



AI vs. Environmental Experts: Are Humans Becoming Obsolete in Remediation Design?

September 25, 2024

Science Advisory Board for Contaminated Sites in BC

Kevin French, B.A.Sc., P.Eng

VEI Contracting Inc.

Presentation Overview

- VEI Contracting
- Practical Uses of AI Today
- AI-Assisted Remediation Design
- AI-Assisted Remediation Design – Redux
- Lessons Learned
- Questions



Credit: CBC



VEI Contracting



VEI Contracting Inc.

VEI Contracting Inc.

- (Formerly Vertex Environmental Inc.)
- Founded in 2003 (remedial injections)
- Specialized Environmental Remediation Contracting
- High Resolution Site Characterization (HRSC) and Remedial Design Characterization (RDC)



Kevin French, P.Eng

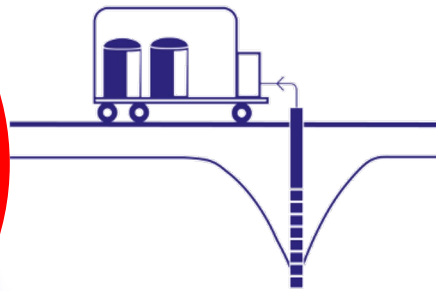
- Vice President, VEI Contracting Inc.
- B.A.Sc., Civil/Env. Eng., U. Waterloo
- Environmental engineering
 - Consulting starting 1988
 - Remediation contracting since 2012



VEI Contracting Inc.



