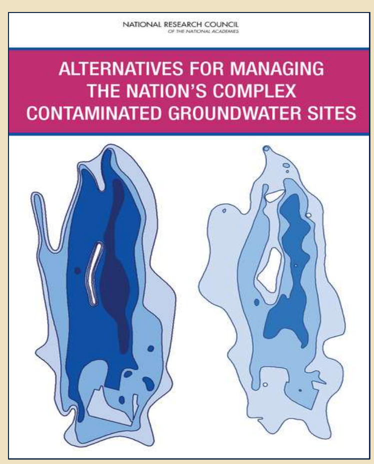
Evidence of Sustained Treatment at about two-thirds of Bioremediation sites with 3 to 12 years post-treatment data (n=34)

McGuire et al., submitted to Groundwater Monitoring & Remediation, 2015.

39

IMPLICATIONS FOR SUSTAINABILITY

- **Consider "Transition Assessment" when further active remediation not much benefit; instead focus on risk and containment**
- **Performance data can be used to support transition from active to passive remedy**
- **Incorporate performance data into 5-Year Reviews at Superfund sites**



National Research Council, 2012

40

IMPLICATIONS FOR SUSTAINABILITY

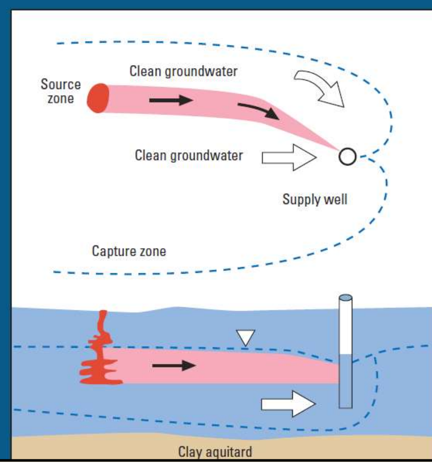
- **More emphasis on Mass Discharge**
    - What is the risk to water supply well?
    - What will the mass discharge be after a remediation project that achieves 1 to 2 OoM reduction?

Einarson and Mackay, 2001. ES&T, 35(3), 66A-73A

FIGURE 1

Plume capture by a supply well

A dissolved plume of contaminants can be hydraulically captured by a downgradient supply well. The contaminant release shown is migrating within a uniform sand aquifer (no fill) overlying a clay aquitard. Clean water on all sides of the plume is also extracted, diluting the concentration of dissolved contaminants in the water pumped from the well.



IMPLICATIONS FOR SUSTAINABILITY

EXAMPLE. Before Treatment:

- 60 ft wide x 10 ft thick source
- Seepage velocity = 1 ft/d
- PCE = 2.5 mg/L

⇨ **Mass discharge ≈ 11 g/d**

- Supply well Q ≈ 260 gpm

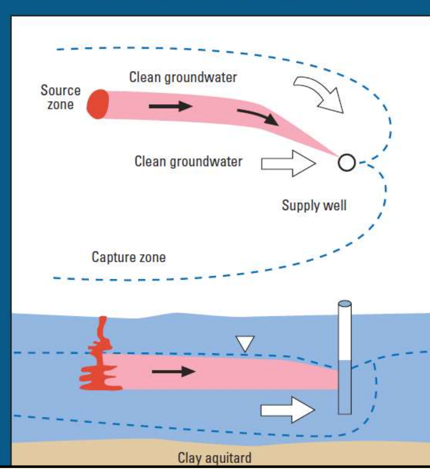
⇨ **Supply well TCE ≈ 8 µg/L**

Exceeds MCL of 5 µg/L

FIGURE 1

Plume capture by a supply well

A dissolved plume of contaminants can be hydraulically captured by a downgradient supply well. The contaminant release shown is migrating within a uniform sand aquifer (no fill) overlying a clay aquitard. Clean water on all sides of the plume is also extracted, diluting the concentration of dissolved contaminants in the water pumped from the well.



IMPLICATIONS FOR SUSTAINABILITY

EXAMPLE. After Treatment that Achieves 1 OoM Reduction in Source:

- PCE = 0.25 mg/L

⇨ **Mass discharge ≈ 1 g/d**

- Supply well Q = 260 gpm

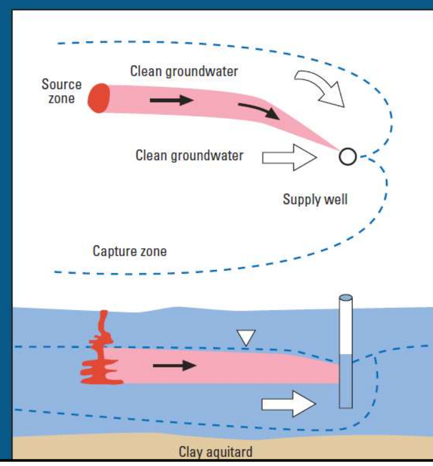
⇨ **Supply well TCE ≈ 0.8 μg/L**

Below the MCL of 5 μg/L

FIGURE 1

Plume capture by a supply well

A dissolved plume of contaminants can be hydraulically captured by a downgradient supply well. The contaminant release shown is migrating within a uniform sand aquifer (no fill) overlying a clay aquitard. Clean water on all sides of the plume is also extracted, diluting the concentration of dissolved contaminants in the water pumped from the well.



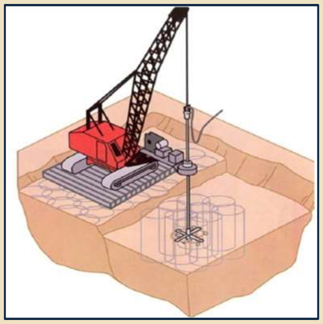
IMPLICATIONS FOR SUSTAINABILITY

- **More emphasis on Aquifer Management**
  - Isolate the source
    - ⇨ Stop new groundwater contamination
    - ⇨ Less influence from heterogeneity
    - ⇨ More contact time inside source zone
    - ⇨ Natural attenuation of downgradient plume

44

IMPLICATIONS FOR SUSTAINABILITY

Deep Soil Mixing / ZVI Clay



Source: Colorado State University

45

IMPLICATIONS FOR SUSTAINABILITY

"FLUX CLOG"

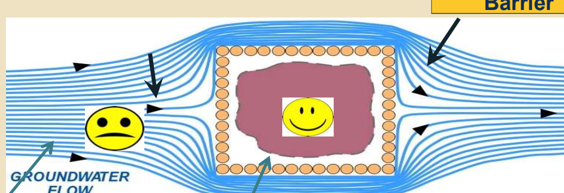
Competing Electron Acceptors:

Dissolved Oxygen (O_2)

Nitrate (NO_3)

Sulfate (SO_4)

Flux Reduction Barrier



GSI ENVIRONMENTAL

ESTCP Project 201328

ESTCP

46

WRAP UP

Conclusions:

- MCLs achieved at less than 1 in 10 sites
- Typical performance was about 0.5 to 2 OoM reduction in groundwater concentrations
- Costs generally $100 to $200 per cubic yard
- Bioremediation appears effective for long-term, sustained treatment at most sites

Future:

- Quantifying sustained treatment benefits
- Continued emphasis on mass discharge
- More evaluation of matrix diffusion
- A Containment Comeback?

47

FOR MORE INFORMATION

- Draft Final Report under review by ESTCP
- Final Report available late 2015 (www.serdp-estcp.org)
- Several manuscripts in preparation

GSI ENVIRONMENTAL

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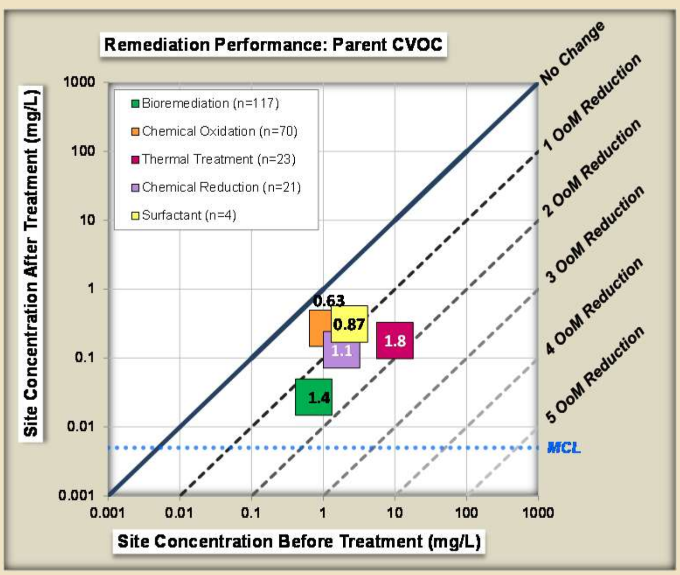
Houston, TX
77098
O: 713-522-6300

Travis M. McGuire, P.E.
tmm@gsi-net.com

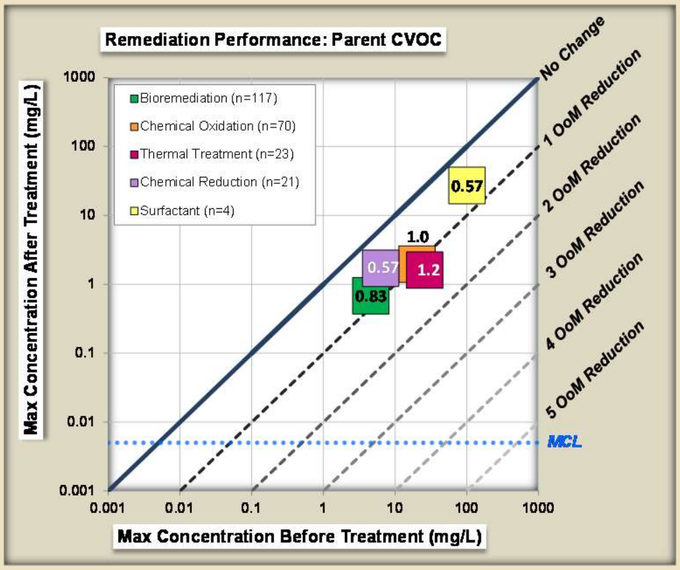
48

BACKUP SLIDES

BACKUP SLIDES



BACKUP SLIDES



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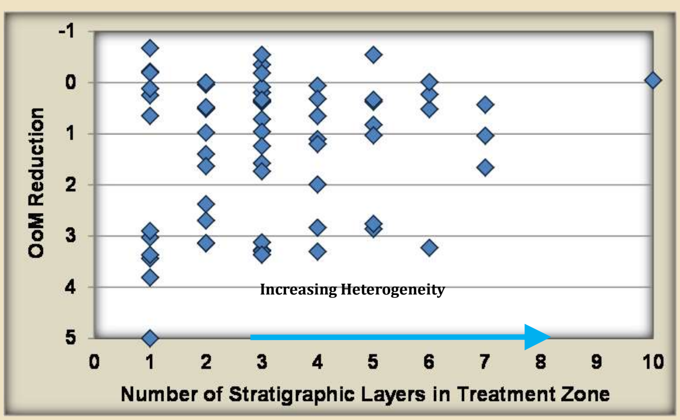
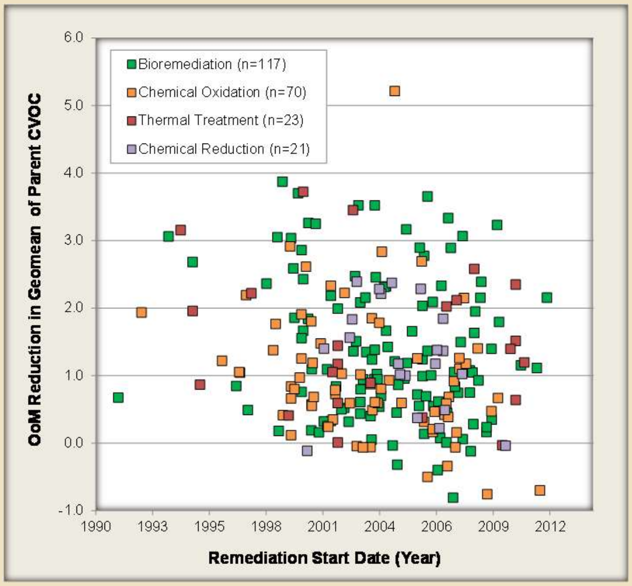


52

BACKUP SLIDES



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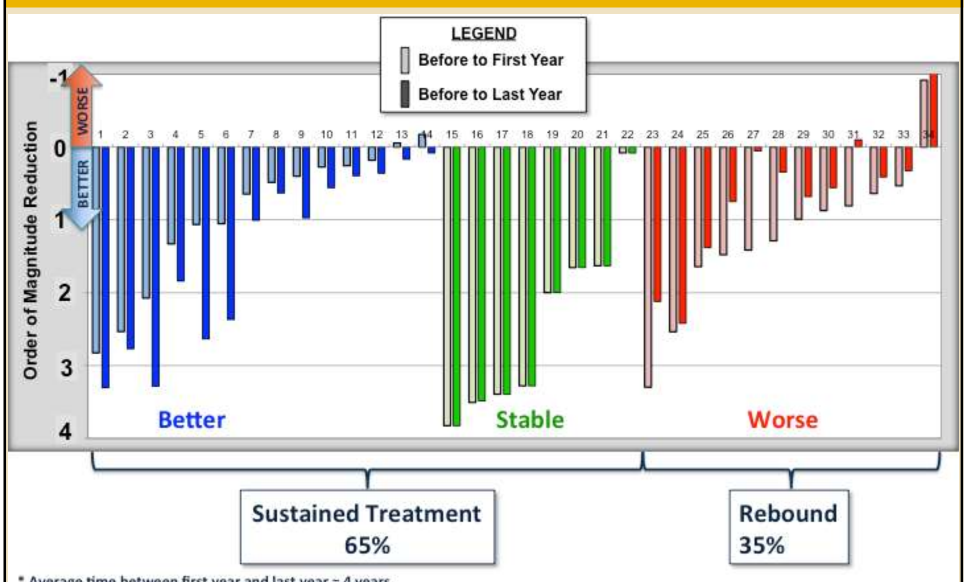
BACKUP SLIDES



Attachment 8

Beneficial Reuse of Treated Groundwater for Plant Operations

Beneficial Reuse of Treated Groundwater for Plant Operations

SURF 30 – October 2015

William A. Butler, P.E., BCEE – ERM – Atlanta, GA

Mitchell Gertz – Solvay Specialty Polymers – West Deptford, NJ

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Contents

- Background
- Challenges
- Solution
- Benefits
- Results

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Solvay Plant – West Deptford, NJ

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Background

- Site History
  - Fluoropolymer manufacturing facility since 1985
  - Refrigerant gas plant from 1975 to late 1970s
  - Agricultural use prior to 1975
  - 243 acres with active manufacturing on 35 acres
  - Industrial area with some agricultural and residential properties
  - Delaware River borders the northern property boundary
- Site Investigation and Remediation Drivers
  - ECRA triggered site investigation in 1989 followed by additional ECRA/ISRA triggers in 1992, 2002 and 2012
  - RCRA Corrective Action – RCRA 2020 site
  - NJDEP is lead with USEPA Region 2 involvement

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Background

- Geology/Hydrogeology
  - Depth to water ranges from 15 to 20 ft bgs
  - Groundwater flow is toward SSE – away from Delaware River due to regional groundwater pumping
  - Potomac-Raritan-Magothy (PRM) aquifer system – critical-stressed aquifer
  - Fine to coarse sands with some clay and gravel lenses until a confining clay layer encountered at 80 ft bgs on site and 200 ft bgs approx. 2 miles SSE
  - Plant water supply wells screened below the confining clay layer
- Groundwater plume extends off site with COCs exceeding NJ GWQS
  - 1,1,1-trichloroethane and breakdown products
  - Carbon tetrachloride
  - Site specific compounds (SSC): 1-chloro-1,1-difluoroethane (142b); 1,1-dichloro-1 fluoroethane (141b); and 1,1,1-trifluoroethane (143a)
  - Low pH (3-5) on site – naturally lower pH off site (5-6.5)

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Challenges

- Remedial Action Objective
  - Reduce off-site migration of COCs at concentrations exceeding NJ GWQSs
  - Reduce potential vapor intrusion risks on and off site
- NJDEP would not approve MNA
- In Situ Remediation Treatability Studies
  - Anaerobic bioremediation
  - Chemical reduction – ZVI
  - Oxidation – persulfate
  - Limited success for site-specific compounds
- Air Sparging/SVE Pilot Test
  - COCs and site-specific compounds (SSC) can be effectively removed
  - Layered geology and installing within an active plant makes it difficult to cost-effectively implement

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Challenges

- Groundwater pump and treat selected
  - Technically viable alternative – although not preferred
  - 4 extraction wells in shallow, unconfined aquifer – 264 gpm
  - Initial design included 2 injection wells
  - NJ GWQS – stringent discharge limits
  - Need to treat for aluminium, iron and manganese in addition to COCs
  - Air stripper, chemical precipitation, two-stage ion exchange, neutralization
  - High capital and O&M cost – how can costs be reduced?
- Treated groundwater discharge alternatives
  - Potential cost reduction?
  - Other benefits?

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Solution – Discharge Alternatives Evaluation

Option	Pros	Cons
Discharge to Groundwater	1. No interference with plant operations 2. Returns water to stressed aquifer	1. Need DGW permit 2. Additional treatment for metals 3. High capital and O&M cost
Discharge to Surface Water	1. Existing NJDPES permit in place 2. Reuse of existing WWTP equipment	1. Required permit modification 2. Potential impact to river 3. Additional treatment for metals 4. High capital and O&M cost
Discharge to POTW	1. Existing discharge permit in place 2. Reuse of existing WWTP equipment	1. Requires permit amendment 2. Additional treatment for metals 3. Infrastructure required 4. High capital and O&M cost
Reuse	1. Reduces load on lower, critically-stressed aquifer 2. Less stringent treatment requirements 3. No additional treatment for plant use 4. Reuse of existing WWTP equipment 5. Lower capital and O&M cost	1. Water allocation permit and DRBC Docket modifications needed 2. Treatment Works Approval (TWA) needed 3. Potential impact to plant operations

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Solution – Groundwater Reuse

- Existing Plant Water Supply
  - Two wells screened below the confining clay layer
  - Water Allocation Permit in place
  - Groundwater treated using ion exchange to remove iron
- Groundwater Reuse
  - Off set volume of groundwater pumped from existing water supply wells
  - No impacts to plant operations due to shallow groundwater quality – water quality actually better in regards to iron
  - Existing ion exchange system sufficient to meet plant needs
  - Both NJDEP BWA and DRBC approved Water Allocation Permit modification
    - 572 gpm maximum rate
    - Provided flexibility to allow pumping from either aquifer as long as total allocated rate not exceeded
  - Treatment Works Approval received from NJDEP

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Solution – Groundwater Treatment

- **Four (4) recovery wells** – 264 GPM average, 422 GPM max predicted through modelling
- **Equalization tank** – existing tank being used
- **Two (2) low-profile, tray air strippers** rated for 250 GPM each
- **Two-stage neutralization** – existing tanks being used
- **Clarifier** – existing clarifier being used
- **Sludge tank** – existing tank being used – sludge being combined with existing WWTP sludge handling/dewatering equipment
- **Interim post-treatment storage tank** – existing tank being used
- **Existing ion exchange system** being used to treat combined groundwater before plant use
- **NJDEP approved air permit** without air emission control as long as VOC and SSC emissions remain below permitted rates

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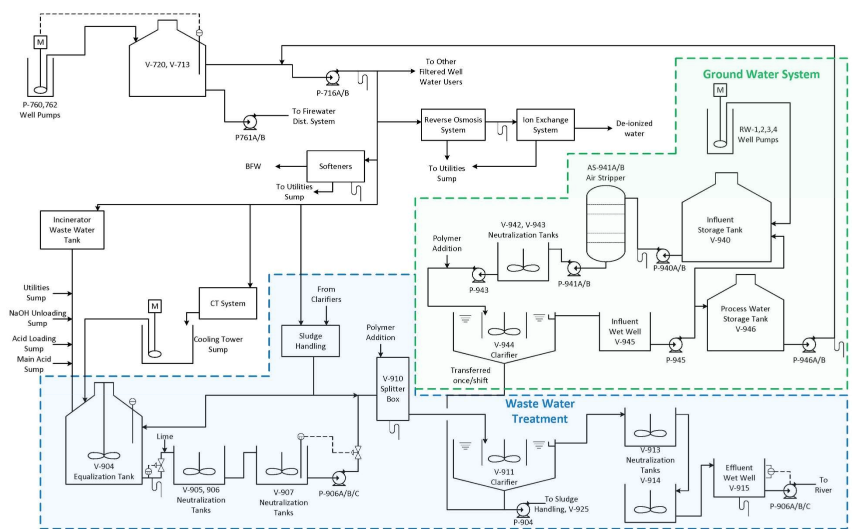
Groundwater and Wastewater Flow Diagram



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Groundwater Treatment System

Recovery Well with Temporary Iron Precipitation Control

Recovery Well Flow Meters & Controls

Equalization Tank

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Groundwater Treatment System

Clarifier

Air Strippers

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Benefits

- Lower cost treatment system ($2.5M savings)
  - No additional treatment via ion exchange required for metals
  - Existing WWTP equipment reused
  - Less stringent treatment requirements
- 175 MGY less groundwater pumped from a critically-stressed aquifer
- Less electrical power consumption and thus greenhouse gas generation
- Water supply options available in the event of water-use restrictions
- Less risk of discharging groundwater above permitted limits
- Less risk of system downtime compared to a more complex system

SUSTAINABLE

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Results Since 2011 Start-Up

- ≥ 90% plume capture
  - Limited due to high COC concentrations that required limiting the pumping rate to maintain air emission rates below permitted levels

- Plant operations improved and costs decreased
  - Better groundwater quality resulted in **$50,000/year less treatment and chemical cost** for existing ion exchange system – in addition to $2.5M cost savings
  - Less ion exchange regeneration resulted in less discharge of regeneration backwash water to POTW
- Modifications to treatment system
  - Iron precipitation control – inhibitor added at recovery wells to reduce precipitation
  - Polishing step added to improve water quality for reuse
    - Proactive measure – NJDEP did not require this
    - Sand filtration and GAC added post clarifier

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Thank You for Attending!

