Potential for In Situ Treatment of Cyanide in Groundwater by Iron Addition

Scott Mason

Hydrometrics, Inc

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Problem

- Iron cyanide complexes are obstinately uncooperative
- Very stable in groundwater and resists "destruction"
- Conventional pump and ex situ treatment is expensive

Typical Groundwater Remedy:

$ Pump groundwater

$ Ex situ treat in engineered treatment plant

$ Dispose treatment residuals

Typical Groundwater Remedy:

$ Very active management

$ Well proven, reliable but expensive

$ Ex. Cost $25 million to treat 200 gpm for 30 years

Potential In Situ Remedy:

- Create &/or stabilize iron cyanide minerals within aquifer
- Reduce solubility of iron cyanide complexes
- Reduce Total and WAD CN concentrations in groundwater

Potential In Situ +/-

+ May be passive or low management
+ Cost fraction of ex situ treatment

- No full scale or long term field tests, so
- Long term reliability is unproven

Case Study: Kaiser Mead, WA Groundwater Cyanide Plume

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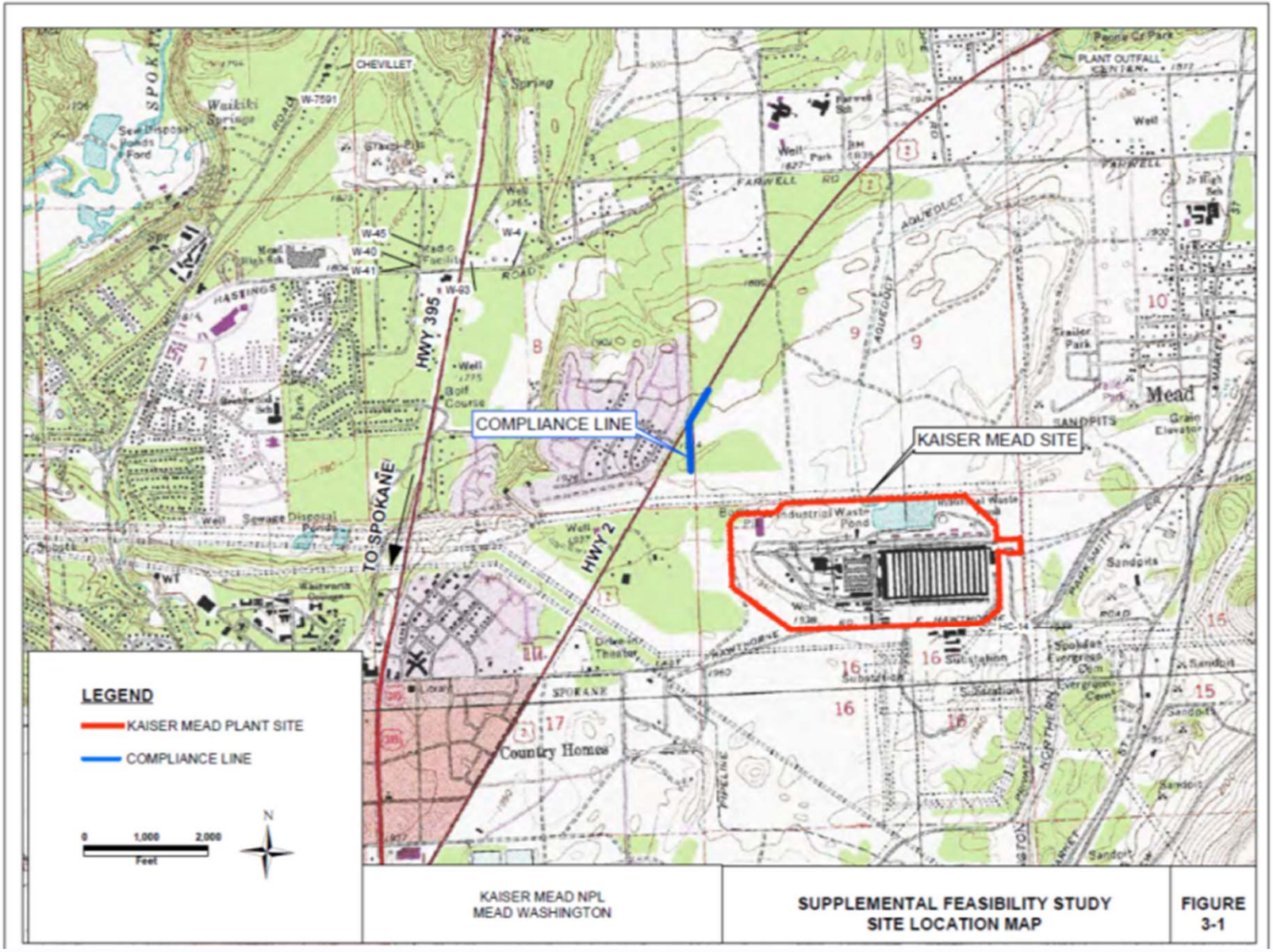

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Natural Cyanide Sources

Numerous including:

- Biological - all plants, many microbes, even few arthropods.
- Forest Fires
- Lightning
- Carbonaceous meteorite impacts

Industrial Cyanide Sources

Numerous including:

adhesives, electroplating, cement stabilizer, fire retardant, herbicides, pesticides, pharmaceuticals, &

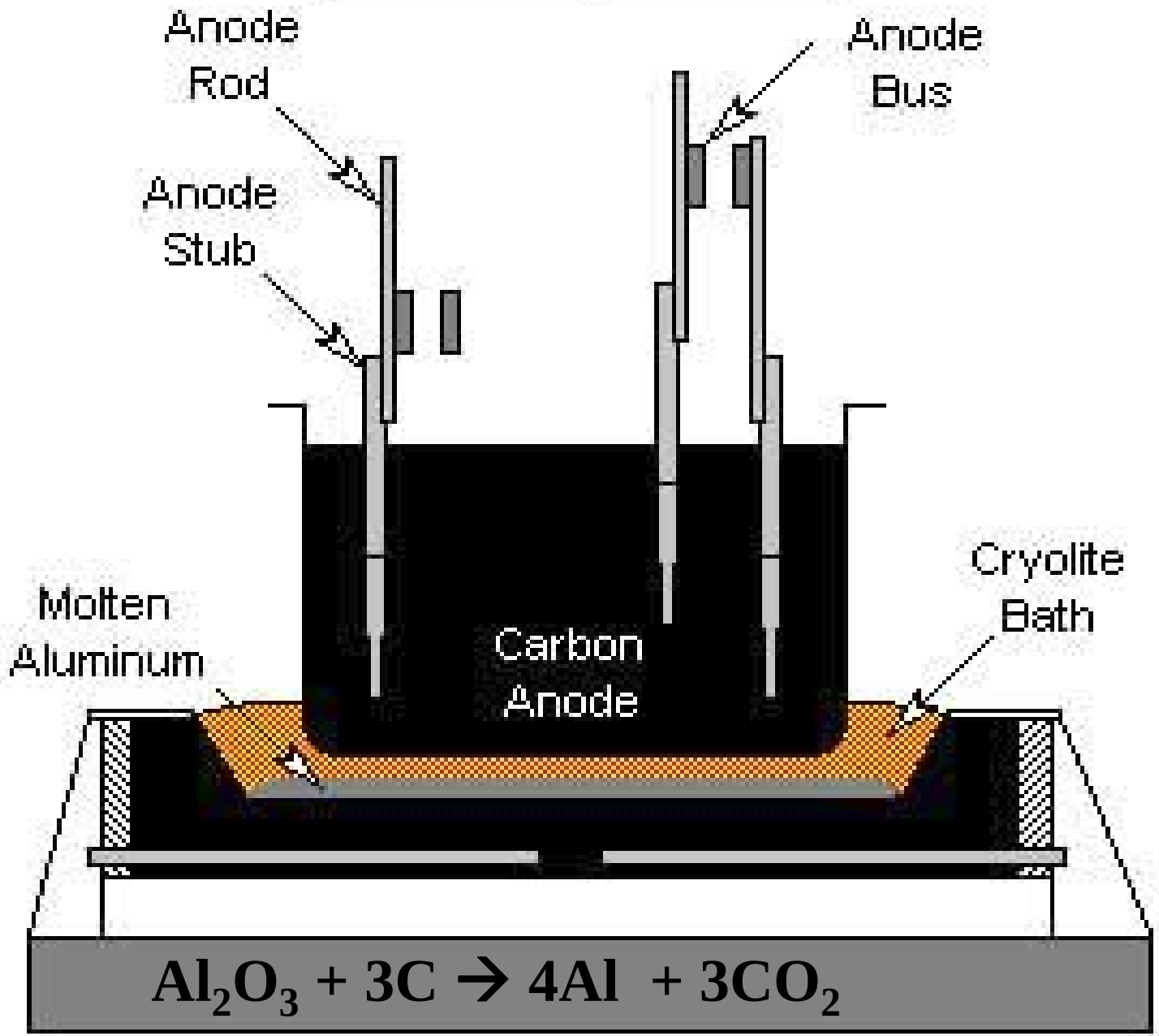
hydrometallurgy

Incidental Cyanide Sources

Numerous as produced during thermal processing of carbonaceous materials:

- Coking and coal gasification,
- Municipal waste sludge incineration
- **Alumina reduction**

Soderberg Method



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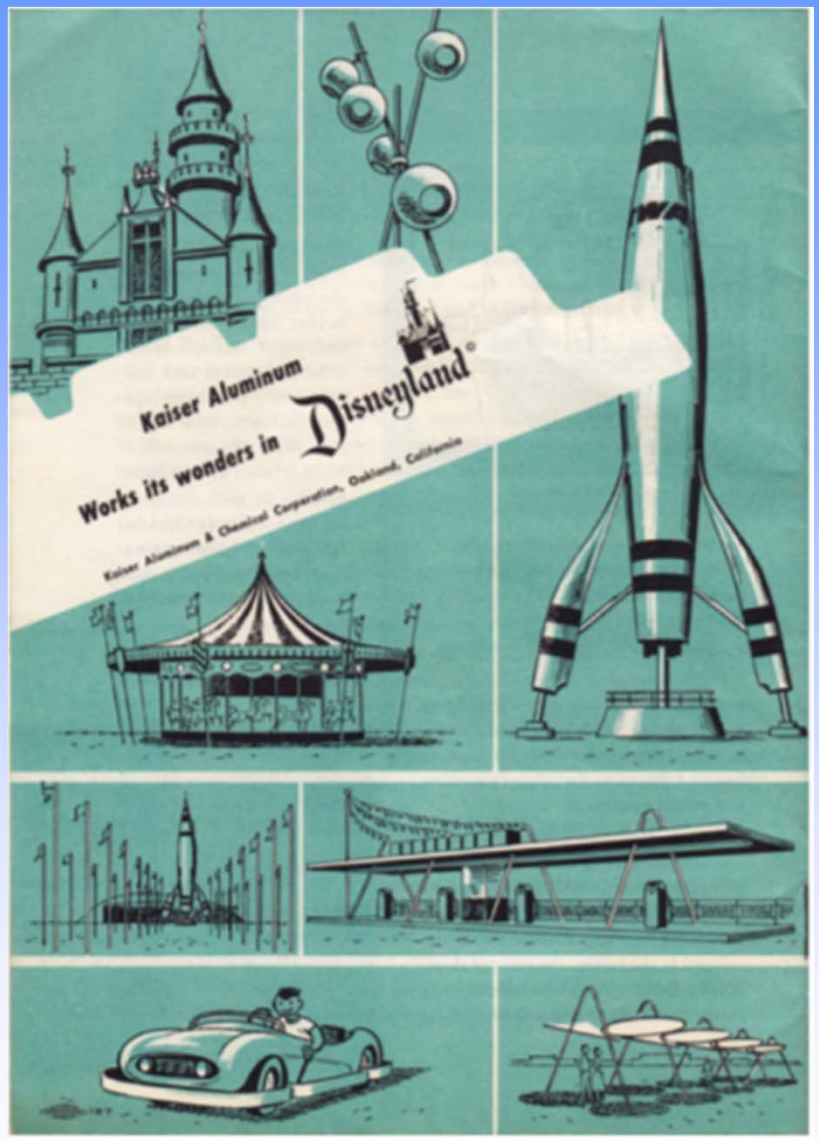
SPL Leachate Characteristics

Alkaline	pH 9 to 12
Fluoride	1,000 to 8,000 mg/L
Total Cyanide	200 to 4,000 mg/L
Ferricyanide	200 to 4,000 mg/L
WAD and Free CN	0 to 20 mg/L

Kaiser Mead Operational Timeline:

1942

Alumina reduction facility built by ALCOA for US government - High quality Al used to build airplanes



Operational Timeline:

1946 ALCOA forced by US to divest due to fear of Al monopoly

1946 – 2000 Operated by Kaiser

2004 Kaiser bankruptcy & Consent Decree to resolve CERCLA liability

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Asset Sales | Sale Details – 2-Day Onsite & Webcast Auction - Formerly 1.6MM SqFt Kaiser Aluminum Facility

Details | Preview/Removal | Contacts | Documents | Terms & Conditions

Former Kaiser Aluminum Facility

Multi Million Dollar 2 Day Auction Sale. Over 3,000 Lots Equipment Across 182 Acres and in over 200 Buildings. Including a Complete Carbon Anode Plant, Machine and Metal Fabrication, Heavy Mobile Equipment, Plant Support Equipment, Millions of Dollars of Spares and MRO.

Sale Type
On Site / Webcast Auction

Sale Location
2111 E Hawthorne Road
Mead (Spokane), Washington, 99021
Map/Directions

Currency
USD

Online Bidding
Click Here

Date & Time
Wed. May 2nd. & Thurs May 3rd.
Start Time 9am (PST)

Inspection / Preview
Tuesday May 1st (9am-4pm) Or by Appointment
Contact: tracym@newmillcapital.com

Buyer's Premium
15% Onsite and 18% Online Buyer's Will Apply to All Sales in Addition to Applicable Local and State Sales Tax

Featured Items

- Photo Gallery
- Equipment List
- Brochure
- Lot Catalog
- Help

Related Sales

Onsite & Webcast Auction - Imperial Valley Cheese
Wednesday | May 7, 2014
El Centro, CA - Imperial Valley Cheese Swiss & Muenster Production & Packaging Facili... Details...

Real Estate Available - Imperial Valley Cheese
El Centro, CA - Real Estate For Sale - 30,000 SqFt Dairy Products Manufacturing Plant... Details...

Webcast Auction - Assest No Longer Required by Gossner

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Remediation Timeline:

1978 - CN and F found in drinking water wells

1983 - Placed on CERCLA NPL list

1983 – 2000 Interim remedial actions

2000 – Final Cleanup Action Plan Selected

Remediation Timeline

2002 Corrective Actions implemented –
(source control only)

2012 Performance Evaluation concludes groundwater cleanup standards not met

2014 Draft Supplemental Feasibility Study

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Aqueous Forms of Cyanide

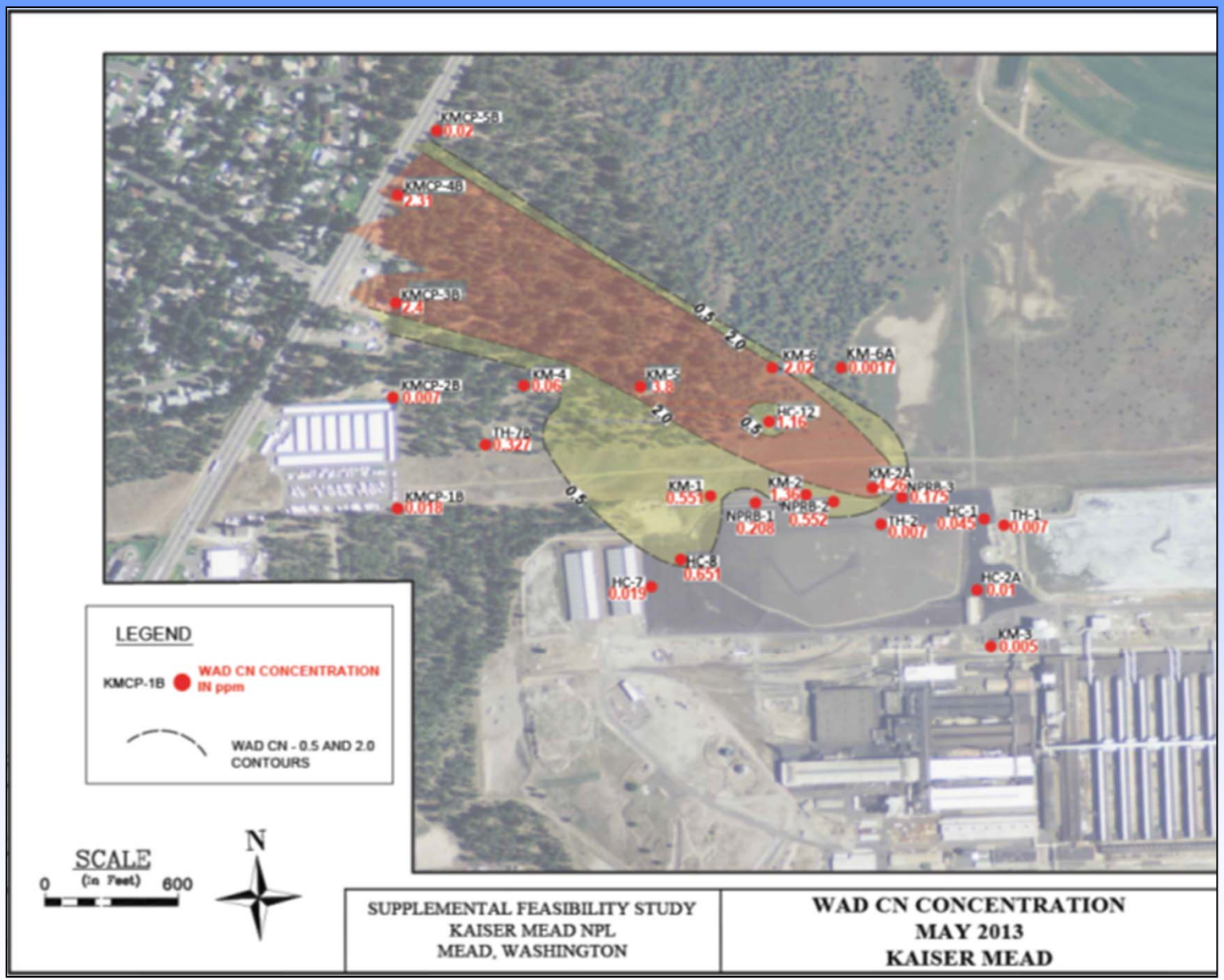
"Free Cyanide"