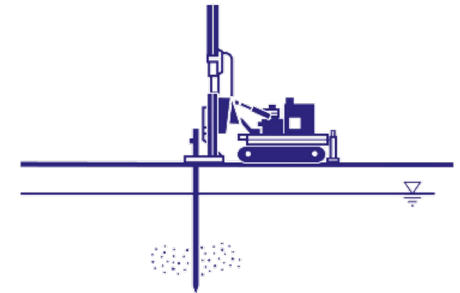
In-Situ Remediation



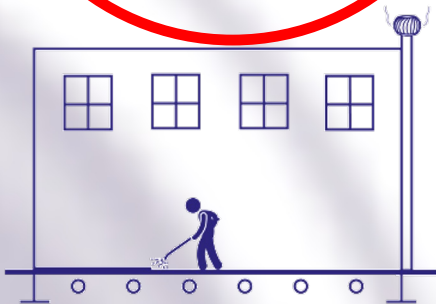
WTS & Dewatering



Ex-Situ Remediation



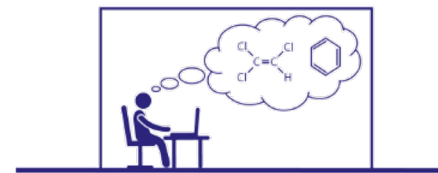
HRSC & RDC



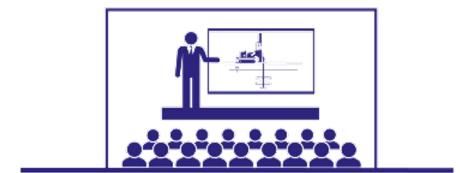
Vapour Intrusion



Bench-Scale Testing

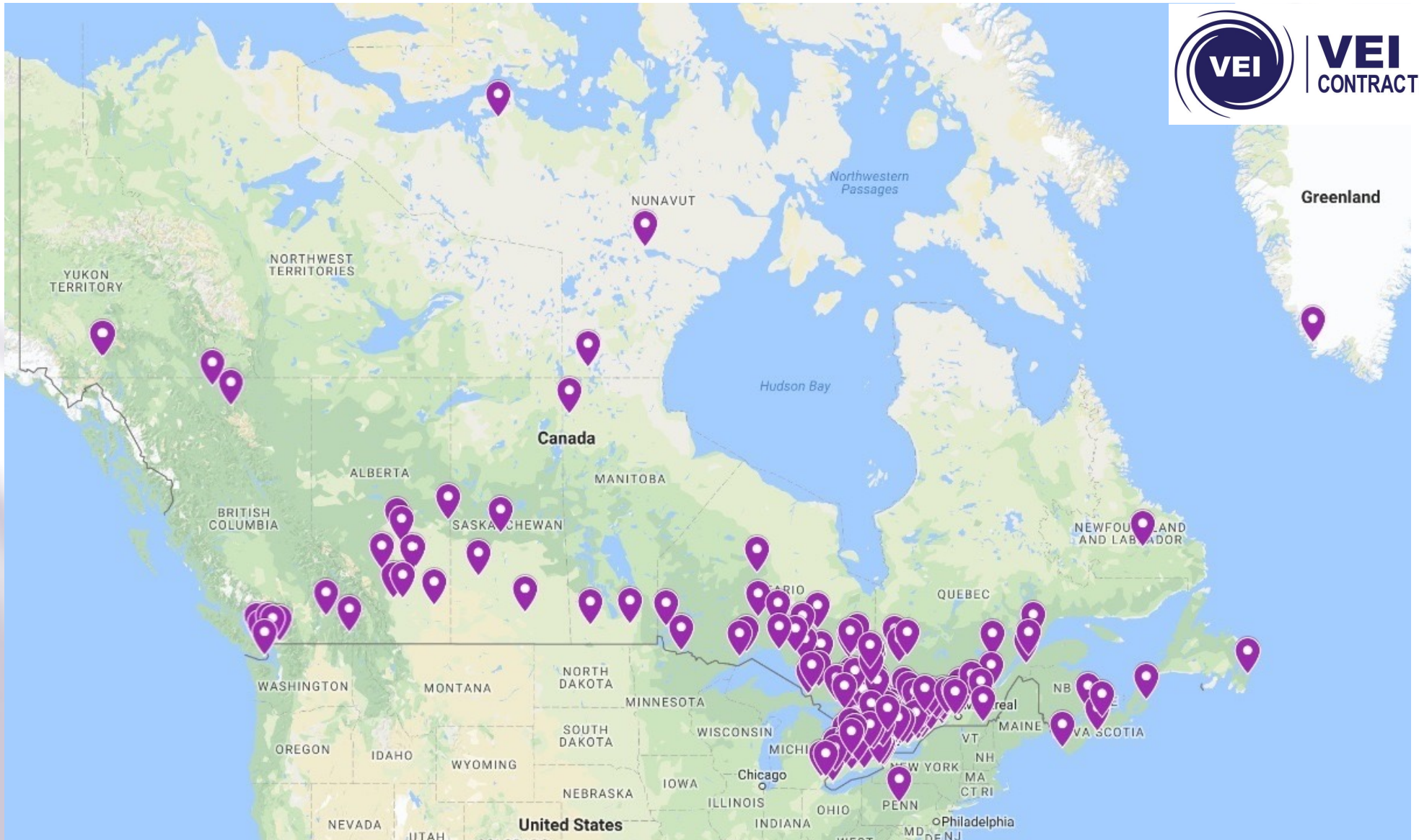


Remedial Design



Outreach

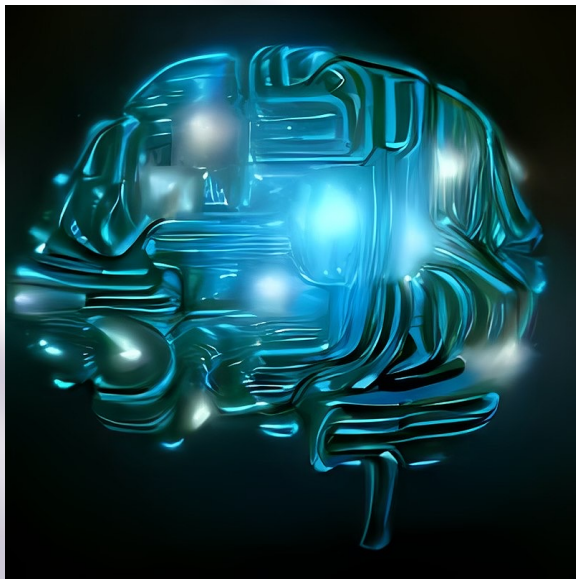




Practical Uses of AI Today



Practical Uses of AI Today



© JPxG and Boris Dayma

Good:

- Digital assistants (Google, Siri, Alexa, Co-Pilot)
- Search engines
- Real time traffic directions
- Banking fraud detection
- Self-driving cars
- “You may also like...” (Amazon, Netflix)
- Chatbots
- Facial recognition
- Facebook news feeds
- ChatGPT?

Evil:

- Phishing emails
- Deepfake videos
- Plagiarism
- Automation-spurred job losses (even ours?)
- Weapons automatization
- Self-aware AI (Agent Smith, the Terminator)
- Chatbots
- Facial recognition
- Facebook news feeds
- ChatGPT?



Emergence of ChatGPT

Origin:

- Chat Generative Pre-trained Transformer
- Large, language model-based chatbot developed by OpenAI and launched Nov. 30, 2022
- Enables users to refine and steer a conversation towards a desired length, format, style, level of detail, and language
- Successive prompts and replies, known as prompt engineering, are considered at each conversation stage as context

What it is useful for right now:

- Writing report content, essays, resumes,
- Writing / debugging source code
- General learning: explaining concepts, solving math problems
- Writing poetry, songs, jokes, love letters...
- Creating custom graphics
- Write environmental conference abstracts?



Emergence of ChatGPT

KE

I would like to write an abstract for an environmental conference. The topic would be on the use of AI like yourself to help design remediation programs. Specifically permeable reactive barriers to treat chlorinated solvents or petroleum hydrocarbons. The abstract will pose the question as to whether human environmental professionals are becoming redundant for this activity. I would like to pose the question as to whether human professionals are now only needed to pose the problem and provide the data inputs or whether they still need to do a reality check on the AI-generated remedial design. I would like the title to be catchy and kind of hyperbolic.



AI vs. Environmental Experts: Are Humans Becoming Obsolete in Remediation Design?

As the environmental remediation landscape evolves, the integration of Artificial Intelligence (AI) has emerged as a transformative force in designing effective solutions. This abstract challenges the traditional role of human environmental professionals by exploring the potential of AI, such as ChatGPT, in shaping and executing remediation programs...





AI vs. Environmental Experts: Are Humans Becoming Obsolete in Remediation Design?