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Attachment 9

Groundwater Conservation and Reuse Update and Panel Discussion

Improving the Sustainability of Cleanups Through Conservation and Reuse of Groundwater: A SURF Initiative

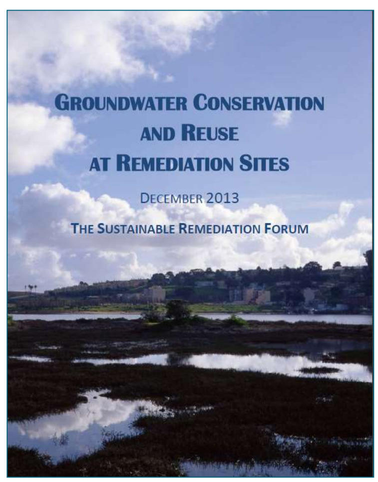
Paul Hadley (retired)
Jake Torrens
Amec Foster Wheeler

SURF 30
Rice University
October 6-7, 2015

SURF

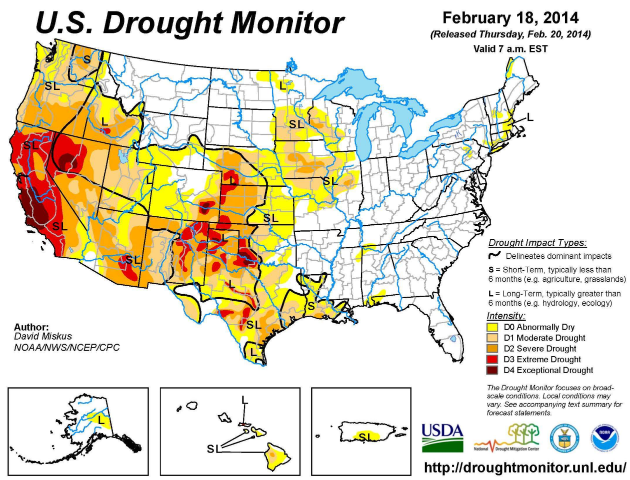
SURF Technical Initiative

- Encourage paradigm shift
- Debunk myths
- Summarize current practices
- Provide education and resources

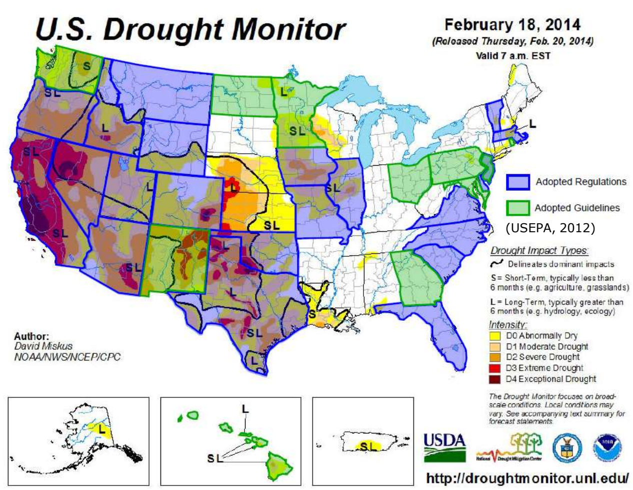


SURF

U.S. Drought Map



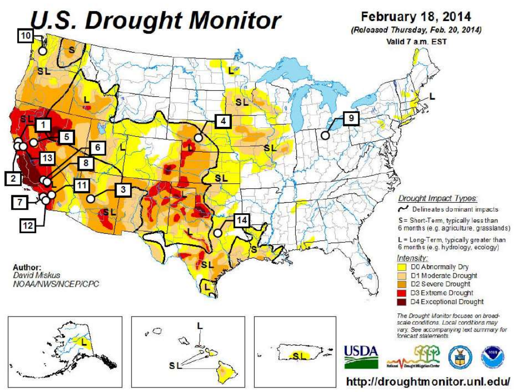
Water Reuse Regulations



USEPA. 2012. Guidelines for Water Reuse. EPA/600/R-12/618.

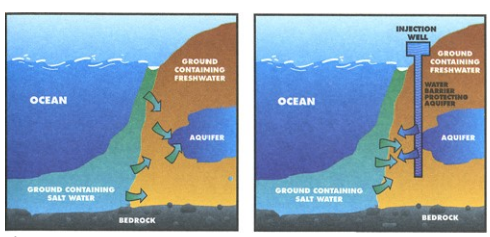
SURF Case Studies

- 14 projects demonstrating water conservation and reuse
- Case studies summarized the following attributes of the project:
  - Location
  - Drivers
  - Contaminants of concern
  - Amount of water reused
  - Regulatory framework
  - Barriers
  - Type of reuse
  - Cost
  - References



Orange County Water District

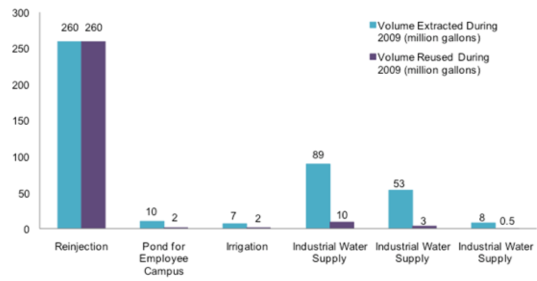
- Orange County Water District Groundwater Replenishment System
- Freshwater injection to prevent seawater intrusion
- 70 mgd of wastewater treated
  - 40 MGD percolation ponds
  - 30 MGD injected into coastal aquifer



Source:
West Basin Municipal District. 2013.
http://www.westbasin.org/education/water-information/groundwater

San Francisco Bay Area Study

- 56 facilities surveyed within jurisdiction of San Francisco Bay RWQCB
- 6 currently reusing treated groundwater
- 20% of treated water being reused



Source:
Byler, T.; S. Bourne; A. Petti; M. Cunningham. 2010. *Treated Groundwater Reuse from Site Remediation in the San Francisco Bay Area*

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San Francisco Bay Area Study

- Barriers
  - Lack of infrastructure
  - Lack of incentives
  - Unable to identify reuse application
- Treated groundwater is of higher quality than water from treatment plants

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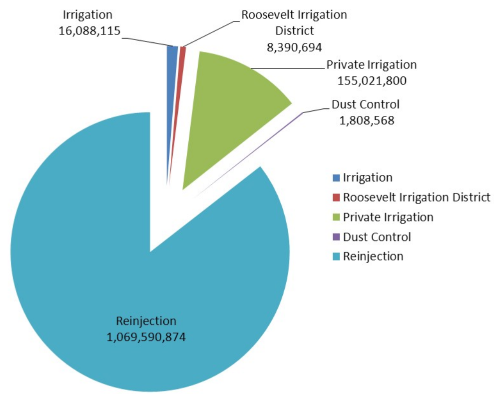
Unidynamics – Phoenix, AZ

- Superfund site
- Sonoran Desert (avg. annual rainfall of 8 in.)
- P&T system (2,800 gpm)
- Agreements negotiated with local entities
- Cooling water then reinjected



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Aerospace – Huntington Beach, CA

- VOCs in groundwater
- Remedial approach of P&T with integrated water conservation and reuse principles
  - Optimize P&T system to minimize water extracted
  - Reuse treated groundwater
    - Engage facility operators
    - Conduct a water audit
    - Prepare a contingency plan
    - Evaluate the potential for VOC exposures

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Lessons Learned from Case Studies

- Water reuse is happening
  - Primarily in the west
- Reuse practices appear to be a voluntary grass-roots effort with little to no regulatory pressure
- Risk assessments augment the practice by addressing the potential health concerns related to emerging contaminants
- Perceived liability is chief obstacle
- Early wastewater reuse projects seem to have solved the ‘yuck’ factor

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Closing Thoughts

- Education and outreach
  - Professionals/practitioners
  - Regulators
  - Policy makers
  - Water purveyors
  - Water advocacy groups
  - Professional societies
  - Urban planners
  - Community members
- Building partnerships and networking
  - Cross-disciplines
- Sharing experiences and best practices
  - Journal publications
  - Case studies

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Contributors

- Technical Initiative Team Leaders
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  - Yamini Sadasivam, University of Illinois at Chicago
  - Maile Smith, Northgate Environmental Management
  - Kathy Adams, Writing Unlimited

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Attachment 10
How Can a Green Remediation Project Benefit by Incorporating Sustainability?

How Can a Green Remediation Project Benefit by Incorporation of Sustainability?

SURF 30: Exploring the Energy/Water Nexus
Rice University, Houston, Texas

Michael E. Miller, CDM Smith
Melissa A. Harclerode, CDM Smith
Pankaj Lal, Montclair State University

October 2015

CDM Smith

Overview

- Definitions
- Case study site: remedial alternatives
- Method: monetization of impacts
- Results: estimated costs borne by society
- Decision point for remedy selection
- Conclusions

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Green Remediation (GR)

- Consider environmental effects of remedy.
- Maximize net environmental benefit.

- REFERENCES:
  - USEPA, 2008. Green Remediation Primer
  - USEPA, 2010. Green Remediation Strategy
  - USEPA, 2012. Methodology for Understanding and Reducing a Project's Environmental Footprint
  - USEPA, 2013. Memorandum: ASTM's Standard Guide for Greener Cleanups

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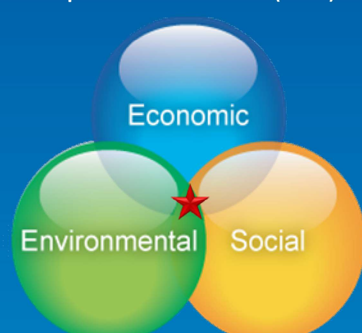
Sustainable Remediation (SR)

- ***"…meets the needs of the present without compromising the ability of future generations to meet their own needs."***
  -Brundtland Commission, 1987
- Aim to balance the triple bottom line (TBL) -*Elkington, 1994*



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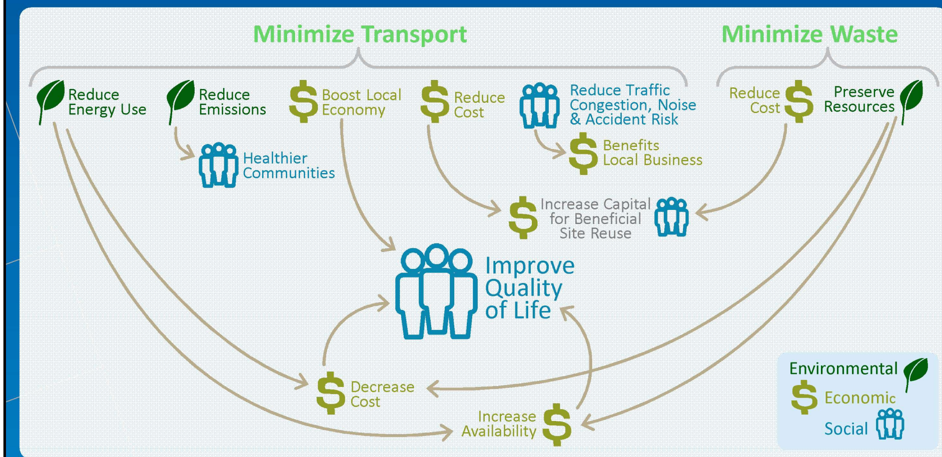
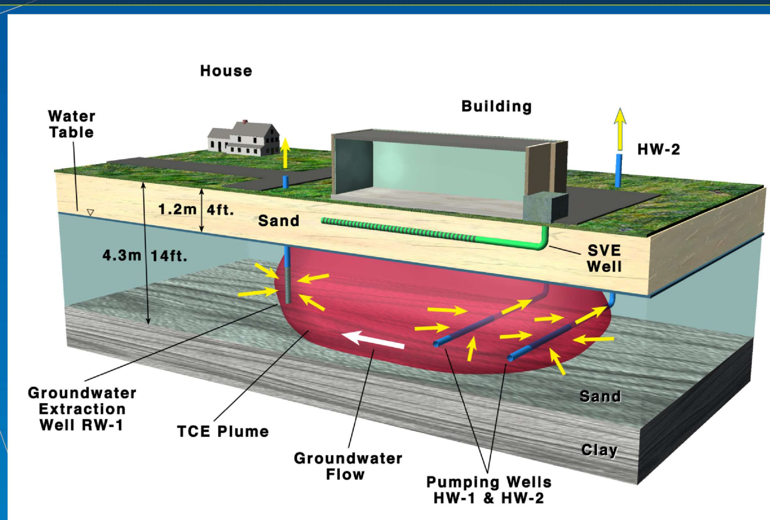
Overlapping Benefits of the TBL

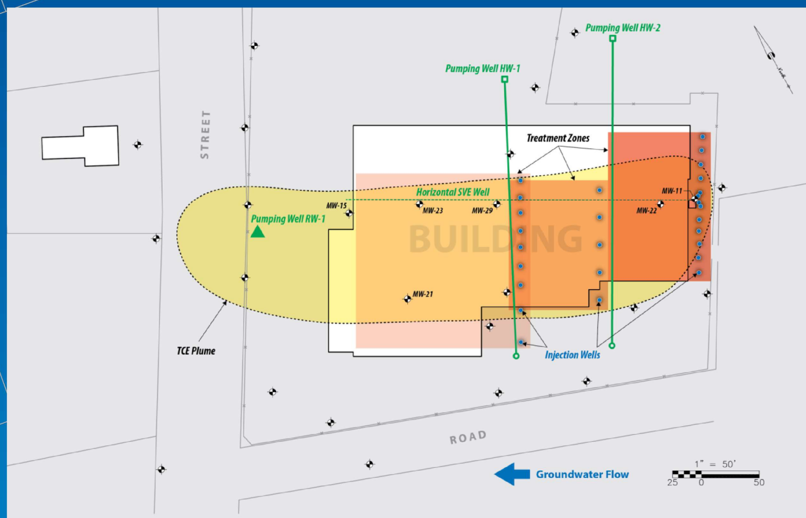
- Green remediation BMP: **Use on-site/local materials** ⟶



GR Case Study: Manf. Facility in Connecticut



Replaced Pump-and-Treat with Bioremediation



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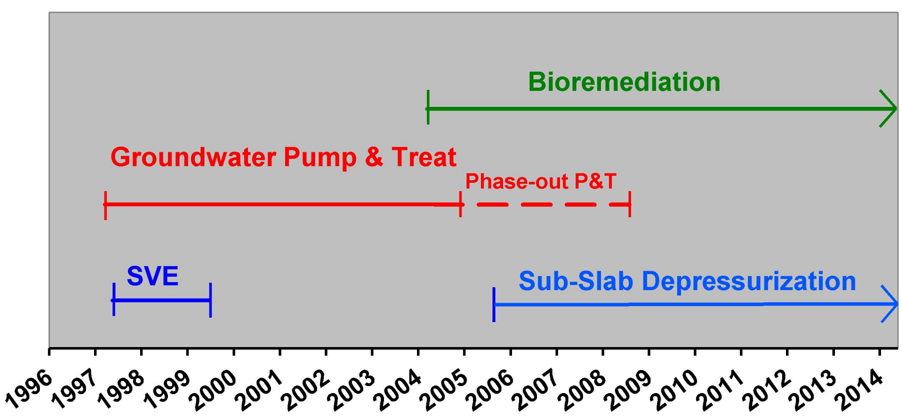
Case Study Timeline



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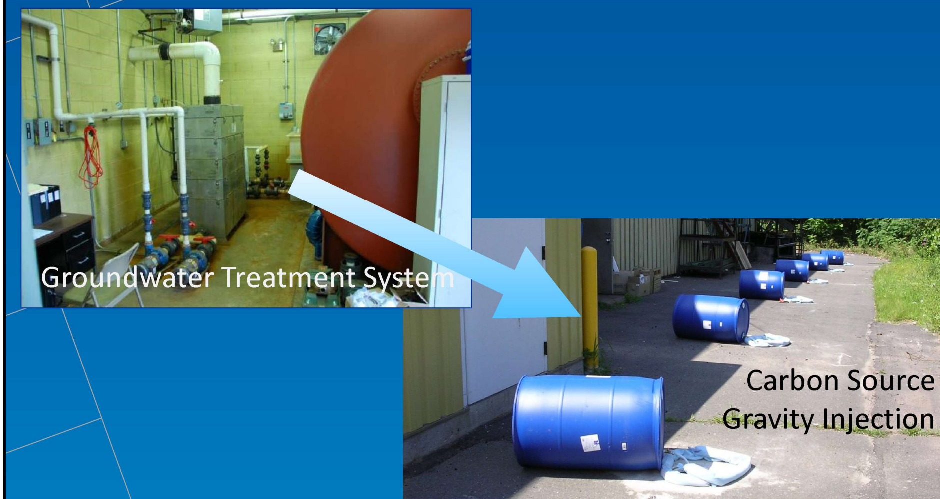
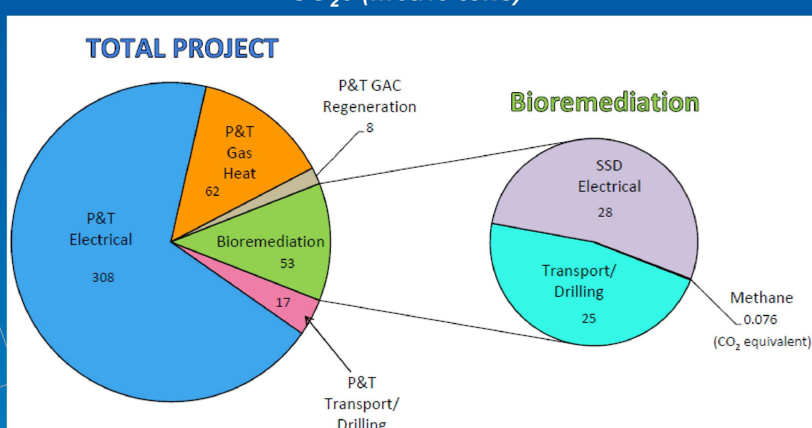
Transition

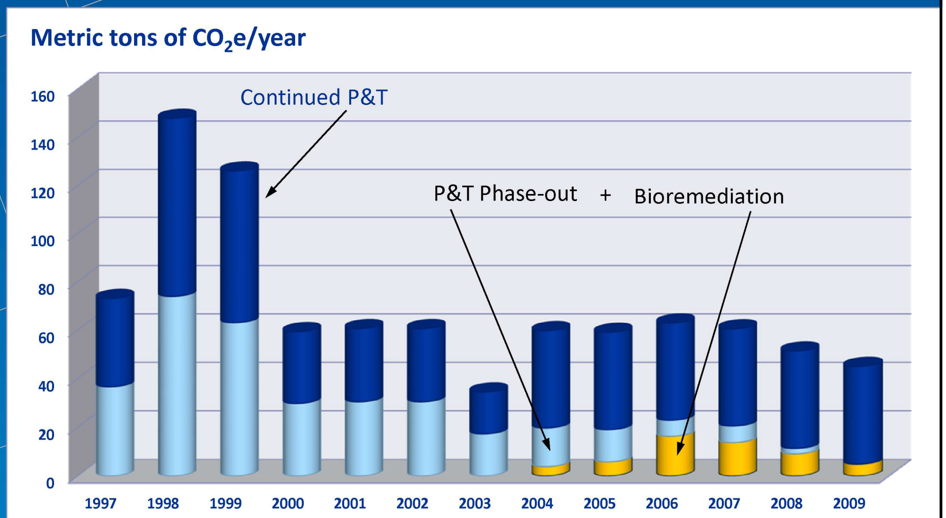


Allocation of Carbon Impacts

CO_2e (metric tons)



Carbon Footprint Totals



Social Cost of an Environmental Metric

Private Costs + **Environmental Externalities** = **Social Cost of Environmental Metric**

- Production
- Manufacturing

- Cost of societal damages (dis-amenities)

Monetization Method

Environmental Footprint Analysis Metric × **Unit Social Cost of Metric** = **Costs Borne by Society**

- Sum over all metrics of interest

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Costs Borne by Society (CBS) – Focus here on GHG

- Climate change mitigation and adaptation
- Increased health costs
- Reduced water and energy resources
- Loss of ecosystems and species
- Shifting agricultural zones
- Reduced quality of life
- Etc.

How do we quantify these societal costs?
How could this affect remedial choices?

14

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Literature Sources

Dis-amenities -

- US Government Interagency Working Group* on Social Cost of Carbon
  - Under Executive Order 12866 (2010, and technical update 2013)
  - *Includes USEPA

Market Price of Carbon -

- California GHG Cap-and-Trade Program, 2014
- Regional GHG Initiative, 2014
- Quebec's Carbon Market, 2014
- 2011 Carbon Dioxide Price Forecast (Synapse Energy Economics)

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Costs Borne by Society for Energy

$$CBS_t = (CO_2e_t \times SCC_t) + (kWh_t \times SCNC_t)$$

- **Carbon emissions**
  - CO_2
  - CO
  - CH_4
- **Non-carbon emissions**
  - SO_2
  - NO_x
  - Particulates

- **TOTAL = sum over years t**

$$V_{1997} = \sum_t \frac{CBS_t}{(1+DR)^{t-1997}}$$

DR = discount rate

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Energy Nexus of Remedial Systems

$$CBS_t = (CO_2e_t \times SCC_t) + (kWh_t \times SCNC_t)$$

Environmental Metric	Societal Dis-Amenities
Carbon Dioxide (CO_2,)	Long-term global impacts of climate change, including changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services (USG 2013).
Energy (non-carbon social cost)	Long-term societal impacts, including health costs, shortened life spans, environmental mitigation, and broad impacts of climate change (Greenstone et al. 2011)

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How To Choose a Social Cost of Carbon Value?

$$CBS_t = (CO_2e_t \times SCC_t) + (kWh_t \times SCNC_t)$$

Social Cost of Carbon Value

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How To Choose a Social Cost of Carbon Value?

Revised Social Cost of CO_2, 2010 – 2050 (in 2007 dollars per metric ton of CO_2)

Discount Rate	5.0%	3.0%	2.5%	3.0%
Year	Avg	Avg	Avg	95th
2010	11	33	52	90
2015	12	38	58	109
2020	12	43	65	129
2025	14	48	70	144
2030	16	52	76	159
2035	19	57	81	176
2040	21	62	87	192
2045	24	66	92	206
2050	27	71	98	221

Source: *Technical Support Document – Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis. Interagency Working Group on Social Cost of Carbon, United States Government, May 2013.*

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How To Choose a Social Cost of Carbon Value?

- A lower discount rate means society places more weight on future impacts
  - (e.g., climate change and chronic human health impacts).
- A higher discount rate means society places more weight on present impacts
  - (e.g., daily congestion and inconvenience due to remedial activities taking place)

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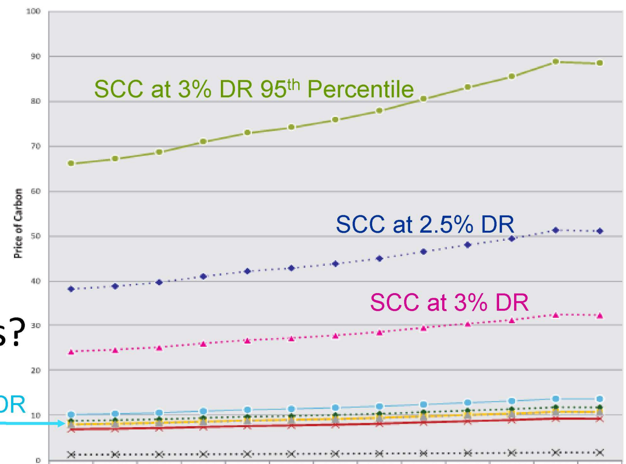
How Does Discount Rate Relate to Market Values?