$$HCN_{gas} \leftrightarrow CN_{aq}^{-} + H^{+} \qquad pK_a = 9.24$$

WAD Cyanide Analytical Form

- "weak acid dissociable" = HCN gas released by weak acid digestion (pH 4.5 to 6)

- WAD = free CN + weak metal complexes (e.g. Ag, Cd, Cu, Zn)



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Total Cyanide Analytical Form

= HCN released by strong acid digestion
(pH < 2)

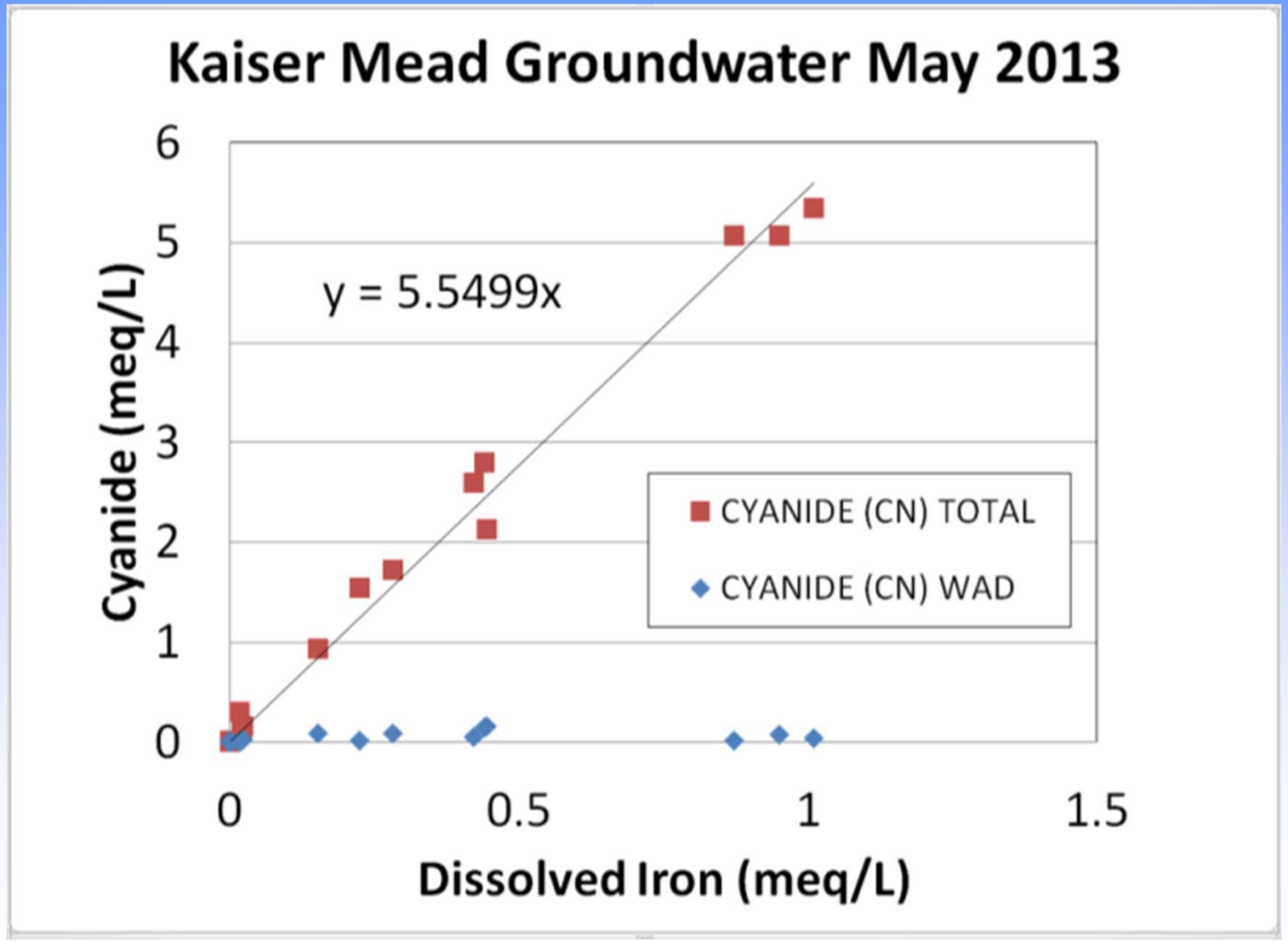
= WAD CN + strong CN complexes

Strong Cyanide Complexes

- Notably Iron and mixed Fe-metal-CN

  (ex. $Fe(CN)_6^{4-}$; $KFe(CN)_6^{3-}$)

- But also Co, Pt, Au, Pd



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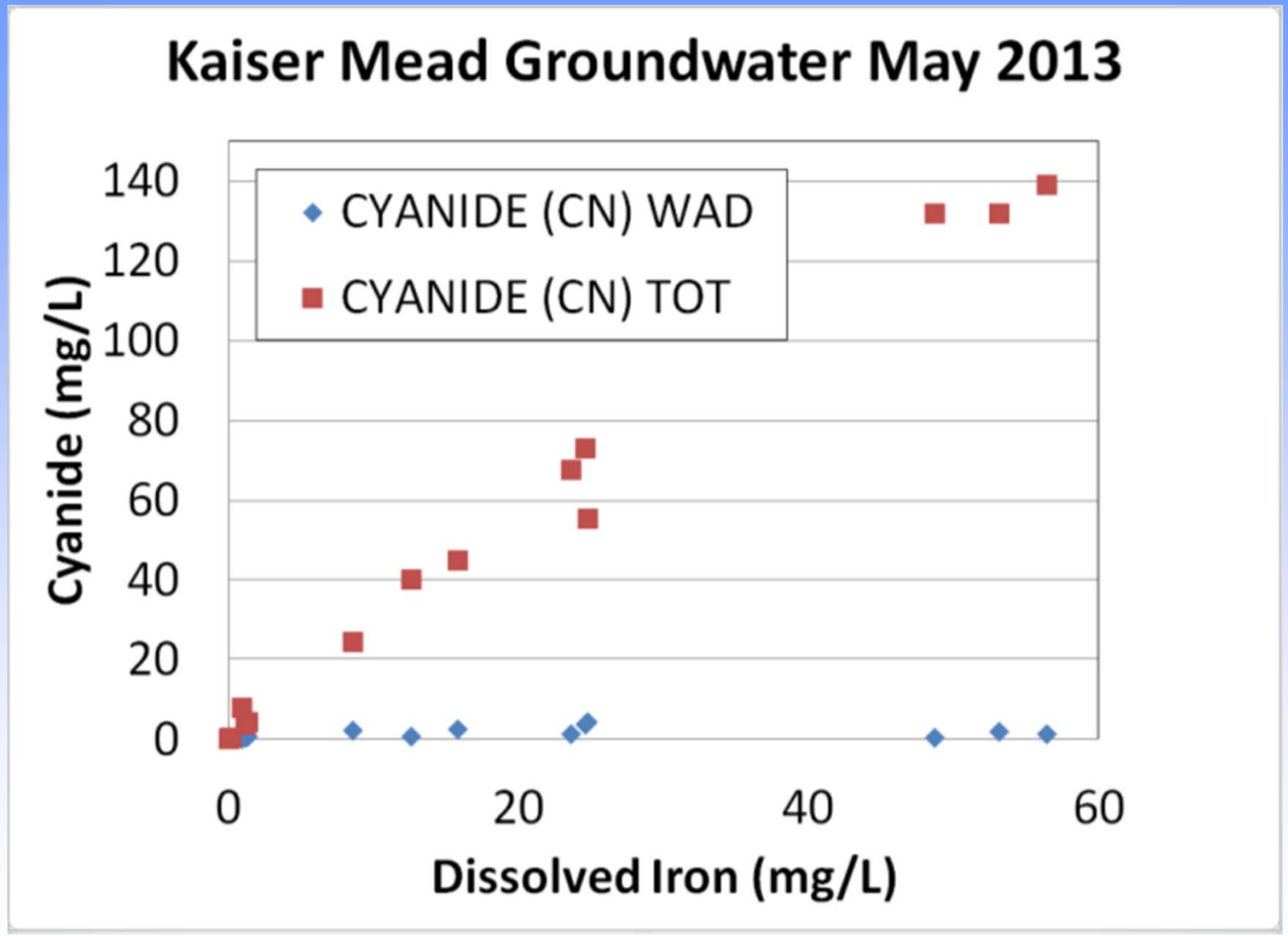