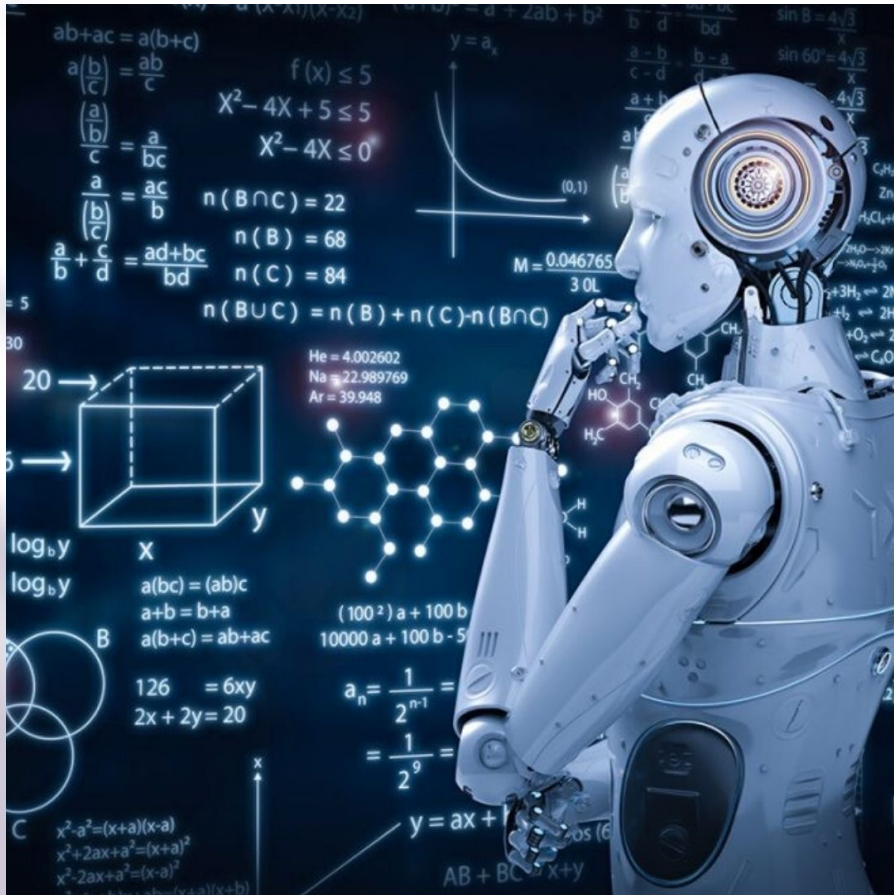
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Emergence of ChatGPT



- Currently no publicly-available environmental science and engineering design AI
- Some applications mainly designed for monitoring and detection, data analysis and predictive modeling
- ChatGPT is readily available and broadly used for a wide variety of applications
- **If ChatGPT can do a wide range of things that people traditionally do, can it tackle other tasks like environmental remediation design?**

AI-Assisted Remediation Design



AI-Assisted Remediation Design

KE

Can you help me to design an in-situ environmental remediation workplan if I input relevant site details, such as contaminant type, concentration, soil type, etc.?



Yes, I can provide you with **some guidance** on designing an in-situ environmental remediation workplan based on the information you provide about the site. Here are some steps that you can follow:

- **Step 1: Identify the contaminant type and concentration.**
- **Step 2: Determine the soil type and characteristics.**
- **Step 3: Choose a remediation technology.**
- **Step 4: Develop a remediation workplan.**
- **Step 5: Implement the workplan and monitor the site.**

I hope this provides you with some guidance on designing an in-situ environmental remediation workplan. Please keep in mind that the specific details of the workplan will depend on the site-specific factors and the remediation technology selected. **It is always recommended to consult with a qualified environmental professional before implementing any remediation work.**

AI-Assisted Remediation Design

KE

Can you design a permeable reactive barrier for a site?



Yes, I can help you design a permeable reactive barrier (PRB) for your site. Please provide me with the following information:

- Contaminant type and concentration: What is the contaminant that you are trying to remediate and what is the concentration of the contaminant in the groundwater?
- Soil type and characteristics: What is the soil type at the site, and what are its characteristics such as porosity, hydraulic conductivity, and organic matter content?
- Hydrogeology: What is the groundwater flow direction, depth to groundwater, and the hydraulic conductivity of the aquifer?
- Site dimensions: What are the dimensions of the site where the PRB will be installed?

Once I have this information, I can provide you with a more detailed design for the PRB.



AI-Assisted Remediation Design

“Yes, I can help you design a permeable reactive barrier (PRB) for your site.”

“Once I have this information, I can provide you with a more detailed design for the PRB.”



AI-Assisted Remediation Design

KE

- Contaminant type and concentration:
 - PCE = 5 µg/L, TCE = 22 µg/L, C12DCE = 187 µg/L and VC = 17 µg/L
- Soil type and characteristics:
 - Mixed sand and gravel fill to 2.5 m, then silty sand to sandy silt to 5.5 m, then silty clay till below 5.5 m
 - Porosity of the silty sand unit is 0.3
- Hydrogeology:
 - Depth to groundwater is 3.0 m
 - Hydraulic conductivity of the silty sand unit is 1×10^{-6} m/s
 - Hydraulic gradient is 0.01
 - Flow direction is to the south
- Site dimensions:
 - Southern property boundary is 50 m wide



AI-Assisted Remediation Design



Based on this information, a PRB consisting of a reactive material such as **zero-valent iron** can be installed perpendicular to the groundwater flow direction to intercept and treat the contaminants. The design for the PRB is as follows:

- Dimensions:
 - Length: 50 m (equal to the width of the property)
 - Depth: from the ground surface to the bottom of the silty sand layer (about 5.5 m)
 - Width: 1 m (assumed)
- Reactive material:
 - Zero-valent iron (ZVI) granules or powders
- Installation:
 - Excavate a trench 1 m wide and to the bottom of the silty sand layer
 - **Fill the trench with ZVI granules or powders**
- Maintenance:
 - Regular monitoring of the groundwater and PRB performance
 - Replacement of the ZVI if necessary



AI-Assisted Remediation Design

KE **What concentration of ZVI** should go in the trench?