SCC at 5% DR

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CA GHG Cap-&-Trade (metric ton)	6.99	7.10	7.26	7.50	7.71	7.84	8.01	8.23	8.51	8.78	9.03	9.38	9.34
Regional GHG Initiative (RGGI) (metric ton)	1.35	1.37	1.40	1.45	1.49	1.51	1.55	1.59	1.64	1.69	1.74	1.81	1.88
Quebec's Carbon Market (metric ton)	6.99	7.10	7.26	7.50	7.71	7.84	8.01	8.23	8.51	8.78	9.03	9.38	9.34
USG Social Cost - 5.0% Discount Avg. Yr. (metric ton)	8.10	8.22	8.40	8.69	8.93	9.08	9.28	9.53	9.85	10.17	10.46	10.86	10.82
USG Social Cost - 3.0% Discount Avg. Yr. (metric ton)	24.29	24.67	25.21	26.06	26.79	27.23	27.85	28.59	29.56	30.51	31.38	32.58	32.47
USG Social Cost - 2.5% Discount Avg. Yr. (metric ton)	38.27	38.87	39.73	41.06	42.21	42.90	43.88	45.05	46.57	48.08	49.45	51.34	51.16
USG Social Cost - 3.0% Discount 95th Percentile Year	66.24	67.28	68.76	71.07	73.05	74.25	75.94	77.97	80.61	83.21	85.58	88.86	88.55
Synapse High Bound Price Forecast (short ton)	10.25	10.41	10.64	11.00	11.31	11.49	11.76	12.07	12.48	12.88	13.25	13.76	13.71
Synapse Mid Bound Price Forecast (short ton)	8.86	9.00	9.20	9.51	9.77	9.93	10.16	10.43	10.78	11.13	11.45	11.89	11.84
Synapse Low Bound Price Forecast (short ton)	8.03	8.16	8.34	8.62	8.86	9.00	9.21	9.45	9.77	10.09	10.38	10.78	10.74

Year

Smith

Costs Borne by Society

For CO_2e:

	Damages		Damages		Market Price C	
Year	P&T 2.5% DR	Bio 2.5% DR	P&T 5% DR	Bio 5% DR	P&T Average	Bio Average
1997	$2,061	$2,061	$436	$436	$315	$315
1998	$4,133	$4,133	$853	$853	$631	$631
1999	$3,513	$3,513	$707	$707	$536	$536
2000	$1,667	$1,667	$328	$328	$255	$255
2001	$1,708	$1,708	$328	$328	$261	$261
2002	$1,693	$1,693	$317	$317	$259	$259
2003	$958	$958	$175	$175	$146	$146
2004	$2,242	$1,095	$400	$195	$342	$167
2005	$2,261	$1,065	$394	$185	$345	$163
2006	$2,277	$1,291	$262	$219	$348	$197
2007	$2,285	$1,161	$257	$193	$349	$177
2008	$2,315	$647	$375	$105	$353	$99
2009	$2,250	$270	$356	$42	$343	$41
TOTAL	*$29,369*	*$21,267*	*$5,195*	*$4,089.53*	**$4,483**	**$3,247**

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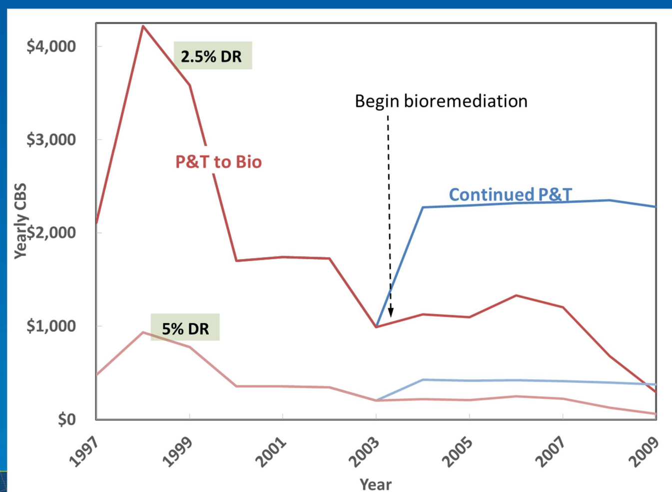
Costs Borne by Society of CO_2e

- Using Discount Rates to Drive the Decision Making Process



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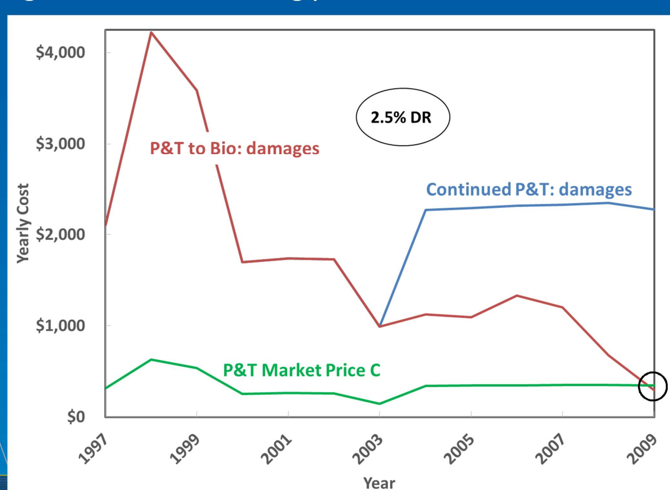
Calculated Costs of CO_2e

- Damages vs. carbon trading price



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Costs Borne by Society: Results

- Lower discount rate → estimate long-term impacts
- 13 years of operation
  - Continued P&T: CBS = $30,000
  - P&T transition to bio: CBS = $22,000
- CO_2e damages ≥ carbon trading price

- **Decision Point for comparison of remedial alternatives: Lowest CBS**

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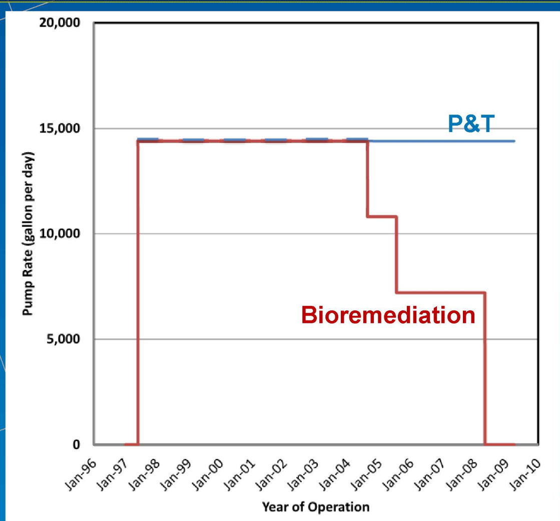
Water Footprint



- Social cost of water consumption?
  - Limited data
  - Much spatial variability

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Conclusions

- Monetization of impacts: universally recognized unit
- Normalization of disparate elements
- Lower discount rate to capture long-term effects
- Quantify social and economic implications of GR
- Bridge to SR without compromising cleanup

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Broader Implications: Monetization of Impacts

- Convince skeptics of benefits
  - Green remediation
  - (and sustainable remediation)
- Mechanism to “sell” climate change adaptation of remedial systems
- Gateway drug to sustainable remediation

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Questions and Answers

Harclerode, M. A., P. Lal, and M. E. Miller. 2015. *Quantifying Global Impacts to Society from the Consumption of Natural Resources during Environmental Remediation Activities.* Journal of Industrial Ecology, Special Issue: Linking Local Consumption to Global Impacts. In Press.

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Attachment 11
Water and Waste Treatment Practices in Oil and Gas:
Current Practices, Technologies, and Opportunities for Improvement

Water and Waste Treatment Practices in Oil and Gas – Current Practices Technologies, and Opportunities for Improvement

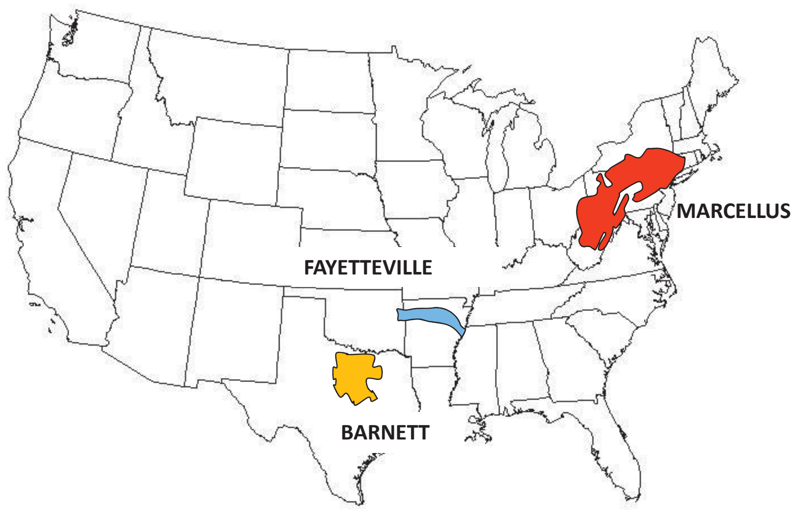
Laura Capper
President & CEO, CAP Resources
President & CEO, Knomatic
lcapper@cap-res.com
www.cap-res.com
Contact information and copy of presentation:

Complexity Drivers

Industry Challenge: One Size does not "Fit All"

Every basin is (entirely) unique; mass volume efficiencies are thus difficult to gain.

Business models are instead customizing to basin / operator requirements (which is more expensive)



3

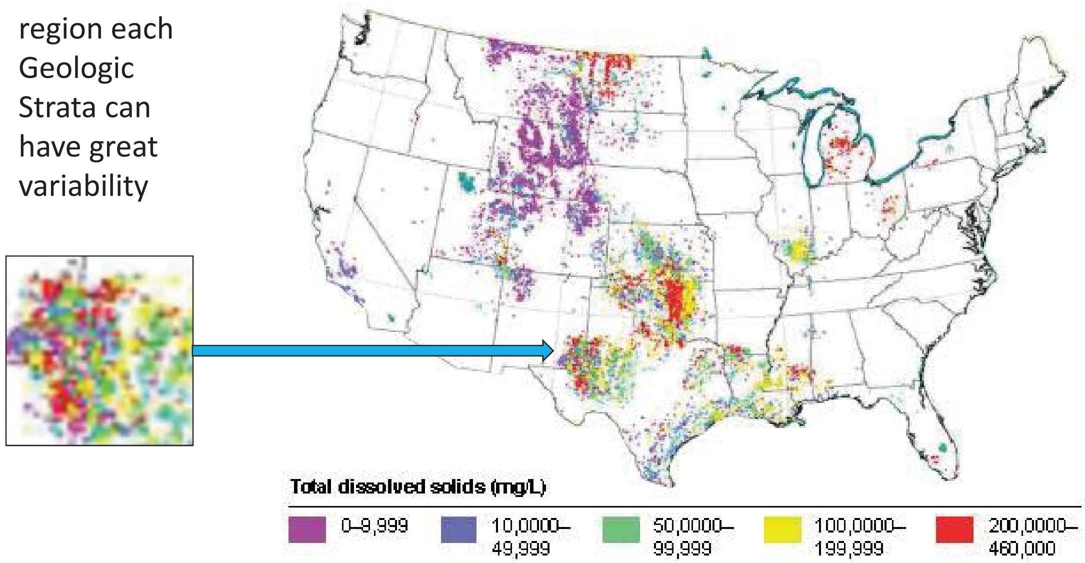
Basin Variability

TDS / SALINITY LEVELS (ppm) IN PRODUCED WATER	120,000	12,500	250,000
TYPICAL BACTERIA COUNTS IN SOURCE WATER	MEDIUM	HIGH	LOW
DISPOSAL WELL COUNTS (STATE)	50,000	450	<10

Illustration: Variance within in a given Region

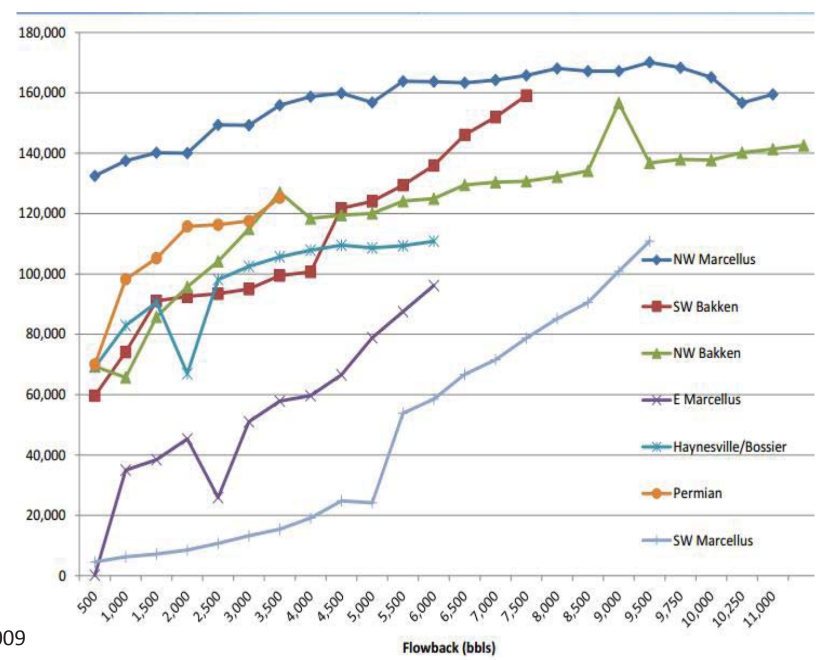
Within a region each Geologic Strata can have great variability

Chemistry of produced fluids across the United States



Typical TDS Variance / well over Time

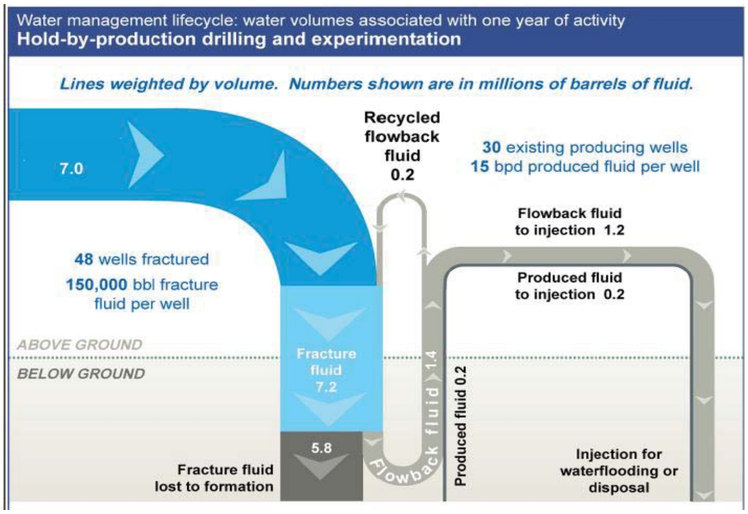
TDS Levels (Mg/L) Climb dramatically over the first year of production



Ref: SPE 125740, Blauch, et.al. 2009

Now Consider Water Mgmt Throughout the Field Life

Hold-by-production drilling and experimentation. Operators want to hold as many leases as possible by production.   They also start to assess the productivity of the acreage position.

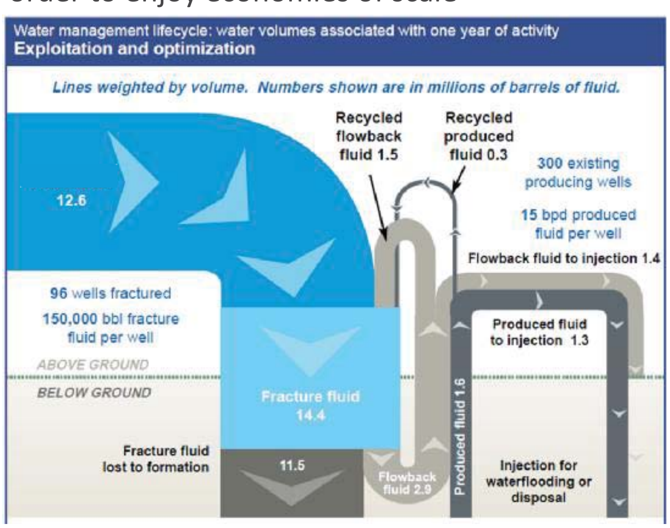


Modest water for frac'ing, Modest re-use and injection

Source: CAP Resources/ IHS The Future of Water in Unconventional Oil and Gas - Water Management Opportunities/ Strategies

Exploitation and Optimization

Exploitation and optimization. most acreage is held by production, boundaries of productive acreage are established, and operators start to drill more multi-well pads in order to enjoy economies of scale

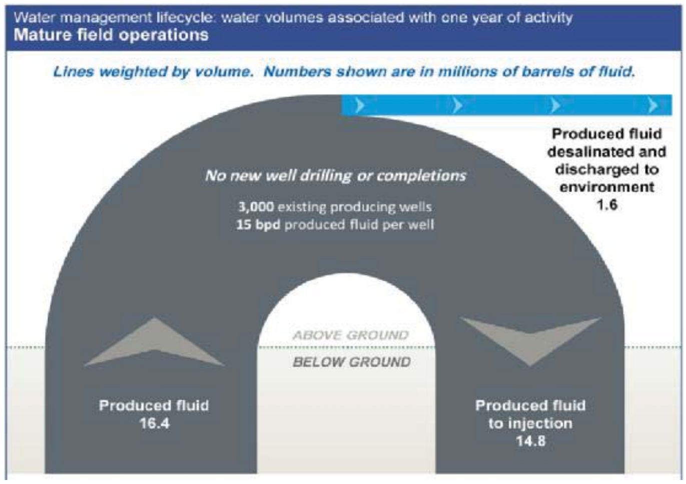


Tremendous fracwater requirements, Modest re-use and injection

Source: CAP Resources/ IHS The Future of Water in Unconventional Oil and Gas - Water Management Opportunities/ Strategies

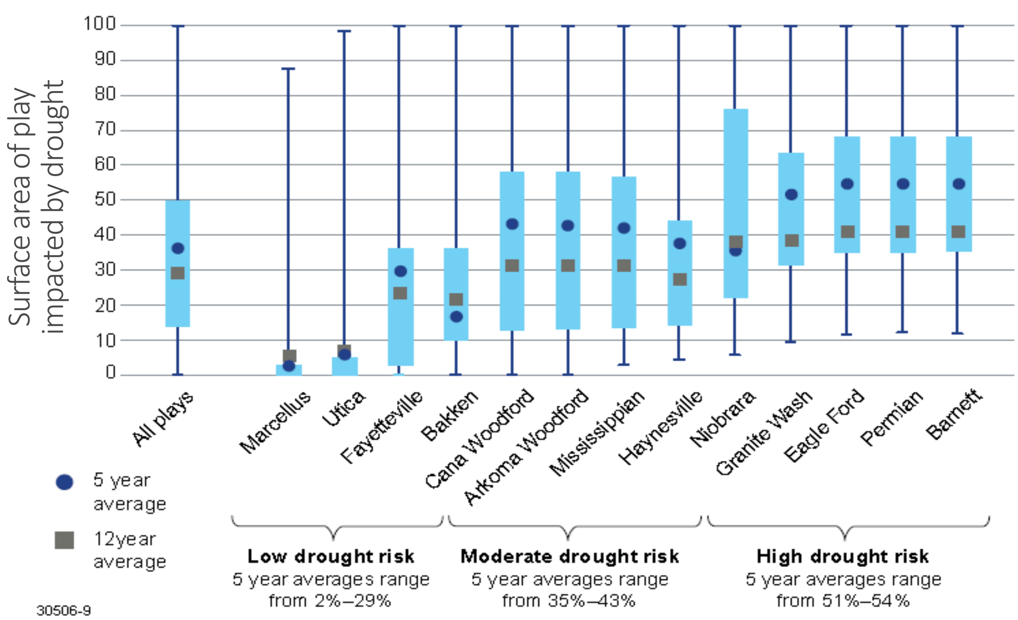
Mature Field Operation

Mature field operation. With drilling and completion programs completed, and wells drilled on optimal spacing, focus shifts to well maintenance, artificial lift optimization, secondary recovery, and tertiary recovery.



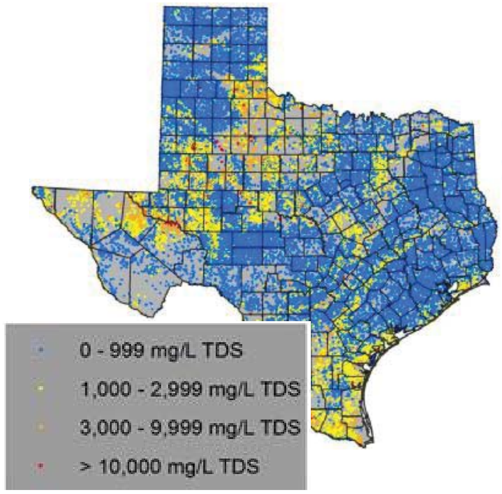
Source: CAP Resources/ IHS The Future of Water in Unconventional Oil and Gas - Water Management Opportunities/ Strategies

Drought impact is unpredictable, and has increased



Source: CAP Resources/ IHS The Future of Water in Unconventional Oil and Gas - Water Management Opportunities/ Strategies

Saline Water: A Prolific Source

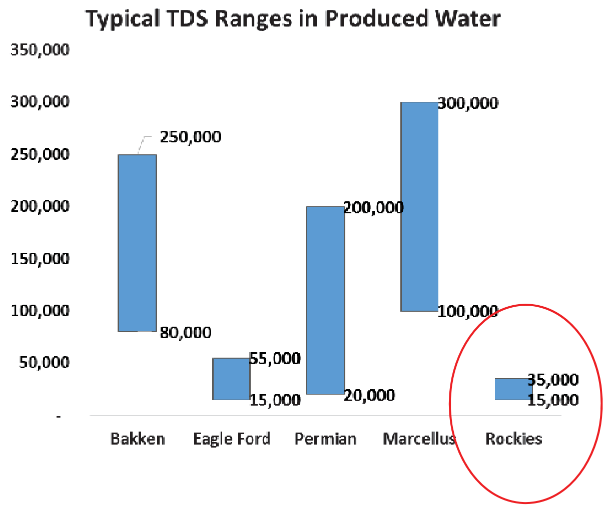


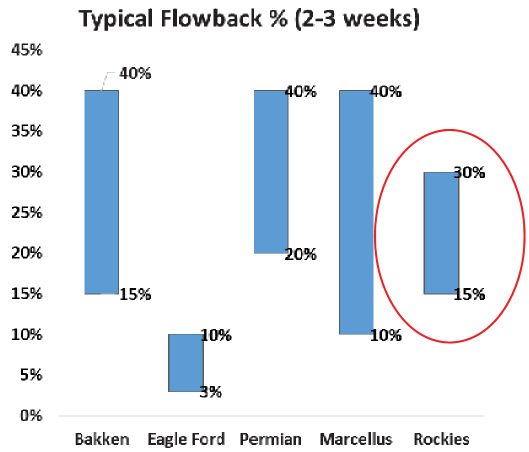
Source: Texas Water Development Board Groundwater Database

http://www.shaleplaywatermanagement.com/2013/11/exploring-water-treatment-reuse-and-alternative-sources-in-shale-production/

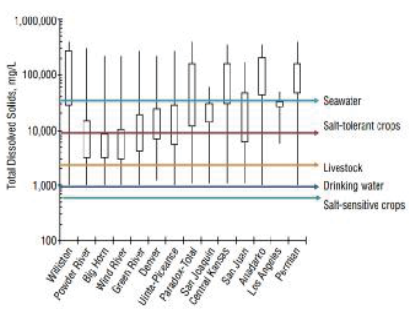
Case Study – Low Salinity Basins (U.S. Central Rockies)

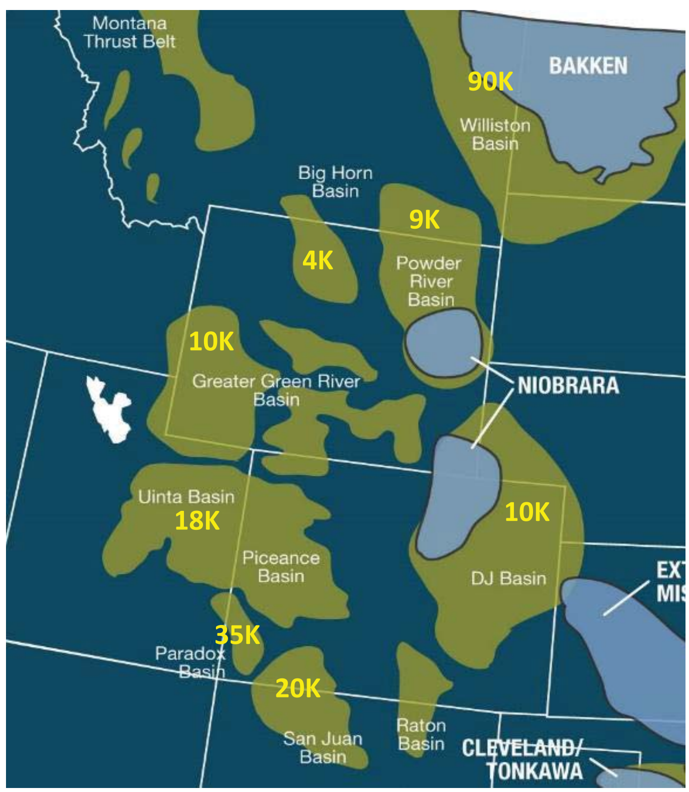
General Comparisons – Other Basins





Regional TDS Comparisons, Produced Water





Source: Dwayne Dalrymple, 19 February 2013 as published in Oil and Gas Facilities Magazine, April 2013

Treatment Requirements

Why Treat?

