

SEAR Combined With MPE To Resolve Recalcitrant NAPL At Coal Tar Brownfield Site



Ivey-sol® Surfactant Remediation Technology Presentation



Remtech East
Niagara Falls ON
May 30, 2023



Lanyard Sponsor



"TODAY'S ENVIRONMENTAL SOLUTIONS FOR A BETTER TOMORROW"



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IVEY GLOBAL DISTRIBUTION NETWORK

IVEY is an Award Winning Remediation Technology Company that has Developed Innovative Patented and Proprietary Remediation Products including: Ivey-sol[®], DECON-IT[®], and PFAS-SOL[®]





Observations of contamination in soil and groundwater following a spill is your observing SYMPTOMS

Presence of Dissolved, Sorbed, **NAPL** and VOC are the DISEASE

Remediation Practitioners have to correctly diagnose the DISEASE, causing the SYMPTOMS in your Sites 'PATIENTS'

Failure to fully understand SYMPTOMS & DISEASE, can lead to Incomplete Diagnosis, Incorrect Treatment (prescription), and Slower Recovery (Time), and Challenging Healing (Costly) for your PATIENTS 'Your Sites'



USEPA 542-R-18-002, May 2018

- **This USEPA publication evaluated 30 in-situ remediation projects involving NAPL;**
- **With n=30 (number of observation), this is of statistical importance to draw conclusions with a 95% Confidence Level;**
- **The 30 sites used a variety of physical, biological and chemical remediation methods;**
- **The in-situ soil and groundwater remediation took between 3 and 27 years, with a median of 8 years; and**
- **Site remediation was generally shorter for sites with less complex hydrogeological settings, with the exception of 3 sites with mild heterogeneity that required >15 years for remediation.**

~8 Years For Site Remediation...I Suggest Can Do Much Better in 2023.

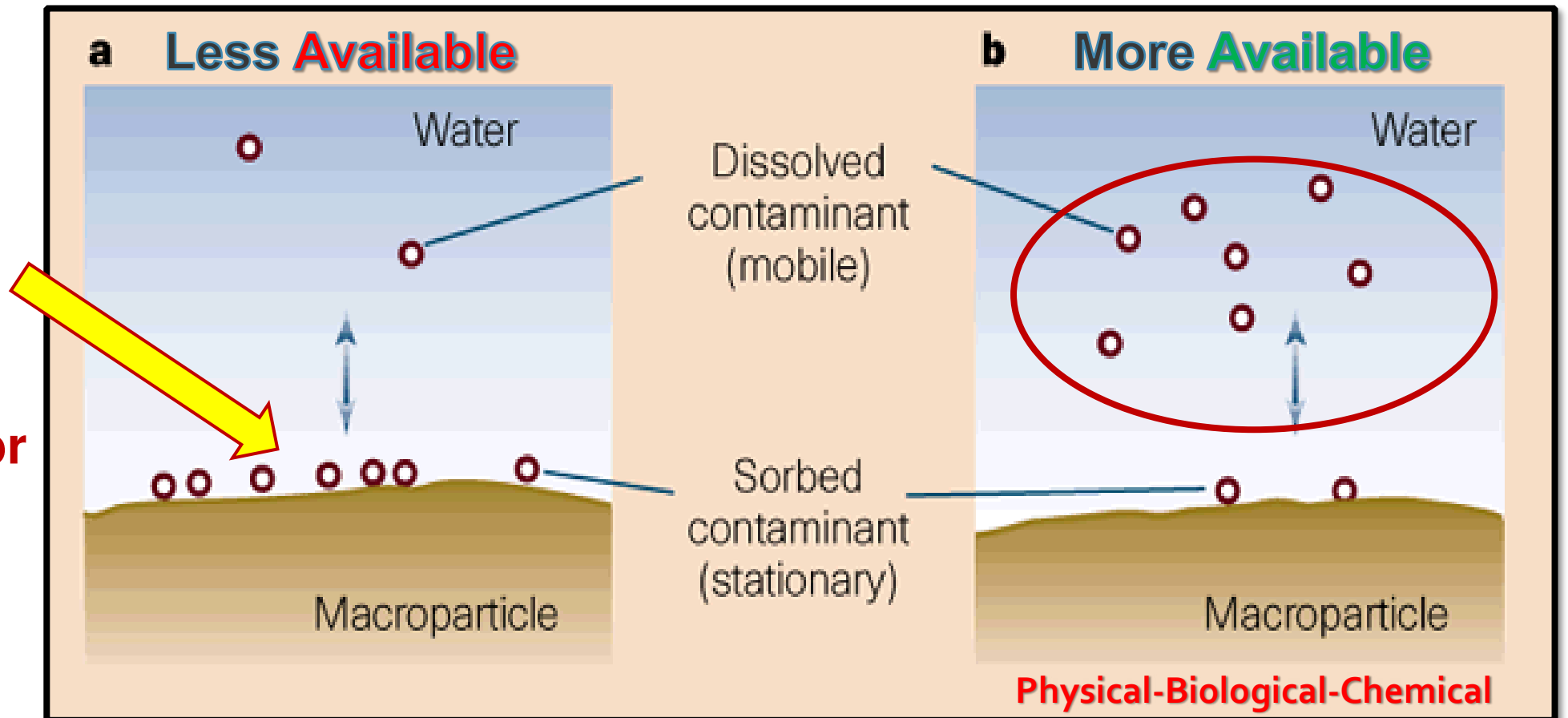
WHY SO LONG ?

Phase Partitioning (PP): Sorption - Globule - NAPL - VOC

LNAP, DNAPL and VOC have limited solubility in groundwater.

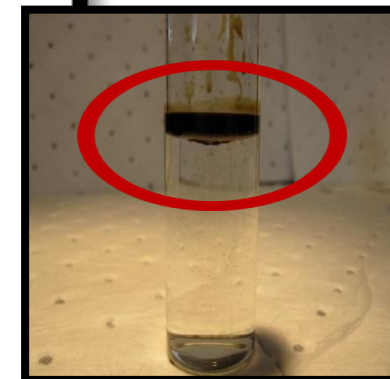
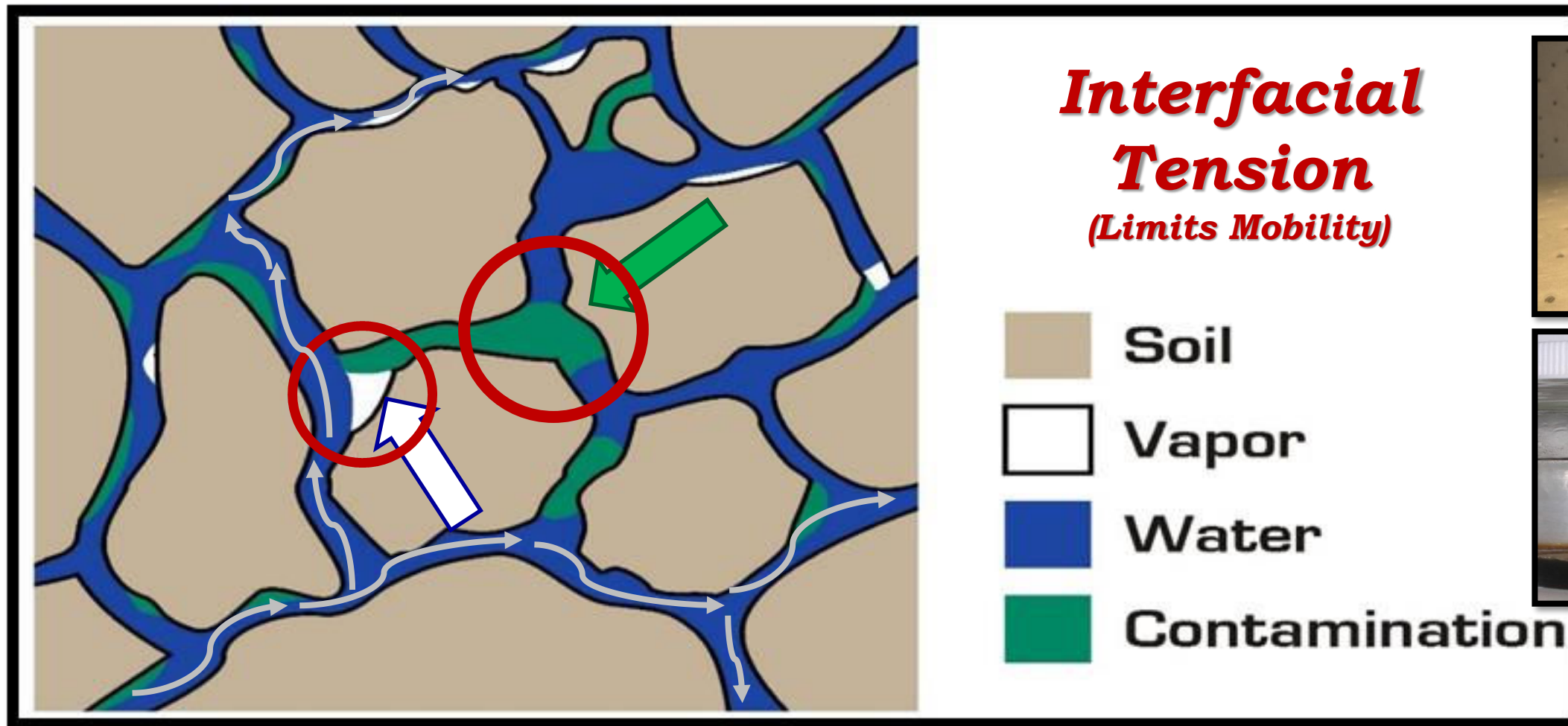
Hence these contaminants will PP to Sorb onto the Soil Surfaces, Agglomerate to form Globules, NAPL, or VOC = Reduced '**Availability**' for Remediation.