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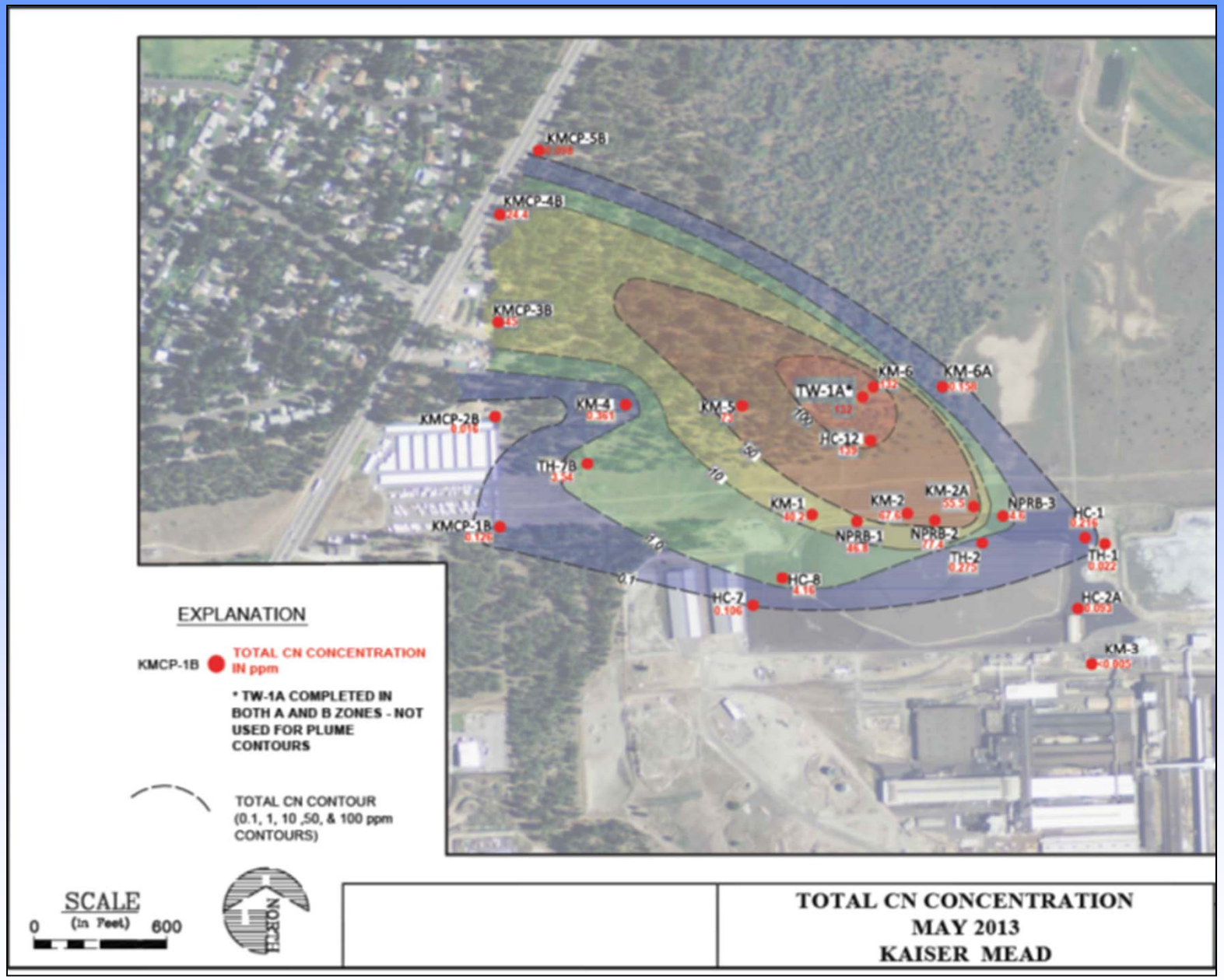

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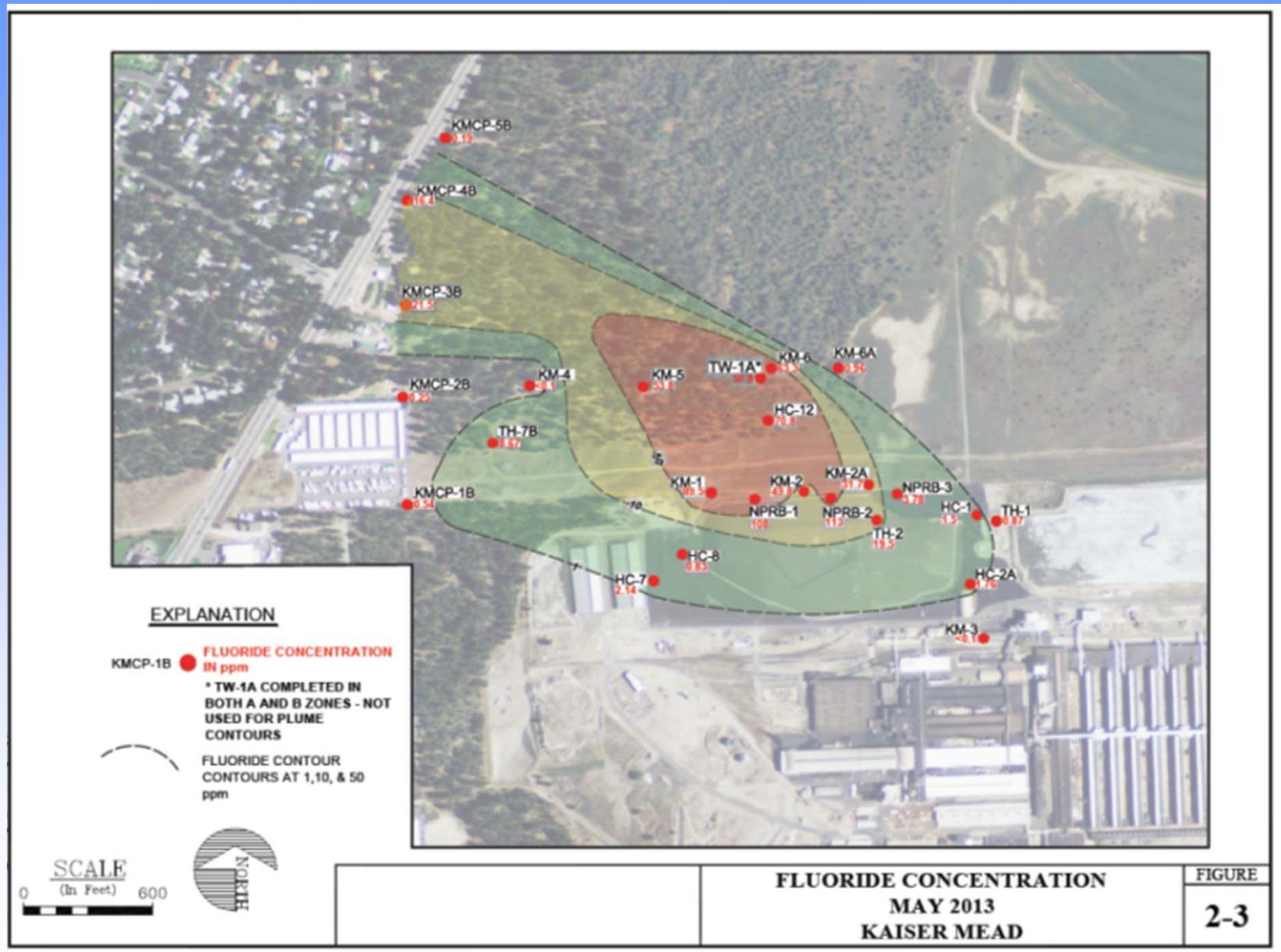