Bacteria
- Reduces viscosity
- SRBs / H2S Production
- Biofilm / equipment Fouling
- Emulsions
- Equipment corrosion
- Plug formations

TSS
- Equipment clogging
- Reservoir clogging
- Appearance

Chlorides
- Hydration

pH
- Inadvertent crosslinking
- Hydration

Bicarbonates
- Buffering
- Crosslinking impact
- Scaling

Calcium and Magnesium
- Scaling
- Friction Reducer effectiveness
- Borate cross links
- Contribute to Norm Concentration
- Increases HP needs

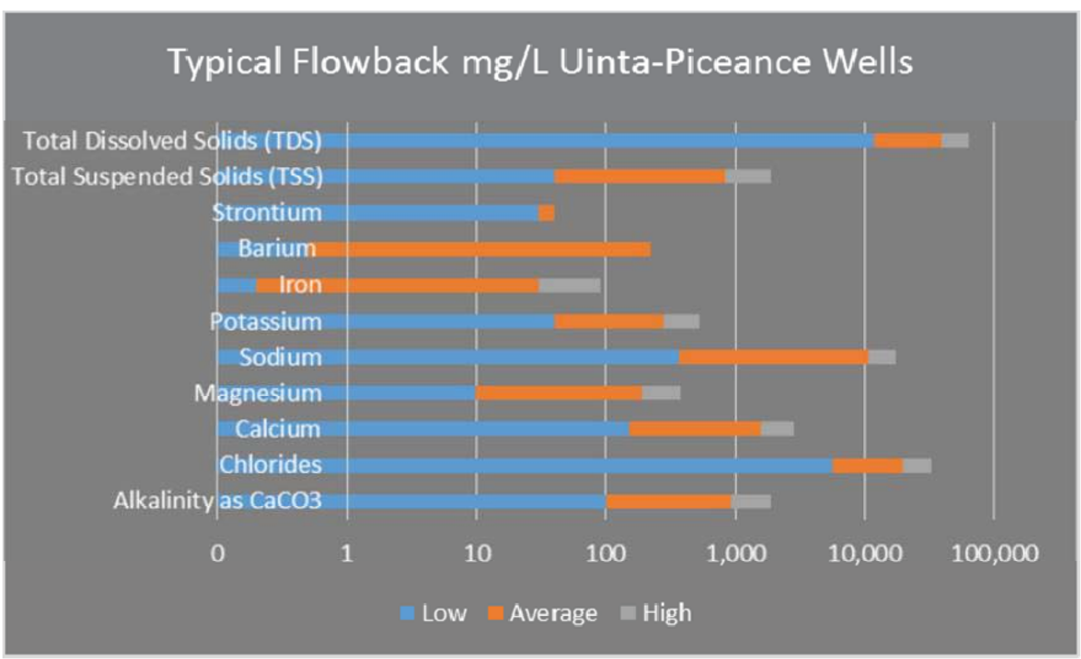
Iron, Manganese, Heavy metals
- Reactive with O2, solids may plug formation
- Crosslinking
- Equipment reliability

Phosphates
- Crosslinking

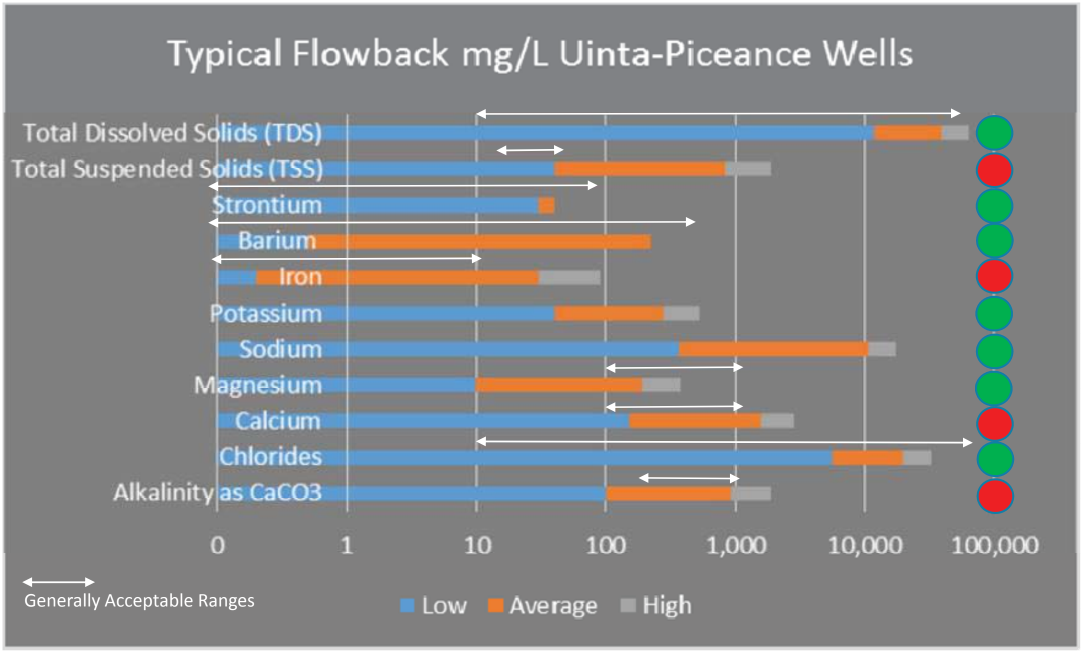
Sulfates
- Crosslinking
- Scale Precipitation

Representative Flowback

Uinta Piceance Basin Shale, Water Quality

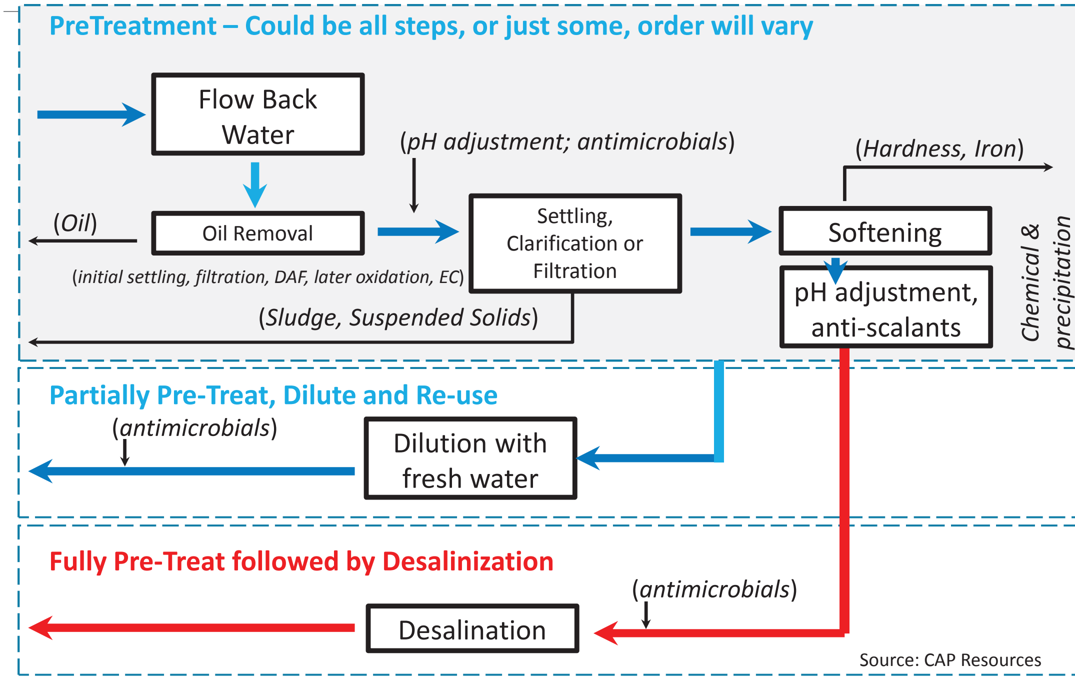


Uinta Piceance Basin Shale, Water Quality



Treatment Technologies

Current Practices



No single technology can treat it all:

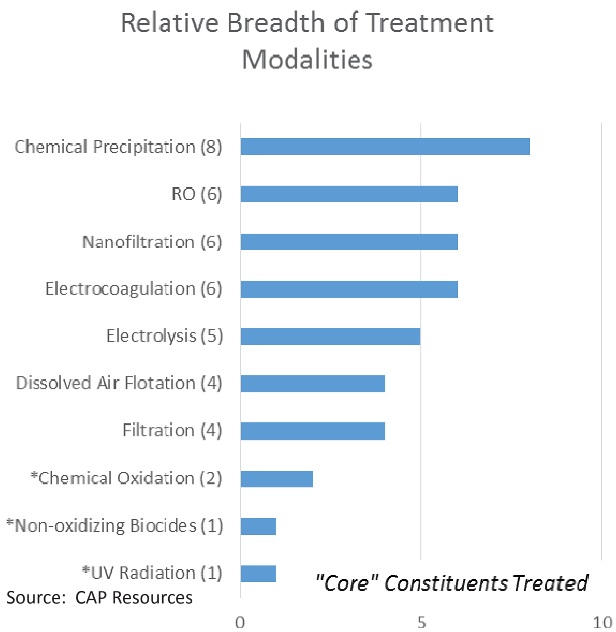
This slide not available for public dissemination.

To request copy for internal use (only) please provide email address and company name at this registration site:

www.Knomatic.com/5-mobile-strategies-to-reduce-cost

Mention SURF in your registration and we will follow up promptly, thank you.

Base Treatment Technologies and How they Stack up



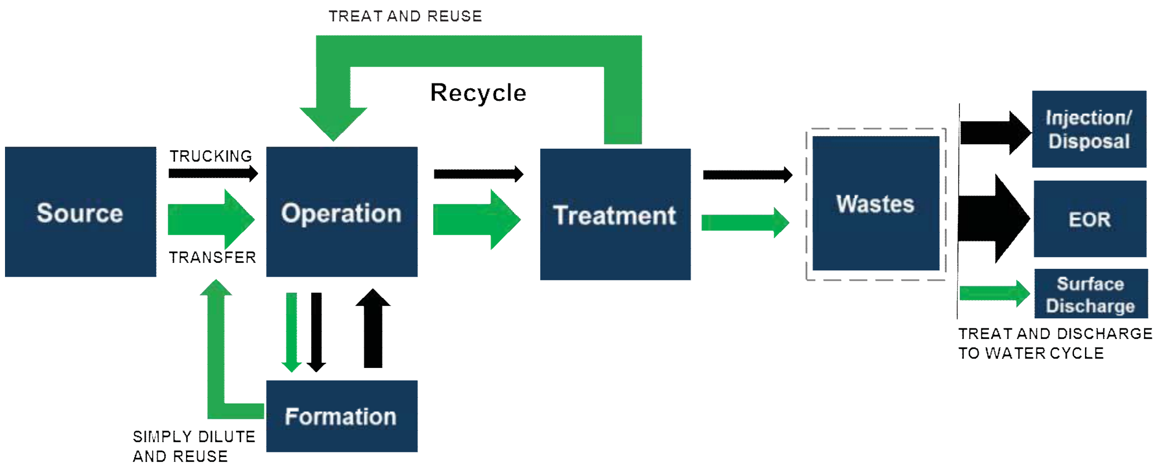
Source: CAP Resources

We then mapped typical treatment requirements to generally used, commercially available treatment approaches. Figures refer to how many constituents are treated reasonably well with a given technology. ***No weighting factors were applied.***

*Note: Bacteria are particularly pernicious, and bacteria treatment is dominantly required, although in this chart the primary bacteria treatments show low in the rankings.

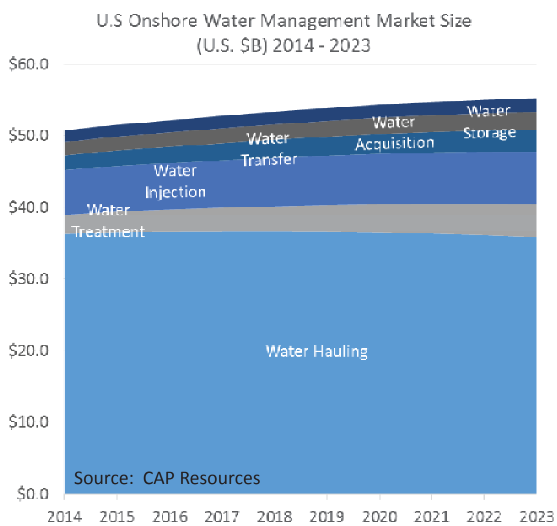
The State of "Things"

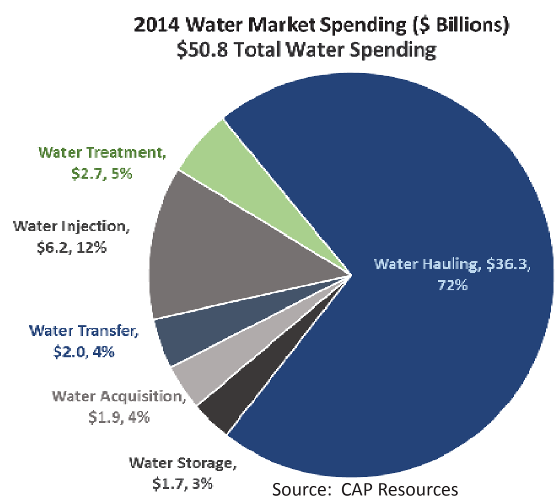
Best Practices in Water Management is a Continuum



U.S. Water Management Spend 2014 - "Before"

Source: CAP Resources Annual U.S. Onshore Water Management Spending Outlook (excludes California, Alaska)





Water Hauling: Trucks are the "real" enemy

If Hauling is the only option for the operator, it can require:

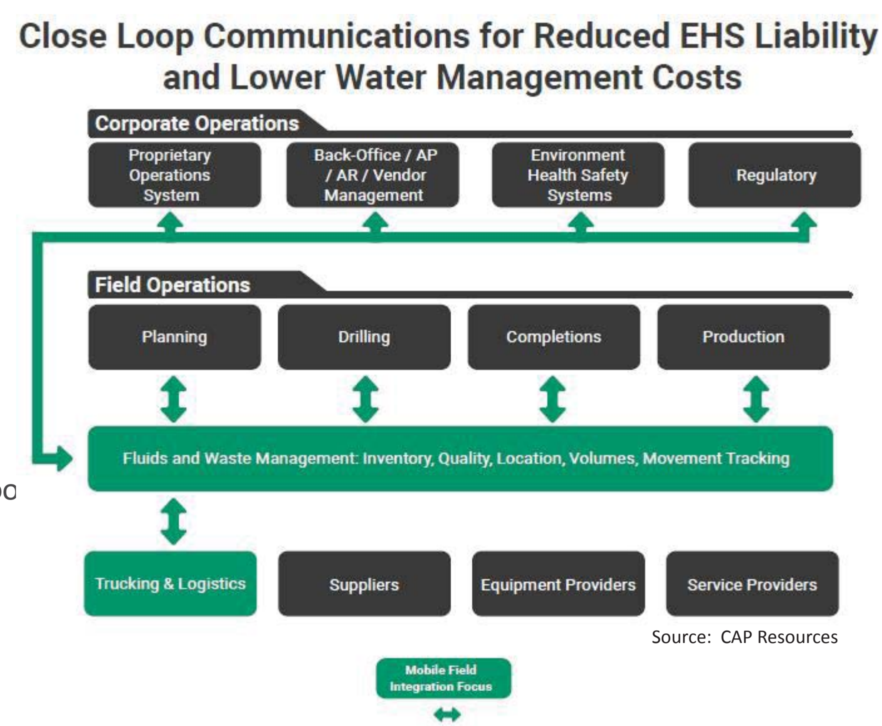
700-1,000+ truckloads of fluid per well

A host of environmental and safety issues :
- Emissions
- Dust
- Wear and tear on roads (up to $250K)
- Traffic through small towns
- Safety

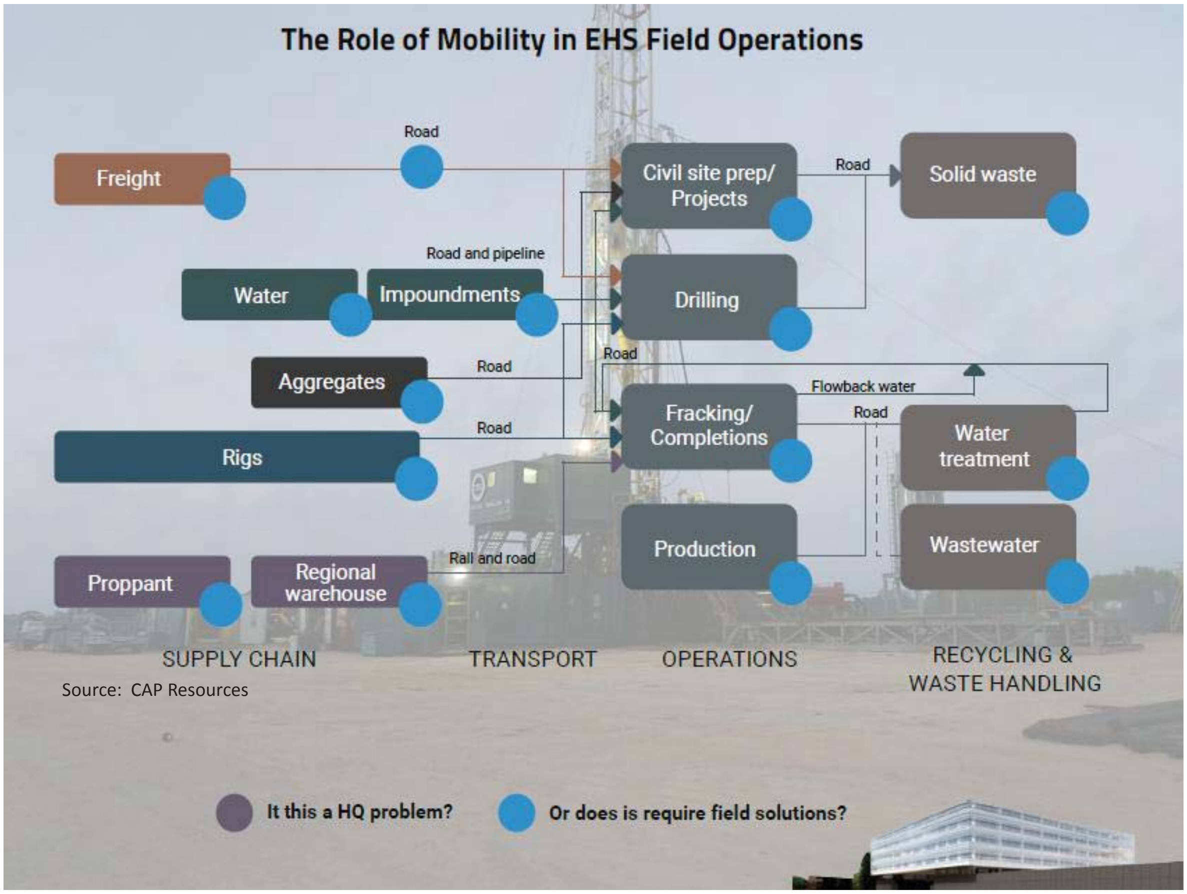
And often, huge costs for the operator
- Wait time (hours to load and unload)
- Costs: $200K - $700K / well*

*Example: 1000 trucks, 3 hours drive and wait time, $1.00/barrel/hour, 130 barrel truck capacity = $390,000

We studied water management EHS risks and overall costs where Real Time Inventory Monitoring and systems were in place with good backoffice integration, but poo field integration.



Source: CAP Resources



Analysis of the top software characteristics desired in EHS systems shows more than half of system capabilities must be **field accessible** for integrated EHS operations

Survey of 58 Companies on top software characteristics, your preference may vary

Mobility Mapping Source: Knomatic
EHS Prorites Source: EHS and Sustainability Software Buyers Guide © NAEM 2015 24

In water management, fewer trucking hours > lower costs and liability reduction and improved EHS

1. Elimination of unwarranted fluid Hauling (or waiting) time directly reduces costs
2. Reduction in hours on the road directly reduces liabilities and improves general public perception by reducing or eliminating
   - Spills,
   - Emissions and GHG impacts,
   - Road wear and tear,
   - Traffic congestion
   - Traffic-related risk to the public

Addressing the biggest issues entails:

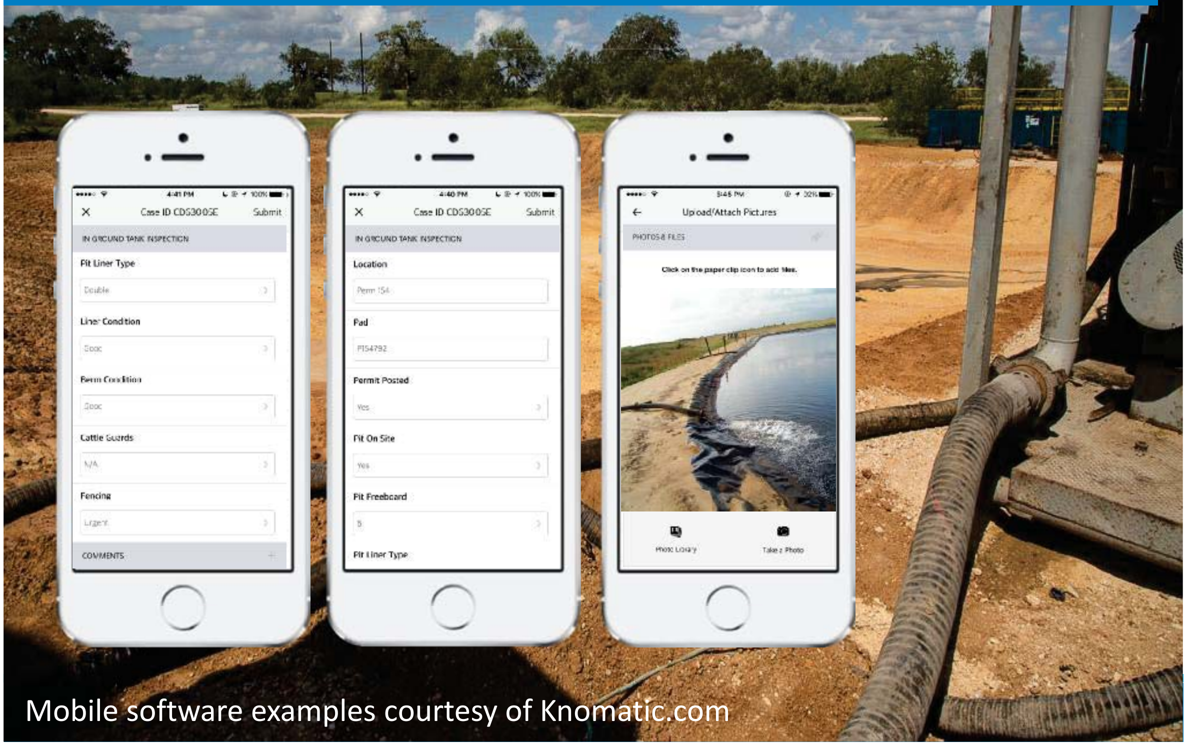
1. Eliminating errors before they happen (Informed Dispatch) – or –
2. Identify errors as they happen – in real time – so personnel can be informed and activities halted or redirected (Active Monitoring)
3. Systems must work in the field – with or without Internet access
4. Solutions must be easily adapted as needs change . Project managers must have a mindset of continuous improvement- largely driven by personnel inputs and preferences
5. Responsiveness to personnel requests will accelerate adoption in the organization

Key Findings

1. The greatest improvements came from providing operators with better information in the field - prior to them issuing orders to vendors. We call this "Informed Dispatch".