**Sorbed
Oil or NAPL
Expressing
Limited
Availability For
Remediation**



Phase Behavior: VOC - NAPL - Globule - Sorbed

Lets Take A Closer Look

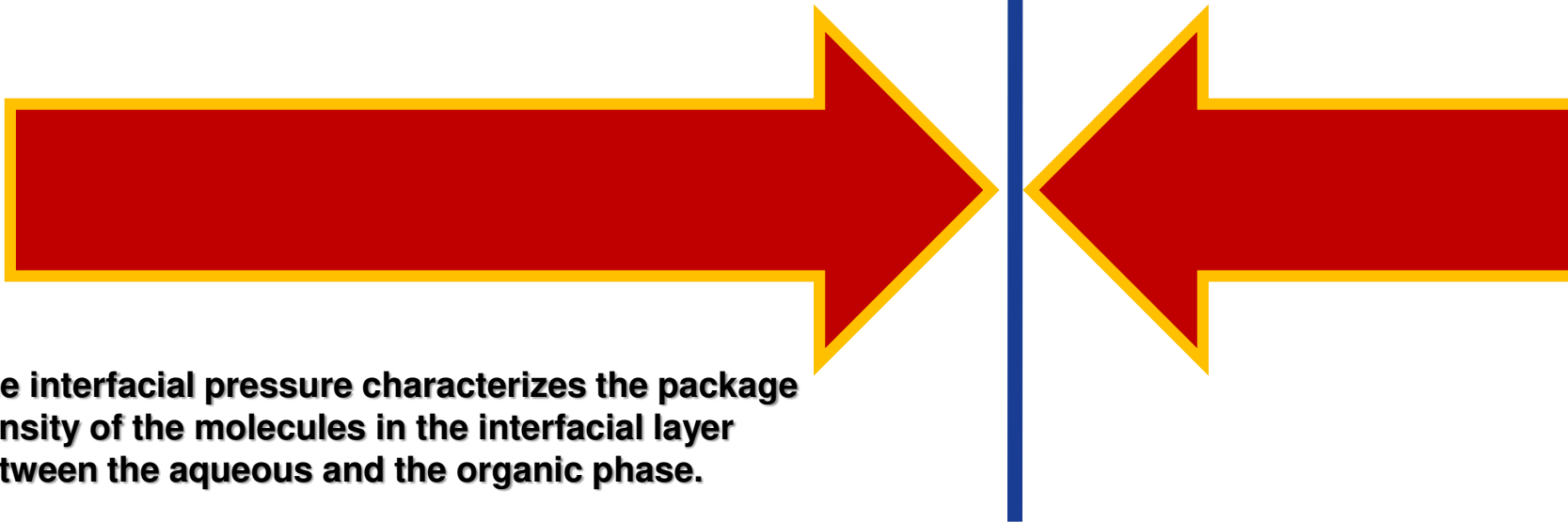


Interfacial Tension Between Phases

Oil - Water and VOC-Water

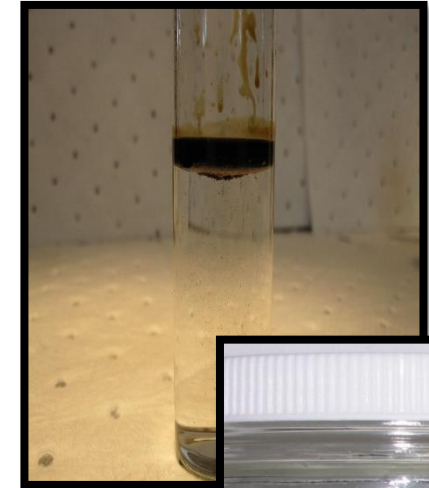
Water *Clusters* Have
Interfacial Tension of ~73 Dynes

LNAPL - DNAPL – VOC Interfacial Tension
~21 to 23 Dynes

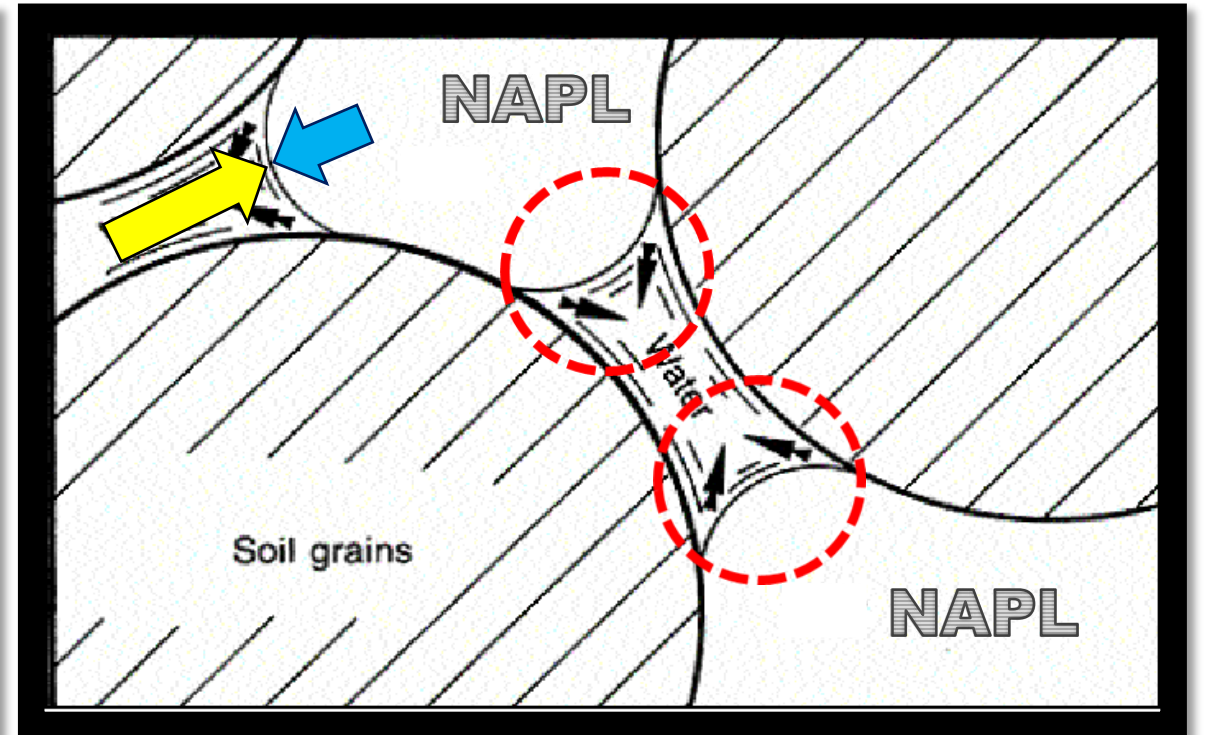
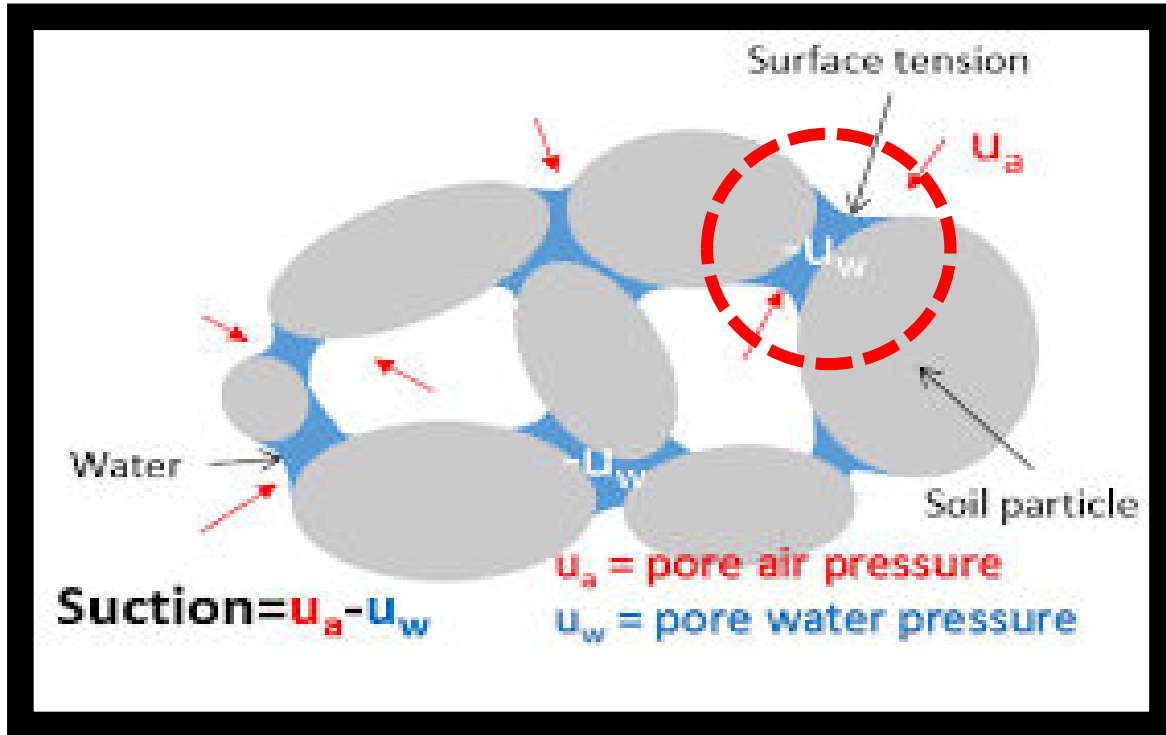


The interfacial pressure characterizes the package density of the molecules in the interfacial layer between the aqueous and the organic phase.

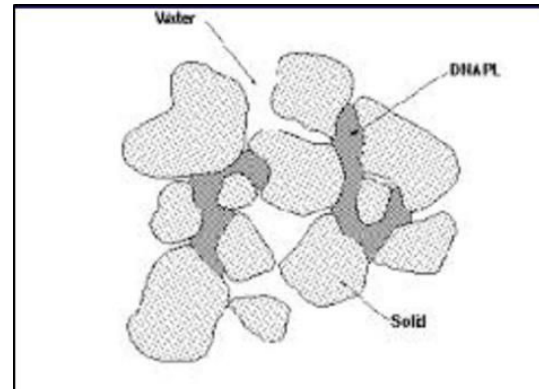
NAPL molecules at molecular interface between the 2 phases actually reorganize to cause a net increase in NAPL Interfacial Tension to >>30 Dynes!!



Interfacial Tension



Non Aqueous Vapor (VOC)



~LNAPL



Agglomeration

Contaminant **agglomeration** is the 'sticking' (cohesive or adhesive forces) of organic molecules to one another, onto surfaces (Sorption), can increase in thickness....its a very a natural phenomenon.

(like dissolves like & like attracts like)

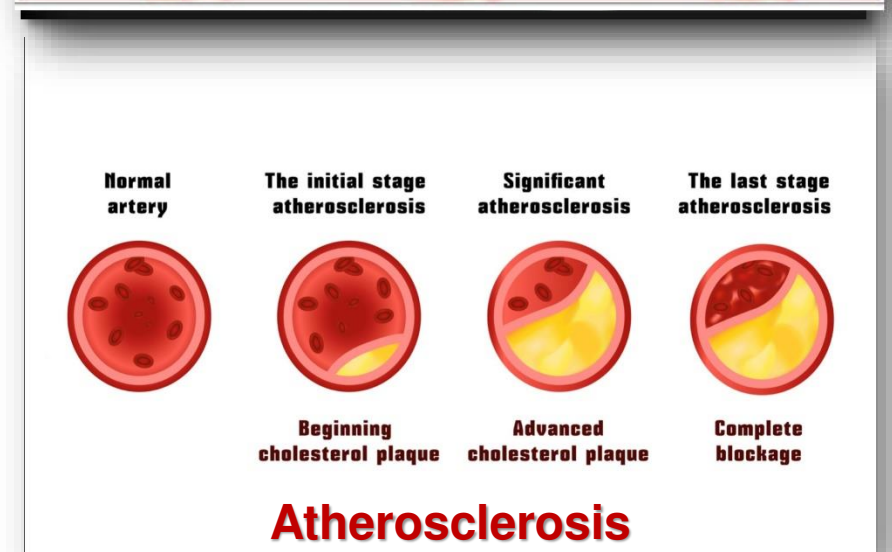
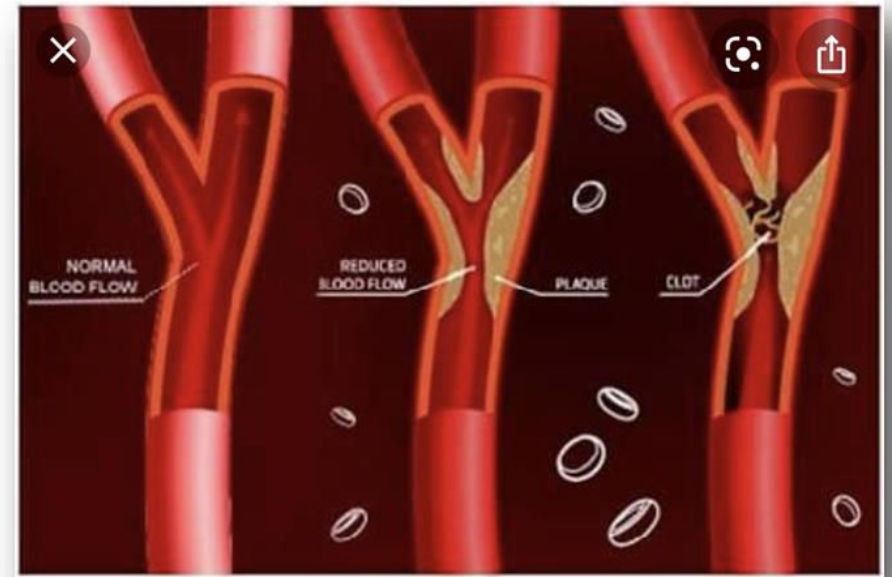
Agglomeration may be viewed as unwanted surface Sorption, that amasses to Globules or Ganglia, to NAPL and/or VOC layers in formations.

