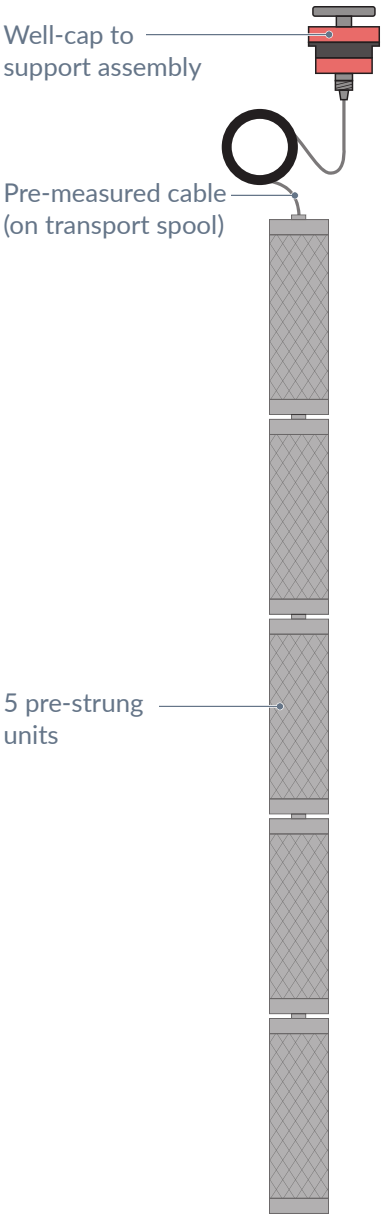
REGENESIS®

QUESTIONS AND ANSWERS

Groundwater and Contaminant Mass Flux

A Modern View and Approach to Measuring, Reporting, and Designing with Mass Flux Data

FluxTracer®
Flux Mapping Tool



About FluxTracer

FluxTracer® Flux Mapping Tools are easy-to-use devices that vertically delineate contaminant mass flux and groundwater velocity within an existing monitoring well to aid in site characterization and remedial designs. The FluxTracers consist of five separate two-foot-long stainless-steel screen canisters that are secured in series on a pre-measured central wire line equipped with a modified J-Plug well cap. FluxTracers are always pre-assembled, arriving at your site ready to deploy with no on-site construction required. The unique design provides joint-like flexibility between the closely stacked canisters to easily install and remove from a well.

Each FluxTracer canister is filled with granular activated carbon pre-loaded with biodegradable tracers. The tracers are composed of five different alcohols each having well-known partitioning characteristics with the activated carbon. As groundwater passively flows through a FluxTracer canister over the deployment period, the alcohol tracers are depleted from the activated carbon, with the net loss of the tracers directly correlating to the groundwater speed. At the same time, any contaminants present in the groundwater adsorb to the activated carbon during the deployment period. The total mass of contaminants accumulated on the activated carbon is then quantified and the contaminant mass flux is calculated.

A study consists of a FluxTracer installation into a well across a predetermined vertical interval of the saturated zone. The FluxTracer unit is typically in the well for two weeks and then retrieved. Once removed from the well, the FluxTracer devices are simply repackaged into the provided sleeves with zip ties and returned to the REGENESIS Lab for analysis. No on-site disassembly or sampling is required.

Upon receipt in the REGENESIS lab, each FluxTracer canister's contents will be sampled and analyzed at one-foot intervals. From those analyses, an accurate vertical profile of contaminant mass flux ($mg/m^2/day$) and groundwater Darcy flux (speed) (cm/day) is generated, and the results are provided in a report. The generated data provides remedial designers with important information on the flux zones within the aquifer, which ultimately aids to improve the results of remediation efforts.

Questions	Answers
Can you use this tool for site characterization? If so, do you need to have the screen throughout the water-bearing zone?	These tools are a good way to identify and characterize groundwater zones that control the size and shape of a plume when placed in properly installed wells. Prior characterization is needed to identify the contaminant-carrying zones, including high-resolution and/or discrete water and soil sampling. We think that the characterization step is best performed in monitoring wells that are well placed along the plumes long axis and that have a longer screened interval or are nested.
Does water circulation in the well (up and down due to temperature differential) affect your mass flux measurement? Have you found vertical flow within a well to be a significant issue? If so, how do you address it?	Vertical groundwater gradients are recognized but are generally considered to have a very limited effect on the data collected. In the vast majority of sites, the horizontal movement of groundwater far exceeds any vertical movement. There are always exceptions to this notion (more common in fractured bedrock for instance), but we think that FluxTracers obtain reasonably accurate measurements. Furthermore, FluxTracers are engineered to limit any potential vertical migration with solid spacers or device hardware limiting flow to 1 ft vertical intervals.
Are any geophysical methods, and specifically electromagnetics being used to support the mass flux measurements?	No there are not. The measurements are all based on chemical analysis. Mass flux is calculated directly from the amount of contaminant mass showing up during the two-week FluxTracer deployment window. groundwater velocity is derived from following how much leachable tracers are left in the pre-loaded sorbent material inside the device.
What is the influence of well construction on direct-measured flux values?	The monitoring well design and installation quality has a direct impact on the results the devices provide. These passive devices are directly dependent on how well or how poorly the well is installed and so how well it is connected to the surrounding aquifer. Essentially a monitoring well is traditionally designed to represent a given section of the aquifer. If the well does not accurately represent the aquifer conditions present then the device will be subject to the same level of error. The ITRC *Manual on Mass Flux/Mass Discharge* specifically talks about a high degree of variability between passive flux tools and other flux measurement methods when interrogating a well that has little or no engineered filter pack.

Can you get groundwater velocity with only one FluxTracer deployed?	The devices do provide a reasonably high resolution of groundwater velocity (one-foot vertical intervals) accross the well's entire saturated screened interval. This and the mass associated with samples provide a view into the zones within the Target Treatment Zone that matter the most. We see a great deal of vertical variaiblity in groundwater velocity, we anticpate that this variability is present laterally as well as vertically. We would recommend a flux study be performed along the long axis of the plume to mitigate bias associated with too small of a sample size.
What site contaminants are FluxTracers compatible with?	Currently we only analyze for PCE, TCE, and cis-DCE. We do have plans to expand our mass flux analysis capabilities to PFAS, additional cVOCs, and petroleum hydrocarbons in the future. Enviroflux can analyze for many more contaminants, including some inorganic species.
In your design of a barrier do you assume a continuous flux for a number of years, or do you include an assumption of dilution of the source over time?	Source depletion rates are of great interest to us, but as of now we use a static value over the course of the remedial design. This provides an additional level of conservatism.
These measure horizontal flux. How would you measure vertical flux?	To date researchers studying unconsolidated aquifers with standard wells have been unable to document the presence of vertical gradient e.g. up- or down-flow as being present on sites or that when present it is significant in terms of biasing the results yielded by passive flux measurement devices. This does not include fractured bedrock. However, if a significant vertical flux was to be present in a particular well we would anticipate that the up- or down-flow system would result in a relatively homogenized results across the individual flux devices. Finally, these devices are not designed to measure vertical flux.
How many wells would you deploy the tool in, and how are the differing results among the tool accounted for?	It is difficult to provide you with a hard number, we do know that more devices are needed for longer or larger plumes than for smaller and short plumes. We know that aquifers with a high degree of heterogeneity require more flux tools that do lower heterogeneity ones.
What is the minimum well diameter in which the FluxTracer tool can be used?	At present, FluxTracers are only built for 2-inch schedule 40 wells. We may design devices to service other well types in the future.

How do you calculate the groundwater and/or mass flux from the alcohol tracer loss?	Groundwater flux is calculated from the tracer loss, and mass flux is calculated directly from the amount of contaminant mass showing up during the two-week FluxTracer deployment window. More information on the analysis and mathematics can be found in this publication: *Field-Scale Evaluation of the Passive Flux Meter for Simultaneous Measurement of Groundwater and Contaminant Fluxes*, Michael Annable, et al. Environ. Sci. Technol. 2005, 39, 7194-7201
How do you estimate the flow field distortion around the well/cartridges to be sure that the groundwater flux you get is representative of the aquifer Darcy's flux?	We are aware there is a groundwater convergence/divergence associated with the distortion of the native aquifer by the well pack material, the device material, and other factors. At present, we do not make an active correction for this based on each site, but understand it does impart an error. Our devices are always more permeable than the surrounding aquifer, so we do usually know the type of distortion. We are more interested in knowing the general level of contamination present and the vertical differences within a given site. For remedial design purposes this is adequate.
What is the cost of FluxTracer?	In the US, the service is competitively priced, and depends on the length of device needed. Contact a REGENESIS regional representative for more information. We will not be servicing Europe at the moment with FluxTracers.
What drives the frequency of FluxTracer measurements in case of long term remediation?	We think that measurement frequency is a site-specific item. This should be based on the mass flux and groundwater flux rates present at baseline and informed by the dynamics of the remedial system being deployed.
How does mass flux measurements play out in fractured bedrock sites and also does the 90% rule apply at these sites?	In our world and without geophysical logging or other similar methods to determine fracture porosity we just assume a bulk 5% fracture porosity and of those fractures it's anybody's guess what percentage is transporting contaminant mass (flux).
The examples discussed had concentrations in mg/L. Is there a minimum concentration for the tool to be useful? In other words what is the sensitivity?	Contaminant mass flux is a product of groundwater concentration and velocity, so in theory there is no hard minimum concentration. If the groundwater is very fast-moving and/or the device is left in the well for a longer collection period, very low sensitivities are possible. A mass flux of 1-10 $mg/m^2/d$ or even higher will be addressed very similarly (all being low) and so a higher level of resolution is not normally useful for remedial design purposes.

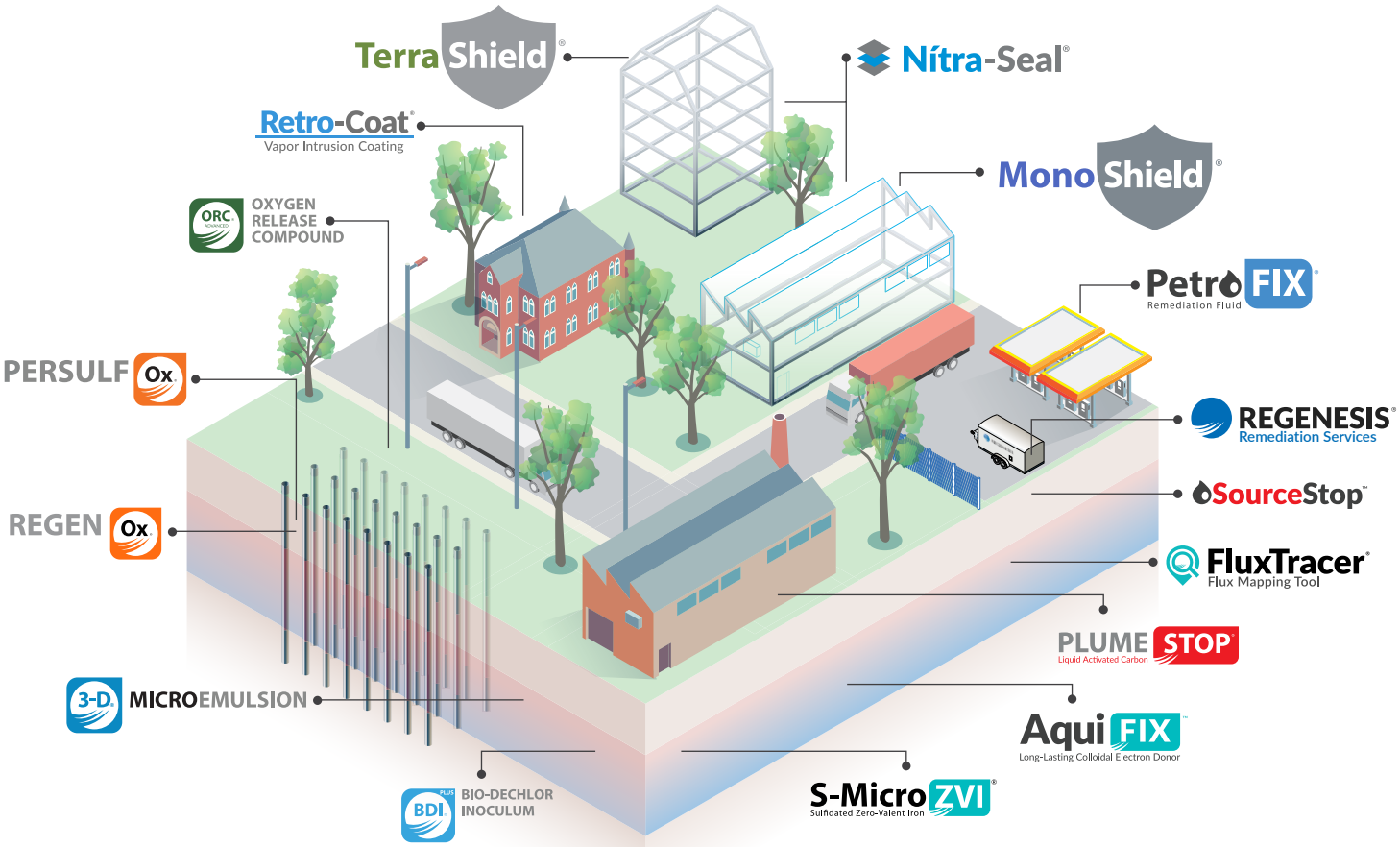
Discuss borehole diameter vs. well screen diameter and any filter pack in the annulus and short-circuiting that could compromise the integrity of the measurements	The ITRC manual of mass flux/mass discharge discourages the use of wells with no well pack. The degree of variability between flux tool measurements and other flux measurement methods was very high, whereas when flux tools were deployed in well that had standard design and installation methods had a reasonably high correlation/low degree of variability.
What is the typical price structure for FluxTracer?	FluxTracer service is competitively priced, and depends on the length of device needed. Contact a REGENESIS regional representative for more information.
What does vertical variation in mass flux matter if you are putting in a 20-ft deep PRB? Do you try to focus the reactive material at the depths where the flow occurs? Seems like you have limited ability to do so.	The significant variability in mass flux across short vertical intervals (on the order of 3-5x) makes it critical to know where to emplace the sorption/ destructive reagents. If you use a bulk average flux rate it means some of the zones will be over dosed (no problem and probably it's lost in the noise) but use the same dose to attempt to manage a zone that is 3-5x higher than that bulk average in terms of mass flux and you have holes in the PRB that you are not able to manage without a reapplication prior to the anticipated PRB operational life. We typically break the mass flux down into relatively short application units. We apply the remedial reagent at a relatively conservative concentration, then vary the volume based on the application units measured mass flux. We do have the ability to target particular zones with more amendment when needed.
10 analytical measurements per well, probably 3 to 5 tracers sets per transect and the example showed 8 transects. The analytical will add up quickly - how much does each 10-measurement train cost?	We think that flux transect studies are important in determining mass discharge, but we also recognize the costs. A 10 ft. measurement array with sample analysis at 1 foot intervals is reasonably priced- for exact costs please contact REGENESIS directly. However, we would probably recommend fewer transects than the ITRC approach for a mass discharge study. We think that a set of flux study wells positioned along the centerline of the plume and augmented with Hi-Res methods might optimize cost and provide a similar level of design confidence.
How does the technology perform with weathered products? Is there any difference with a weathered Gx or Dx plume?	Gx and Dx refer to gas and diesel range organics, we do not have any data on this currently. I would speculate, however, that the mass flux may bias somewhat lower for more weathered ranges if not properly accounted for in the extraction procedure due to an increasing fraction of heavier hydrocarbons remaining. For individual chemicals that are being quantified, there will be no change due to weathering.

Does injection directly into the source area elongate the remedy time?	It depends on the rates and kinetics of the destructive reagent applied. If you are asking if significant contaminant spreading occurs as a result of the injection work, the answer is no. Most of the contaminant mass in source zones is found as residual free-phase and or in lower permeability zones. Because of this and the low overall volumes used, amendment injection does not lead to problematic contaminant mass displacement.
Are flux measurements applicable for residual petroleum in pore spaces only, or are flux measurements possible in contaminant-saturated zones where there may be sheen or evidence of free-phase petroleum, for example?	We do not think that the use of flux tools should be performed in areas of NAPL or DNAPL. The high mass loadings in these areas may lead to unreliable results.
Can you deploy a FluxTracer in an open borehole (say, for shallow aquifers, less than 25-30 ft deep)	Open borehole completions imply a bedrock setting, we do not have flux tools in custom diameters that will provide sufficient contact with the aquifer to prevent up-or down-flow conditions from confounding the results.
Is a WDR required for your device in California? We have been required for TBA tracer in eagled before.	These devices have been approved for use in Southern California as well as on multiple sites in Northern California. Please reach out to our Western Regional Manager directly for specific questions about approvals and approval requirements. DNunez@REGENESIS.com
Is there any difference in how the FluxTracers perform in fractured rock aquifers vs. unconsolidated aquifers?	There is limited data collected from fractured bedrock using passive flux devices. From my understanding there are a number of obstacles that have prevented obtaining good data.
How is vertical flow accounted for? Thinking of a large open borehole or well screen in fractured rock.	We do not reccommend the use of passive flux devices in a traditional open bore hole, fractured bedrock for reasons you have mentioned as well as other practical reasons e.g. deployment and retrieval has been found to be troublesome.

You're putting these into wells with longer screens than typical, and could result in vertical flow through well when the FluxTracer is not installed. **Are you recommending installing these long screened wells?**	Although we do not recommend long screen monitoring type wells be installed specifically for flux studies, there is a case to be made for that, however, it's a matter of practicality. In these types of studies we do rely on the wells being screened through the key flux zones driving the plumes dynamics, so confirmation of this is vital. Shorter screens or ideally a series of multiple nested wells across the target treatment zone is another option. At a majority of sites practitioners have already installed long (10 ft or more) screened wells that are generally well positioned vertically along the plume's long axis. We investigate the entire saturated screen intervals of those existing wells. We also recognize that upward gradients are present at some sites, in unconsolidated aquifers the upward (vertical) gradient component is typically dwarfed by the horizontal flow gradient. From a practical standpoint EnviroFlux and REGENESIS separate their devices in discrete sections using a washer/gasket that is positioned at regular intervals within the unit. For the REGENESIS FluxTracer we have discrete 2 ft canisters each with a spacer at the mid-point of each canister... essentially creating a one-foot increment.
How does the tracer and mass flux calculations account for retardation of contaminants in the groundwater, which can differ?	Retardation is an aquifer matrix-contaminant phenomena and really has little influence on the dissolved phase mass fluxing thru the flux device, particularly when steady state systems are in reasonable equillibria and all the potential sites that would contribute to retardation are used. What the flux devices see is what the contaminant present in the groundwater fluxing through the device under the current aquifer conditions.
What do you expect to be the average turnaround time from receipt of the tool from the field and issuance of a report?	The standard turnaround time for the report after receipt of the devices is 2 weeks.
Would longer deployment times yield more accurate results?	The two-week timing mitigates the potential for tracer washout by fast groundwater advection rates as well as the biodegradation of the tracers. Longer deployment time can increase the sensitivity (but not accuracy) of the method to flux, like a camera shutter staying open longer can give a better image of a faint or very dimly lit object.

Can these tools be used with baffles in open bedrock boreholes that are larger diameter (e.g., 4-inch or 6-inch borings)? If so, can they be spaced to target fracture zones that are not immediately adjacent to one another?	To date that work has not been successfully completed. A great deal of pre-application assessment would be necessary as with all fractured bedrock settings. Device design and delivery would need significant level of change to accommodate these types of aquifer settings, including workarounds involving upflow or downflow issues.
If you are trying to focus injection into high mass flux zones in a well screen (e.g., 20 foot screen), how can you best focus injection into that specific zone? It seems like the well screen/filter pack would still push injectant into preferential pathways.	Application of reagents should always be via injection wells with an appropriate screen, casing and seal. Long injection well screens will likely result in placement of remedial reagents in the wrong zone. We can deploy FluxTracers in long screen monitoring wells as an assessment step only. This helps us define the flux zones that matter the most. Based on the flux results we can recommend installation of short screened dedicated injection wells to address those zones.
What type of tracers? Where are tracers collected?	The tracers are for measuring groundwater velocity. Methanol, ethanol, isopropanol and tert-butanol are all pre-loaded on the sorbent in the device at mg/L levels before deployment. These alcohols leach off at known rates as water passes by, and we use the remaining mass of each to help calculate the groundwater velocity.
How does mass flux measurements change between considering all chemicals of concern vs. individual chemicals? (ie, PCE only vs. PCE+TCE+cis-DCE)	If your question is about capture and quantification, the presence of each does not have a substantial effect on the collection of the others. There is ample sorptive capacity on the carbon for the length of time the devices are deployed. If you are asking more generally about the ratios of each present, it depends greatly on site conditions. If anaerobic biotreatment has been done in the area already, or the aquifer is naturally anoxic there may be a substantial amount of daughter products present already. In a highly oxic aquifer we may only find PCE. The vertical distribution of the parents and daughters has been highly variable on some sites, likely related to the exact location of earlier product injections and or native aquifer conditions.
I have a non CVOC site that I am interested in the vertical profile of Darcy velocity only. Could the device be simplified to just report vertical Darcy velocities?	Yes, this is possible. Both mass and groundwater flux are measured with the same sorbent and this could be easily done. If not with us, then also Enviroflux as well.