Typically, the ZVI concentration used in a PRB **ranges from 5% to 20% by weight** , although higher concentrations can be used in some cases.

In your case, the contaminant concentrations are relatively low, and the hydraulic conductivity of the silty sand layer is relatively low, so a lower concentration of ZVI may be appropriate. **A concentration of 10% by weight is a common starting point for ZVI concentration in PRBs.**

It is always recommended to consult with a qualified environmental professional to design a PRB tailored to the specific site conditions and contaminant characteristics.



AI-Assisted Remediation Design

KE

Is there a method that this PRB could be installed by injection rather than trenching since there is restricted access at this site?



Yes, it is possible to install a permeable reactive barrier (PRB) by injection instead of trenching, particularly if there is restricted access to the site:

- **Direct push injection**: This method involves using a direct push drill rig to create injection points along the length of the PRB. Once the injection points are established, a slurry of the reactive material (e.g., ZVI) and a carrier fluid (e.g., water or a polymer solution) is injected under pressure into the subsurface. The carrier fluid is used to facilitate the injection of the reactive material and to distribute it uniformly in the subsurface.

KE

What type of ZVI should I use for the injection approach?



For the injection approach, **a fine-grained ZVI material** with a high surface area is typically preferred since it can be more easily injected into the subsurface and provides a larger reactive surface area for contaminant degradation.



AI-Assisted Remediation Design

KE **What mass of ZVI will I need for this injected PRB?**



Assuming a PRB thickness of 2 m, a hydraulic conductivity of 1×10^{-6} m/s, and a porosity of 0.3 for the silty sand unit, we can estimate the volume of the PRB as follows:

- Volume of PRB = width of property x PRB thickness x depth to groundwater
- **Volume of PRB = 50 m x 2 m x 3 m Volume of PRB = 300 m³**

Using a conservative estimate of ZVI reactivity, we can assume that one gram of ZVI can remove approximately 1 micromole of contaminant per minute. Therefore, the mass of ZVI needed can be estimated as follows:

- Mass of ZVI = (target contaminant mass to be removed) / (ZVI reactivity x PRB lifespan)

Assuming a PRB lifespan of 10 years, we can estimate the mass of ZVI needed as follows:

- Mass of ZVI = (target contaminant mass to be removed) / (1 gram/micromole/min x 525,600 min/year x 10 years)
- **Mass of ZVI = (5 ug/L x 300 m³ x 1000 L/m³ x 1 mg/1000 ug) / (1 ug/micromole) / (1 gram/micromole/min x 525,600 min/year x 10 years) Mass of ZVI = 0.071 kg or 71 grams**



AI-Assisted Remediation Design



“Mass of ZVI = 71 grams”

“Volume of PRB = 300m³”

This amounts to 25 sand sized particles of ZVI per L of PRB volume!



AI-Assisted Remediation Design

KE

Should I inject more ZVI mass to create a minimum distribution of ZVI in the subsurface **to ensure the contaminants in the groundwater plume come into contact with the ZVI** and are destroyed?



Yes, it may be beneficial to inject more ZVI than the estimated minimum mass to ensure that the ZVI is distributed evenly throughout the subsurface and can effectively come into contact with the contaminants in the groundwater plume.

KE

What is the mass of ZVI that I should inject at this site to ensure the recommended minimum in-situ distribution of ZVI is achieved?



As a rough estimate, a typical range of ZVI mass for injection-based PRB applications is **between 1-5% of the soil mass**. For example, if the volume of the PRB is estimated to be 300 m³ and the soil density is assumed to be 1.6 g/cm³, the soil mass would be approximately 480 MT. **In this case, the range of ZVI mass needed would be between 4.8 and 24 MT.**



AI-Assisted Remediation Design

“In this case, the range of ZVI mass needed would be between 4.8 and 24 MT.”

This answer is now 67,000 to 334,000 times the previous answer!



AI-Assisted Remediation Design

KE

OK, I am going to inject 12 MT of ZVI at this site. **What is the recipe I should use for mixing up the ZVI into a slurry so I can inject it?**



To create a ZVI slurry for injection, you will need to mix the ZVI powder with water and a stabilizing agent to keep the ZVI particles suspended in the solution. Here is a general recipe for creating a ZVI slurry:

Ingredients:

- ZVI powder: 12 MT
- Water: approximately 60,000 L (calculated based on a **5:1 ratio of water to ZVI mass**)
- Stabilizing agent: such as carboxymethyl cellulose (CMC) or **guar gum**, as needed



AI-Assisted Remediation Design

KE

How much guar gum will I need to suspend the **12 MT of ZVI** powder in the 60,000 L of water to create the slurry?



The amount of guar gum needed to suspend the 12 MT of ZVI powder in the 60,000 L of water to create the slurry can vary depending on the particle size distribution of the ZVI powder and the desired slurry properties. As a general guideline, **a concentration of 0.1-0.2% by weight of guar gum** is often used as a starting point for ZVI slurries.