(medical analogy - clogging of arteries)

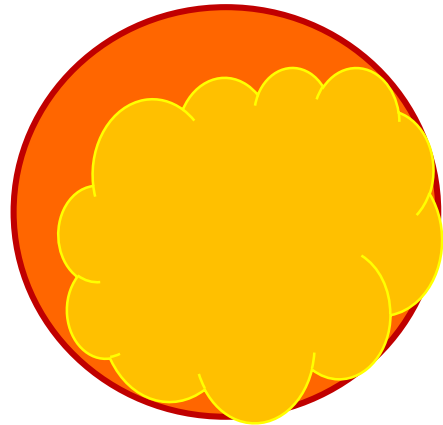
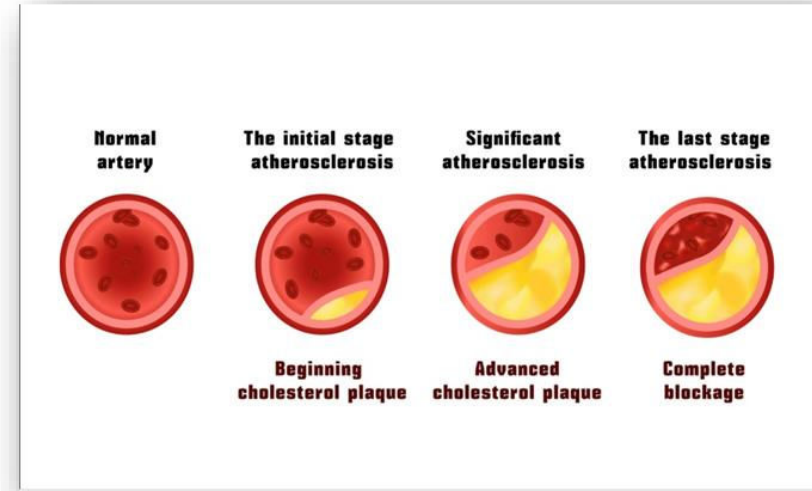
Within geology, this causes caking, bridging, and/or blockage of effective pathways = '*Pathway Interference*'

(hence delivery or extraction issues!)

Diameter of Soil Pore Openings \ll *Diameter of Hair* \ll *Veins* \ll *Arteries*

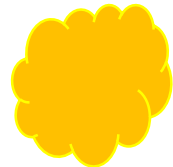


Relative Diameters of Soil Pore Opening to Average Hair, Vein and Artery Diameters



**Artery
(3.5 mm)**

67.3 X



**Vein
(0.95 mm)**

18.3 X



**Hair
(0.125 mm)**

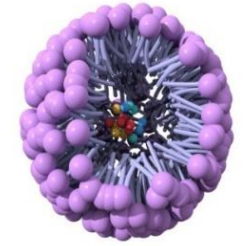
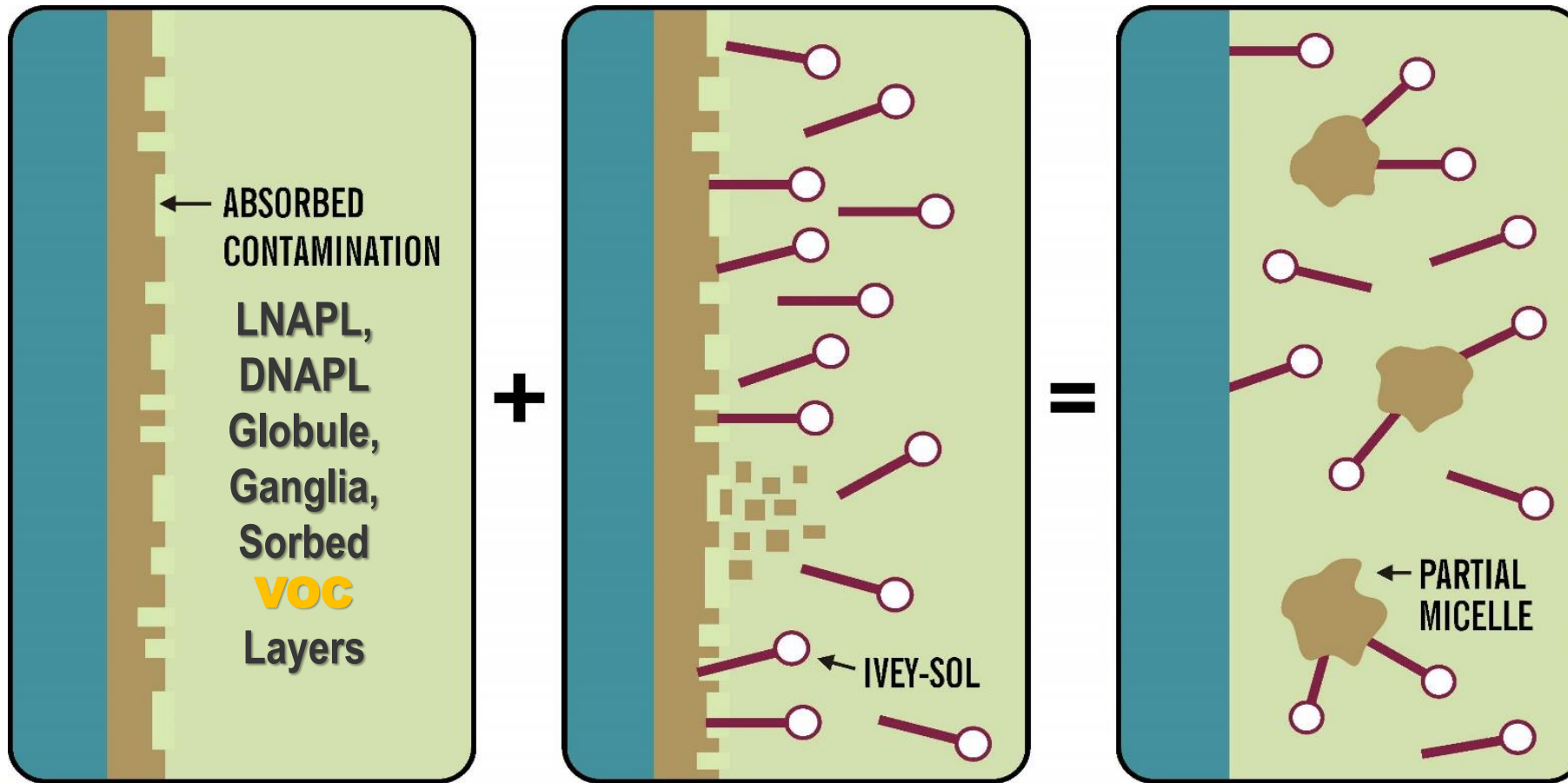
2.4 X



**Soil Pore
(0.052 mm)**

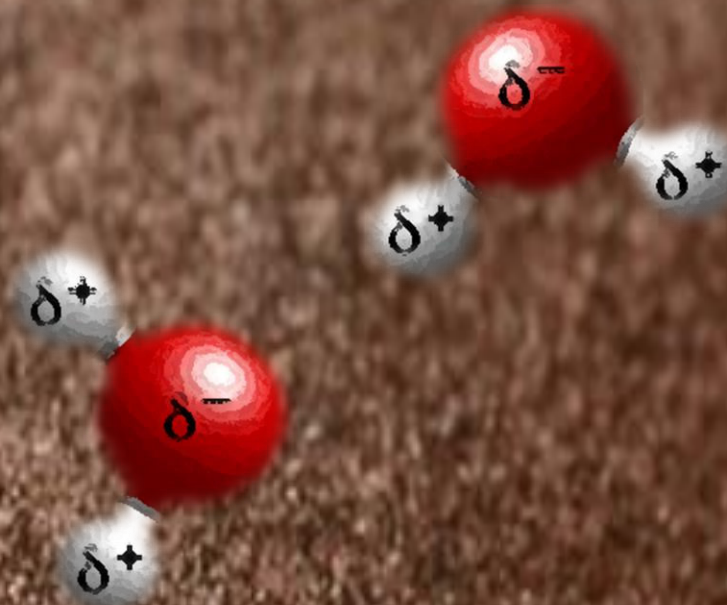
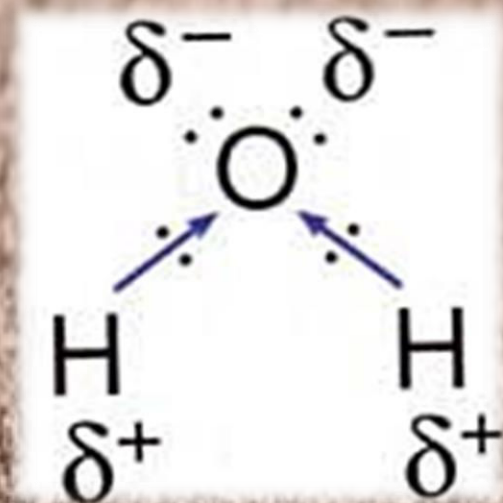
1/20th of a mm

1



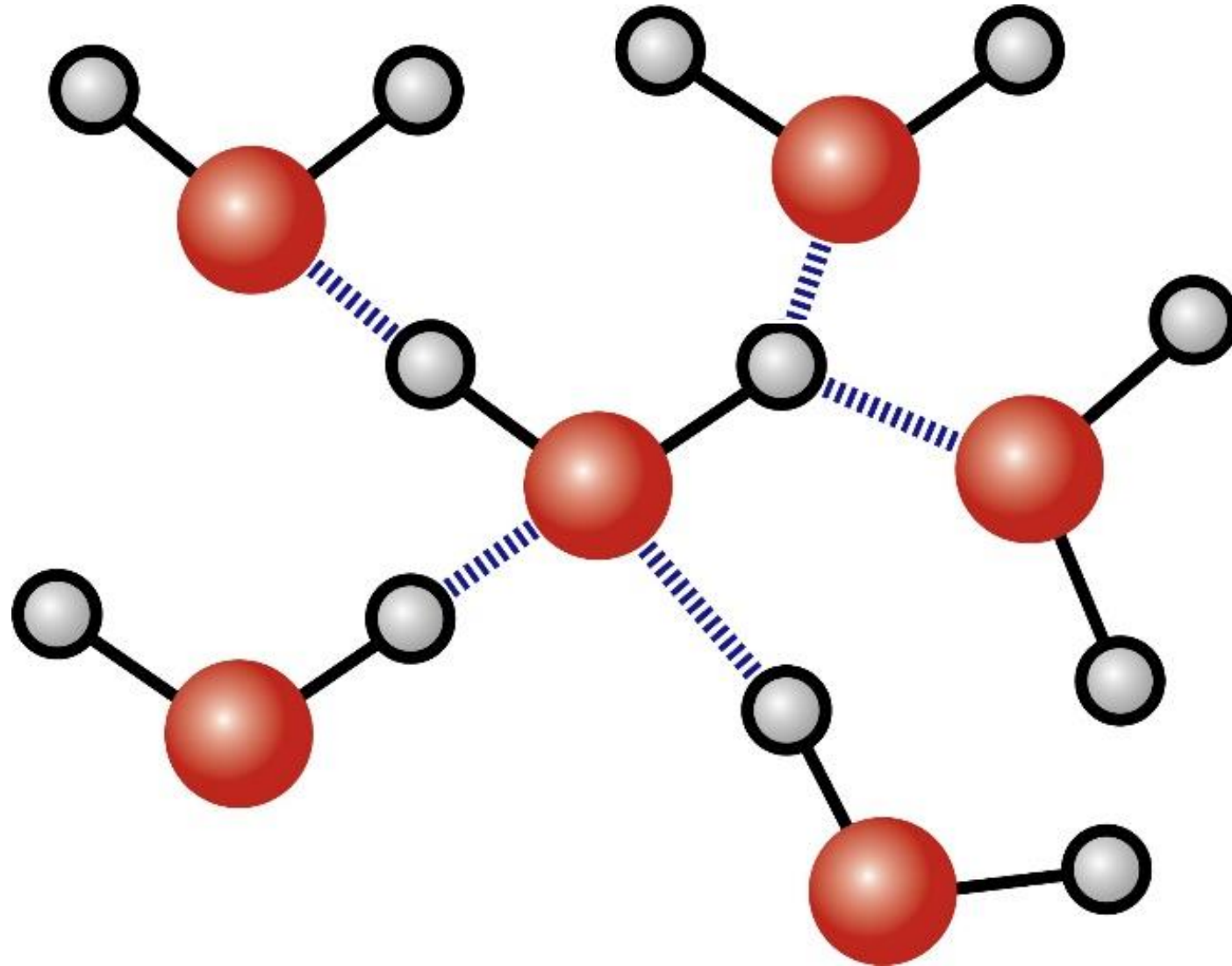
How >95% of surfactants work by encapsulating contaminants hindering their 'Availability' for remediation, and impedes water treatment, and greater potential of plume dispersion.