FLUORIDE CONCENTRATION
MAY 2013
KAISER MEAD

FIGURE
2-3

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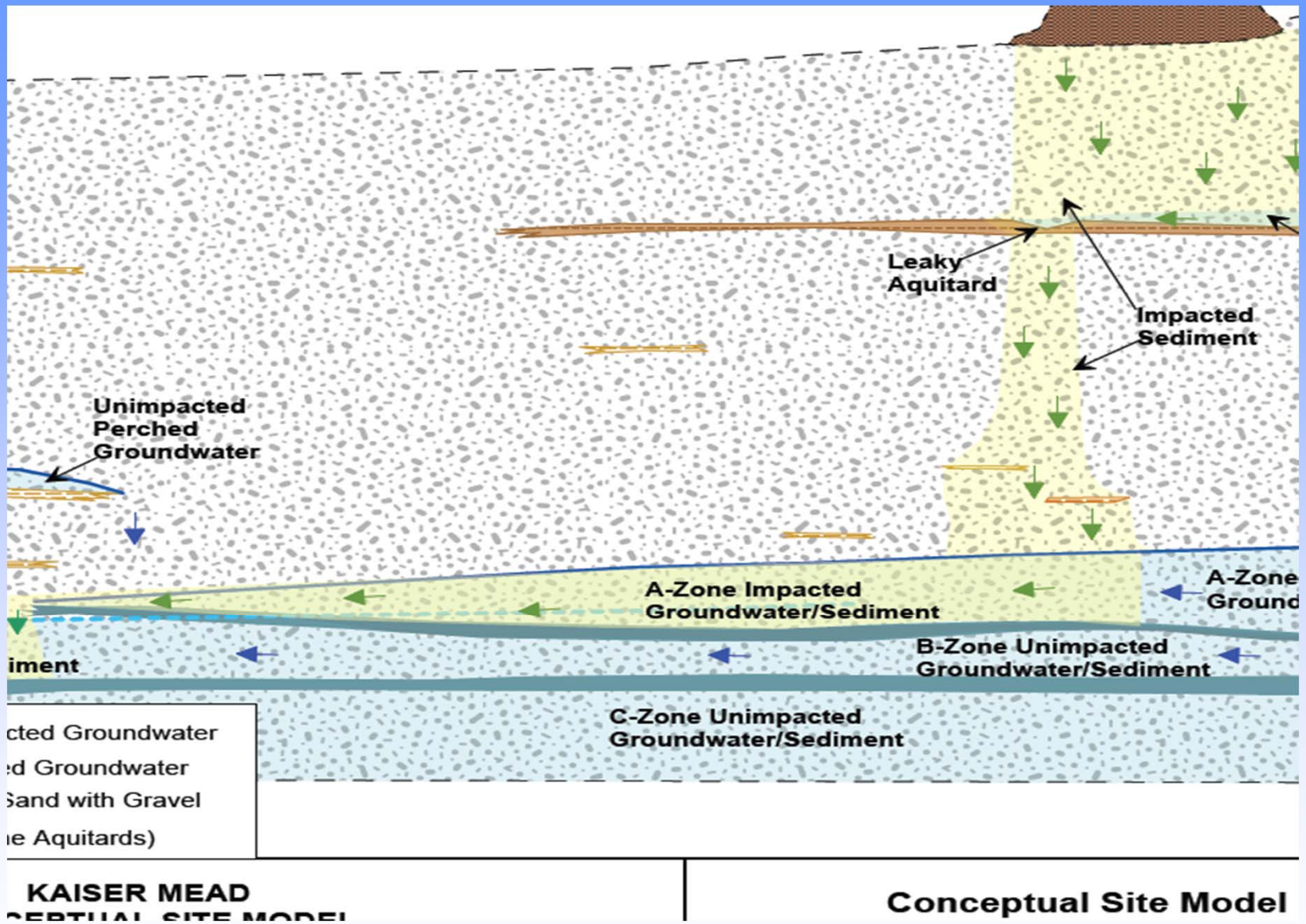

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Interest In In Situ:

- Desire for lower cost option than P&T
- Evidence of secondary source of F & CN in vadose zone &/or aquifer suggest conditions may be right to further stabilize CN & F minerals within aquifer

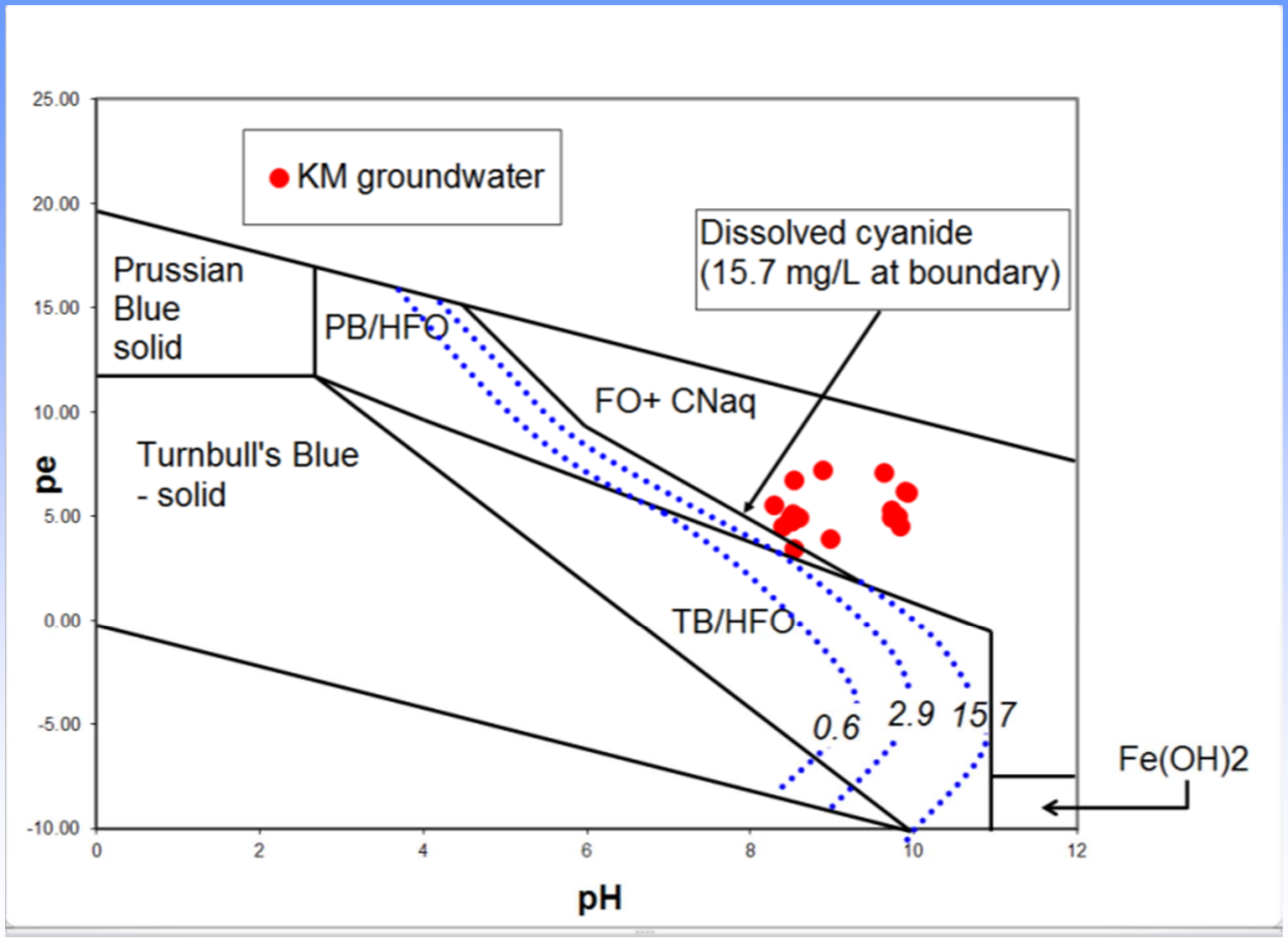
	CONDITIONS	RESULTS
Ghosh et al (1999)	Batch and column testing of PRB with ZVI	60 to 80 percent total cyanide removal
Wildeman et al (2006)	Testing of SRBRs with ZVI	ZVI alone did not remove CN but promoted biological removal
Peale et al (2008)	Bench and pilot-scale testing of PRB with carbon source and ZVI.	WAD CN reduced from 1 to 0.01 mg/L.