Software screenshots courtesy of Knomatic.com and WaterTrac

2. The next tier of improvements came from gathering field information in real-time, coupled with real-time connectivity between field operations and HQ.

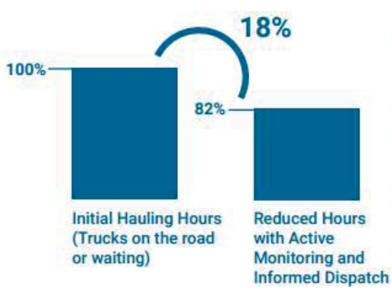


Mobile software examples courtesy of Knomatic.com

EHS Impacts

By reducing truck traffic alone:
- Vastly improved public perception – measurably fewer trucks on the road
- Dramatic reduction of congestion – long lines of trucks
- Correspondingly reduced emissions, road wear and tear, etc.
- 30-40% measured reduction in speeding
- Elimination of mismatched storage and water sources
- Elimination of trucks sitting on water without operators knowledge

EHS Exposure Reduction from Active Monitoring and Informed Mobile Dispatch

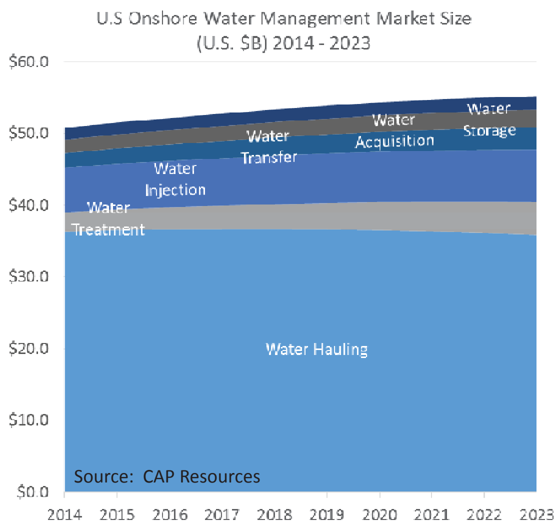


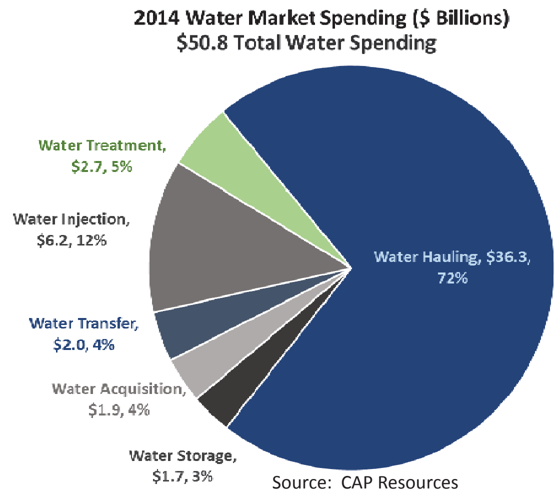
	Target Liability Reduction	Aspect
Informed (Real Time Visibility) Dispatch	5%	Reduced fluid hours in truck/transit
Performance-Based Vendor Selection	3%	
Vendor Behavior Changes due to Pro-Active Monitoring	6%	
Congestion Avoidance	4%	
Pre-Journey Validation / Verification (reduced re-routes)	1%	
	18%	

Information Sources re: Monitoring Capabilities: WaterTrac; Mobile Field Applications: Knomatic.com

U.S. Water Logistics – Ample Opportunity for Improvement

Source: CAP Resources Annual U.S. Onshore Water Management Spending Outlook (excludes California, Alaska)





In Closing....

"We always overestimate the change that will occur in the next two years and underestimate the change that will occur in the next ten. Don't let yourself be lulled into inaction."

From Bill Gates' book, "The Road Ahead," published in 1996.

For a copy of this presentation or related white papers, go to:
http://www.knomatic.com/5-mobile-strategies-to-reduce-cost/

Laura Capper Email: lcapper@cap-res.com - President, CAP Resources, Knomatic www.Knomatic.com

Attachment 12
Management Strategies to Achieve Remedy Complete when Groundwater Concentrations Fluctuate with Water Table Changes and Drought Conditions

Management Strategies to Achieve Remedy Complete When Groundwater Concentrations Fluctuate With Water Table Changes and Drought Conditions

SURF 30 Meeting

Presented by: Matt Alexander and Jerry Jin

October 7, 2015

leidos ENGINEERING

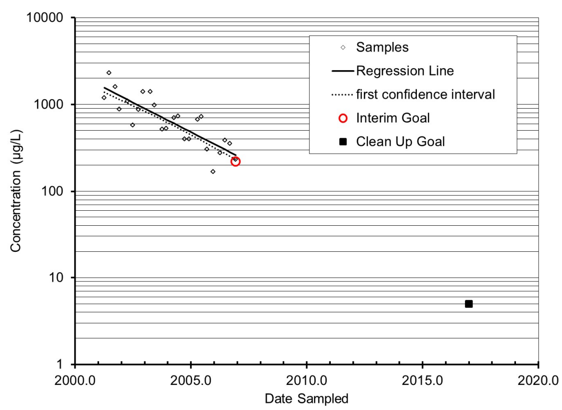
Outline

- **Problem Statement**
  - **Attaining Site Closure with Fluctuating Concentrations**
- Conceptual Site Models for Contaminant Fluctuations
- Management Approaches to Ensure Site Closure

Problem Statement

- Frequent instances of groundwater (GW) concentration fluctuations that correlate with precipitation or similar climate events
  - cyclic (annual) precipitation trends
  - extended drought interrupted by high precipitation events
  - Concentration fluctuations of significant magnitude (around one order of magnitude or greater)
- Challenge in predicting when site is expected to attain remedy complete (RC) or site closure (SC) after long-term monitoring (LTM)

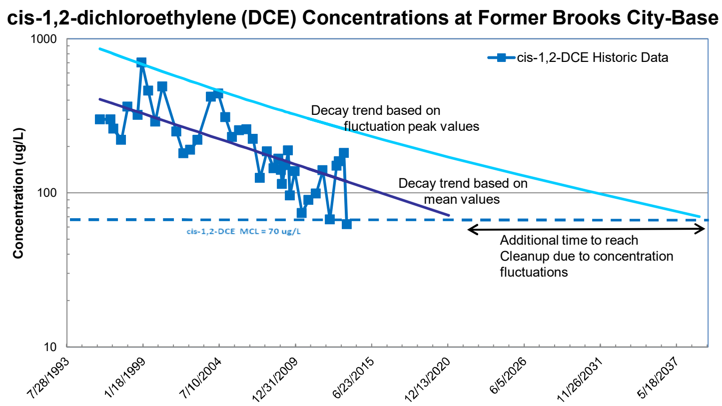
Concentration Fluctuations



Example TCE data set from EPA MNA document—concentration fluctuations are roughly only 2X from mean

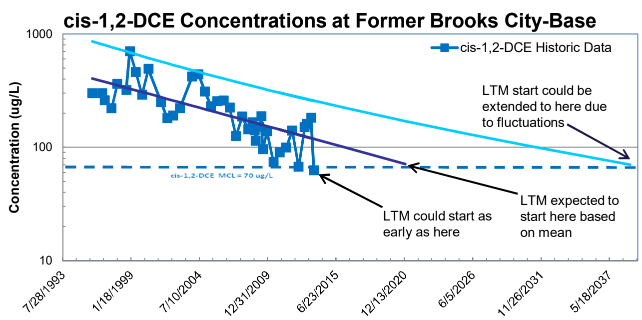
From: An Approach for Evaluating the Progress of Natural Attenuation in Groundwater, USEPA 600/R-11/204

Concentration Fluctuations



Fluctuations are as large as a half order of magnitude.

Concentration Fluctuations



Typical LTM requirements to attain SC

- 4 to 8 sample events with concentrations < cleanup objective (CO)
- Events spaced quarterly to semiannually
- Events performed in different seasons
- Total duration can be 2 years

Problem Statement

- Issues Arising from Fluctuations
  - Date for attainment of CO not clear
  - Excessively long LTM period
  - Insufficient program funding due to inaccurately forecasted SC

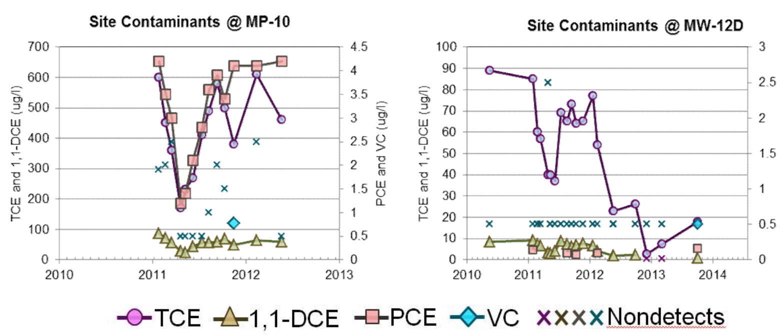
Outline

- Problem Statement
  - Attaining Site Closure with Fluctuating Concentrations
- **Conceptual Site Models for Contaminant Fluctuations**
- Management Approaches to Ensure Site Closure

Conceptual Site Models for Fluctuating Concentrations

- Seasonal variations
  - GW level fluctuations--Periodic leaching from smear zone causes variable concentrations
  - Site precipitation--Periodic higher infiltration rate provides peaks in vadose zone leaching in source area or smear zone
  - Regular seasonal variations somewhat predictable
- Extended drought with sporadic heavy precipitation events
  - Similar leaching events but occurrence is more infrequent and sporadic
  - Less predictable
- Site flooding
  - Extended duration water head that infiltrates through vadose zone
  - Less predictable

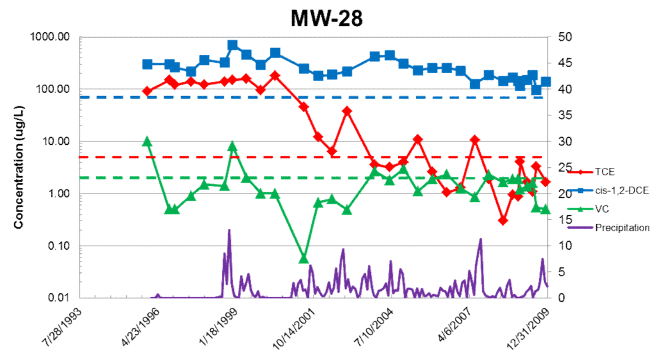
Fluctuating Concentrations at EPA Superfund Site



<u>Seasonal concentration fluctuations</u>

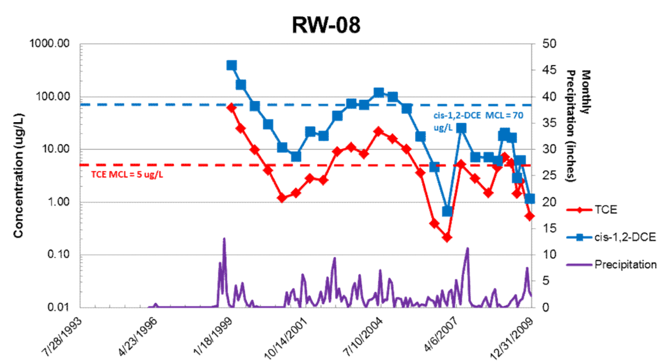
- First 1-2 years prior to in situ treatment effect
- Lows in late winter/early spring
- Highs in summer through winter

Fluctuating Concentrations at Former Brooks City-Base



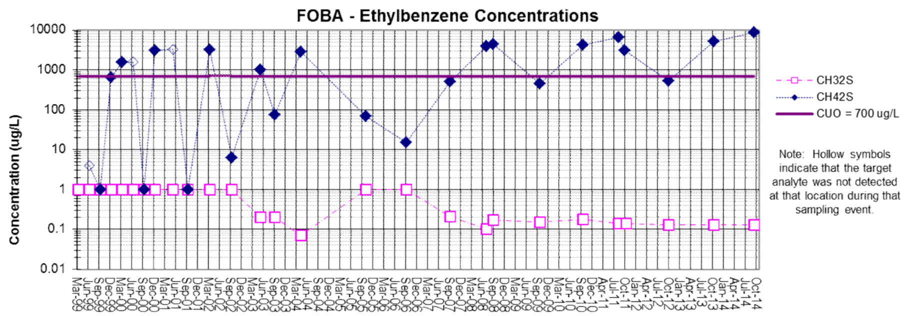
Very slow decrease in cis-DCE, concentrations exacerbated by sporadic intense precipitation events

Fluctuating Concentrations at Former Brooks City-Base



Decrease in TCE and cis-DCE generally overpower the increases that appear to occur with sporadic intense precipitation events

Fluctuating Concentrations at Former Chemical Plant Site Located on Mississippi River



Sporadic flooding on site causes high rate of contaminant leaching from vadose to GW, overpowering significant degradation rate in GW zone. Fluctuations of 1 to 3 orders of magnitude.

Fluctuating Concentrations—Other Examples

- Explosive compounds at Army Ammo Plant
  - Large (>1 order of magnitude) fluctuations, no apparent seasonal relationship
  - GW in Karst, historic sampling frequency inconsistent
  - Historic primary source area removals, residual sources unknown
  - Unknown cause of fluctuations
- TCE solvent at Air Guard base in Southeast
  - Moderate level fluctuations (<1 order of magnitude) in parent contaminant
  - Karst GW environment
  - Residual sources in depressions of hummocky bedrock surface

Conceptual Site Models for Fluctuating Concentrations

- Summary
  - Climate variations (precipitation resulting in infiltration variations), and subsequent subsurface effects, are likely cause for GW concentration fluctuations that confound attainment of CO
    - In some instances, fluctuations are not strong enough to have a significant negative impact
    - In other instances, fluctuations are primary controlling factor preventing RC and successful entry into LTM phase (and remain in LTM phase)
  - Incomplete treatment of source / inaccurate conceptual site model may also lead to additional sporadic contaminant leaching to GW

Outline

- Problem Statement
  - Attaining Site Closure with Fluctuating Concentrations
- Conceptual Site Models for Contaminant Fluctuations
- **Management Approaches to Ensure Site Closure**

Approaches to Mitigate Effects of Fluctuating Concentrations

A. Implement in situ treatment strategically for maximum effect
   - Take advantage of GW level conditions (timing)
   - Implement in situ treatment more aggressively to overcome climate-associated effects

B. Temporarily and artificially enhance vadose or smear zone leaching to exhaust that contamination as soon as possible

C. Modify site regulatory approach to lessen impact of fluctuating concentrations

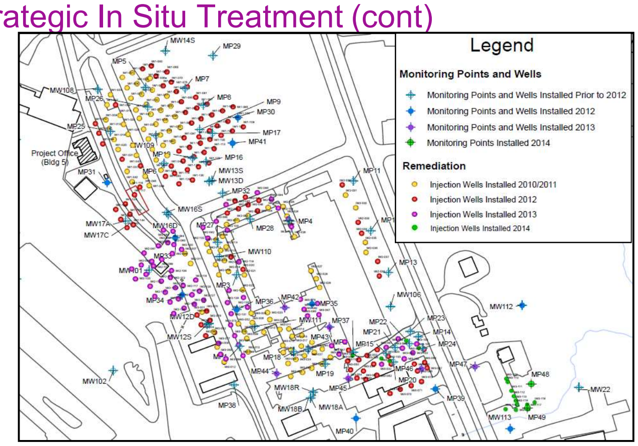
A. Strategic In Situ Treatment

- Timing--Perform chemical injections during high water table to enhance treatment of smear zone contamination
  - Pro: quick treatment of source of leaching contamination
  - Cons: possible inadequate understanding of site hydraulic characteristics, drainage rate, timing inconsistent with program schedule
- Amendments--Select and use treatment chemicals with effectiveness lifetimes consistent with high water table duration condition
  - Pro: quick treatment overall more beneficial
  - Con: potential challenge to achieve good distribution within favorable condition period

A. Strategic In Situ Treatment (cont)

- Implementation Approach (Aggressive)—Administer amendments to GW using a recirculation system
  - Pro: more aggressive and complete distribution of amendment chemicals, potentially better contact with smear zone contamination
  - Cons: cost of recirculation system, regulatory hurdles in reinjection of extracted groundwater

A. Strategic In Situ Treatment (cont)



Implementing in situ treatment of ~40-acre TCE plume at EPA Superfund site---Evaluated amendment injection with GW recirculation---not selected due to:

- Cost for capital and O&M
- Regulatory barrier—required GW treatment prior to re-injection

B. Artificially Enhanced Leaching

- Create artificial leaching conditions (surface irrigation) to promote faster exhaustion of leachable contaminant in the vadose zone
  - Pro: simple means to accelerate natural leaching process, especially if source of water such as recycled water is available, especially applicable in semi-arid environment
  - Con: may require excessive amount of water to have necessary impact

C. Site Regulatory Approaches

- Nuances of regulatory program utilized to lessen impacts
  - Plume management zone (PMZ)—allows on-site concentrations above CO as long as exposure point outsize PMZ does not have exceedances
  - Closure to residential standards outside PMZ without attaining non-detect levels

Implemented Management Approaches

- Chemical injectate: Selected fast-acting electron donor material to take advantage of high water table conditions (commercial / industrial site)
  - Results not yet available for evaluation
- At former Brooks City-Base, change from TCEQ Risk Reduction Rule Program to Risk Reduction Standards Program allowed an off-base OU to meet residential closure standards with TCE concentrations greater than non-detect but less than MCL

Summary and Conclusions

- GW contaminant trend data demonstrates climate effects (primarily precipitation variations) that can confound the approach of contaminant levels towards COs
- Innovative strategies needed to counteract the uncertainties in GW concentrations created by climate effects
  - Strategic treatment approaches
  - Site irrigation for artificial leaching
  - Regulatory approaches to minimize LTM management impacts
- Challenges to Implementing
  - Stakeholder understanding of impact of concentration fluctuations
  - Project / contract cycles and budget limitations
  - Unpredictable duration of drought / non-drought conditions

Acronyms

› CO	cleanup objective (GW concentration)
› DCE	cis-1,2-dichloroethylene
› GW	groundwater
› LTM	long-term monitoring
› MCL	maximum contaminant level
› OU	operable unit
› PCE	perchloroethylene
› PMZ	plume management zone
› RC	remedy complete
› SC	site closure
› TCE	trichloroethylene
› TCEQ	Texas Commission on Environmental Quality
› VC	vinyl chloride

Thank You

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Attachment 13

Green and Sustainable Sediment Remediation and Evaluating Sediment Sites Using SiteWise™ Version 3.1

Sam Moore and
Russell Sirabian
Battelle Memorial Institute,
Columbus, Ohio

Green and Sustainable Sediments Remediation and Evaluating Sediment Sites Using SiteWise™ Version 3.1

Presented at SURF 30, October 6-7, 2015, Rice University, Houston TX

Introduction to SiteWise™

- Microsoft® Excel-based tool developed to calculate the environmental footprint of remediation in terms of sustainability metrics
- User-friendly lifecycle analysis (LCA)-based tool
- Originally developed by Battelle, further development performed jointly with the Navy, US Army Corps of Engineers, and the Army in a collaborative effort

Evolution of SiteWise™

2007: SiteWise™ development began as Battelle Internal R&D Project
- Triggered by EO13423 and other industry trends
- Applied to Navy and USACE projects as Battelle tool

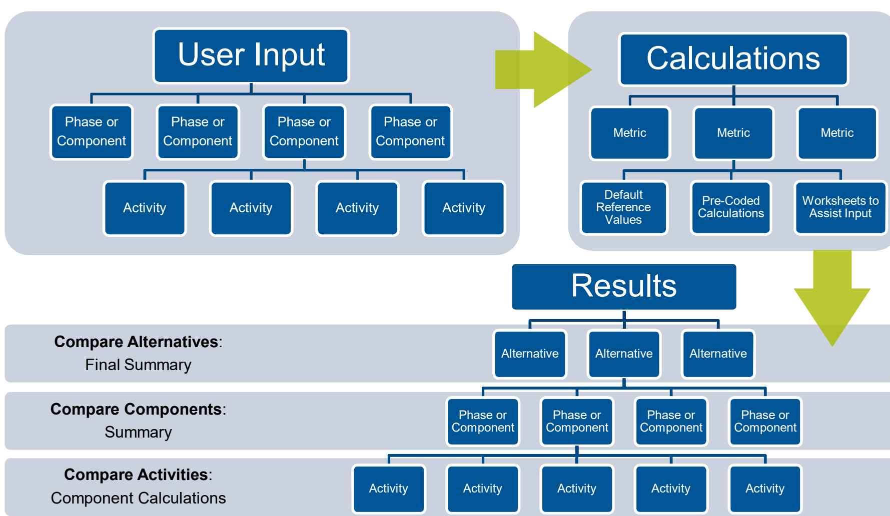
May 2010: Release of SiteWise™ to public
- Collaborative effort among Battelle, US Navy, USACE lead to making SiteWise™ publically available

June 2011: SiteWise™ V2 released
- Added footprint reduction methods, additional equipment and materials, and ability to upload previously generated input sheets
- April 2012: US Navy policy requires use of SiteWise™ during remedy evaluation and recommended for optimization
- ESTCP funded project to evaluate SiteWise™ V2 and compare to SimaPro

June 2013: SiteWise™ V3 released
- Revisions were outcome of ESTCP project to:
  - Improve consistency with SimaPro
  - Improve ease of use

June 2015: Release of SiteWise™ V3.1
- Includes provisions for sediment sites
  - Prompted by recognition that sediments sites are important parts of DoD cleanup programs