Ivey-sol[®] selectively desorbs, Sorbed, NAPL, VOC below the CMC
Increasing Physical, Biological and/or Chemical Availability For Remediation



Hydrogen Bonding
Between H_2O Molecules

Hydrogen Bonding - Expanded

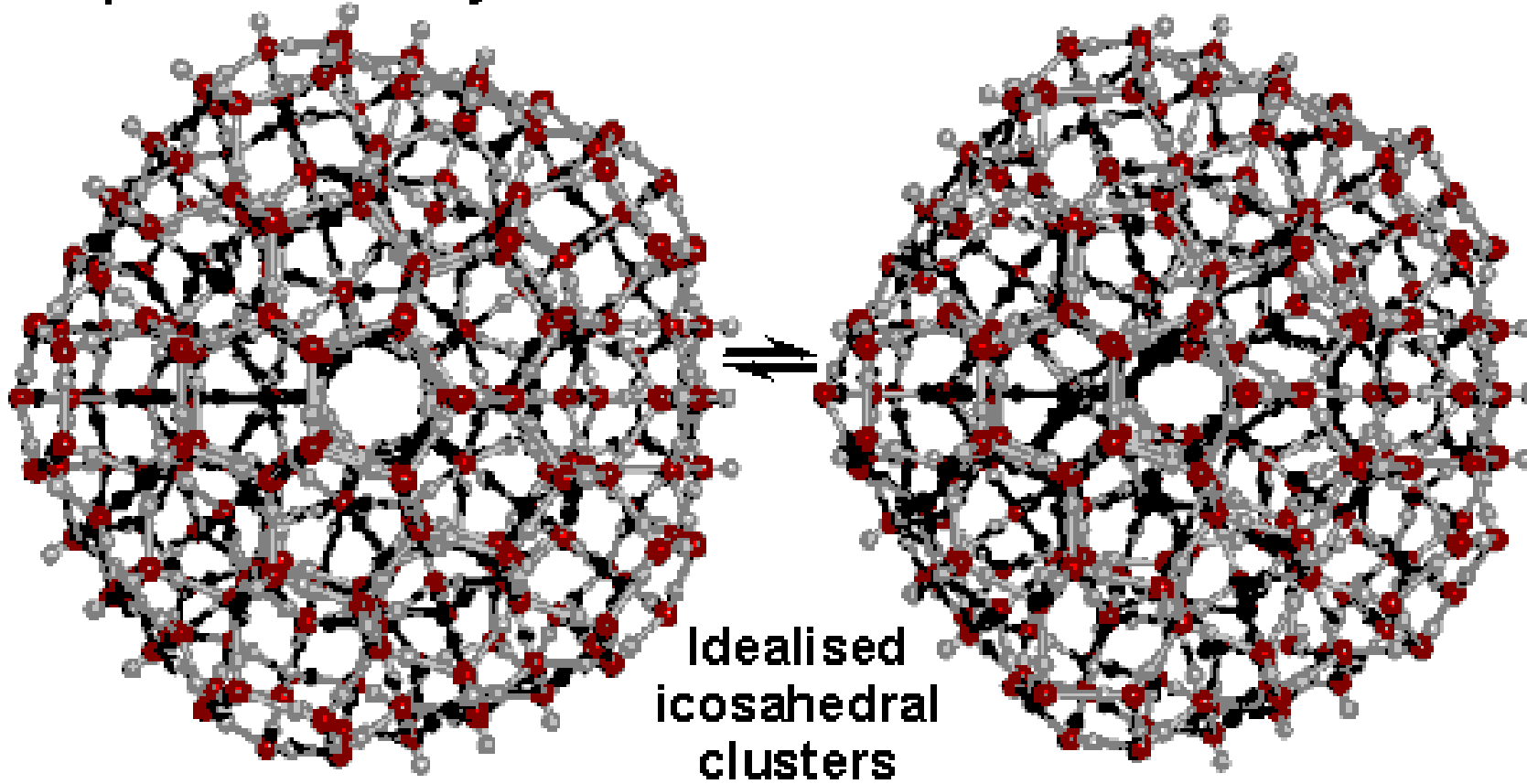


**Water Is A 3-Dimensional 'Cluster' - With Surface Tension of 73 Dynes
Water Cluster Size Limits (K) It's Ability To Move In Finer Texture Geology**

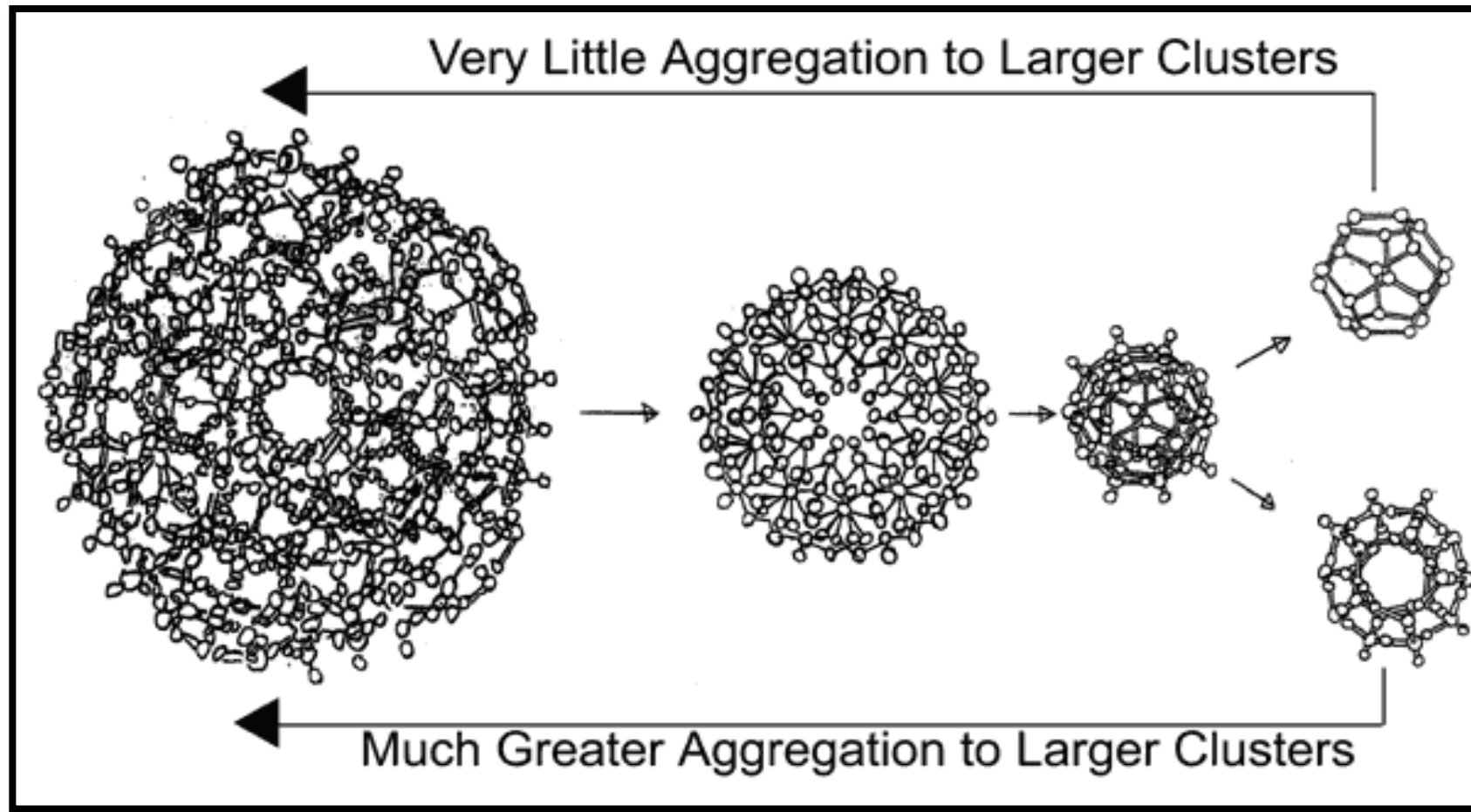
**Ivey-sol® Makes Water Clusters Smaller So Enter & Transport More Easily
Through Finer Grain Soil [Lower Surface Tension <30 Dynes + Overcome IFT]**

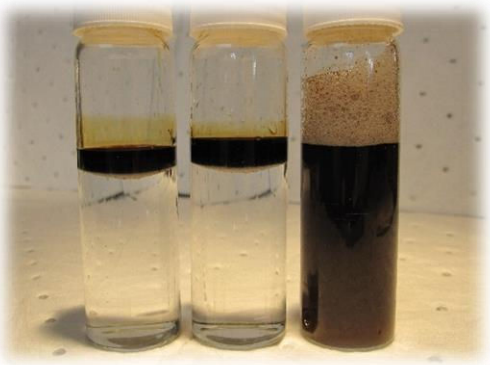
Open low density structure

Condensed structure



Ivey-sol Reduces The Size of Water Clusters Improving (Lower Surface Tension from 73 Dynes to $\lt 30$ dynes) Access & Regress within Fine Grain Soil Textures ~ Improving K



