Fractals, Chaos… and Groundwater?

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Fractals and chaos have numerous practical applications, ranging from computer animation, in which fractals make realistic-looking landscapes, to the design of fighter jets, where chaos allows rapid response to pilot commands. Fractals are self-similar structures whose geometric dimension falls between the integer values of 0 (points), 1 (lines), 2 (planes), and 3 (solids). Chaos is the idea that sensitive dependence on initial conditions can render deterministic systems—those without randomness—as completely unpredictable. But how do fractals and chaos relate to groundwater?

Groundwater, found in soils and aquifers, represents 99% of the world's supply of liquid fresh water. It is therefore a crucial component of our water supply, especially in arid states like Colorado. Unfortunately, gravity means that pollution often finds its way into groundwater, necessitating the art, science, and multi-billion dollar business of groundwater remediation. This talk will describe two related studies that address fundamental technical problems in groundwater remediation using fractals and chaos:

- **CLOGGING:** Groundwater remediation can alter the structure of fine particles, mineral precipitates, or microbial communities in soils and aquifers, which can cause significant clogging—by factors up to 1000. Clogging makes it difficult or impossible to operate groundwater remediation as an optimized system. To address this problem, this study aims to quantify the structure of fine particles in the pore space as a fractal dimension, using laser scattering in transparent porous media. The goal of this work is to test whether deposit fractal dimension can serve as a simplifying variable, to summarize how clogging depends on chemical and physical effects, and as a metric to optimize chemical additives and well hydraulics used in groundwater remediation.

- **PLUME SPREADING:** The lack of turbulent mixing soils and aquifers makes it difficult to blend chemical additives, which is why the National Research Council has observed that groundwater remediation reactions are usually confined to a narrow interface zone between the injected additives and the contaminated groundwater. This study uses a key result from the literature on fluid mechanics: Mixing in laminar flow can be optimized by designing chaotic flows. The goal if this work, in collaboration with Boulder's Roseanna Neupauer and Amy Piscopo, is to take the literature on fluid mechanics and turn it into an engineered sequence of injections and extractions at wells that, it is hoped, will provide a new paradigm for the hydraulics of groundwater remediation.

Details on both studies are available at http://carbon.ucdenver.edu/~dmays.