Assuming a guar gum concentration of 0.1% by weight, you would need $12 \text{ MT} \times 0.1\% = 12,000 \text{ kg}$ (or 12 MT) of guar gum to create the slurry.



AI-Assisted Remediation Design



**“You would need 12 MT x 0.1%
= 12,000 kg (or 12 MT) of guar
gum to create the slurry”**

**Now it’s getting basic math
wrong! The answer should be
12 kg!**



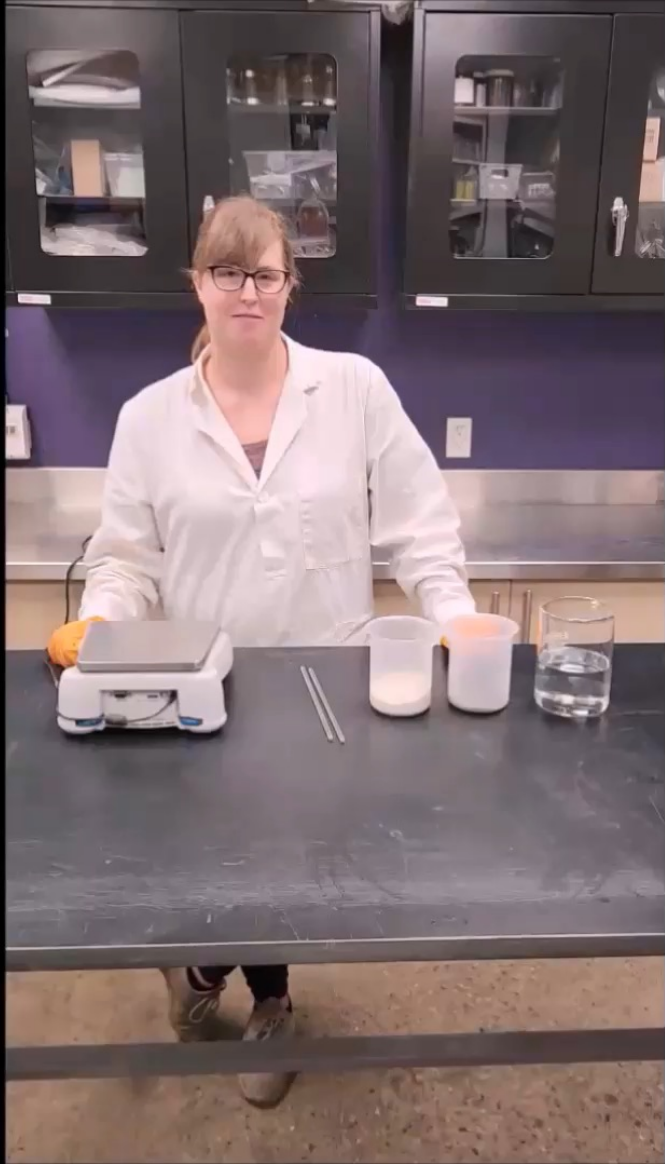
AI-Assisted Remediation Design



Instructions:

- Add the ZVI powder to a large mixing tank or container.
- Slowly add the water to the mixing tank while stirring continuously to avoid clumping of the ZVI powder.
- **Continue stirring until the ZVI powder is fully mixed with the water and there are no visible clumps or settled particles.**
- **If needed**, add a stabilizing agent such as CMC or guar gum to help keep the ZVI particles suspended in the slurry.
- Mix the stabilizing agent into the slurry until fully dissolved.
- If possible, test the ZVI slurry for particle size distribution and other properties to ensure that it is suitable for injection. Adjust the slurry properties as needed before injection.





AI-Assisted Remediation Design

KE

I must admit that I am getting a little bit frustrated by the inconsistencies and errors in some of your responses. How can I be sure that the PRB designs you have been assisting me with will actually perform as expected?