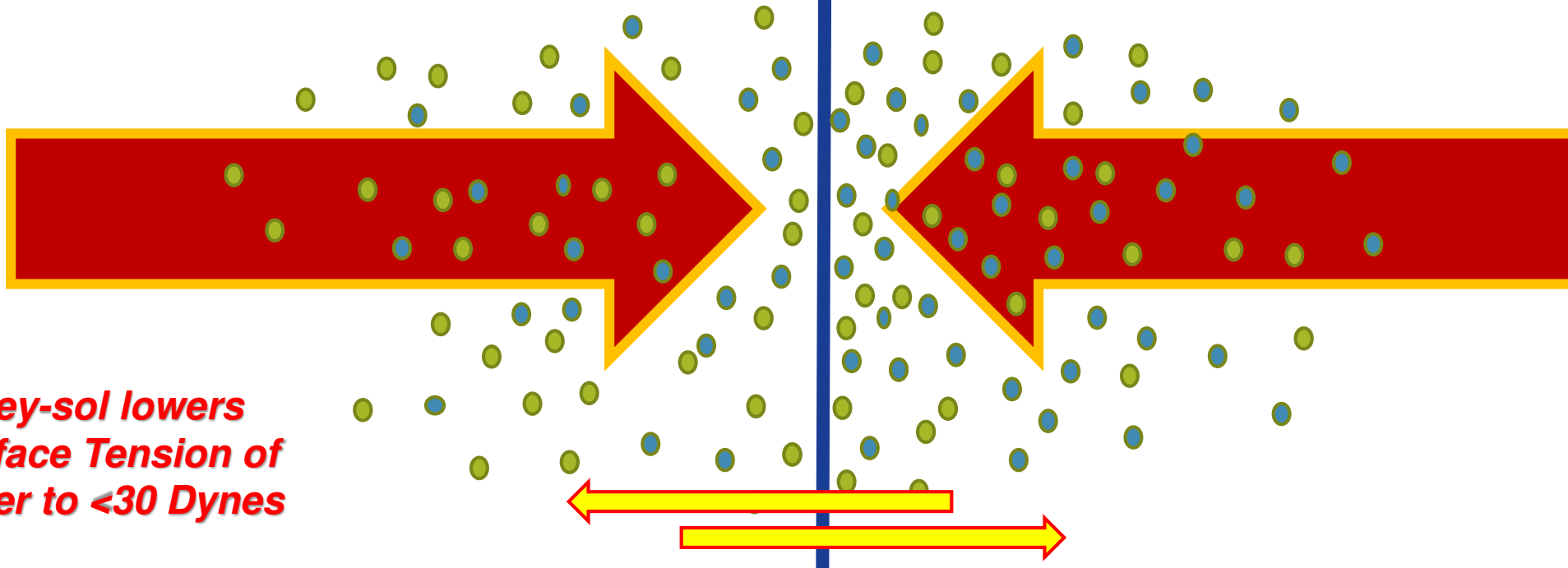


Overcoming Interfacial Tension (*Pressure*)



Water Has Interfacial Tension of 73 Dynes

VOC and NAPL Have (On Average) Interfacial Tension of 21-23 Dynes

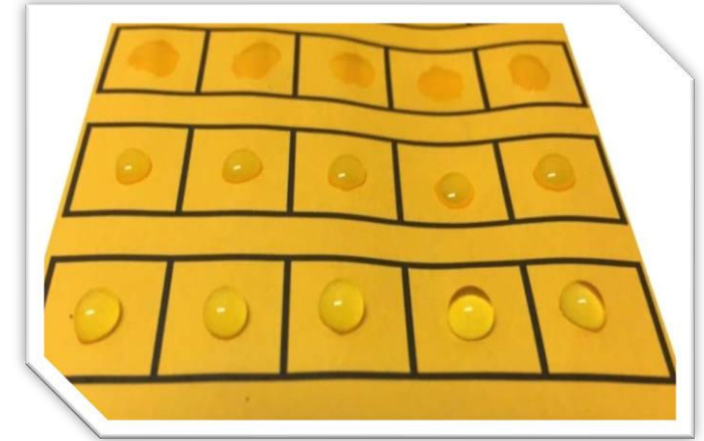


Ivey-sol lowers Surface Tension of Water to <30 Dynes

Overcoming Interfacial Tension (<30 vs <30) Increases NAPL, Sorbed, Dissolved, **VOC** 'Availability' For Remediation

New Hydro-Geo-Chemical Considerations That Limit Contaminant Availability...*that you can overcome.*

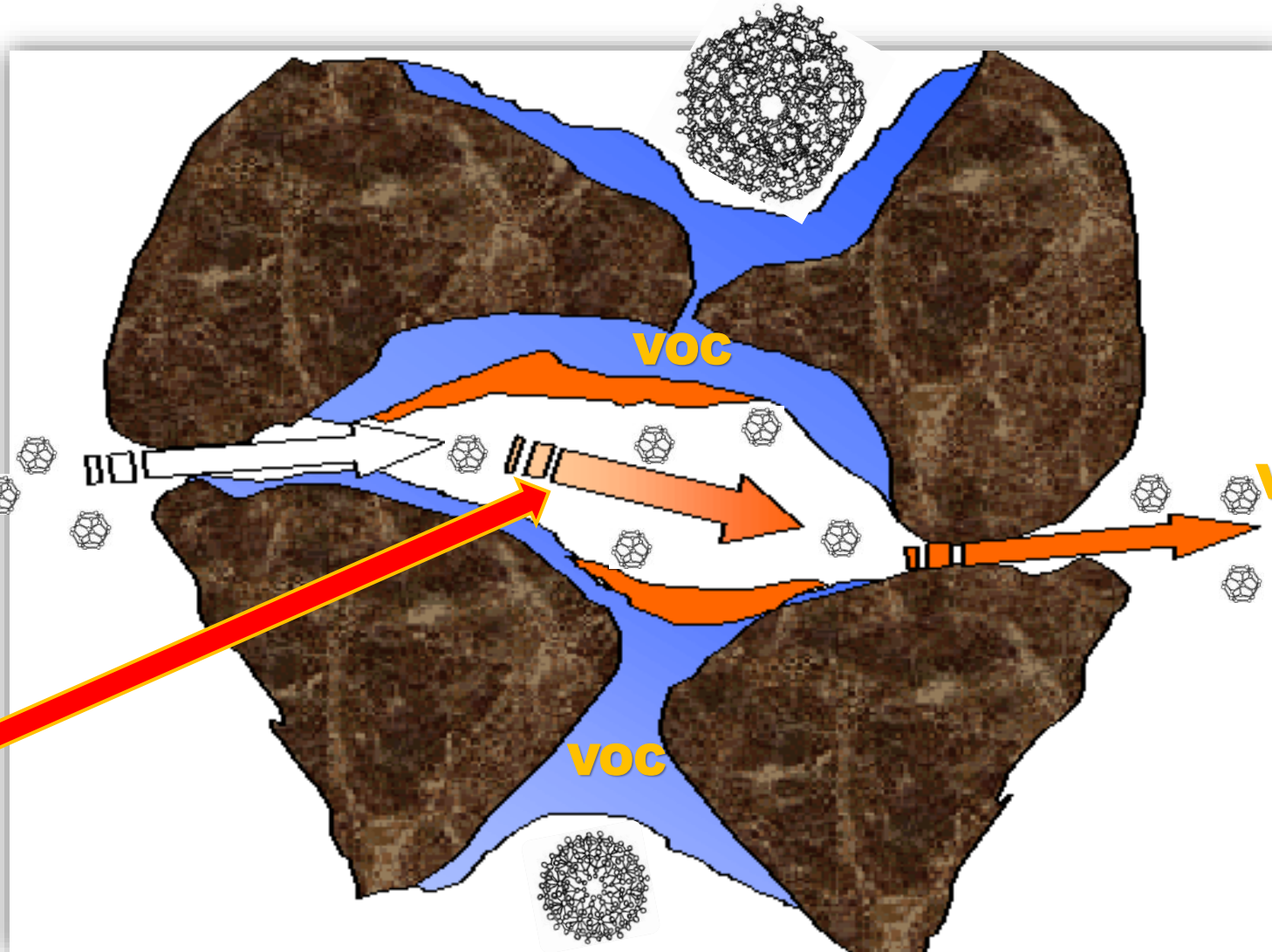
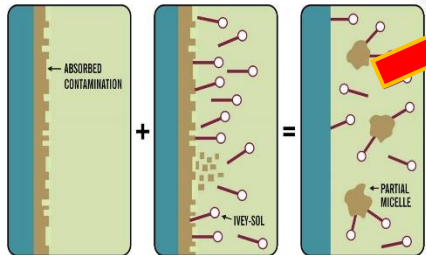
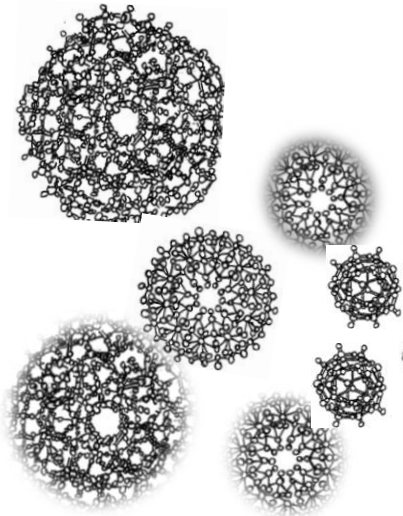
- Sorption (Adsorption & Absorption)
- Phase Partitioning (Sorption, Globule/Ganglia, LNAPL and DNAPL, and VOC)
- Agglomeration (*Not aggregation*)
- Interfacial Tension (Interfacial Pressures)
- Water Clusters (Water is not simply H₂O)
- Water Cluster Size Dictates K More Than Soil Grain Size
- Pathway Interference (Caking, Bridging, and Blockages)



Ivey-sol® Can Resolved All The Above To Improve 'Availability'
For Physical, Biological, and Chemical Remediation

Ivey-sol Overcomes Low K and Retardation In Finer Grain Soil Improving Access, Regress, and Remediation

ACCESS



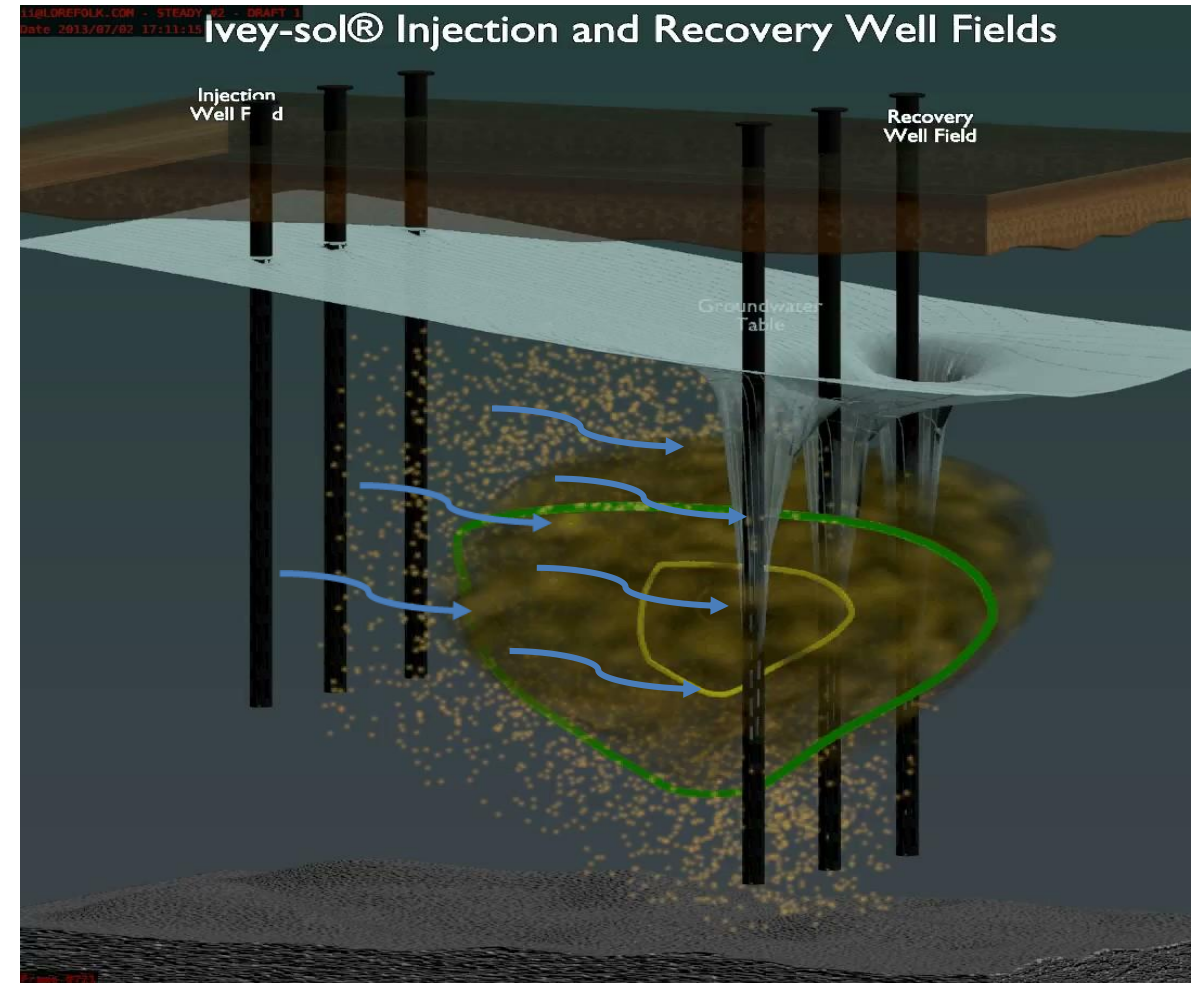
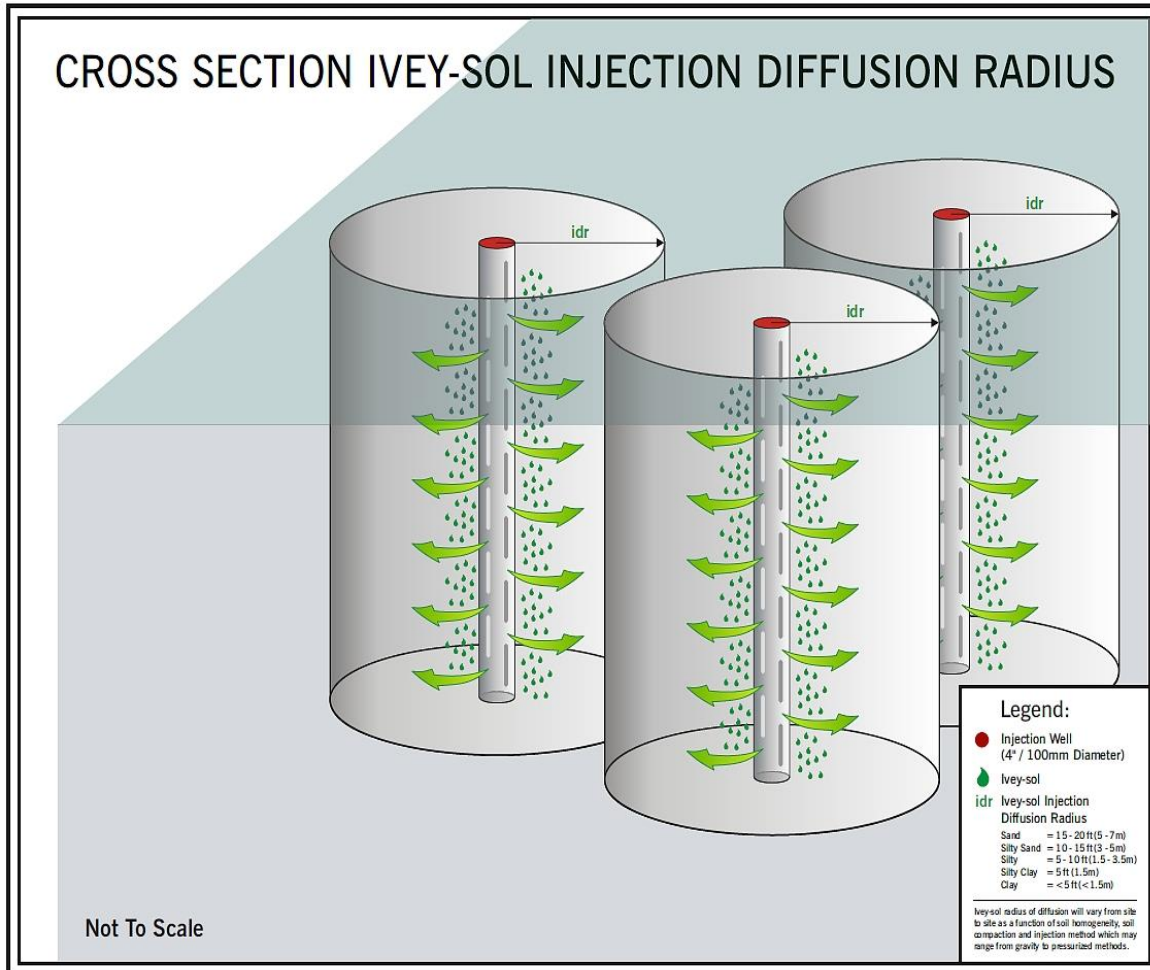
Interfacial Tension Will Effect NAPL Behaviors

More Available
(Physio-Bio-Chem)

REGRESS

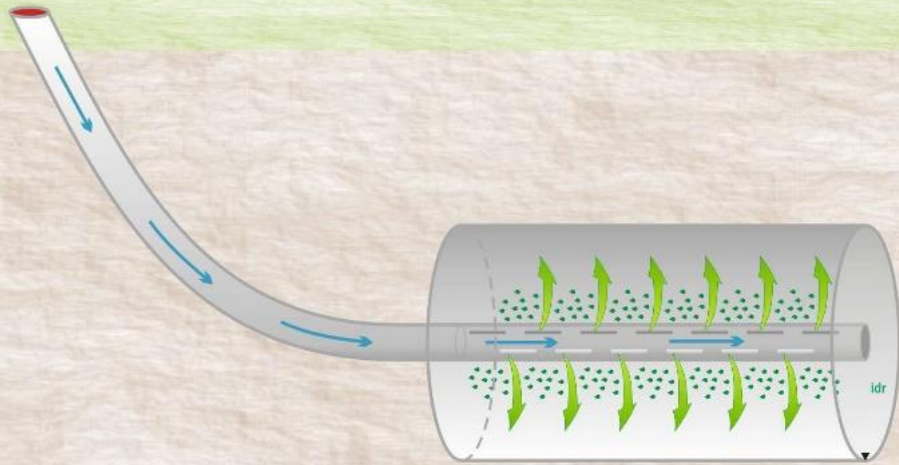


In-situ Ivey-sol® 'Push-Pull' & 'Sweep' Applications



Horizontal Well Applications

CROSS SECTION IVEY-SOL HORIZONTAL INJECTION WELLS

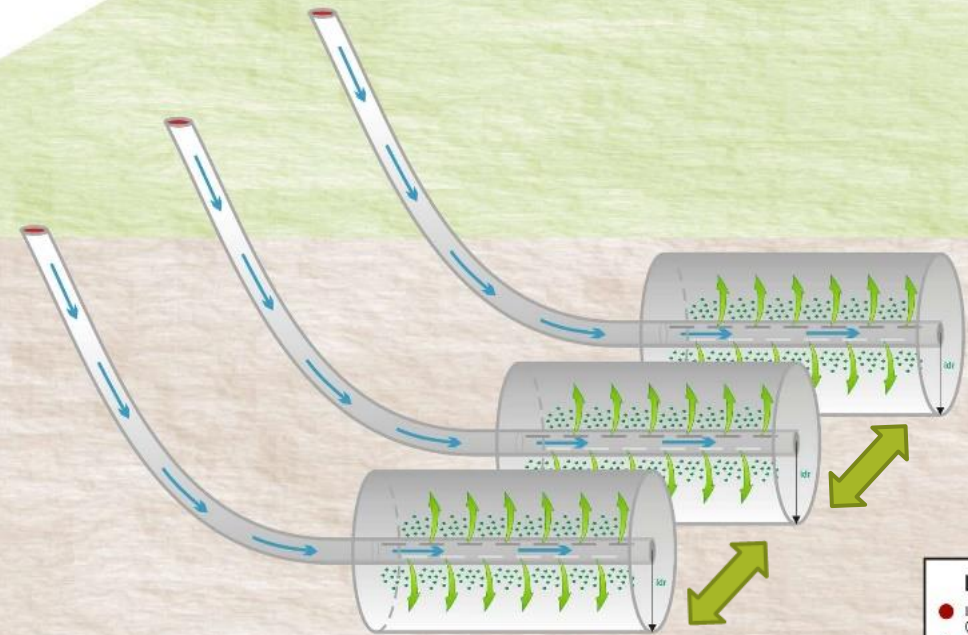


Legend:
● Injection Well (4" / 100mm Diameter)
● Ivey-sol
idr Ivey-sol Injection Diffusion Radius

Ivey-sol radius of diffusion will vary from site to site as a function of soil heterogeneity, soil compaction and injection method which may range from gravity to pressurized methods.

Not To Scale

CROSS SECTION IVEY-SOL HORIZONTAL INJECTION WELLS



Legend:
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Not To Scale

Ivey International, Inc.
Ivey-sol[®] Injection and Diffusion Radius



**Abbreviated Presentation
Version. Contact IVEY for
full version if interested.**

Sustainable outcomes with Ivey-sol[®] surfactant enhanced aquifer remediation (SEAR) of coal tar NAPL with MPE

Australasian Groundwater Conference 2019,
Updated 15 January 2020

Daniel Hirth, CEnvP
BlueSphere Environmental Pty Ltd
113 Ferrars Street
Southbank, VIC 3006
Australia