In Situ Concept

- Create &/or stabilize iron cyanide minerals within aquifer
- Reduce solubility of iron cyanide complexes
- Reduce Total, WAD and Free CN concentrations in groundwater

Iron Cyanide Minerals

- Prussian Blue : $Fe_4(Fe(CN)_6)_3$
  - Acidic oxidizing conditions
- Turnbull's Blue: $Fe_3(Fe(CN)_6)_2$
  - Neutral to alkaline reducing conditions
- Solid Solutions
  - Turnbull's Blue\Ferric Hydroxide ($Fe(OH)_3$)
  - Prussian Blue\Ferric Hydroxide



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Proof of Concept Testing

Two Reagents

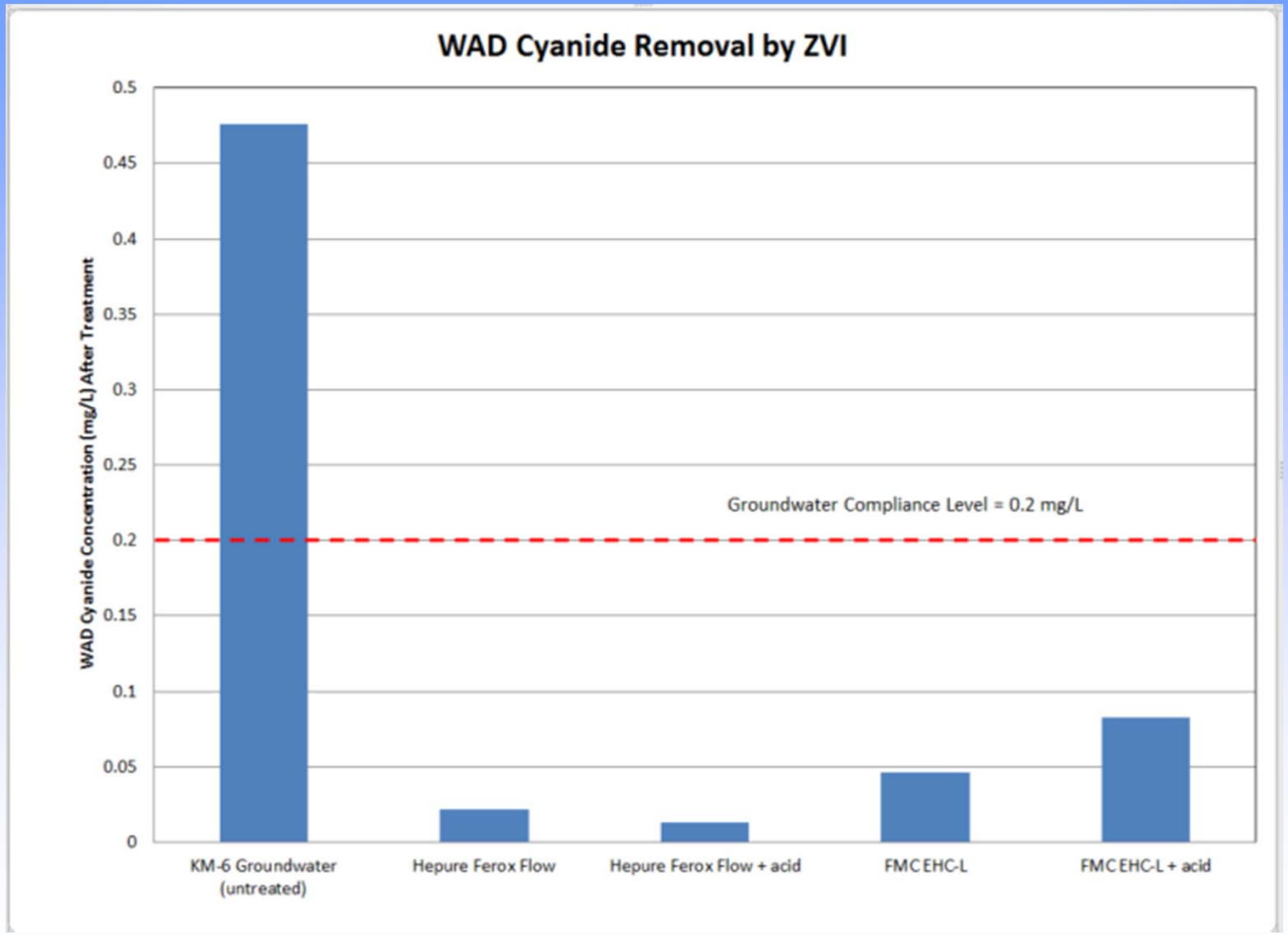
Hepure Technologies:

- Ferox™ Flow brand ZVI

FMC Environmental Solutions:

- EHC-L emulsified ZVI with carbon and nutrients

Results



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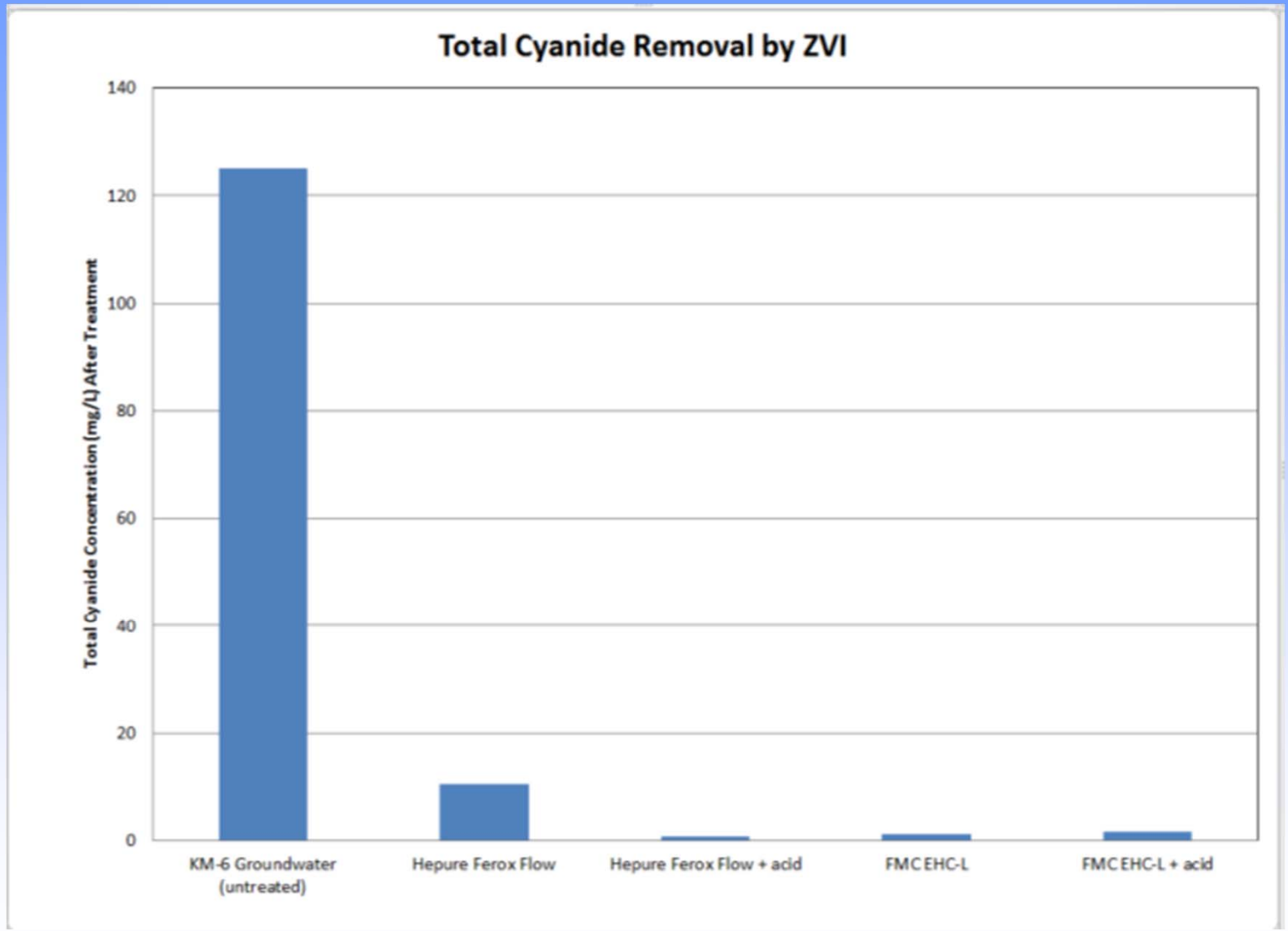
Results



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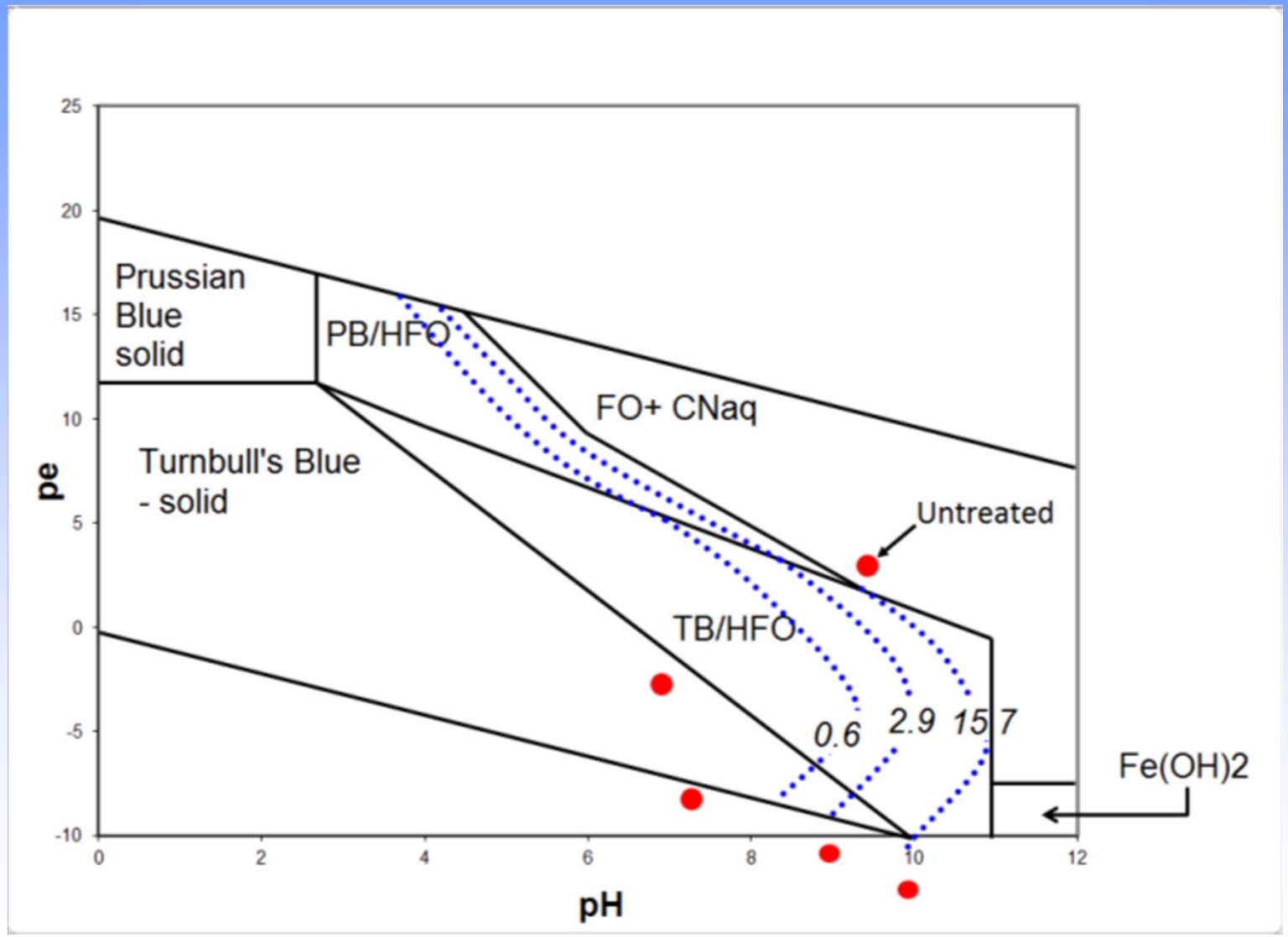
Results



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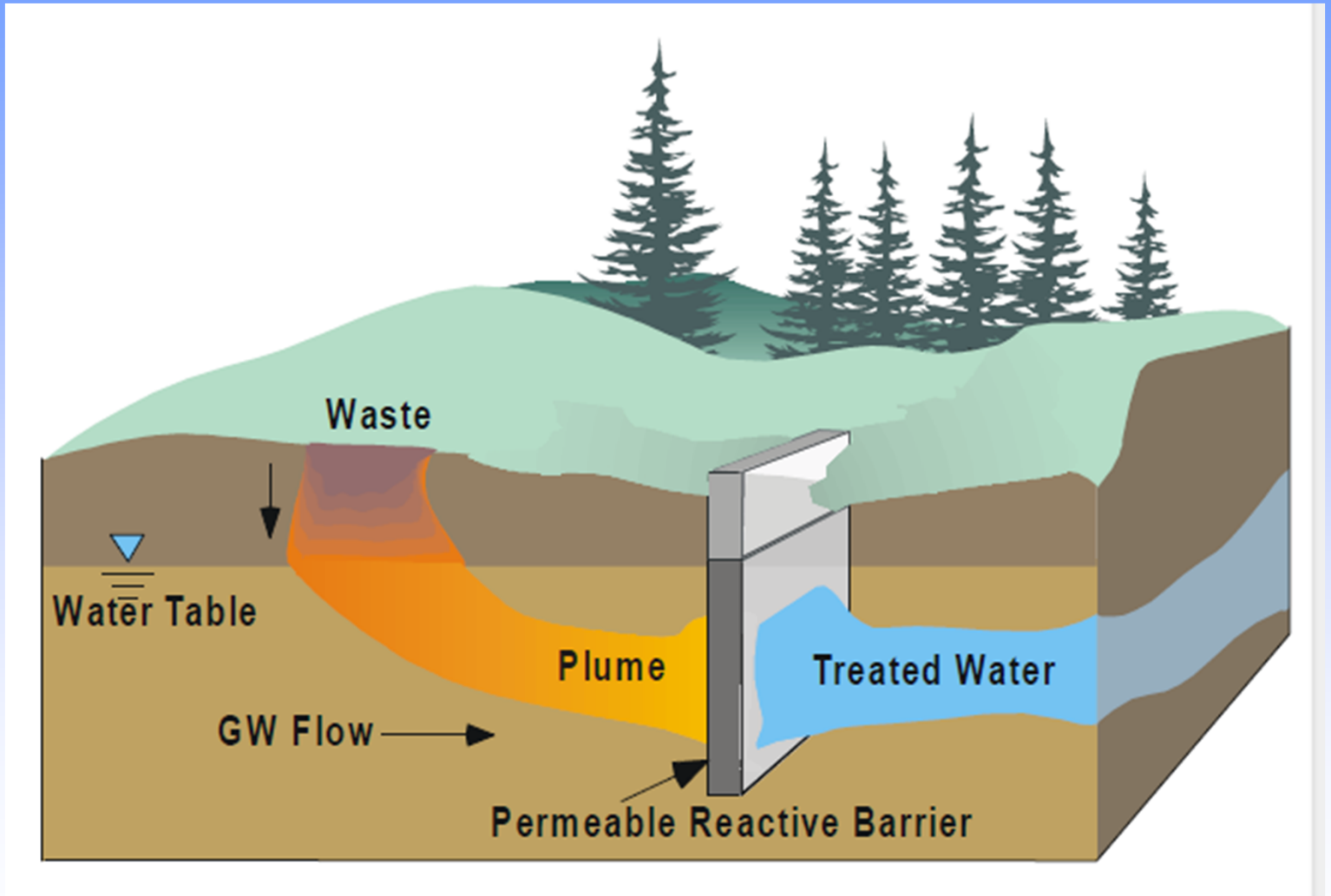
Implementation