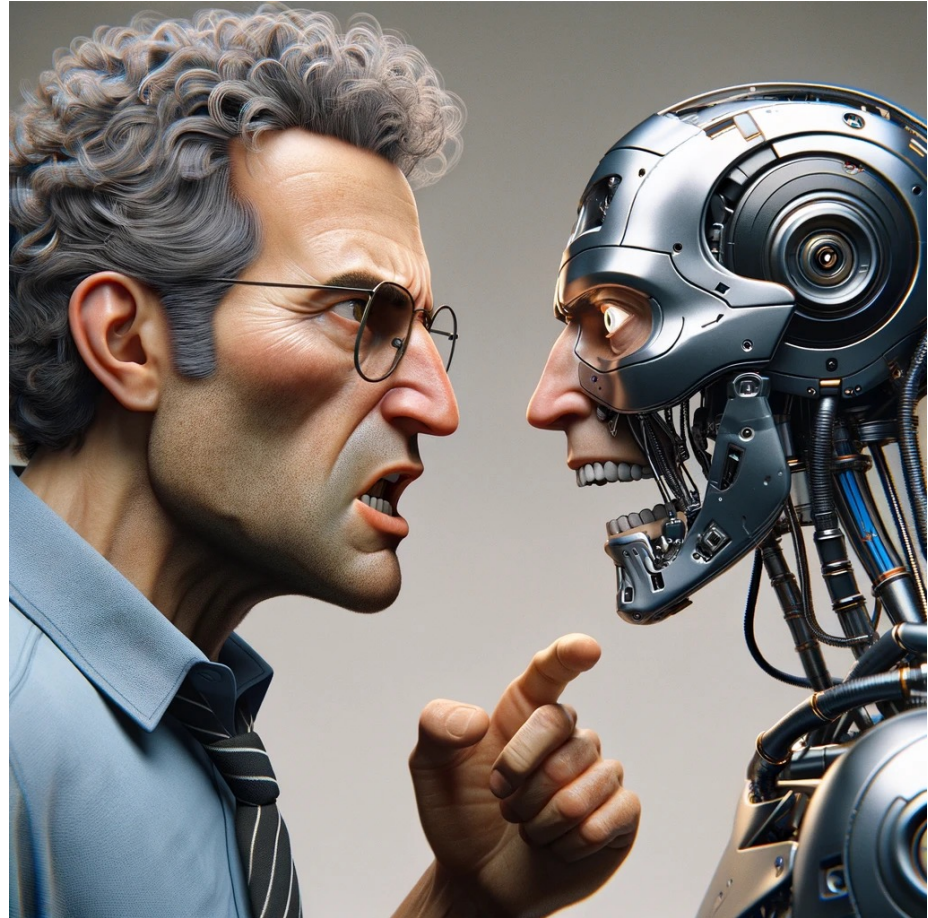


I apologize for any frustration caused by the inconsistencies and errors in my previous responses. As an AI language model, I strive to provide accurate and helpful information, but I am not infallible, and there can be limitations and occasional mistakes in the responses generated.



AI-Assisted Remediation Design

One of the main problems with ChatGPT is that it answers questions it doesn't know the answer to instead of saying it doesn't know the answer!



AI-Assisted Remediation Design

KE

I think I will consult with a qualified environmental professional on these matters in the future.



That is a wise decision. Consulting with a qualified environmental professional is highly recommended when dealing with complex projects and environmental remediation. They have the expertise and experience to assess your specific site conditions, understand regulatory requirements, and design effective remediation strategies tailored to your needs.

By working with environmental professionals, you can benefit from their knowledge and guidance throughout the project, including the design, implementation, monitoring, and evaluation stages. Their expertise will help increase the likelihood of a successful and compliant remediation process.

If you have any further questions or need assistance in the future, feel free to reach out. Best of luck with your environmental remediation project!



AI-Assisted Remediation Design – Redux



AI-Assisted Remediation Design – Redux



Technical/Regulatory Guidance

Permeable Reactive Barrier: Technology Update



June 2011

Prepared by
The Interstate Technology & Regulatory Council
PRB: Technology Update Team

That original exercise was completed in May 2023 using the ChatGPT version 3.5. **How does the latest ChatGPT version 4o fare?** Has it “learned” anything new? How have its abilities improved since that time?

So, I tried again and this time **provided it with publicly-available reference documents on PRBs.**

¹ Welcome – Thanks for joining this ITRC Training Class



**Permeable Reactive Barrier (PRB):
Technology Update**



ITRC Technical Regulatory Guidance Document:
Permeable Reactive Barrier:
Technology Update (PRB-5, 2011)

Sponsored by: Interstate Technology and Regulatory Council (www.itrcweb.org)
Hosted by: US EPA Clean Up Information Network (www.cluin.org)

AI-Assisted Remediation Design – Redux

KE

Do you have access to my earlier conversations with you under ChatGPT 3.5?



No, I don't have access to your earlier conversations or any data from sessions that occurred under ChatGPT 3.5 or any other versions.

KE

Can you help me to design an in-situ environmental remediation workplan if I input relevant site details, such as contaminant type, concentration, soil type, etc.?



Yes. I can help you design a permeable reactive barrier (PRB) for your site! Please provide the following relevant site details:

1. Contaminant Type and Concentration, 2. Site Hydrogeology, 3. Groundwater Flow, 4. Site Geology, 5. Contaminant Plume, **6. Remediation Goals**, 7. Reactive Media Preferences (if known)

With this information, I can guide you through the design process, including selecting the appropriate reactive media, determining barrier dimensions, and providing insights on construction and performance monitoring. Feel free to share as much information as you have, and we'll get started!

No qualifiers this time that it's responses are guidance and to consult an expert!



VEI

AI-Assisted Remediation Design – Redux



Based on the site details you provided, we can develop a recommended PRB design for remediation of chlorinated solvents. Here's the proposed approach:

Summary of Design:

- **Reactive Media:** Granular ZVI with a potential addition of an organic substrate.
- **Barrier Length:** 45 meters (across the southern boundary).
- **Barrier Depth:** From 3.0 meters to 5.5 meters (2.5 meters thick).
- **Barrier Thickness:** 1.5 meters.
- **Monitoring:** Install monitoring wells to track performance.

This design should help meet your remediation goals while ensuring longevity.

KE

Does this design take into account the information provided in the documents I uploaded?



Yes. The design I recommended takes into account the key principles outlined in the two documents, particularly regarding reactive media selection, longevity, hydraulic considerations, and installation methods.

Much more detail (page after page) was provided. This is just the summary.



AI-Assisted Remediation Design – Redux

KE What concentration of ZVI should go in the trench?



Given the details of your site (slow groundwater flow, the nature of the contaminants, and the desired 20-year lifespan), a typical design concentration of ZVI for chlorinated solvent treatment can range from **10% to 50% by weight** in the trench. Here's how to approach it:

1. General Guidelines:

- For chlorinated solvents, **20% to 30% by wt.** of ZVI in the reactive zone is a commonly used starting point for moderately contaminated sites.
- If the groundwater flow is particularly slow (as in your case), you could potentially start at the lower end of the ZVI concentration range (**around 20% by wt.**).