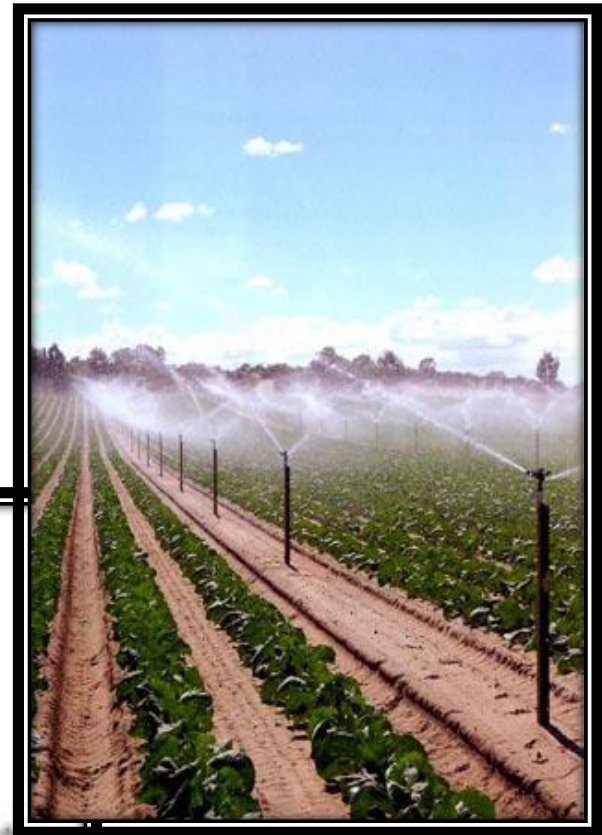
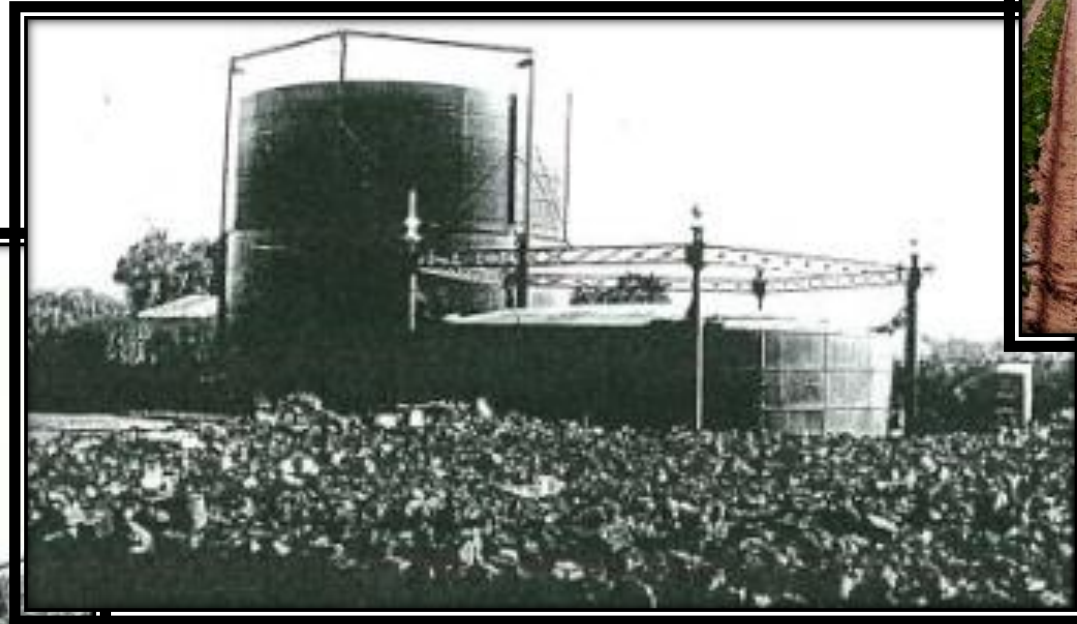
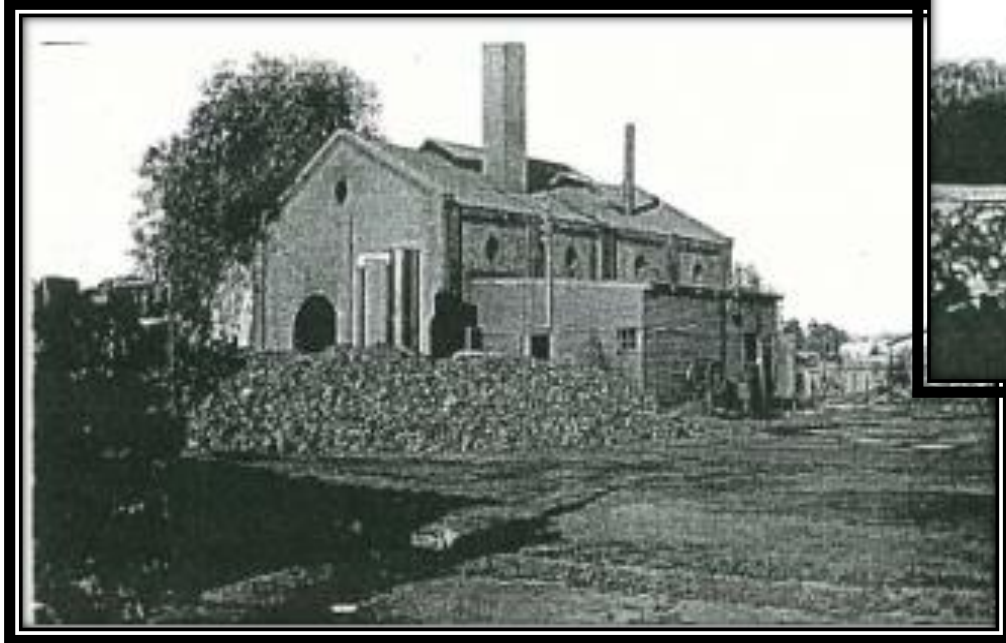
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Background

Rural gasworks from 1889-1973

Coke, tar and ammonia by-products generated

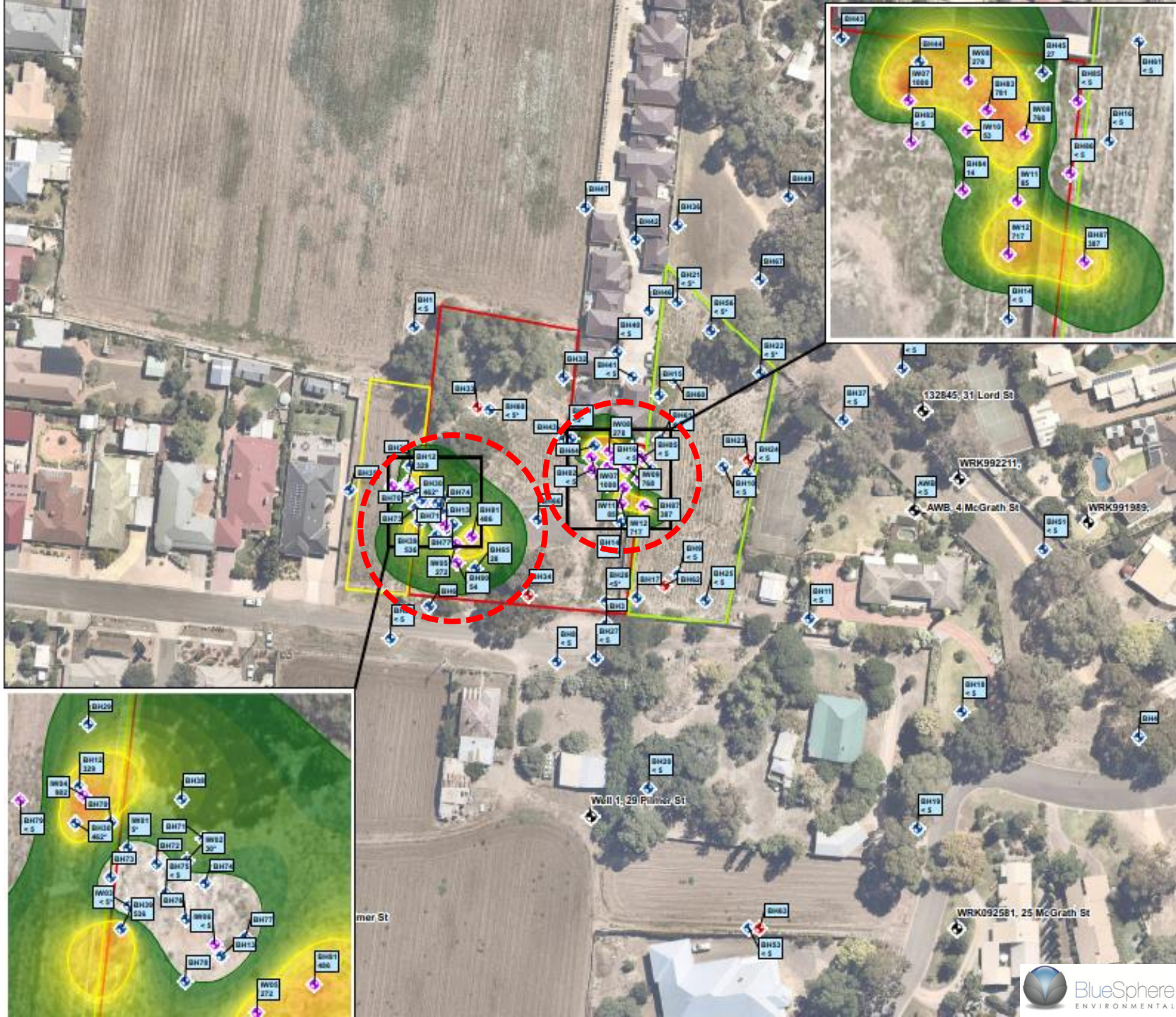
Soil and groundwater impacted.



Background

Two source zones: former tar/liquor disposal wells. Plan shows dissolved naphthalene as an indicator of NAPL.

- Legend**
- DTF Parcel Boundaries**
- Site - 28 Pilmer Street (Former Bacchus Marsh Gasworks)
 - 28 Pilmer Street (Former Provenzano Property (DTF))
 - DTF McGrath Street
- Well Types**
- Newly Installed Well
 - Shallow Aquifer Well
 - Deep Aquifer Well
 - Private Well
- Naphthalene Concentration (µg/L)**
- 10
 - 100
 - 1000



Objective

Issues:

- Non-aqueous phase liquid (NAPL) presence
- Dissolved chemicals of concern: naphthalene, benzene, ammonia, cyanide (free), sulfate

Site objective:

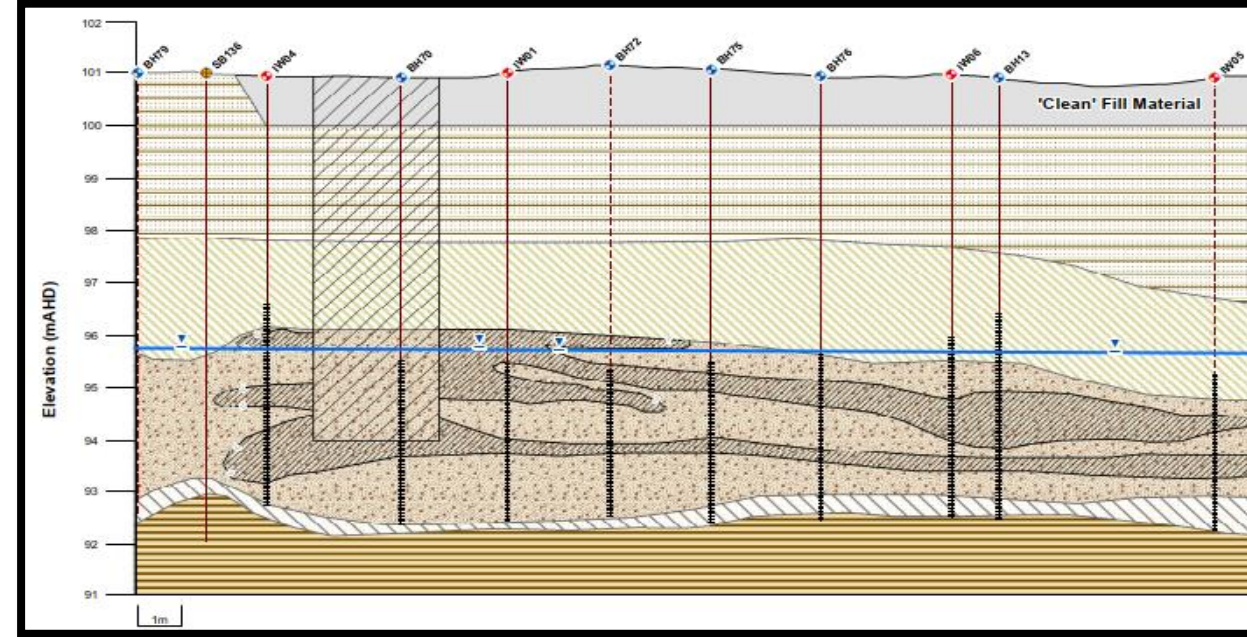
- Remove/reduce contamination liability
- Limit impacts to adjoining sensitive receptors including residences
- Divestment of surplus land (*for future redevelopment*)

Remediation Objective:

- Reduce source zone contaminant mass, so far as reasonably practicable.

