Proposal to Implement a Dye Tracer Test near Malad Gorge Springs

By Neal Farmer IDWR

Background and Objective:

Two previous groundwater tracer tests were performed at the Malad Gorge State Park picnic area well to trace groundwater flow paths and determine other aquifer characteristics earlier in 2009. This test is an extension of the previous tests and builds upon the knowledge gained to refine methods and expand the scale from 1,000 feet distance for the 'Park Test' to 3,000 feet distance using a domestic supply well located southeast of the Gorge (Figure 1). The owner is has been contacted, informed of the details of the test and is agreeable to allowing two dye traces be performed using his well. 'Phase One' will use Fluorescein dye and charcoal packets placed at monitoring locations while 'Phase Two' will use Rhodamine WT dye and use a 'SCUFA' instrument to record dye concentrations in the spring with the highest dye discharge determined from Phase One.

The type of tracer selected for a tracer test is dependent on many factors. One such factor includes the purpose of the study. For example, if information such as the velocity of the ground water, porosity, and the dispersion coefficient are of interest, then a conservative tracer should be used such as dyes in conduit and highly porous formations. Other factors include type of medium (clay verses basalt), available funds, the stability of the tracer, detectability of tracer, difficulty of sampling and analysis (availability of tracer, ease of sampling and availability of technology for analysis), physical/chemical/biological properties of tracer and public health considerations (Davis et. al., 1985).

Various components go into the design of a tracer test. For the previous tracer test, the following elements were considered and evaluated: the conceptual design, down gradient receptors such as humans, aquaculture industry and endangered species, transient hydrologic barriers such as canal recharge, selection of initial mass of tracer or its concentration, observation wells, sampling schedule and locations, and monitoring. Safety of both Fluorescein and Rhodamine WT is documented from scientific studies over the past 50 years. The EPA approves both of these dyes to be used in public drinking water supplies and notes them as "non-toxic" (see appendix of reference sources) and conforms to the ANSI/NSF Standard 60 for potable water as set forth by the EPA in the Clean Water Act. The FDA has approved the use of Fluorescein in 'over the counter' consumer products.

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CERTIFIED TO MEET EPA STANDARDS

BRIGHT DYES

This is a Certification that these products conform to the ANSI/NSF Standard 60 for potable water as set forth by the EPA in The Clean Water Act.

NSF

* Official Listing as Certified by NSF detailed on back of certification

<u>Location and Site Conditions</u>

The legal location is Range 13E, Township 6S, section 36, SW ