Review of Tracer Use in the
Newberry Volcano EGS Demonstration Project

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I have been asked to provide a review and assessment of the tracers that are planned to be used in the Newberry Volcano EGS Demonstration Project. I am a Professor Emeritus of Hydrologic Sciences, University of Nevada, Reno (UNR), and President of Wheatcraft & Associates, Ltd. During my career at UNR and at the Desert Research Institute, I taught and conducted research in the area of groundwater hydrology, specializing in groundwater contamination. I have more than 35 years of experience in this area, with more than $20 million dollars of funded research, primarily from the National Science Foundation, the Department of Energy and the U.S. Environmental Protection Agency. I was selected by the National Groundwater Association to the 1990 Henry Darcy Distinguished Lecturer. I delivered my Darcy Lecture at more than 35 universities and government laboratories in the U.S., and internationally. I have conducted groundwater contamination studies all over the world, including the Nevada Test Site, Enewetak and Bikini Atolls, Hawaii, Amchitka Island, just to name a few. In recent years, I have conducted groundwater contamination studies at the Semipalatinsk Nuclear Test Site in Kazakhstan, by invitation of the Kazak government. I have used groundwater tracers in many of the projects I have been directly involved in, and I have evaluated groundwater tracer tests in many places all over the world. I do not work for or with AltaRock Energy and have had no previous association with AltaRock or any of their employees.

The tracers that are planned for use in the Newberry Project fall into three categories: naphthalene sulfonates, fluorescent dyes and salts. I will discuss each of these tracer categories in separate sections below.

Naphthalene Sulfonates

Naphthalene Sulfonates were developed in the 1990s to provide a safe and non-toxic tracer for high-temperature geothermal applications. Toxicity studies in a peer-reviewed journal showed that this class of chemicals are neither carcinogenic nor mutagenic (Greim et al., 1994). They have been used in the field in actual geothermal tracer tests many times over the past twenty years. Several of these tests have been reported on in peer-reviewed journal articles (Rose et. al., 2001; Rose et. al., 2003). Naphthalene Sulfonates are non-toxic enough that they could be used in relatively large concentrations. However, because of their fluorescent properties, they can be detected with fluorescent detection methods in concentrations as low as 100 parts per trillion. The plan at the Newberry Project is to use them in very low concentrations. Naphthalene Sulfonates have clearly been shown to be environmentally safe and a stable tracer for high-temperature

applications and will not pose any threat to the geothermal waters, nor to any potable water sources.

Fluorescent Dyes

In this category, I include Rhodamine WT and fluorescein. Both of these fluorescent dyes are extremely common tracers, used in groundwater and surface water tracer studies. Both of these chemicals are so safe and non-toxic that they are often used in concentrations high enough that the dye color is visible to the unaided eye, in other words, they are visible tracers. However, both are easily detectible in very low concentrations by fluorescent detection methods. The Newberry Project intends to use them in very low concentrations (less than 100 parts per billion).

Salts

In this category, I include lithium iodide, cesium iodide and rubidium iodide. All three of these compounds are common groundwater tracers that Newberry plans to use in very low concentrations. Lithium iodide has an LD50 of 1,800 mg/kg. At Newberry this tracer will be injected at a concentration that will produce concentrations in the 100 μg/kg, which is more than 10,000 lower than the LD50 concentration. Cesium iodide has an LD50 of 2,386 mg/kg. Planned production concentrations are in the 100 μg/kg, similar to lithium bromide, and also more than 10,000 times lower than the LD50. Similarly, rubidium iodide has an LD50 of 4,708 mg/kg with planned production concentrations in the 100 μg/kg range, also more than 10,000 times lower than the LD50. In summary all three of these tracers are commonly used in groundwater studies and the planned production concentrations are thousands of times lower than any toxicity concerns.

Although Newberry originally planned to use Safranin T as a tracer, it has since been excluded and so needs no further discussion.

References

Greim et al., (1994) Toxicity and Ecotoxicity of Sulfonic Acids: Structure-Activity Relationship: Chemosphere, **28(12)**, 2203-2236.

Rose, P.E., Benoit, W.R., and Kilbourn, P.M., (2001), The application of the polyaromatic sulfonates as tracers in geothermal reservoirs: Geothermics, 30(6), pp. 617-640.

Rose, P.E., Mella, M., and Kasteler, C., (2003) A new tracer for use in liquid-dominated, high-temperature geothermal reservoirs: GRC Transactions, 27, pp. 403-406.