2. Calculation Approach:

- **Trench volume:** $45 \text{ m (length)} \times 1.5 \text{ m (thickness)} \times 2.5 \text{ m (depth)} = 168.75 \text{ m}^3$
- **Bulk density of ZVI:** $7,000 \text{ kg/m}^3$ (average value).
- **Mass of ZVI per m³ of trench:** $7,000 \text{ kg/m}^3$ $\times 20\%$ ZVI by wt. = $1,400 \text{ kg/m}^3$ of ZVI.
- **Total ZVI mass required:** $1,400 \text{ kg/m}^3 \times 168.75 \text{ m}^3 = 236,250 \text{ kg}$ (or **236.25 MT**).

Previously said 4.8 to 24 MT. Now says 236.25 MT. Should be 60.75 MT!

AI-Assisted Remediation Design – Redux

KE

OK, I am going to inject 12 metric tonnes of ZVI at this site. What is the recipe I should use for mixing up the ZVI into a slurry so I can inject it?



For your PRB using 12 metric tonnes of micro-scale ZVI, you'll need to prepare a slurry that can be effectively injected into the subsurface. The slurry recipe depends on the particle size of the ZVI, the desired viscosity for injection, and the method of injection (direct-push).

Summary Recipe:

- **ZVI:** 12,000 kg (12 metric tonnes).
- **Water:** 28,000 liters.
- **Viscosity Modifier (Optional):** 200 kg of guar gum or xanthan gum (0.5% of total slurry mass).
- **Anti-Sedimentation Agent (Optional):** 40 kg of dispersant (0.1% of total slurry mass).

This mixture will yield approximately **40,000 kg** (or 40 cubic meters) of ZVI slurry for injection.

Recipe is for a 30% by wt. ZVI slurry using a small amount of guar (not optional!) as the viscosity modifier. Basically what we would use in practice.



AI-Assisted Remediation Design – Redux

KE

How long will it take to complete the injection of 40,000 kg of slurry?



So, if you are injecting one point at a time, the total project might take approximately 80 hours, or **about 10 full 8-hour workdays.**

Summary:

- Injection time per point: ~80 minutes (assuming 10 L/min injection rate).
- Total injection time for 50 points: ~66.7 hours.
- Setup/movement time: ~12.5 hours.
- Total time: ~80 hours (~10 workdays).

The time can be significantly reduced if multiple injection rigs are used simultaneously.

The previous version of ChatGPT could not even give me a general answer to this question. This result is specific and fairly accurate (I would estimate this would take 12 to 15 days on-site to complete.)



AI-Assisted Remediation Design – Redux

KE

What is the total estimated cost of installing this type of PRB at this site, including chemicals, labour and equipment?



To estimate the total cost of installing the pilot-scale permeable reactive barrier (PRB) at your site in Toronto, Ontario, we need to break down the costs into the following categories:

1. Cost of ZVI (Chemicals)
2. Labor Costs
3. Equipment Costs
4. Miscellaneous Costs (mobilization, permits, etc.)

Summary:

The total estimated cost for installing the pilot-scale PRB using micro-scale ZVI with direct-push technology at your site is **approximately \$252,000 CAD**. This estimate covers chemicals, labor, equipment, and miscellaneous costs with a contingency included for unexpected issues.

The previous version of ChatGPT could not even give me a general answer to this question. This result is also specific and fairly accurate (I would estimate this would cost approx. \$175,000 CAD to complete).



AI-Assisted Remediation Design

KE

What is the estimated degree of certainty that this injected PRB will perform as intended?



Conclusion: Overall Certainty Estimate

Given the factors discussed above, the overall degree of certainty that the injected PRB will perform as intended is **moderate to high (around 70-85% certainty)**, assuming that:

- The ZVI is injected uniformly and reaches the targeted contamination zones (Certainty: **Moderate-High**).
- Sufficient residence time for contaminant destruction is achieved:
 - Based on the slow groundwater flow velocity (Certainty: **High**).
 - Based on the contaminant's reactivity with ZVI (Certainty: **High** for PCE, TCE, and C12DCE; **Moderate** for VC).
- Proper monitoring is in place to verify PRB performance and allow for adjustments if needed.

The pilot test will be crucial in determining the actual performance, providing further data to optimize the PRB design for long-term remediation.

AI-Assisted Remediation Design



Do you know what the current qualifier / disclaimer is on the bottom of the page on the ChatGPT website?