SiteWise™ Process



SiteWise™ Metrics

Energy Consumption	• Expressed as British Thermal Units (BTUs) • Electricity from renewable and non-renewable sources
Greenhouse Gases Emitted	• Metric tons CO_2e (Includes CO_2, CH_4, and N_2O)
Criteria Air Pollutants Emitted	• NOx, SOx, PM in metric tons (on-site and total emissions)
Water Consumption	• Expressed as gallons
Worker Safety	• Accidental injury and death and lost hours
Resource Consumption	• Landfill space, top soil
Cost of Footprint Reduction	• Wind, solar, microturbines
Ecological Impacts	• Qualitative evaluation (*e.g.*, land, surface water and aquifer impacts)
Community Impacts	• Qualitative evaluation (*e.g.*, noise, traffic, odors)

Policy/Guidance: Executive Orders

- EO 13423 – *Strengthening Federal Environmental, Energy, and Transportation Management* (2007)
- EO 13514 – *Federal Leadership in Environmental, Energy, and Economic Performance* (2009)
- **EO 13693 – *Planning for Federal Sustainability in the Next Decade* (2015)**

Policy/Guidance: Sediments

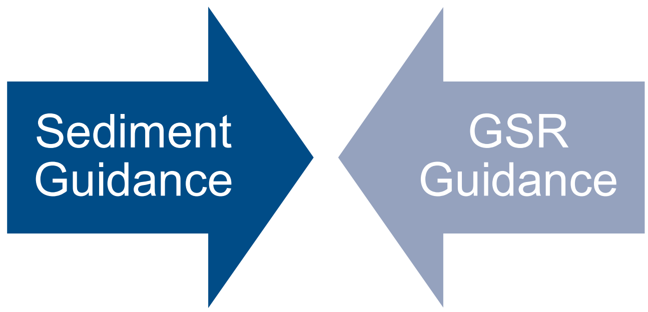
- *Policy on Sediment Site Investigation and Response Action* (DON, 2002)
- *A User's Guide for Determining the Sources of Contaminants in Sediments* (Space and Naval Warfare Systems Command [SPAWAR], 2003)
- *Contaminated Sediments at Navy Facilities: Policy, Guidance, and Characterization* (NAVFAC, 2002)
- *Implementation Guide for Assessing and Managing Contaminated Sediment at Navy Facilities* (NAVFAC, 2005)
- *User's Guide for Assessing Sediment Transport at Navy Facilities* (SPAWAR, 2007)
- *Guidance for Habitat Restoration Monitoring: Framework for Monitoring Plan Development and Implementation* (NAVFAC, 2004)
- *Guidance for Environmental Background Analysis, Volume II: Sediments* (NAVFAC, 2003)
- *2014 ITRC Contaminated Sediments Remediation Guidance*

Policy/Guidance: GSR/Optimization

- *DON Guidance for Planning and Optimizing Monitoring Strategies* (NAVFAC, 2008)
- Defense Environmental Restoration Program (DERP) Manual, updated in March 2012 (DoD, 2012)
- *Policy for Optimizing Remedial and Removal Actions at All DON Environmental Restoration Program Sites* (DON, 2012)
- *Department of the Navy Guidance on Green and Sustainable Remediation* (NAVFAC, 2012a)
- *2010 U.S. EPA's Superfund Green Remediation Strategy*
- *2011 ITRC Green and Sustainable Remediation: A Practical Framework*

Motivation:

- Bridge Sediment-GSR guidance gap in *Sustainable Sediment Remediation White Paper* (NAVFAC, 2015)
- Update SiteWise™ for evaluation of sediment remedies



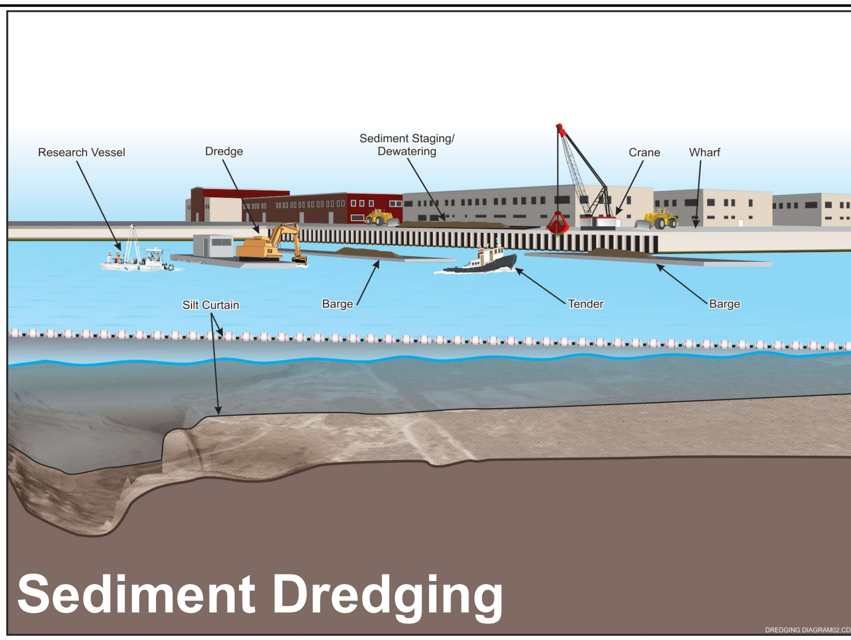
SiteWise™ Updates

- Updated SiteWise™ Version 3.0 to Version 3.1 (V3.1)
- Added new modules for sediments remediation-specific activities
- Remaining typical sediments remediation activities are accounted for in V3.0 modules
- Updates are based on industry-accepted or peer-reviewed sources and professional experience
- Backwards compatibility with V2.0 and 3.0 input sheets
- The User Guide will be updated for V3.1 release

Sediment Remediation Alternatives

Sediment Remediation

- **Dredging**
  - Dredging Equipment Operation
  - Management of Dredged Sediments: off-loading, dewatering, T&D
  - Materials (e.g. silt curtain, stockpile lining)
  - Monitoring: Watercraft Operation
- **Capping**
  - Capping Material Placement Equipment Operation
  - **Cap Material Handling** (Staging, On-loading, Transportation)
  - Materials (e.g. capping materials, silt curtain)
  - Monitoring: Watercraft Operation
- **Monitored Natural Recovery**
  - Monitoring: Watercraft Operation



Sediment Dredging Components

- Sediment Dredging
  - Sediment Dredging
    - Mechanical Dredging
    - Hydraulic Dredging
  - Sediment Management
    - Off-loading
    - Dewatering, Staging, Handling
    - Transportation and Disposal
  - Materials
    - Silt Curtain
    - Stockpile Lining
  - Monitoring
    - Watercraft Operation

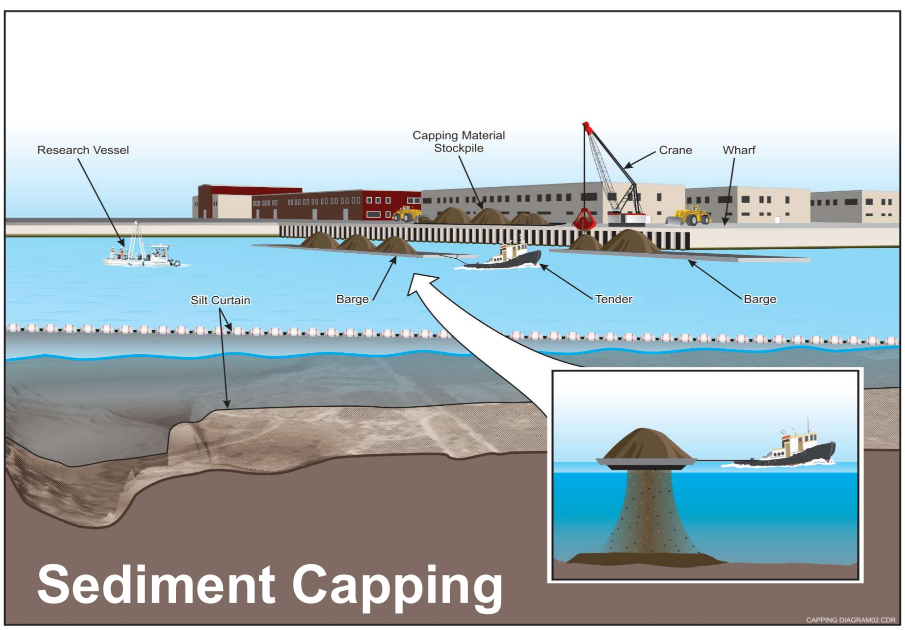
Sediment Dredging Details

- Sediment Dredging
  - Mechanical Dredging
    - Clamshell Dredger Operation
    - Dredge Tender
    - Scow Tenders
    - Research Vessels
  - Hydraulic Dredging
    - Hydraulic Dredge Head Operation
    - Dredge Tender
    - Research Vessels
    - Pump Operation

Sediment Management Details

- Sediment Management
  - Off-loading
    - Heavy Equipment Operation per Volume Sediment
  - Dewatering, Staging, Handling
    - Heavy Equipment Operation per Volume Sediment
    - Pump Operation
    - Other Dewatering Equipment
  - Transportation and Disposal

Battelle
The Business of Innovation



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Sediment Capping Components

- **Sediment Capping**
  - **Sediment Capping**
    - Direct Mechanical Placement
    - Hydraulic (Pipeline) Placement
    - Surface Release Placement
  - **Cap Material Handling**
    - Staging
    - On-loading
    - Transportation
  - **Materials**
    - Cap Material
    - Silt Curtain
  - **Monitoring**
    - Watercraft Operation

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SiteWise™ Sediments Step-by-Step

- Input Sheets
- Calculation Assumptions
- Calculations Sheets

Battelle
The Business of Innovation

SEDIMENT DREDGING	Equipment 1	Equipment 2
Choose dredge equipment type from drop down menu	Mechanical	Hydraulic
Choose dredge fuel type from drop down menu	Diesel	Diesel
Input volume of material to be dredged (yd3)		
Choose dredge equipment size	awler Crane, 25 ton, 1	ic Dredge Head, 15
Suggested dredge equipment size	Crawler Crane, 25 ton, 1 C	ic Dredge Head, 1
Input number of dredge tenders (default already present, user override possible)	Crawler Crane, 50 ton, 2 C Crawler Crane, 100 ton, 4 C	1
Choose dredge tender fuel type from drop down menu	Crawler Crane, 150 ton, 6 C	Diesel
Input operating time for dredge tenders (hr) (default calculated value, user override pos	Crawler Crane, 200 ton, 8 C	0
Input number of scow tenders (default already present, user override possible)	2	0
Choose scow tender fuel type from drop down menu	Diesel	Diesel
Input operating time for scow tenders (hr) (default calculated value, user override possi	0	0
Choose size of research vessel from drop down menu	esearch Vessel (large	esearch Vessel (large
Choose research vessel fuel type from drop down menu	Diesel	Diesel

SEDIMENT MA

SEDIMENT CAPPING	Equipment 1	Equipment 2	Eq
Choose capping method from drop down menu	Surface Release	Pipeline Placement	Surf
Choose capping equipment fuel type from drop down menu	Diesel	Diesel	
Input volume of capping material to be placed (yd3)			
Choose capping equipment size/type	Hopper Barge	aulic Dredge Head, 1	Ho
Suggested capping equipment size/type	Hopper Barge	Hydraulic Dredge Head, 15	Ho
Input number of dredge tenders (hr) (default already present, user override possible)	1	Hydraulic Dredge Head, 25	
Choose tender fuel type from drop down menu	Diesel	Diesel	
Input operating time for dredge tenders (hr) (default calculated value, user override pos	0	0	
Input number of scow tenders (default already present, user override possible)	0	0	
Choose scow tender fuel type from drop down menu	Diesel	Diesel	
Input operating time for scow tenders (hr) (default calculated value, user override possi	0	0	
Choose size of research vessel from drop down menu	Light Craft (small)	Light Craft (medium)	esearc
Choose research vessel fuel type from drop down menu	Diesel	Diesel	
Input number of research vessels (default already present, user override possible)	1	1	
Input operating time for research vessels (hr) (default calculated value, user override po	0	0	
Will DIESEL-run equipment be retrofitted with a particulate reduction technology?	No	No	

WATERCRAFT OPERATION	Equipment 1	Equipment 2	Eq
Choose size of research vessel from drop down menu	Light Craft (medium)	esearch Vessel (large	esearc
Choose research vessel fuel type from drop down menu	Diesel	Diesel	
Input number of vessels			
Input operating time (hours)			

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Calculation Assumptions

- Calculations broken down by processes
- Design assumptions from literature, manufacturers' data sheets, professional experience

Component	Input	Process Calculation Assumptions
Clamshell Dredge Operation [1, 2, 3]	Sediment Dredging: Crawler Crane	• RSMeans specifies crew with 25 ton, 1 cubic yard (CY) crawler crane and a 213 to 310 CY/day production rate • From professional experience, production rates for several other bucket sizes (2, 4, 6, or 8 CY) were estimated • Manufacturer/Model specifications were retrieved relating tonnage and HP rating, assuming 25 ton rating per CY of bucket • Crawler cranes were binned according to EPA NONROAD emissions for each bucket size • Production rates were used to determine recommended volume ranges for bucket size (based on approximately maximum 100 days of operation)

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Sustainable Sediment White Paper

![NAVFAC Naval Facilities Engineering Command — Engineering and Expeditionary Warfare Center]

NAVFAC
Naval Facilities Engineering Command
ENGINEERING AND EXPEDITIONARY WARFARE CENTER

SUSTAINABLE SEDIMENT REMEDIATION WHITE PAPER

Prepared for NAVFAC EXWC under Contract No. N62583-11-D-0515

August 2015

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- Calculations assumptions for all sediments processes
- Includes incorporating GSR/SiteWise™ and BMPs
- Final report will be posted on the Navy's ERB Sediment Web page in November:

http://www.navfac.navy.mil/navfac_worldwide/specialty_centers/exwc/products_and_services/ev/erb/seds.html#pubs

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SEDIMENT DREDGING - DREDGE CUTTING

	Equipment 1	Equipment 2	Equip
Choose dredge equipment type from drop down me	Mechanical	Hydraulic	Mecl
Choose dredge fuel type from drop down menu	Diesel	Diesel	Di
Input volume of material to be dredged (yd3)	0	0	
Will DIESEL-run equipment be retrofitted with a particulate reduction technology?	No	No	
Dredge equipment size	awler Crane, 25 ton, 1	raulic Dredge Head, 1	awler Cran
Production rate (yd^3/hr)	0	0	
Consumption rate (gal/hr)	3.3	0.9	
Equipment operating hours (hr)	0.0	0.0	
Fuel used (gal)	0.0	0.0	
BTU per gallon fuel used	135,847	135,847	135
CO_2 emission factor (g/hr)	4.03E+04	1.03E+04	4.0
N_2O emission factor (g/hr)	8.48E-01	1.88E-01	8.4
CH_4 emission factor (g/hr)	4.69E+00	4.27E-01	4.6
Onsite NOx emission factor (g/hr)	3.08E+02	8.20E+01	3.0
Onsite SOx emission factor (g/hr)	4.63E+01	1.80E+01	4.6
Onsite PM_{10} emission factor (g/hr)	1.95E+01	1.00E+01	1.9
Offsite NOx emission factor (g/hr)	2.0E+01	5.3E+00	2.0
Offsite SOx emission factor (g/hr)	1.0E+01	2.7E+00	1.0
Offsite PM_{10} emission factor (g/hr)	3.0E+00	7.9E-01	3.0

SEDIMENT DREDGING - DREDGE TENDER

	Equipment 1	Equipment 2	Equip
Input number of dredge tenders (default already pre	1	1	
Choose dredge tender fuel type from drop down me	Diesel	Diesel	Di
Input operating time for dredge tenders (default calc	0	0	

SEDIMENT DREDGING - SCOW TENDER

	Equipment 1	Equipment 2	Equipm
Input number of scow tenders (default already prese	2	0	2
Choose scow tender fuel type from drop down menu	Diesel	Diesel	Dies
Input operating time for scow tenders (default calcul	0	0	0

SEDIMENT DREDGING - RESEARCH VESSEL

	Equipment 1	Equipment 2	Equipm
Choose size of research vessel from drop down me	esearch Vessel (larg	esearch Vessel (larg	esearch Ve
Choose research vessel fuel type from drop down m	Diesel	Diesel	Dies
Input number of research vessels (default already pr	1	1	1
Input operating time for research vessels (default ca	0	0	0
Will DIESEL-run equipment be retrofitted with a particulate reduction technology?	No	No	No
Consumption rate (gal/hr)	6.5	6.5	6.5
Equipment operating hours (hr)	0.0	0.0	0.0
Fuel used (gal)	0.0	0.0	0.0
BTU per gallon fuel used	135,847	135,847	135,8

TOTAL FROM SEDIMENT DREDGING -
CO_2 e Emission (metric ton)
Onsite NOx Emission (metric ton)

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Case Study: Sediment Remediation in Open Water Sites at Bishop Point, Pearl Harbor

- Sites with inorganic contamination of sediments by surface water runoff
- Moderate risk of re-contamination during maintenance dredging
- Feasibility Study published in April 2014—one remedy included focused dredging/capping with MNR
- A GSR evaluation was re-performed for this alternative using SiteWise™ V3.1 and its updated capabilities

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Case Study: SiteWise™ V3.1 Inputs

- Inputs for SiteWise™ V3.1:
  - Bulk Materials: 3,267 cubic yards of sand and transport of sand
  - Materials: Silt curtain and transport of curtain materials
  - Sediment Dredging: 13,065 CY removed mechanically, includes: dredge tender, two scow tenders, and one medium research vessel
  - Sediment Management: 13,065 CY saturated sediment transloaded by a crawler crane, dozer, and loader
  - Sediment Management: 3,267 CY cap transloaded by a crawler crane
  - Sediment Capping: 3,267 CY of material placed mechanically, includes: dredge tender, two scow tenders, and one medium research vessel
  - Residual Handling: Transportation of dried sediment
  - Landfill Operations: 13,065 CY of non-hazardous landfill in Hawaii

25

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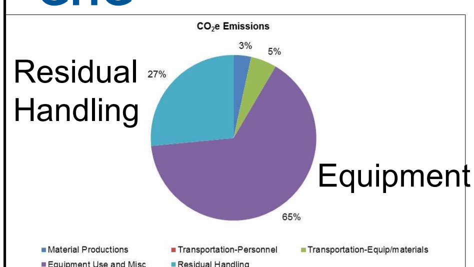
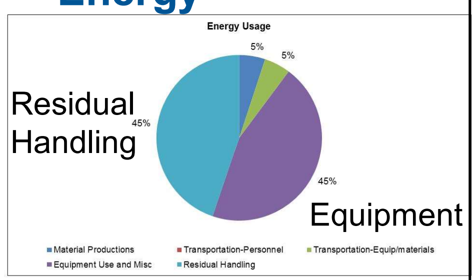
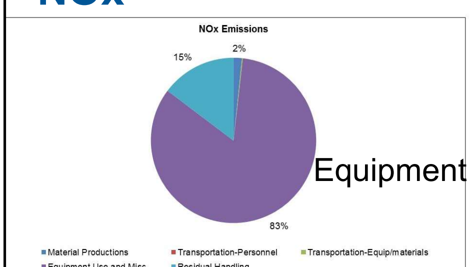
GHG



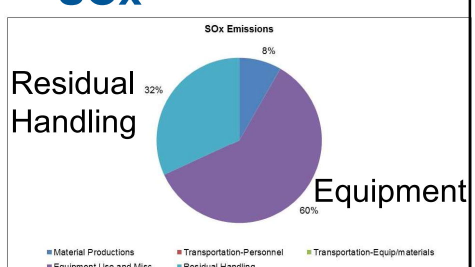
Energy



NOx



SOx



26

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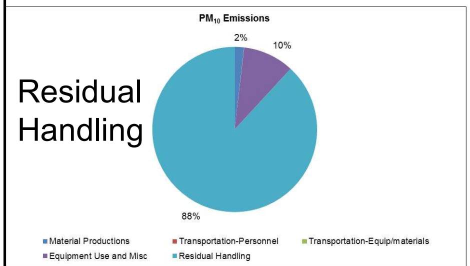
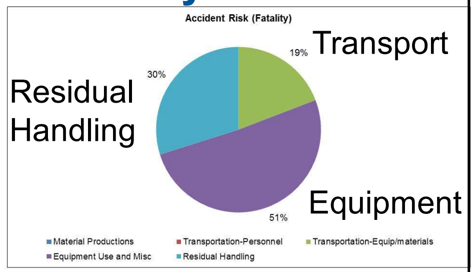
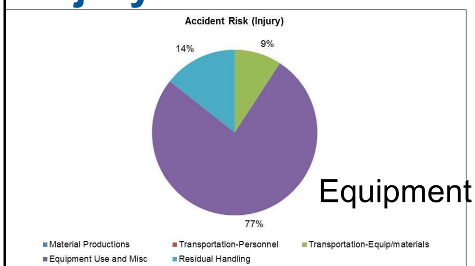
PM



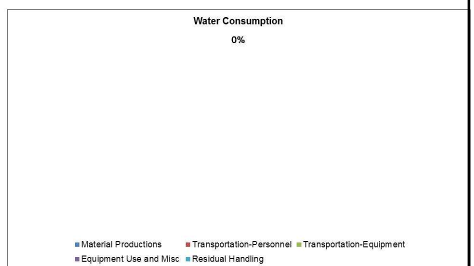
Fatality Risk



Injury Risk



Water



Summary of Sustainable Practices for Sediment Site Cleanup

- Dredging
- Capping
- *In Situ* Amendments

Sustainable Dredging Practices

- Minimize the dredging footprint
- Minimize remediation time by optimizing production rates and process flow
- Identify opportunities for beneficial reuse of dredged sediments and/or produced waters
- Utilize energy efficient equipment
- Identify habitat avoidance options/implement habitat restoration

Sustainable Capping Practices

- Minimize the capping footprint
- Optimize cap thickness
- Optimize the delivery of capping materials to minimize transportation risks
- Integrate optimization principles in planning for and executing sampling and monitoring tasks
- Identify habitat avoidance and preservation options/implement habitat restoration

Sustainable *In Situ* Amendment Practices

- Minimize the treatment footprint
- Optimize treatability of contaminants of concern
- Optimize the delivery of amendment materials to minimize transportation risks
- Integrate optimization principles in planning for and executing sampling and monitoring tasks
- Identify habitat avoidance and preservation options while placing amendments

Conclusions

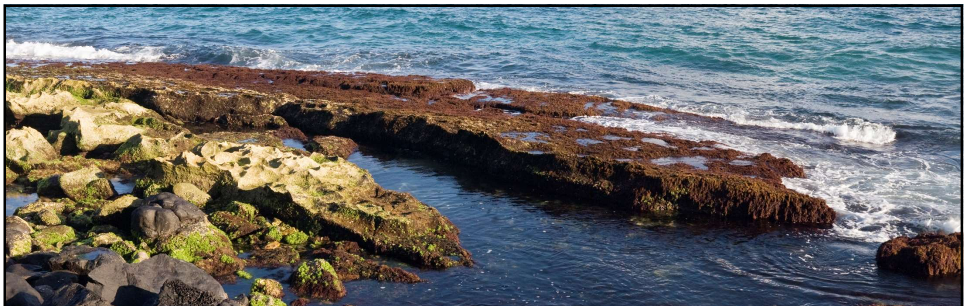
- SiteWise™: iterative tool to explore sustainable options
- SiteWise™ V3.1 accounts for typical activities associated with sediment remediation, acts as a checklist
- New calculation modules compliment existing SiteWise™ capabilities
- Result: improved accuracy, transparency, and documentation of GSR evaluations for sediment sites

SiteWise™ V3.1 is currently available on the SURF Website at:
http://www.sustainableremediation.org/library/guidance-tools-and-other-resources/sitewise-version-31/

SiteWise™ V3.1 User Guide is under Navy review and will be available soon (Currently User Guide for V3.0 is on the SURF Website)

SiteWise™ V3.1 with User Guide will be on Navy Web site shortly (~Nov 2015)
http://www.navfac.navy.mil/navfac_worldwide/specialty_centers/exwc/products_and_services/ev/erb/gsr.html

Attachment 14
Integrating Sustainable Metrics into Remedial Decision Making



Integrating Sustainability Metrics into Remedial Decision Making

Presented by
Erin Healy and Mark Meyers, Anchor QEA

October 2015

Contents

- Problem statement
- Sustainability in remedial decision-making
- Regulatory framework
- Approach - metrics development and assessment process
- Example case

Problem Statement

Remedial Action decisions are based on estimated reductions in risk to human health and the environment, with few mitigating factors and without consideration of all stakeholder interests

Can we improve remedial outcomes for the benefit of all parties?