How are we deploying FluxTracer into 5' and 15' sections given that the canisters come in 2' sections?	The devices for 5' and 15' monitoring wells are constructed as 6' and 16' respectively. When these devices are deployed, only the bottom 5' and 15' sections are analyzed since the top foot of each device does not actually sit within the target well interval.
I have a non CVOC site that I am interested in the vertical profile of Darcy velocity only. Could the device be simplified to just report vertical Darcy velocities?	FluxTracer is designed to be more user friendly than comparable technologies in the market in that the cable is premeasured and preassembled for deployment based on the evaluation form submitted. Clients also do not have to disassemble the device and sample in the field or dispose of contaminated GAC upon retrieval. The FluxTracer device is retrieved from the well and repackaged into the cooler and sent back to the lab for analysis.
For a 10' FluxTracer device, how many intervals are being sampled for PFAS? 5' device? 15' device?	For a 10' device, 5 intervals are sampled for PFAS and 5' intervals are samples for groundwater velocity, interchangeably. For a 5' device, 2 intervals are sampled for PFAS and 3 intervals are sampled for groundwater velocity. For a 15' device, 7 intervals are sampled for PFAS and 8 samples are sampled for groundwater velocity.
What is the best practice for checking bends in a well?	To visually check for bends, one would use a mirror and reflect the light down the well. If you see the water clearly (full moon) then the well is straight. If you see a half-moon shaped reflection, then that indicates there is some bending to the well.
What is the best practice for checking silting in a well.	For silting, we advise that clients measure the total depth of the well and compare the recent measurement to the boring log. If the boring log indicates that the total depth of a well is 30' but the measured total depth is 28', then there is potentially 2' of silt in the bottom of the well. Clients can also feel for the bottom; if the bottom feels soft then there is a possibility that silting has occurred.



About REGENESIS

At REGENESIS we value innovation, technology, expertise and people which together form the unique framework we operate in as an organization. We see innovation and technology as inseparably linked with one being born out of the other.

Inherently, innovation imparts new and better ways of thinking and doing. For us this means delivering expert environmental solutions in the form of the most advanced and effective technologies and services available today.