NAPL Conceptual Model:

- Over 100 wells installed, half in the source zones.
- Alluvial aquifer 16 to 28 feet BGL (5 to 8.5 m BGL);
- Clayey lignite lower confining unit (Werribee Fm);
- Distributed NAPL beneath tar wells, minor LNAPL



**They Understood
Their Patient!**

Methodology

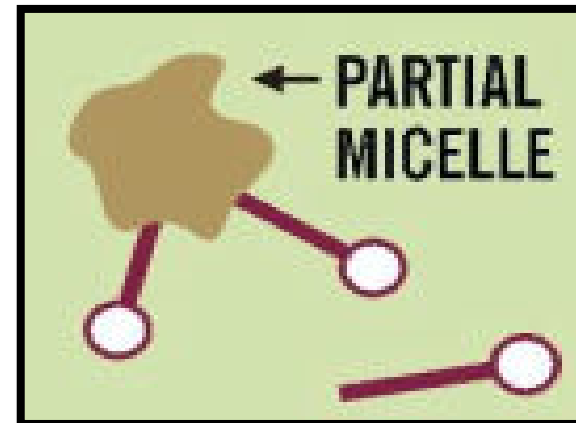
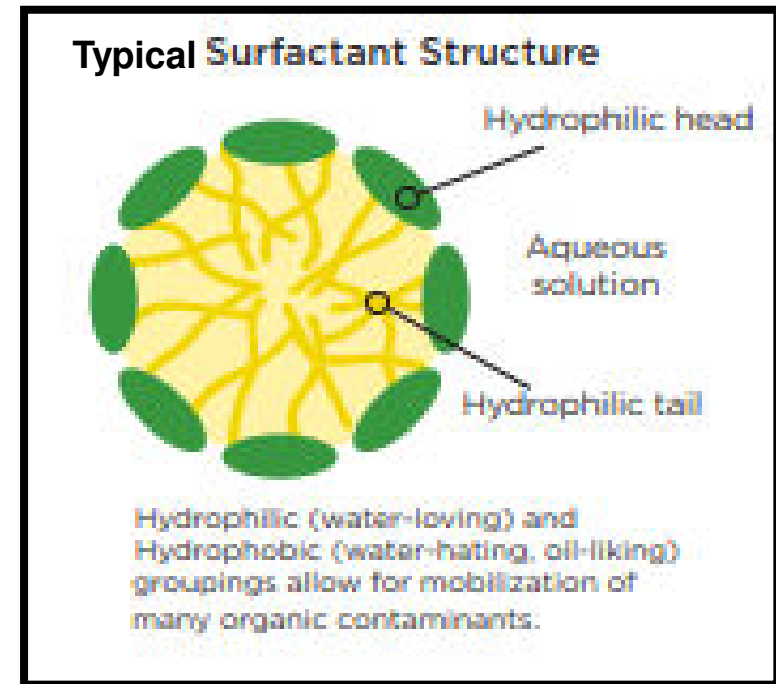
Process:

ROA → Trials → RAP → Approvals

Surfactant Enhanced Aquifer Remediation (SEAR)

We used a non-ionic, selective surfactant (Ivey-sol) engineered for use with long-chain hydrocarbons to lower the surface tension (not to emulsify).

- Sub-critical micelle application
- Applied through injection and recirculation
- NAPL continuously removed from recirculated water
- Last stage is to extract surfactant and treat
 - 1) re-injection (limited by cyanide concentrations)
 - 2) trade waste (primary method of disposal)
 - 3) Off-site transport



Ivey-sol only needs to form a partial micelle. So lower dosage and greater SEAR economics.

Ivey-sol does not need to emulsify contaminants. As selective below the CMC = greater precision and accuracy for in-situ SEAR applications.

Methodology

SEAR (Ivey-sol) - MPE system



Results

What we observed:

Very rapid NAPL coalescence (~15min); and

NAPL mobilisation for enhanced recovery (both LNAPL & DNAPL)

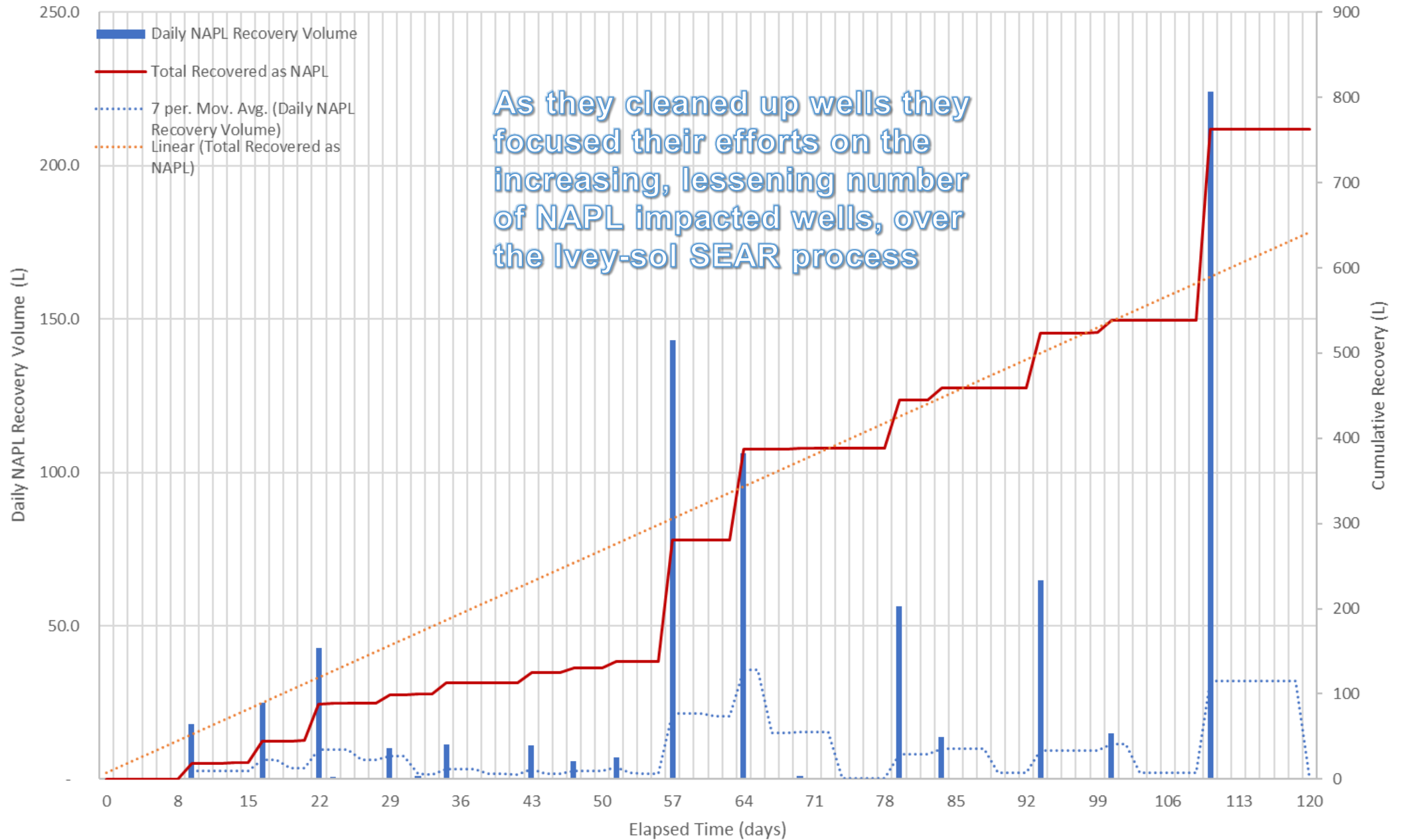


Both visual and quantitative NAPL recovery over Ivey-sol® SEAR four (4) month application.

Realizing Effective NAPL mass removal.

Results

Coal Tar NAPL Recovery





Conclusions

- **SEAR (Ivey-sol)** with groundwater extraction can be a viable remediation method for tar NAPL in aquifers that have:
 - Limited human and environmental receptors
 - Unconsolidated sediments
 - Sufficient effective permeability for NAPL entry,
 - And sufficient, interconnected permeability for NAPL extraction.
- **Sustainability**
 - Economic: <cost than other possible methods (e.g. co-solvent, thermal, stabilisation, etc.)
 - Social: low noise, no odour, reduced street traffic
 - Environmental: Biodegradable Ivey-sol
 - Ivey-sol surfactant, reduced wastewater generation, reduced filter media requirements
- **Audit CUTEP completion by late 2020.**
 - With land returned to normal use.
 - Site Closure Has Since Been Achieved
- ***Remediation system turn off planned for late January 2020.***



BlueSphere
ENVIRONMENTAL

Monarch Butterfly-Endangered Species

Monarchs are threatened by deforestation of wintering forests in Mexico, disruptions to their migration caused by climate change, and the loss of native plants (*including milkweed species but also all nectar-producing native plants*) along their migratory corridors.



Available At Our Booth Near Registration Desk
Seed Packs Mixture Differs For EASTERN and WESTERN Regions

CONTACT INFORMATION

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Web: www.iveyinternational.com



Steps To Using Ivey-sol At Petroleum, Chlorinated, and PFAS Remediation Sites

Step #1 (Evaluation)



Ivey-sol® Surfactant Technology
"TODAY'S ENVIRONMENTAL SOLUTIONS FOR A BETTER TOMORROW"®
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Tel: 1-800-246-2744
Fax: 1-888-640-3622
Email: budivey@iveyinternational.com

General Site Information Form

Client Information

Date: _____ Ivey Contact: _____
 Company name: _____ Contact Person: _____
 Email: _____ Phone: _____
 Fax: _____ Cellular: _____
 Street address: _____
 Shipping address: _____

Project Information:

Project Name: _____
 Project Location: _____
 Project Number: _____
 Regulatory Agency: _____
 Land Use and Zoning (Circle): Parkland Agricultural Residential Commercial Industrial

Site Information:

Remediation Objectives: _____
 Contaminant(s) of concern (TPH, BTEX, TCE, PCB, etc.): _____
 Soil Impacted: Yes / No Groundwater Impacted: Yes / No Vapor Impacts: Yes / No
 Is NAPL Present: _____ Time Since Release: _____
 Soil Type(s): _____ Soil Porosity: _____
 Depth to Groundwater: _____ Hydraulic Conductivity (K): _____
 Hydraulic Gradient: _____ Groundwater Flow Direction: _____
 Area of Contamination: _____ Maximum Depth of Contamination: _____
 Current Remediation Activities: _____

Monitoring Well Network Information:

Number of Existing or Proposed Monitoring Wells: _____
 Number of Proposed Injection Wells: _____
 Number of Proposed Extraction Wells: _____

Please Provide the Following:

- Site location map or drawing
- Site map showing source/treatment area and isoconcentration contours (if available)
- Site map showing monitoring and injection well locations and ROI estimates
- Table summarizing well construction details and GW level history
- Pilot test results (if available)
- Geologic cross section
- Copy of laboratory analytical results or summary table of contaminants of concern
- Site photographs
- Site investigation report

Please complete this site information form and return to: budivey@iveyinternational.com
©Ivey International Inc.

Step #2 (In-situ/Ex-situ Application Model Development)



Step #3 (Ivey-sol Selection)

Contaminant of Concern (COC)	Ivey-sol® Formulation Required
BTEX, Gasoline, Jet Fuel	103
Diesel (Light-Medium Heavy), PAH	106
Chlorinated Solvents (DNAPL, API <10)	106 (CL)
Motor Oil, Lubricants, Bunker-C	108

Note: For contaminants of concern (COC) not listed above contact IVEY directly.

Step #4 (Dosage Determination)

If Sorbed or Dissolved Phase $\leq 2\%$

If LNAPL or DNAPL Phase
Apply $\leq 4\%$ Ivey-sol.

Step 5 (Proposal)