- *Owner*
- *Community*
- *Environment*

Sustainable Remediation Approach

- A **Sustainable Remediation** approach integrates sustainability goals into the remedial management decision-making, along with the more traditional use of risk-based remediation goals[1,2]
  - Considers environmental, social, and economic benefits within and beyond the site boundaries
  - Endpoint focused, seeking to enhance the environmental, social, and economic benefits of remediation by illustrating the relationship between the project remedial objectives and the environment in which the site exists
- As currently practiced by USEPA, **Green Remediation** focuses on reducing the environmental footprint of the selected alternative

[1] Butler, P.B., L. Larsen-Hallock, R. Lewis, C. Glenn, and R. Armstead, 2011. Metrics for Integrating Sustainability Evaluations into Remediation Projects. Sustainable Remediation Forum [SURF]. *Remediation* 21(3):81-87.
[2] Holland, KS, R. Lewis, K. Tipton, S. Karris, C Dona, E Petrovskis, L.P. Bull, D. Taege, and C. Hook, 2011. Framework for integrating sustainability into remediation projects. Sustainable Remediation Forum [SURF]. *Remediation* 21(3):7-38.

Sustainability in Remedial Decision-Making

Environment

Ecological Risk-based Remediation Goals
Address contaminant-related risk to ecological receptors

Net Environmental Benefit Analysis
Evaluate outcomes of remediation in terms of ecosystem functions, carbon footprint, and environmental

Human (Social)

Human Health Risk-based Remediation Goals
Address contaminant-related risk to human health receptors

Net Social Benefits Analysis of Social and Community Uses of the Site
Evaluate outcome of remediation in terms of social and community benefits

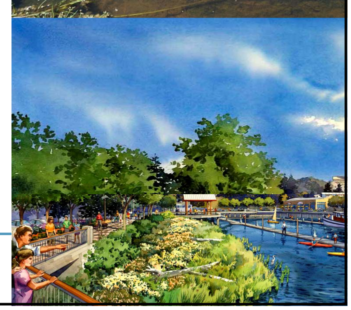
Economic

Net Economic Benefit Analysis
Evaluate outcomes of remediation in terms of benefits and impacts on the local and regional economy

Remedial Decision Making / Feasibility Study

Sustainability Evaluation leads to Improved Outcomes

- Considers the return on investment in terms of the environment, the community (social), and the economy (ESE) – promotes net beneficial outcomes
- Identifies opportunities and obstacles for beneficial outcomes
- Increases the value of outcomes and net benefits of the remedial strategy
- Provides an opportunity for the owner to highlight tangible positive outcomes resulting from the investment in remedial actions

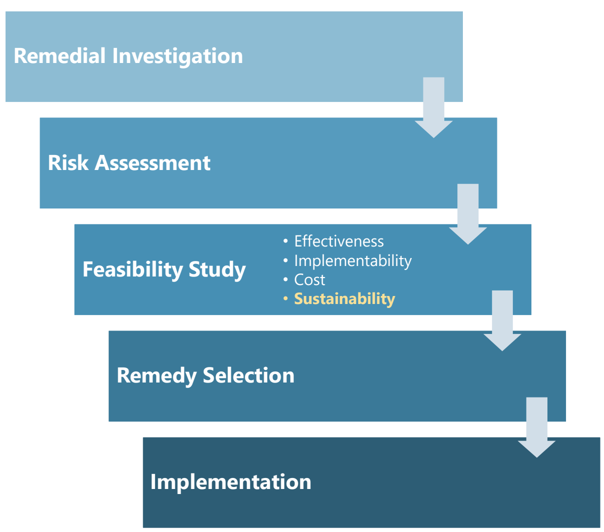


Regulatory Context

- There is no well-defined regulatory basis for incorporating sustainability into remedial alternatives evaluations
- There is no guidance or widely-accepted technical methodology for conducting sustainability evaluations

Engage regulators and stakeholders with a broad view of beneficial outcomes to drive remedy evaluations toward a sustainable approach

Regulatory Framework: Decision-Making Process



This Sustainability Approach Provides Additional Basis for Remedial Decision-Making

Does Not

- Revisit or alter standard ecological or health risk assessments and resultant cleanup goals
- Consider the cost of remedy
- Limit sustainability assessment to USEPA-style Green Remediation

Does

- Describe realistic outcomes of remedial actions before a remedy is selected
- Identify opportunities and obstacles for beneficial outcomes
- Allow owner to focus on positive outcomes of the remediation investment

Overview of Approach

1. Development of Metrics
   - Components that determine Ecological, Social and Economic functions
2. Assessment of Metrics
   - Widely accepted methods used for restoration planning, economic impact analysis and social/community benefits analysis
3. Scoring of Metrics
   - Flexible scoring options and results presentation

- The framework is meant to provide flexibility in how each metric is evaluated
- Keep methods separate from other evaluations such as eco-risk assessment or Habitat Equivalency Analysis (HEA)

Development of Metrics

- List the environmental, social, and economic metrics that may be affected by the remedy
- Develop a set of factors for each metric that can be evaluated for the potential to change during and after the remedy

Example Metrics and Factors

Service Area	Metric and Factors
Environmental	**Water Quality**
	Temperature
	Dissolved oxygen
	Salinity
	Physical Habitat
	Sediment type
	Heterogeneity
	Shoreline
	GHG Inventory
	GHG emissions
Social	Aesthetics
	Recreation
	Flood protection and coastal resiliency
Economic	**Direct Benefits**
	Indirect Benefits

Assessment of Metrics

Evaluate Magnitude of Change in Each Metric for Each Remedial Alternative

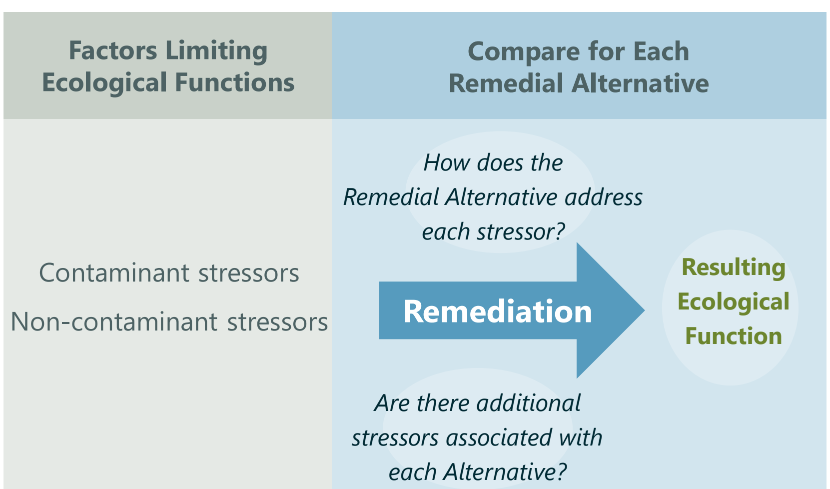
For Each Metric and Factor	
Assess three phases	• Current condition • During remedy implementation • Outcome after remedy implementation
Assess direction of change between phases	• Improvement • No change • Diminishment
Assess magnitude of change	• Best professional judgment • Quantitation • Monetization
Evaluate net benefits of remediation in environmental, social, and economic terms	

Scoring Metrics

- Basis for scoring
  - Data evaluation – both quantitative and qualitative
  - Best professional judgment
  - Literature sources
- Evaluate change: positive, neutral, or negative indicating improved, no change, or diminished condition
- Indicate magnitude of condition

+2, +1 :	Great to some improvement
0 :	Neutral
−2, −1 :	Great to some diminishment in condition

Metrics Evaluation – Ecosystem Example



Metrics Evaluation – Ecosystem Example

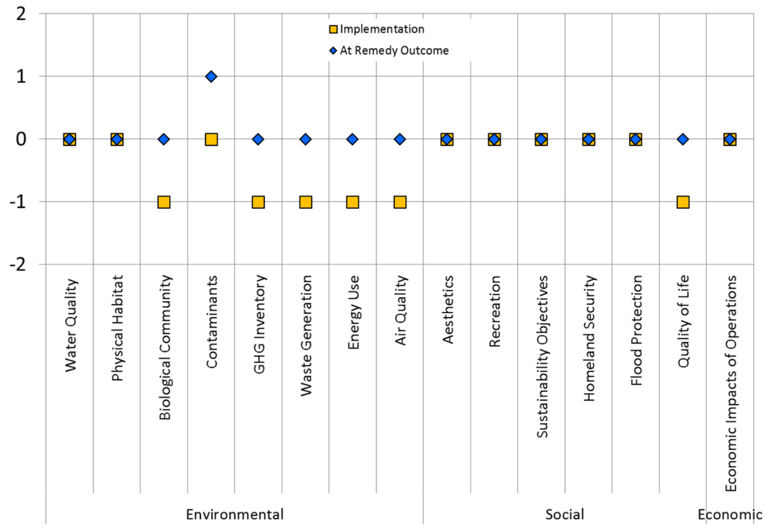
- USEPA's Rapid Bioassessment Protocols provides a habitat scoring system for streams
  - Condition categories for ten parameters: optimal, sub-optimal, marginal, and poor

Parameter	Current Condition
Epifaunal substrate/ available cover	Marginal (10% to 30% mix of stable habitat; habitat lacks variety of grain size or cover for fish)
Pool substrate character	Marginal (all mud, clay, or sand; little or no root mat or submerged vegetation)
Sediment deposition	Poor (heavy deposition of fine material)
Channel alteration	Marginal (extensive channelization; shoring structures present on both banks and 40% to 80% of stream reach channelized)

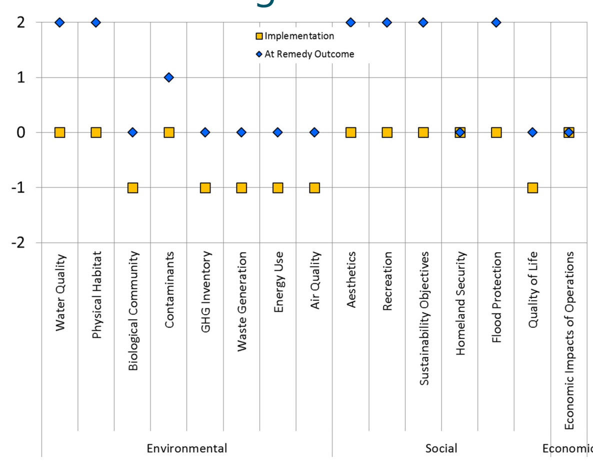
Theoretical Example Site – Current Conditions

- Current conditions of an impacted, modified tidal creek system
  - Contaminated sediment exceeds cleanup goals to 6-foot depth
  - Dams and culverts minimize tidal flushing and promote stagnant conditions
  - Elevated nutrients and temperature, low dissolved oxygen, and limited fish passage due to restricted flows
  - Hardened shoreline limits ecosystem flows, shading, and recreational access
  - Stagnant condition results in low aesthetic and recreational value

Remedy No. 1: Removal of 6-Feet of Sediment

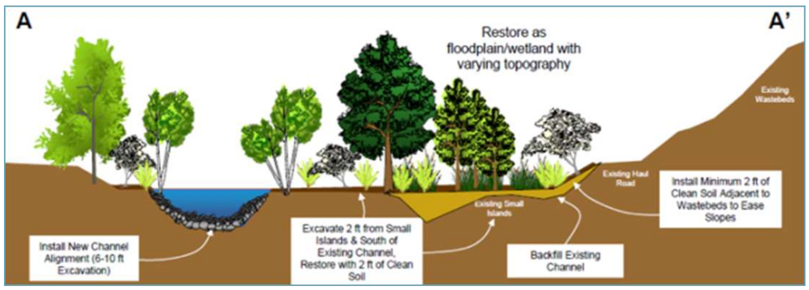


Remedy No. 2: Removal of Sediment in the Bioavailable Layer Removal of Culverts; Partial Softening of Shoreline



New framework…. But we have been doing this

Ninemile Creek

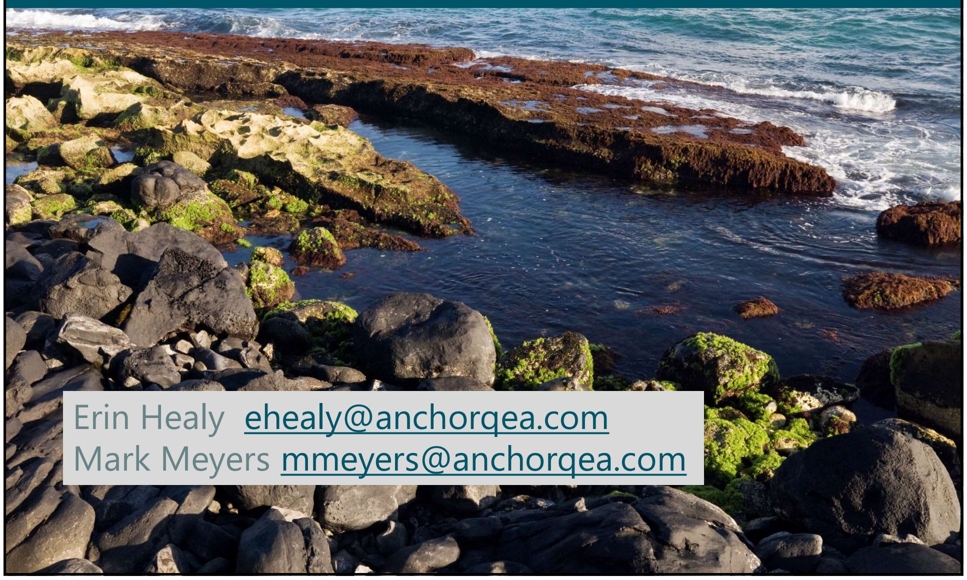


Global Strategy to Advance Sustainability

- We need to make progress on three fronts

- **Regulatory**: evaluation of environmental, social, and economic outcomes needs to have a role in remedial decision making
- **Technical**: need to develop acceptable methodologies; need to promote this through case studies and guidance documents
- **Advocacy**: need to further stakeholder education about how ESE evaluations can contribute to better remedial outcomes

Questions/Discussion



Erin Healy ehealy@anchorqea.com
Mark Meyers mmeyers@anchorqea.com

Attachment 15

Assessing the Resilience and Adaptability of Phytoremediation and Enhanced In Situ Bioremediation (EISB) under Global Climate Change

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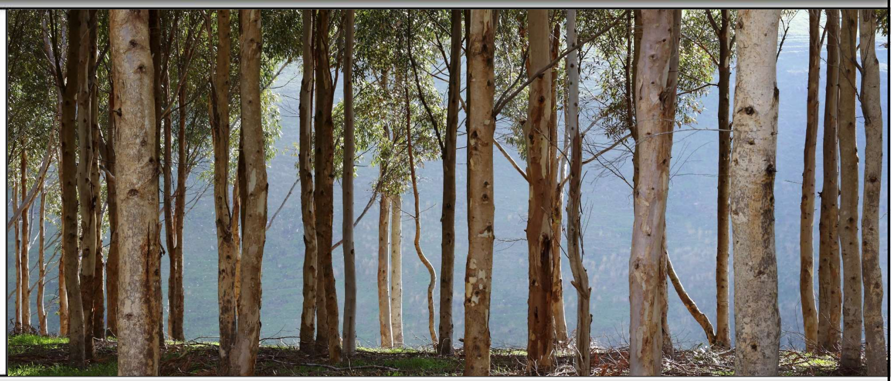
Sustainable Remediation Forum (SURF) 30

Life Cycle Assessment of Phytoremediation and Enhanced In-Situ Bioremediation and Evaluating their Resilience to Climate Change



October 7, 2015

Deyi Hou, Ph.D., P.E.
Deyi.Hou@parsons.com

Outline

- Background
- Method
- Preliminary Results
- Conclusions and Implications

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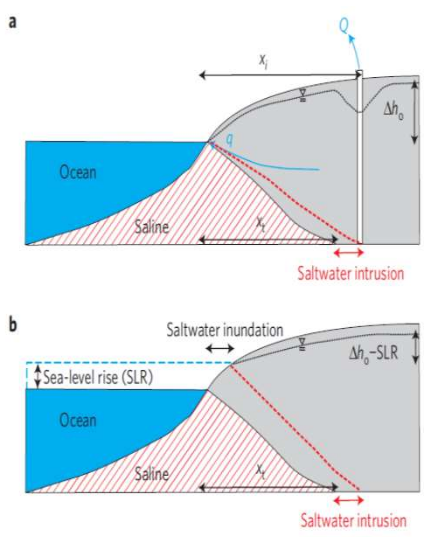
2

Background – Climate Change and GSR

- Atmospheric CO_2 increase 1.4 ppm per year
- Mitigation of climate change requires concerted action by all industrial sectors
- Green and sustainable remediation (GSR)
  - Life-cycle assessment
  - Greenhouse gas emission in upstream processes
    - Material acquisition
    - Energy usage in equipment manufacturing
  - Greenhouse gas emission in downstream processes
    - CO_2 emission due to fossil fuel usage
    - Methane emission due to microbial processes

Background: Sea Level Rise and Groundwater



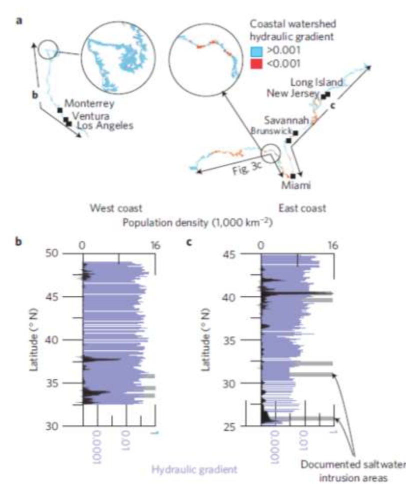


Figure 2 | Present saltwater intrusion areas have a high population density and/or low hydraulic gradients. a, For coastal watersheds in the

Source: Ferguson, 2012

Background – Resilience

- Adaptation vs. mitigation
- What are the implications of climate change to remediation?
- Some examples
  - Reducing effectiveness of in-situ s/s (Al-Tabbaa, 2007)
  - Lower groundwater table and enhance LNAPL removal (O'Connell, 2015, in prep)
  - Changing precipitation pattern affects effectiveness of landfill cover (Worthy, 2015)

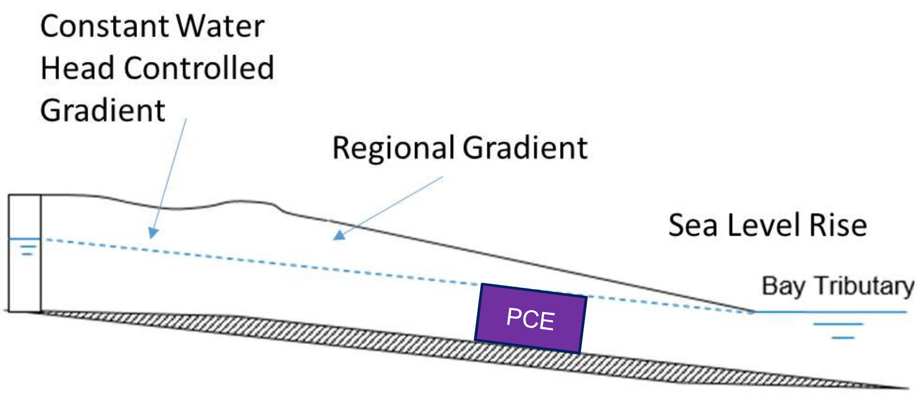
PARSONS 5

Objectives

- Compare the life-cycle impact of enhanced in-situ bioremediation (EISB) and phytoremediation (phyto) in the remediation of PCE plumes
- Evaluate the resilience of EISB and phyto to climate change

PARSONS 6

Hypothetical site



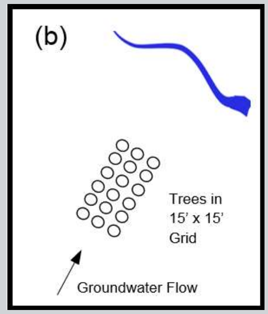
San Francisco Bay Area

Future Change Modeled

- Sea Level Rise
  - L-SLR: 30.5 cm over 100 years (US National Climate Assessment, low end)
  - M-SLR: 63 cm over 100 years (IPCC medium high)
  - H-SLR: 200 cm over 100 years (National Research Council, high end)
- Local Hydroclimatic Change (California Third Climate Change Assessment)
  - Precipitation +9%
  - Evapotranspiration +4%
  - Runoff +34%

Remediation Scenario - Phytoremediation

- Eucalyptus trees
- Tree hole at 15’ x 15’ grid
- Solar powered irrigation system
- Evapotranspiration slows GW flow
- Mass removal



$$\lambda_p = \lambda_0 + \frac{TSCE \cdot T \cdot f}{V}$$

TSCE: ratio of contaminant conc. in transpiration stream and that in groundwater

T: cumulative volume of water transpired

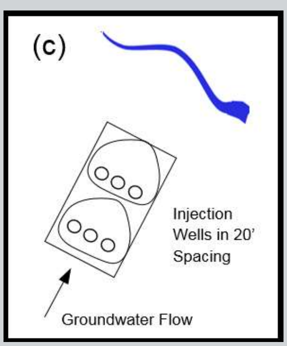
F: fraction of plant water needs met by contaminated groundwater

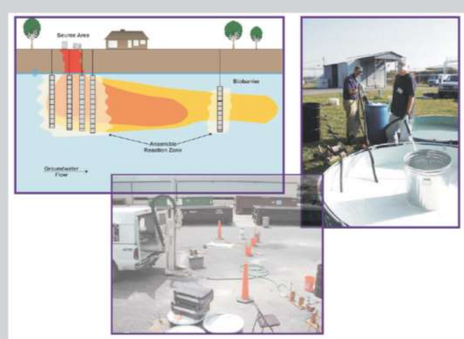
V: volume of groundwater in the treatment zone

PARSONS 9

Remediation Scenario - EISB

- Emulsified vegetable oil induced anaerobic dechlorination
- Injection wells (4’’ diameter) spaced at 20’ intervals





Source: AFCEE, 2007

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LCA Methodology

- ISO 4-Step Method
- Secondary impact LCIA Method: ReCiPe, End Point
- Primary impact

$$I = \int_0^T \int_0^A i \, dA \, dt$$

$$i = \begin{cases} \frac{C_t}{C_r}, if \ C_t > C_i \\ 0, if \ C_t < C_i \end{cases}$$

I: impact points for an individual contaminant

T: time horizon (i.e. 100 years)

i: incremental impact point for time interval dt and area increment dA

C_t: groundwater concentration at time t

C_r: cleanup criteria

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11

Inventory Challenge I: Methane Emission

- Typically ignored
- Lemming, et al used stoichiometry, assuming two pathways
- With electron acceptor (1 mole sucrose → 4 mole methane)
  - Hydrolysis of sucrose to lactate:
    $C_{12}H_{22}O_{11} + H_2O \rightarrow 4CH_3CHOHCOO^- + 4H^+$
  - Lactate fermentation to acetate (21):
    $CH_3CHOHCOO^- + 2H_20 \rightarrow CH_3COO^- + HCO_3^- + 2H_2 + H^+$
  - Methanogenesis from acetate:
    $CH_3COO^- + H^+ \rightarrow CH_4 + CO_2$
- Without electron acceptor (1 mole sucrose →6 mole methane)
  - $C_{12}H_{22}O_{11} + H_2O \rightarrow 6CO_2 + 6CH_4$
- Overall, 0.11 kg methane per kg molasses

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12

Methane Emission

- Vegetable oil has higher methane production potential
  - $C_{18}H_{32}O_2$ vs. $C_{12}H_{22}O_{11}$
- Approximately 0.32 kg CH_4 per kg of oil if using stoichiometry
- Problems: 1) substrate converted to biomass; 2) substrate consumed by oxidant
- Diffusion model based on project data

0.23 kg CH_4 per kg vegetable oil

- The global warming potential of CH_4 is 28-36 times that of CO_2 (100 year)
- Remaining substrate/biomass converted to CO_2 (biogenic, no net GHG emission)

Source: http://epa.gov/climatechange/ghgemissions/gases/ch4.html

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Inventory Challenge II: CO_2 Storage in Phytoremediation

- Biogenic CO_2 emission / storage ignored in ReCiPe
- CO_2 storage in this project is not trivial
- Developed a method to capture this benefit

$$C_{storage} = \alpha \frac{\sum_i B_i\left(t_i^{live} + t_i^{decay} + \beta_i t_i^{SOM}\right) + \sum_j P_j t_j^{use}}{T}$$

- Where α is the average carbon content of biomass, B_i is the i_{th} fraction of biomass, including foliage, branch and trunk, and roots; t_i^{live} is the average living time of the corresponding biomass; t_i^{decay} is the average time it takes for the corresponding biomass, regardless of end-of-life usage type, to convert to soil organic matter; β_i is the ratio of biomass converted to soil organic matter; t_i^{SOM} is the average residence time of soil organic matter; P_j is the amount of biomass used in the j_{th} wooden products; t_i^{use} is the life span of the corresponding wood product, and T is the simulation time period

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CO_2 Storage in Phytoremediation

- Total ~ 123 tonne equivalent abiotic CO_2
  - Live tree (100 years growth), 70%
  - Soil organic matter, 9%
  - Wood product (29 years use life), 21%
- Environmental benefits exceed other secondary impacts

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Overall Comparison of Phytoremediation with EISB

Impact Categories Primary environmental impact	No Action	Phytoremediation	EISB
Vapor intrusion (9000 m^2 x 100 years)	23.4	14.7	1.2
Surface water (150 m^2 x 100 years)	28.4	0.0	2.1
Secondary environmental impact			
Human health (ReCiPe points)	0	-2170	11100
Ecosystems (ReCiPe points)	0	-1670	16100
Resources (ReCiPe points)	0	979	2750
Economic cost ($ in 2015)		1,342,000	330,000
Development benefit (m^2 of land x 100 years)	9000	0	9000

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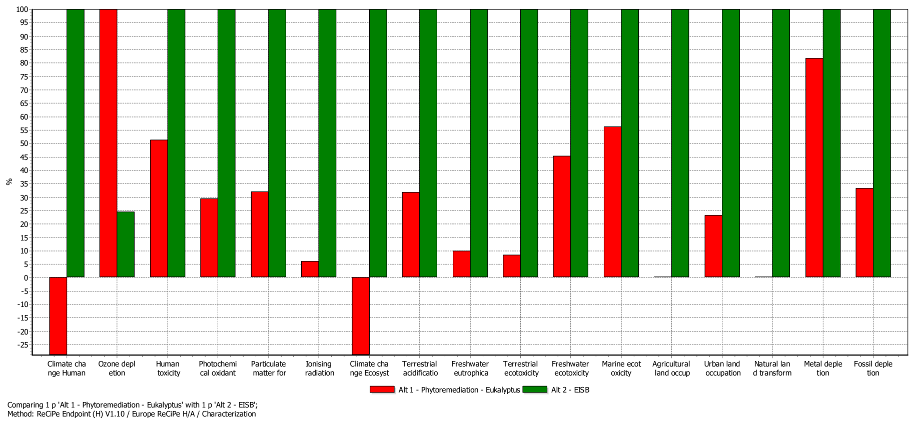
Life Cycle Impact Comparison



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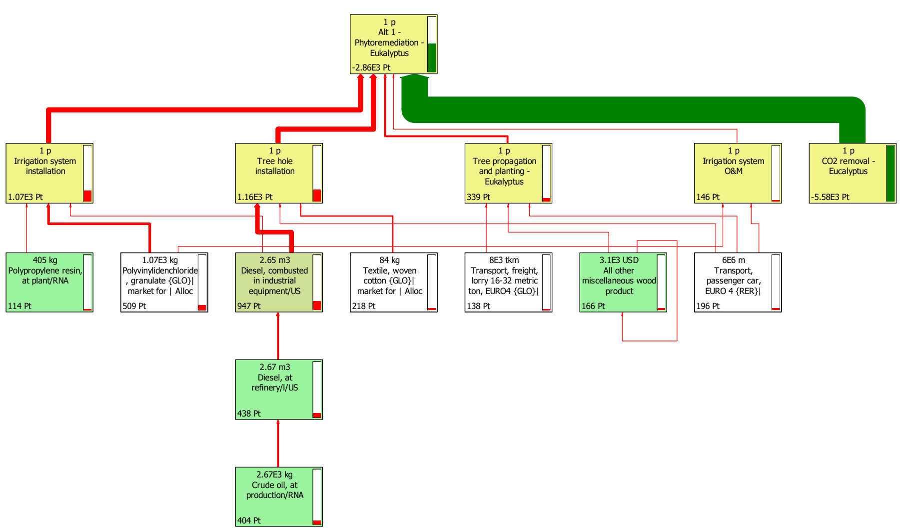
Contribution Analysis - Phytoremediation



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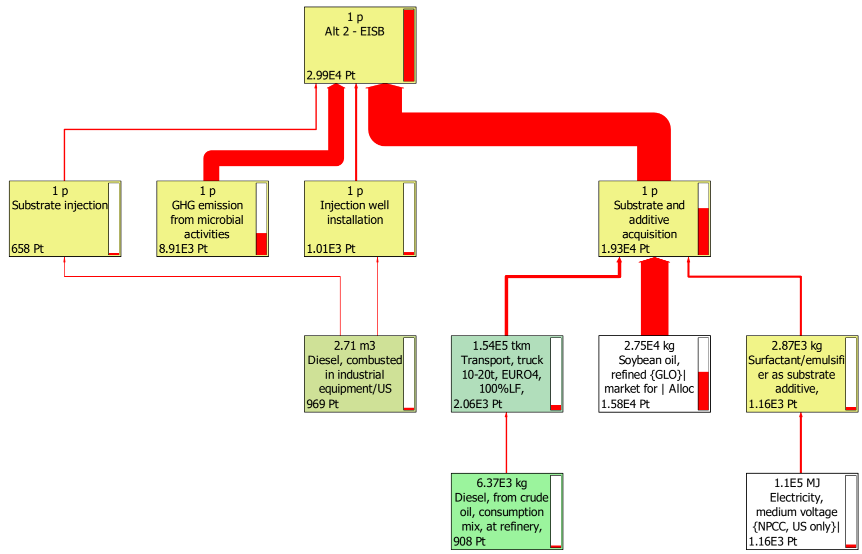
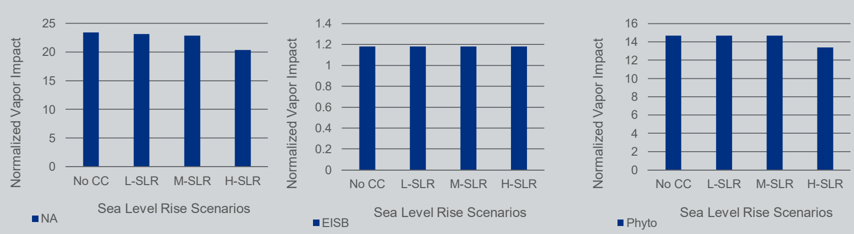
Contribution Analysis - EISB



Effect of Sea Level Rise

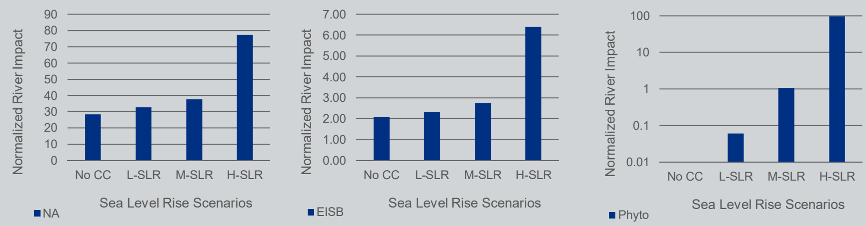
Vapor Intrusion (VI) Impact (constant hydraulic gradient)



- For NA , sea level rise slightly decreased VI risk (up to -13%)
- For EISB, sea level rise resulted in no change in VI risk
- For Phyto, sea level rise slightly decreased VI risk (up to -9%)

Effect of Sea Level Rise

River Impact (constant hydraulic gradient)



- For NA, sea level rise dramatically increased impact to river (up to 172%)
- For EISB, sea level rise significantly increased impact to river (up to 206%)
- For Phyto, sea level rise increased impact to river by orders of magnitude

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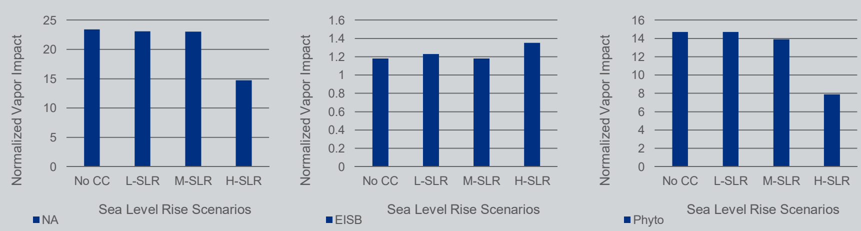
Effect of Sea Level Rise

VI Impact (with varying hydraulic gradient)



- For NA , sea level rise significantly decreased VI risk under H-SLR (-37%)
- For EISB, sea level rise slightly increased VI risk under H-SLR (+14%)
- For Phyto, sea level rise significantly decreased VI risk under H-SLR (-46%)

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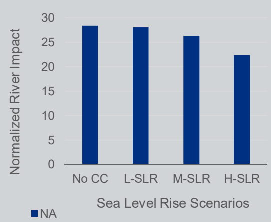
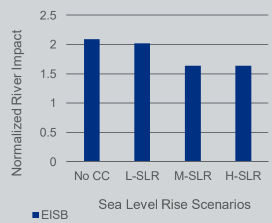
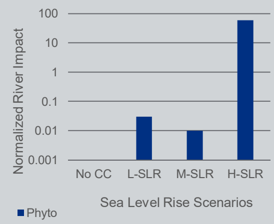
Effect of Sea Level Rise

River Impact (with varying hydraulic gradient)







- For NA, sea level rise slightly decreased impact to river (up to -21%)
- For EISB, sea level rise slightly decreased impact to river (up to -22%)
- For Phyto, sea level rise increased impact to river by 4~5 order of magnitude

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23

Effects of Hydroclimatic Change

- May affect natural decay rate due to change in temperature (not modeled)
- Effects on short-term effectiveness of EISB is not modeled, because EISB lasts for only 9 years
- Effects on phytoremediation may be significant
  - Precipitation +9%, reduced effectiveness of phyto-extraction
  - Potential evapotranspiration +4%, increased effectiveness of phyto-extraction
  - Run off +34%, increased effectiveness
  - Modeled results: VI impact + 0.1% (not significant)
  - Effects on CO_2 storage, maybe significant (not modeled)

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24

Conclusions and Implications

- Both sea water intrusion and hydraulic gradient matter
- Phytoremediation is particularly vulnerable to sea level rise
- A constant upgradient water head nearby mitigates detrimental effects
- Hydroclimatic conditions have insignificant effects because effects of increasing precipitation cancels out effects of increasing temperature

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25

Attachment 16
Sustainability of In Situ Stabilization (ISS) Projects

Sustainability at In-situ Stabilization Projects

Paul R. Lear, Ph.D.

Note: Not all jobs depicted were completed by Envirocon – Dr. Lear brings experience from previous employers

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OUTLINE

- Technology Description
- Sustainability BMPs for ISS
- Case Study
- Conclusions

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TECHNOLOGY DESCRIPTION

- “In situ Stabilization/Solidification (ISS) is the mixing of impacted soils with reagents (such as Portland cement and/or slag) to reduce the leachability of contaminants while decreasing the permeability of the stabilized materials.”
- ISS can be applied using “auger-based” and “excavator-based” soil mixing approaches.
- “Auger-based” ISS mixing has been practiced for many years, primarily in the geotechnical and deep foundations arenas.
- “Excavator-based” ISS mixing has been practiced for many years, primarily at waste impoundments and sites with subsurface obstructions

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TYPICAL ISS CRITERIA

Parameter	Value
UCS	$\geq$ 50 psi
Permeability	$\leq 10^{-6}$ cm/sec
Leachability	UTS or Risk-based Leaching Criterion
Free Liquids	No free liquids

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TYPICAL AUGER ISS EQUIPMENT

4 to 12-foot Diameter Auger

Crane-Mounted Turn Table or Top Drive Drill Rig

Reagent Batch Plant

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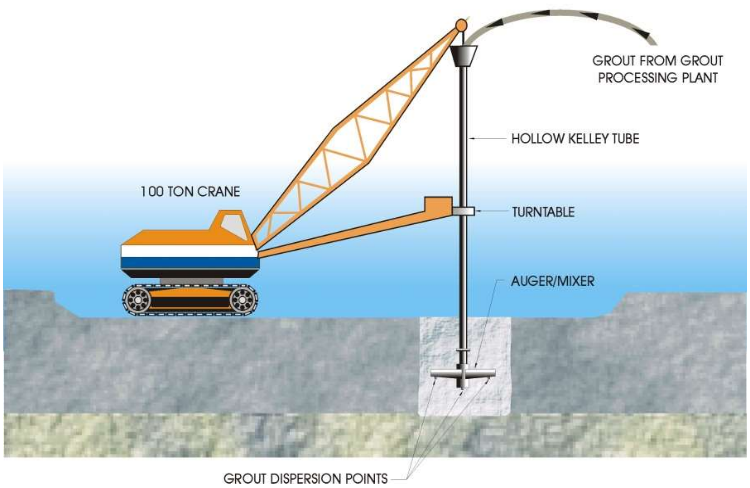
TYPICAL AUGER ISS EQUIPMENT

IN-SITU SOLIDIFICATION/STABILIZATION

TYPICAL IN-SITU AUGER MIXING RIG SCHEMATIC (NTS)



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AUGER ISS WORK SEQUENCING

Pre-excavate each days production (~500 square feet)

- Contains grout and accommodates swell

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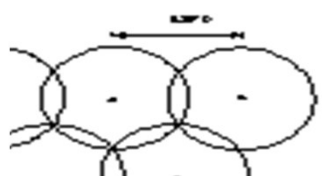
AUGER ISS WORK SEQUENCING

Column Treatment

- Determine grout volume for column based on overlap and depth
- Position auger of center of column
- Advance auger to required depth while adding the required grout volume
- Add water during retrieval
- Conduct additional mixing passes as necessary



Typical in situ treatment pattern

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COMPLETED AUGER ISS COLUMNS

Example of solidified columns from a pilot test

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TYPICAL EXCAVATOR ISS EQUIPMENT

Excavator or Mixing Head

Reagent Batch Plant

Ashing Filter

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EXCAVATOR ISS WORK SEQUENCING

Delineate the area to be treated into treatment cells of ~400 cy

Construct berm around treatment cell prior to treatment

- Contains grout and accommodates swell
- Includes overlap into adjacent treatment cells

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SUSTAINABILITY BMPs FOR ISS

Best Management Practices for ISS

- Minimizing Total Energy Use and Maximizing Use of Renewable Energy
- Minimizing Air Pollutants and Greenhouse Gas (GHG) Emissions and Maximizing Use of Machinery Equipped with Advanced Emission Controls
- Minimizing Water Use and Impacts to Water Resources
- Beneficial Reuse of Materials/Reduction of Materials and Waste Reduction
- Use of Local Labor and Supplies

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MINIMIZING ENERGY USE/MAXIMIZING RENEWABLE ENERGY

- Alternate reagents (e.g., ground granulated blast furnace slag (GGBFS)) instead of cement as part of the mix design
  - Each ton of Portland cement substituted results in almost a ton of avoided CO2 emissions.
- On-site treatment avoids the energy and CO2 emissions associated with off-site T&D
  - Approximately 0.5 gallons of diesel per ton of contaminated material
  - Approximately 0.1 pounds of CO2 per ton of contaminated material
- Solar power for survey and perimeter air monitoring systems

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MINIMIZING AIR POLLUTANTS AND GHG EMISSIONS

- B20 (a biodiesel/petroleum diesel blend) and ultra-low sulfur diesel
- More fuel efficient tier-2 and tier-3 equipment
- Anti-idling for heavy equipment
- Biodegradable suppressant foams

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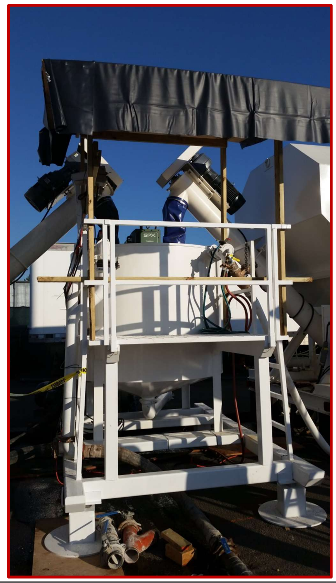
MINIMIZING WATER USE

- Decontamination, stormwater, and treated wastewater can be reused in the reagent batch grout plant.
  - The ISS batch plant can use more than 20,000 gallons per day, allowing large volumes of water to be recycled.



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BENEFICIAL RESUE OF MATERIALS

- Recycled concrete can be reused for riprap
- Trees and stumps from clearing and grubbing can be used to produce mulch
- On-site soils determined to be clean can be reused as onsite fill

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USE OF LOCAL LABOR AND SUPPLIES

- An ISS project can use local labor, vendors and supplies where possible
  - Administrative, skilled labor and general labor
- A substantial percentage of goods and materials can be purchased from local vendors
  - Resulting in local economic impacts.

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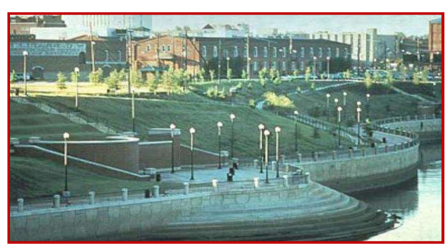
ADDITIONAL SUSTAINABILITY OF ISS

- ISS treatment can facilitate redevelopment
  - High UCS of ISS treated material makes an excellent subsurface/ subbase for construction
  - Utility corridors can be incorporated into the treated material



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SANFORD MGP SITE

- Former gasification plant site and adjacent areas in Sanford, FL

Brian Urban, Carlos Pachon, Julie Santiago-Ocasio, 2011 Conference on Design/Construction Issues at Hazardous Waste Sites

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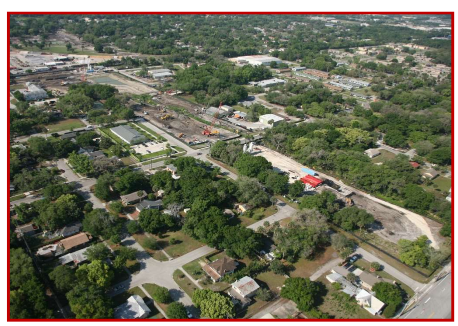
SANFORD MGP SITE

- Soil remedial activities included:
  - Demolition of three abandoned structures,
  - Excavation of the top 2 feet of soil (20,000 cubic yards)
  - ISS of 142,000 cubic yards saturated soils,
  - Extensive utility relocates
  - Installation of nearly 1,000 feet of 7 feet x 7 feet and 11 feet x 7 feet culverts
  - 450 feet of open channel improvement of Cloud Creek.



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SANFORD MGP SITE

- Base CO2 Footprint Calculated:
  - US Energy Information Association emission factors were used
- As-Bid Quantities of reagents, materials, fuel, and transportation utilized
  - Calculated CO2 footprint was 23,659 tons
  - 19,409 tons of CO2 emissions (over 80%) was from the Portland cement used in the ISS

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SANFORD MGP SITE

- Substituted GGBFS for 80% of the cement
- Solar powered backups for perimeter air monitoring
- Used B20, Tier 3 equipment and anti-idling
- 3.7 million gallons of decontamination, stormwater, and treated wastewater reused in the batch plant
- Reused concrete for riprap
- Produced mulch from the trees and stumps
- 12 Local hires for admin and skilled and general labor
- $8 million of purchases from local vendors

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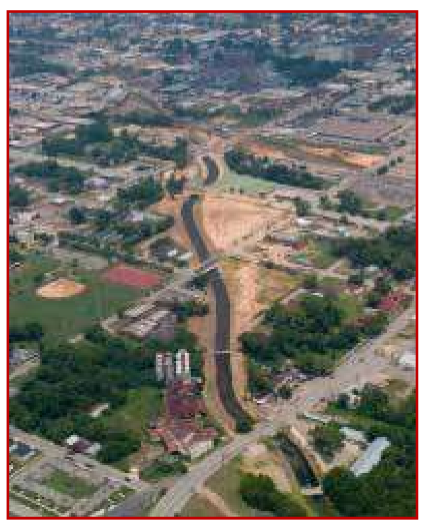
SANFORD MGP SITE

- Final CO2 Footprint Calculated:
  - Actual Quantities of reagents, materials, fuel, and transportation utilized
- CO2 Footprint reduced to 8,893 tons (62% reduction)
  - Most of the reduction came from GGBFS usage (saved 13,700 tons of CO2)
  - Changes in as-bid vs final quantities had a small effect (- 2%)
  - Over 200 tons of CO2 reduced by use of B20

SANFORD MGP SITE

- Complex remedial project
  - ISS, excavation and T&D, utility relocates, stream diversions, restoration
- Successfully completed
  - On time and under budget
- Completed in a sustainable manner
  - 62% reduction in CO2 footprint



CONCLUSIONS

- Sustainability BMPs are applicable at ISS sites
  - Result in a demonstrable reduction in CO2 footprint
- Largest impact will come from the substitution of alternative reagents for Portland cement in the ISS treatment process

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QUESTIONS OR COMMENTS?

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