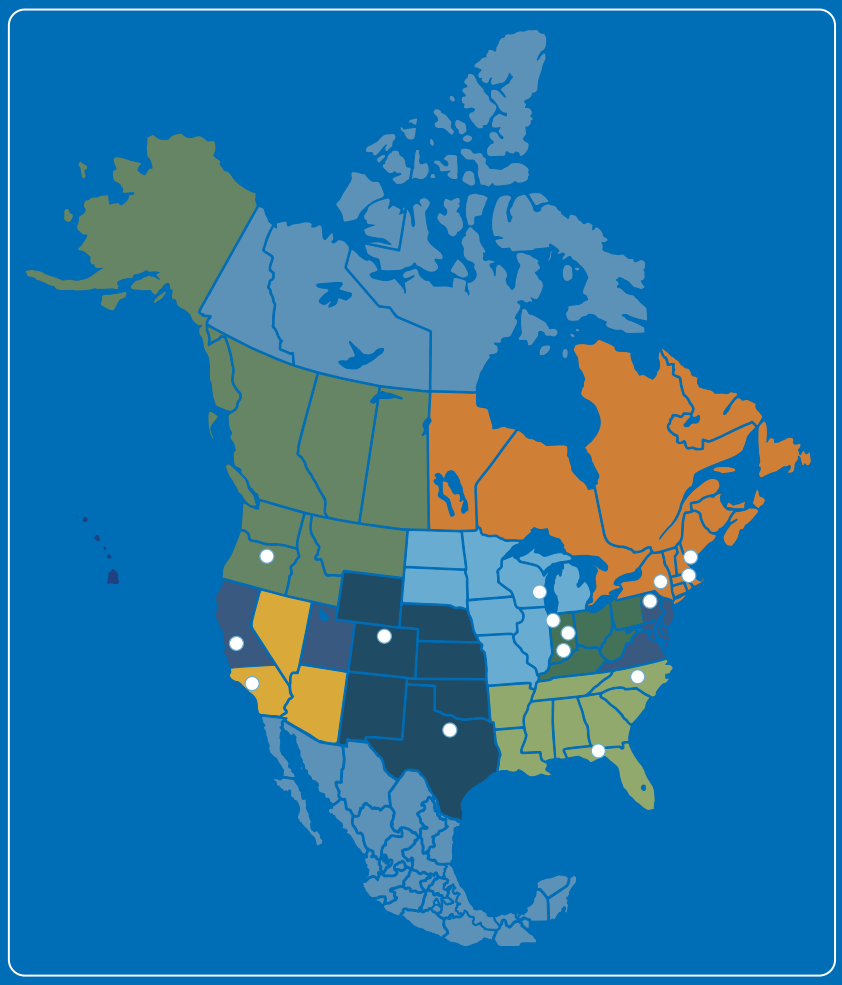
We value expertise, both our customers' and our own. We find that when our experienced staff collaborates directly with customers on complex problems there is a high potential for success including savings in time, resources and cost.

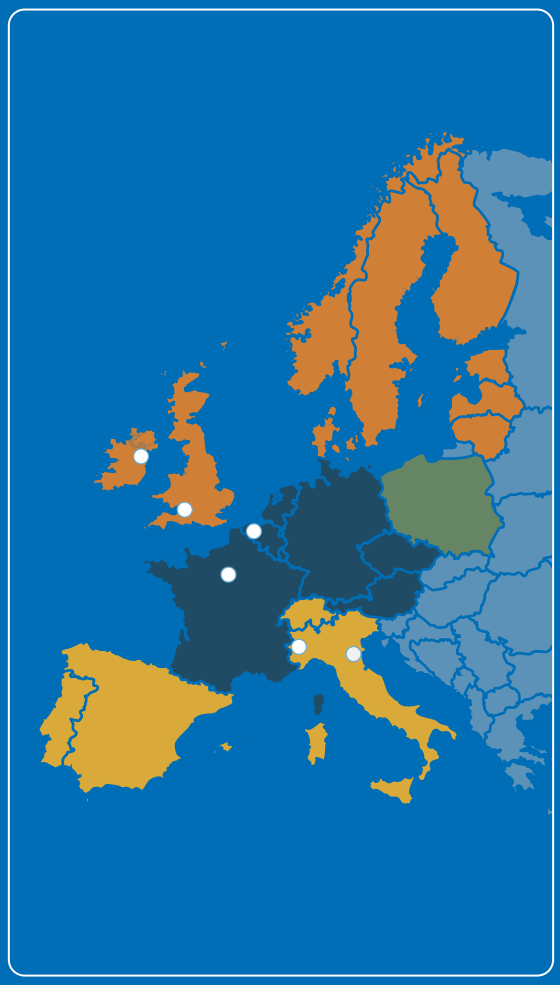
At REGENESIS we are driven by a strong sense of responsibility to the people charged with managing the complex environmental problems we encounter and to the people involved in developing and implementing our technology-based solutions. We are committed to investing in lasting relationships by taking time to understand the people we work with and their circumstances. We believe this is a key factor in achieving successful project outcomes.

We believe that by acting under this set of values, we can work with our customers to achieve a cleaner, healthier, and more prosperous world.

We're Ready to Help You

Find the Right Solution For Your Site





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