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Installation - Excavation

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Installation - Trenching

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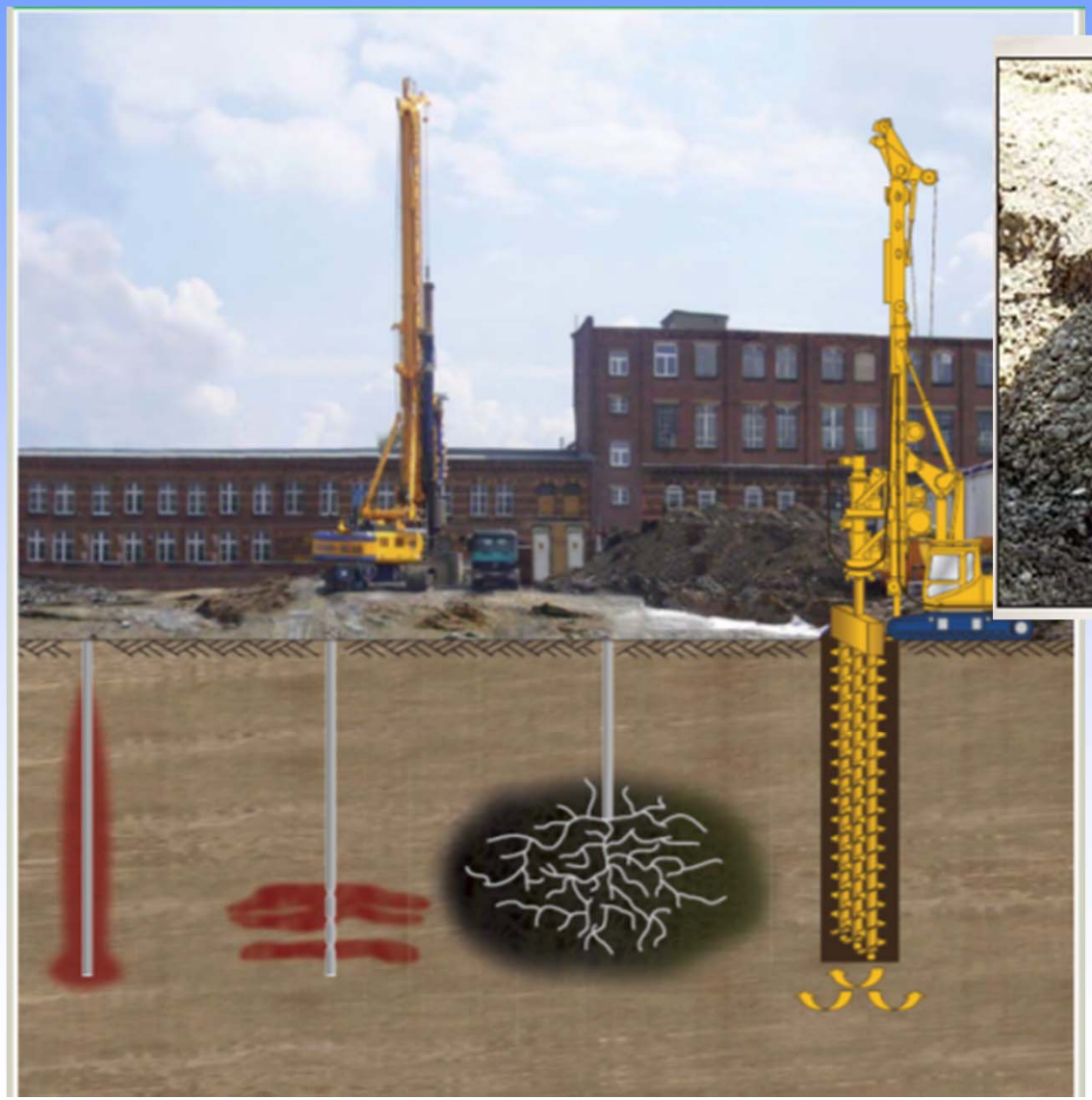
Installation – Auger Mixing



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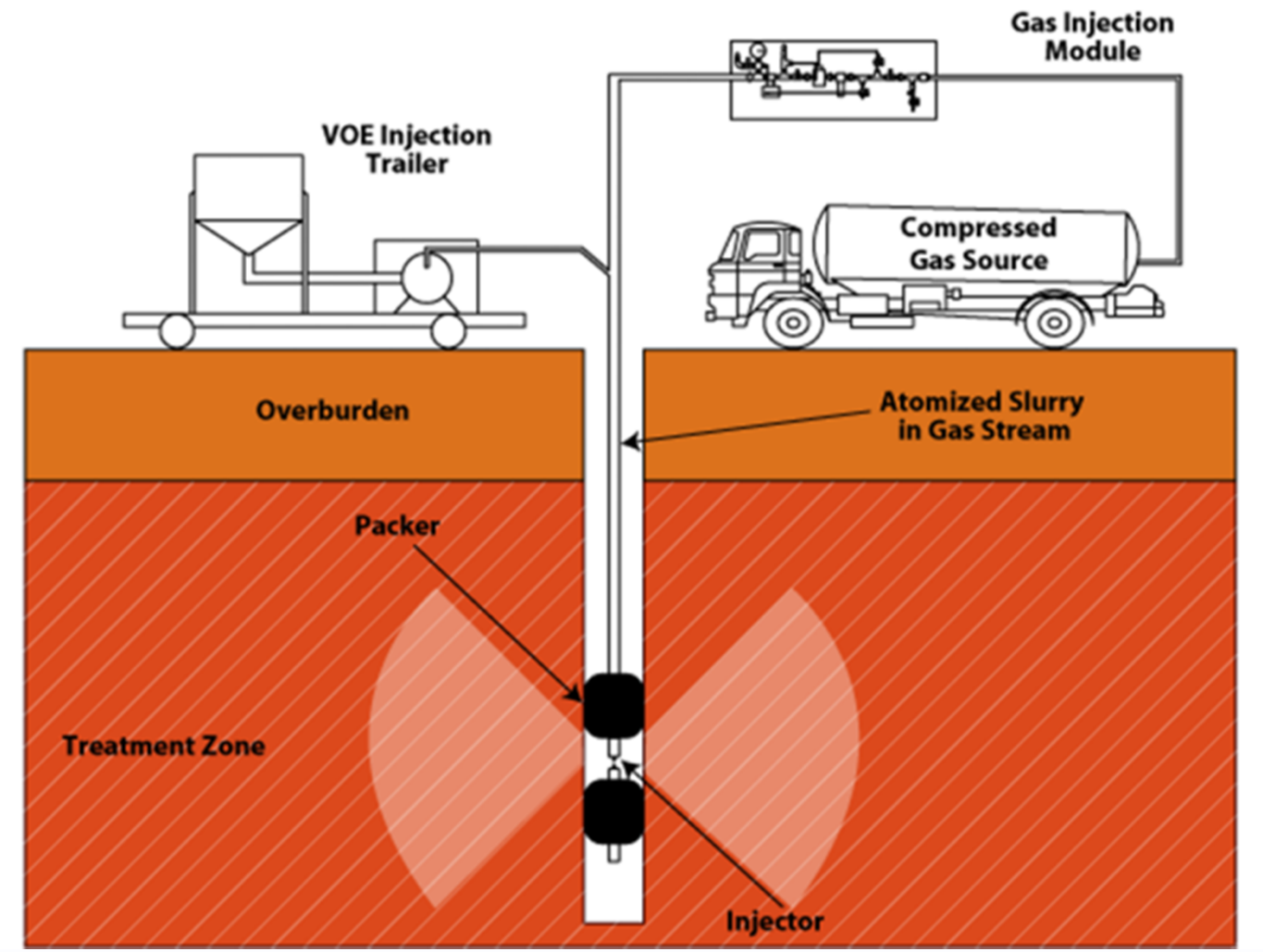
Hydraulic Fracturing



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Status of In Situ Treatment at Kaiser Mead:

- Concept is proven
- Rough cost approx. 20% of ex situ
- Uncertainties

Uncertainties

- No operating full scale systems
- Difficulty/cost of installation
- Hard to reverse/decommission once installed

Uncertainties

- Long term reliability and effectiveness:
  - Aquifer plugging
  - Reagent consumption
  - Noxious byproducts
  - Stability of cyanide minerals

Potential Best Fit for Sites:

- Total cyanide/iron cyanide complexes are particular concern
- Secondary CN source in subsurface
- Shallow aquifer

Potential Best Fit for Sites:

- Desire passive or semi-passive
- Desire minimal surface facilities
- Non-destruction of CN is OK

END