



DIRECT PUSH APPLICATION INSTRUCTIONS



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INTRODUCTION

One of the methods to deliver PetroFix[™] Remediation Fluid (PetroFix) into the subsurface is to inject the material through direct push rods using hydraulic equipment. This approach increases the spreading and mixing of PetroFix into the aquifer. This set of instructions is specific to the direct push injection of PetroFix. For advice on other potential delivery techniques please contact REGENESIS directly at 949-366-8000 or send an inquiry to info@petrofix.com.

PetroFix should be installed with the goal of having the material fully coat all conductive zones of an aquifer to prevent any mobility or escape of contaminants to downgradient locations. Because PetroFix is a liquid-carbon suspension amended with soluble electron acceptors, it flows easily into most aquifers using relatively low-pressure. Adequate injection volume is needed to ensure that PetroFix

contacts enough aquifer pore-space to fully coat aquifer transmissive zones and the starting volumes recommended to achieve this goal is provided as part of the PetroFix design assistant output. To achieve optimal contact and coverage with PetroFix, we recommend that the user consider these estimates as a starting point and be willing to adjust injection volumes and injection tooling as described later in this document.

When PetroFix is injected properly it will evenly coat the soil matrix across the horizontal and vertical transport zones of an aquifer and will appear as if the aquifer was “painted” black as shown in Figure 1. Most soils prior to PetroFix application are either brown or grayish in color and the presence of PetroFix post-application should be evident.

PetroFix Distribution Goal

Fully coat all aquifer conductive pathways in the treatment zone with PetroFix and adjust field injection spacing, injection volumes, injection pressure, or injection tooling to accomplish that goal.



FIGURE 1 The photo on the left shows a soil core collected before a PetroFix application. The photo on the right shows a soil core collected after a PetroFix application exhibiting black soil where the PetroFix was successfully distributed.

DIRECT PUSH GUIDANCE

Typical Installation Equipment and Supplied Needed

- Secure storage area
- Qualified driller/applicator
- Water source for mixing
- Access to electricity
- Appropriate Personal Protective Equipment (PPE) PetroFix SDS
- Direct Push Rig (such as a Geoprobe®) and associated probe tooling
- Mixing tanks – size based on product quantity to be applied per injection point
- Grout and mortar mixer with paddle for homogenizing PetroFix in its 55-gallon drums
- Injection tooling with fluid delivery sub-assembly (see injection tooling section)
- Injection pump rated to at least 200 psi and at least 5 gpm
- Injection hosing and pressure relief valve with a bypass (make sure all equipment is rated for expected injection pressures required)
- Hosing between mixing tank/drum and pump
- Pressure gauges to monitor injection pressure
- Flow meter for tracking injection volumes (or use visual drops in tank volumes over time)
- Pressure regulator to prevent pressure spikes (recommended, but not mandatory)
- Granular bentonite or grout to abandon completed injection boreholes. Some regulatory agencies have specific requirements for backfilling subsurface borings, so check with your local agency prior to beginning field work.
- Quick-set concrete or asphalt patch for surface closing



FIGURE 2

PetroFix ships in 55-gallon poly drums (400 lb of product) plus one 20 lb bucket of electron acceptor blend per drum

PERSONAL PROTECTIVE EQUIPMENT

Personnel working with or in areas where there is a potential for contact with PetroFix should be required at a minimum to be fitted with Level D personal protective equipment. However, this recommendation is only for PetroFix and does not

supersede additional precautions due to site conditions and potential exposures.

PPE should be upgraded from modified Level D based on site-specific hazards and requirements.

STORAGE AND HANDLING GUIDELINES

Storage:

- Store away from incompatible materials
- Store in original container
- Store at temperatures between 40°F and 95°F
- Do not allow material to freeze or store in direct sunlight
- Freezing and hot weather technical memo can be accessed at www.petrofix.com resources or at this [link](#) here
- Dispose of waste and residues in accordance with local authority requirements

Handling:

- Never add additives to solution prior to mixing with water
- Wear appropriate personal protective equipment
- Do not taste or ingest
- Observe good industrial hygiene practices
- Wash hands after handling

PETROFIX APPLICATION STEPS

Injection Preparation and Mixing

- 1) Print a copy of the Area Summaries for your site created in the PetroFix App.
- 2) Review design with drilling crew.
- 3) Review SDS during health and safety tailgate.

- 4) Walk the site and make note of any obstacles or infrastructure that may impede application based on utility locates.
 - a. Make sure you have called in Public utility locates before mobilizing to the site.
 - b. Prior to the installation of PetroFix, identify any surface or overhead impediments as well as the location of all underground structures. Underground structures include but are not limited to: utility lines, tanks, distribution piping, sewers, drains, and landscape irrigation systems. If locations are unknown, a private utility locating service can be contracted to locate these structures.
 - c. The planned installation locations should be adjusted to account for all impediments and obstacles while being mindful of PetroFix distribution needs.
- 5) Mark injection points based on site design provided in the PetroFix App.
 - a. Outline injection area.
 - b. Mark all points and note any points that may have different vertical application requirements or total depth.
 - c. Ensure points are spaced appropriately based on recommended design provided by the PetroFix App.
- 6) Set up area for mixing PetroFix Remediation Fluid with water and PetroFix Electron Acceptor Blend.
- 7) Assemble product transfer system.
- 8) Assemble injection system.
- 9) NOTE:** REGENESIS recommends injecting clean water (i.e. water without PetroFix mixed in) prior to mixing a PetroFix batch to check for leaks within the mixing and injection system. Repair any leaking equipment prior to mixing PetroFix in the mix tank.
 - a. It is critical to always depressurize the injection lines before disconnecting any fittings. This can be accomplished by fitting a bleed off valve near the injection pull cap (see Figure 3 below).
- 10) Advance the probe rods to the first vertical treatment interval and inject clean water into the interval while monitoring for leaks. If the leak test proved successful, continue to mix PetroFix into the mixing system.
 - a. During this step confirm the equipment pressure ratings are matched to the injection pressures.
- 11) Always add water to mixing tank prior to adding PetroFix Remediation Fluid.

12) Always pre-mix PetroFix in its container prior to pumping material out of the container. The best type of mixer for all circumstances would be a high torque, double handle mixer such as a *QEP or Rigid thinset grout and mortar power mixer* with QEP 30" pro spiral mixing paddle, or equivalent. Such equipment can be purchased at most Home Depots or large box hardware stores.

- a. **Note:** PetroFix drums are not completely full and PetroFix fills to roughly 10 to 12 inches below the top of the drum (See Figure 4).

13) Transfer designed ratio of PetroFix remediation fluid to the water in the mix tank. **Recommended batch sizes should range from 50 to 350 gallons to aid in easy mixing and for measuring injection volumes per point.**

14) Thoroughly mix PetroFix solution in the mixing tank using an impeller type drum mixer or by recirculating the product inside the tank.

15) Add recommended ratio of PetroFix Electron Acceptor Blend to the mixed solution in the tank. One tip is to use a scale to measure mass of electron acceptor blend needed for partial mix batches (Figure 4). Standard dosing is one bucket of electron acceptor blend per one drum of PetroFix.

- a. **DO NOT mix PetroFix Electron Acceptor (EA) blend from the 20 lb buckets into undiluted PetroFix Remediation Fluid in the drums or totes. Only add the PetroFix EA blend into the diluted PetroFix solution in the mix tank.**

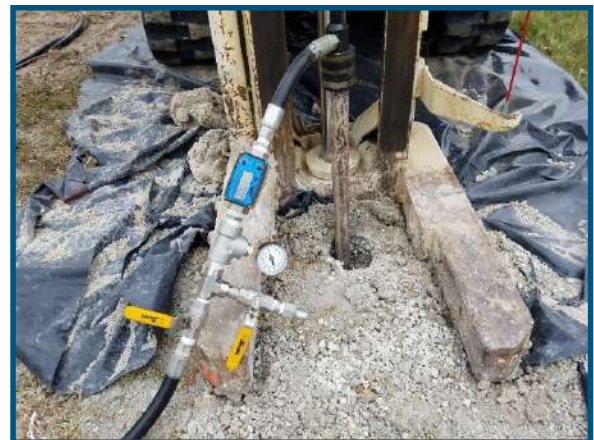


FIGURE 3 LEFT: Geoprobe injection pull cap (1.5").

RIGHT: The pull cap can be outfitted with a bleed off valve to depressurize injection lines prior to breaking probe rods to advance to next vertical treatment interval.



FIGURE 4 Image on left shows undiluted PetroFix in a drum prior to homogenization. PetroFix doesn't fully fill the drum and this is normal (a 400 lb drum of PetroFix contains approximately 41 gallons of product). The image in the middle shows an example transfer and PetroFix mixing setup where a 330-gallon tote was chosen as the mix tank. The picture on the right shows some PetroFix electron acceptor being weighed before placement into the mixing tank.

Injecting PetroFix

- 1) Set up the direct push unit over each specific point and follow the manufacturer standard operating procedures (SOP) for the direct push equipment. Care should be taken to ensure that the probe holes remain vertical. If there are enough personnel, this step can be accomplished while others attend to the mixing phase.
 - a. To prevent fluid and pressure loss between probe rod connections, we advise that the probe rod threads be Teflon® taped for the best possible seal.
- 2) Advance drive rods through the surface and through any pavement or concrete at locations cleared for utilities, as necessary, following SOP.
 - a. Ensure that all personnel in the working area have hearing protection during this step.
- 3) Push the drive rod assembly with your selected tool tip to the desired depth. This depth will depend on if you are performing a bottom-up or top-down injection – see section on “Examples of PetroFix Injection Tooling”. REGENESIS suggests pre-counting the number of drive rods needed to reach depth prior to beginning injection activities.
- 4) After the drive rods have been pushed to the desired depth, apply the designed quantity of prepared PetroFix solution at the target treatment intervals specified in the design. The target injection volume will be determined by multiplying the volume per foot by the injection tooling length. Regenesis recommends dual batch mixing PetroFix such that one mix tank is used for injection while the other is being prepared to follow after it is empty. This allows for uninterrupted fluid injection and minimizes field downtime for mixing.
 - a. **As a rule-of-thumb, 20 to 100 psi and 2 to 7 gpm flow rates are common through a single injection point.**
 - b. **Whip checks should be used throughout the process when working with pressurized hoses.**

- 5) Once target volume is reached, close off the injection line leading to the probe rods and depressurize the injection lines by draining the product into a bucket or similar. Use caution before and during opening any injection lines as there might be backpressure that could kick back or spray. See Figure 3 for an example of an injection pull cap outfitted with a bleed off valve.
- 6) Continue mixing and injecting the combined solution using the target injection volumes for the injection point described in the PetroFix design output page.
- 7) Once all injection points are completed, begin site cleanup by emptying the drums and flushing all injection lines using clean water. Product containers can be recycled after they are rinsed.
- 8) Dispose of any waste and residue in accordance with local authority requirements.

EXAMPLES OF PETROFIX INJECTION TOOLING

Injection tooling can be selected based on the type of soil present, logistic needs of the site, and prior experience of the consultant and injection crews. Our suggestions below are not exhaustive, but enough to outline injection tips common to most injection contractors. We advise that injection distribution is verified in field regardless of injection tooling used (see section of **“Verifying PetroFix Distribution In The Field”**). Injection tooling can be

chosen in a variety of sizes (1.25”, 1.5”, 1.75”, and 2.25”). Most environmental drillers will carry probe rods with 1.5” and 2.25” diameters for soil sampling and these same sizes can be used for injection. Geoprobe manufactures an injection pull cap that is designed to thread directly onto Geoprobe threaded probe rods. These pull caps can be outfitted with a bleed off valve steel pipe fittings available from McMaster-Carr®, Grainger®, or pipe fitting supply stores.

Multi-Port Bottom-Up Retractable or Multi-Port Top-Down Injection Tooling.

For injecting at lower pressures (typically below 60 psi) and maintaining relatively high volumetric injection rates, **REGENESIS recommends using multi-port retractable or top-down injection tooling** using 1-foot, 2-foot, or larger exposed injection screens (See Figure 5). An advantage of these types of tooling is they usually require no

pre-probing and allows targeting larger vertical intervals of the aquifer. Retractable injection tooling also allows for semi-discrete targeting of the aquifer and allowing PetroFix to flow into hard to identify small or large conductive zones that are likely contaminant transport pathways.

EXAMPLES OF BOTTOM-UP RETRACTABLE OR TOP-DOWN INJECTION TOOLING:

- Variety of 1.5" OD bottom-up retractable and top-down injection tooling in different lengths available (Figure 5).
<https://www.shop-esp.com/ESP-Injection-Tooling-C517.aspx>
- See section on remediation injection tooling for retractable remedial Injection tooling (RRIT) options.
<https://www.ams-samplers.com/powerprobe/direct-push-tooling-catalog.html>



FIGURE 5 Image on the left is an Environmental Service Products (ESP) bottom-up retractable tool. Image on the right is an ESP top-down injection tool.