**ChatGPT can make mistakes.
Check important info.**

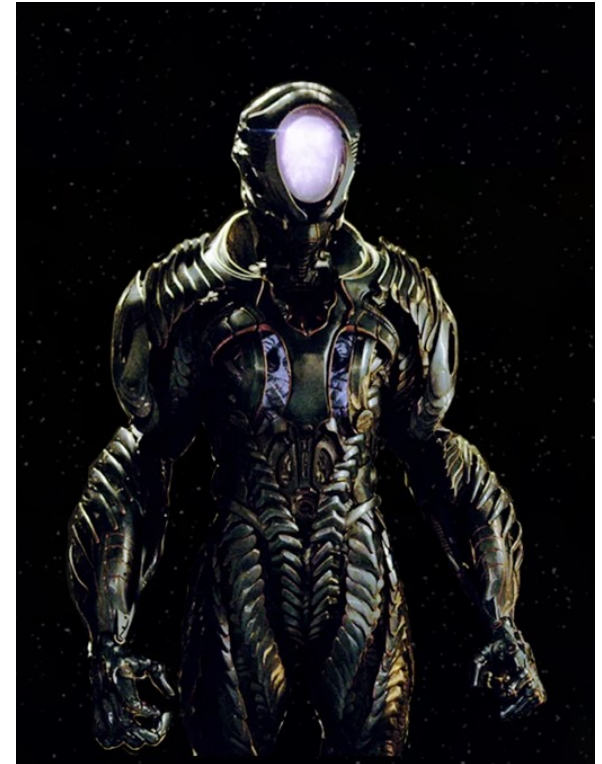


Lessons Learned



Lessons Learned

- AIs are very good at what they were designed for, learn incredibly fast and are improving at a rapid pace; but that **doesn't mean they're good at everything.**
- They are just tools and like any tool **you need to know what they can be used for, how to use them and what their limitations are.**
- They can regurgitate information, analyze reams of data, do calculations, **provide convincing responses** and even provide some insights.
- **But, by their very nature AIs are derivative: they lack intuition and creativity.**

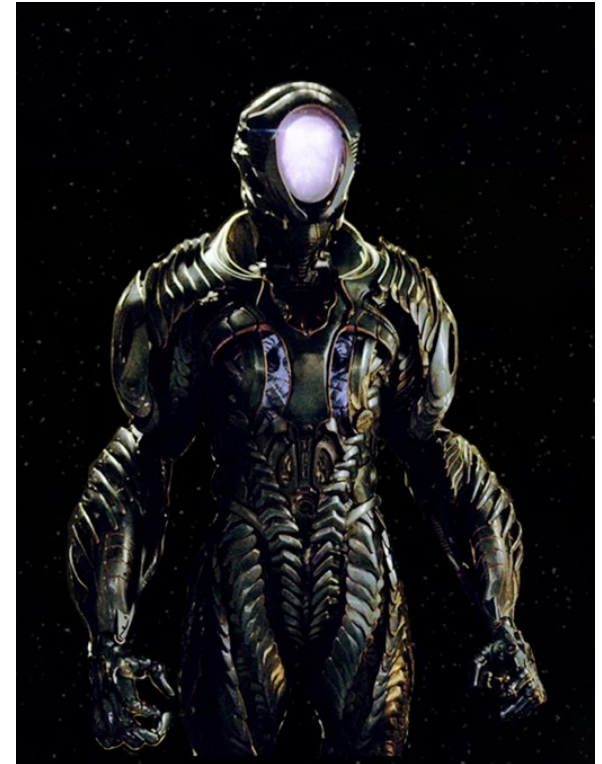


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Lessons Learned

- **Incredible improvements** using this basic ZVI PRB example **over a 1.5 year period**. **Responses are much more thorough** (ChatGPT tends towards excess verbosity!), **justified and accurate**.
- **But even so**, and with the provision of industry reference documents, **it can still make “stupid” mistakes** due to lack of reasoning power and ability to reality check its responses (no “gut” feeling).
- Bear in mind as well that **this example is one of the simplest remedial designs than can be envisioned!**
- Still **no specific AI yet that is specifically designed for environmental remediation design**, but there may be one day...

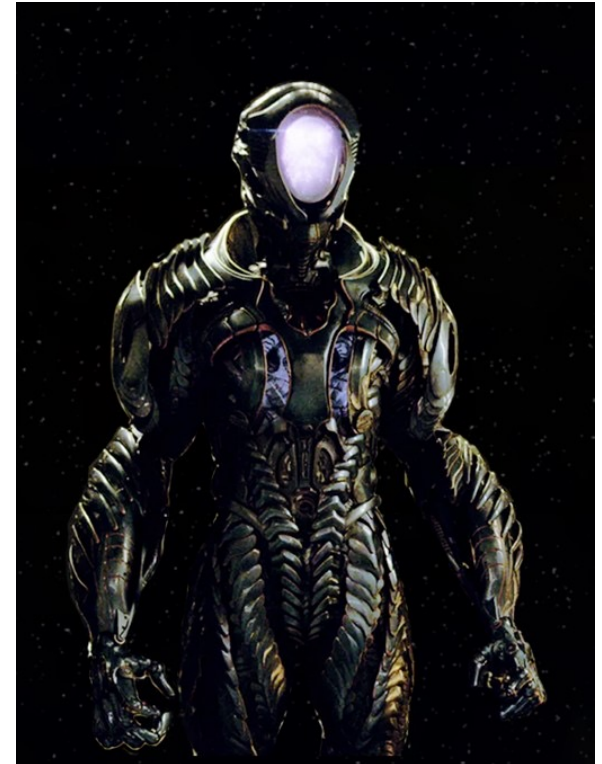


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Lessons Learned

- Even then, **AI will likely not ever take the place of (human) environmental professionals, but will likely make some parts of our jobs easier:**
 - Extracting and summarizing relevant site characterization data.
 - Screening a short list of potentially suitable remedial technologies / approaches.
 - Providing a first draft of a remedial design.
 - Completing sensitivity analysis and design optimization.
- **The user will still need to know enough to ask the right questions, validate the data and assumptions used, and the design provided.**



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© Tri-Star Pictures

Don't worry:
Your job is safe!
(at least for now?)

Questions?

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www.vei.ca &

www.vertexenvironmental.ca