TIPS ON USING BOTTOM-UP RETRACTABLE OR TOP-DOWN INJECTION TOOLING:

- It is advisable not to exceed 24" of exposed retractable screen in silts and clays which will give you better control of the vertical distribution of the PetroFix solution.
- Larger than 24" injection tooling can be used in homogeneous, permeable soils (sand and gravel) where more even product distribution is expected through exposed screen if enough flow rate and pressure can be maintained.
- The selection of bottom-up retractable or top-down injection depends on the preference and experience of the drilling operator. A top-down tool is more robust when hammered into hard soils and allows the applicator to more quickly set a vertical interval without the need to pull the rods back. A narrow slotted well screen can be slipped through the middle of the top-down tool to prevent silts and clays from clogging the injection ports.

PRESSURE ACTIVATED TOOL TIP

Many injection companies make use of a pressure **activated injection probe** (Figure 6) that is supplied by Geoprobe®. These probes are effective in aquifers that have a higher permeability (high percentage of

sand); however, in tighter formations these tool tips tend to generate enough pressure to cause hydraulic fracturing of PetroFix that may result in uncontrolled placement or surfacing.

TIPS ON USING PRESSURE ACTIVATED TOOLING:

- Top-down injection usually recommended in most formations with this tip.
- Be cautious of hydraulic fracturing with this tip. To get the uniform distribution shown in Figure 1 this approach may require that the vertical distance between push-and-inject intervals as low as 1 to 2 feet to prevent gaps in product coverage vertically.



FIGURE 6 Image of Geoprobe[®] pressure activated injection probe

EXPENDABLE DRIVE POINTS AND INJECTION THROUGH ROD BOTTOM

Bottom-up injection using expendable tool tips (Figure 7) is an option if the aquifer grades from tight soils at maximum injection depth to permeable soils at minimum injection depth, for instance injecting into clay or silt that grades to sand as you approach the surface. If the geology were reversed, one needs to be concerned about preferential delivery of PetroFix into deeper zones as the rod is raised and the PetroFix fluid preferentially flows to the zone of

least resistance down the injection hole. For flowing sands and highly permeable environments, injection through rod bottom can achieve effective product delivery. The vertical distance between pull-and-inject lifts may need to be as low as 1 to 2 feet to prevent gaps in product coverage vertically. Bottom-up injection with expendable drive points offers the least control over injection and is least recommended, particularly for soils with silts and clays.



FIGURE 7 *Geoprobe® expendable steel point allowing for bottom-up injection through rod opening.*

VERIFYING PETROFIX DISTRIBUTION IN THE FIELD

PetroFix has the unique advantage of being its own tracer due to its black appearance which can be used to verify its distribution in the field. The PetroFix Design assistant (<https://petrofix.com/design/>) is an excellent starting point to estimate spacing and volumes to use for an application, but one should expect to make some minor adjustments in field due to natural variability of geology and pore space.

The easiest way to determine if PetroFix is distributing is to collect one or more soil cores at your site after the first 2 to 4 injection points have been completed. Most direct push operators have the tools required for rapid soil core sampling and we recommend that you double check this when bidding out your work. We recommend that a soil core be collected with the following criteria:

1. Take the observational soil core half-way between two PetroFix injection points or half the spacing distance away from any given injection point;

2. Take the observational soil core over the entire vertical interval. This may require more than one core be taken.

If you see a strong black color (like Figure 1 or Figure 8 below) coating the conductive zones of your aquifer, then congratulations as you are achieving product distribution. If you don't observe a black color in the soil, then you are not achieving sufficient distribution and should diagnose the reason why. It is important that PetroFix be observed both laterally and vertically at your site. It also is important to investigate if your injection is distributing PetroFix into the one or more geologic conductive zones at your site. A small percentage of sites may have dark or black soils because of hydrocarbon staining and it is important to distinguish if this is the case. Ideally, we recommend that you take a baseline soil core before injection and then compare this to one or more post-injection samples to see the difference.



FIGURE 8 *Photo showing an in-field verification of PetroFix distribution and its optimal coverage. Gray soil in upper right shows the edge of the injection zone where PetroFix not injected.*

Here are a few tips if PetroFix is not observed in your soil core:

- **Double check injection pressures** – Am I injecting with a steady pressure? If not, consider increasing pressure (which will also be increasing volumetric flow rate). If you are very low in pressure (<10 psi) it may be that you are not achieving enough product velocity to cause delivery far enough from your injection points. As a general rule-of-thumb most sites range in pressure from 20 to 100 psi and volumetric injection rates of 5 to 7 gpm. If you are not exceeding fracture pressures and are getting uniform distribution, then feel free to use the maximum volumetric flow rates or pressures that you can achieve.
- **Double check spacing** – Am I within the recommended spacing suggested by the PetroFix design assistant? If not, consider tightening spacing.
- **Double check volumes** – Have I injected the recommended volume of water and PetroFix together? If not, inject recommended volumes of water and PetroFix.

If spacing, volumes, and injection pressures are as initially designed, and you are still not getting distribution, it may be that the aquifer has a higher pore space than assumed for design purposes. Consider increasing the dilution water used for PetroFix by increments of 10% to 15% volume until distribution is achieved. Furthermore, it may be that the injection tooling you are using is not suited to your aquifer type and you should consider changing injection tooling.

Alternatively, you may find that you need less mix water and PetroFix verification testing can be used to minimize needed water if your effective porosity is less than designed for. If less water is needed to obtain the required ROI then we recommend that you reduce the overall injection volume, but keep the same design spacing versus spreading the points farther apart.

Q: “How do I know if I am fracturing soil and having uncontrolled product placement?”

A: Fractures are induced by rapid pressure build-up followed by high volumetric flow rates. If you notice a spike in pressure followed by a rapid drop in pressure, yet high-volumetric flow rates are sustained it is likely that you are pushing PetroFix into created fractures. You may not see any observable evidence of this happening or you may begin to see surfacing into utility corridors, ground surface, etc. We advise that pump pressures are slowly increased as well as volumetric flow rates where everything is steady without big pressure spikes and big pressure drops. The use of a pressure regulator as mentioned in the equipment list to prevent pressure spikes and the use of pressure gauges between the pump and the injection rods is very important to be able to monitor this process. Soil sampling is a good visual method to answer your questions as to if you are getting uniform and complete coverage or if you are creating fractures.

Regarding the monitoring of pressures, it is common to see pressures rise to the point that fluid begins moving into the formation and then those pressures gradually decrease (versus a rapid decrease). This is different than the hydraulic fracturing of soil. We see this as a normal initiation pressure as the PetroFix fluid needs to overcome either partially occluded pore space immediately around the tooling because of soil smearing or through the compaction of soils around the tooling that can happen when the tooling is pushed into the formation.

Q: “What if I want to try and achieve larger injection spacing than the PetroFix Design Assistant Specifies?”

A: Many customers ask if they can use injection spacing larger than specified by our PetroFix Design Assistant. Our answer is that we believe that our recommended spacing is a good recommendation and starting point (typically 5 ft- to 6.5 ft-on-center), particularly for sites with more silt and clay than sand. However, sites do vary in their characteristic effective porosities and percentage of fine-grained to course-grained materials and how they are layered. If stable pressures and flows are maintained, then it may be that larger ROI's can be achieved given the starting volumes that were calculated. If this is the case, our recommendation is to maintain injection spacing but reduce injection volumes to cut down on field time.

However, if you want to spread injection points out, we encourage you to explore the ability to do so by performing an injection and follow the PetroFix distribution verification process we discussed earlier to document that you achieved distribution. If you can document distribution and are able to accommodate the change in volume injected and time spent per point you should feel free to use whatever spacing can be accommodated.

PETROFIX PUMP INFORMATION

REGENESIS strongly recommends using a pump with a minimum pressure rating of 200 pounds per square inch (psi) and a minimum delivery rate of 5 gallons per minute (gpm). A lower gpm rated pump can be used; however, they are not recommended

due to the amount of time required to inject the volume typically associated with a PetroFix injection (i.e. 1,200 lb of PetroFix with 60 lb PetroFix Electron Acceptor will require 2,460 gallons of water to make a 5% by volume PetroFix solution).

PUMP CLEANING

Internal pump mechanisms and hoses can be easily cleaned by circulating water through the pump and injection lines until clear. Flush water can be injected into the treatment zone. Further cleaning and

decontamination (if necessary due to subsurface conditions) should be performed according to the equipment supplier's standard procedures and local regulatory requirements.



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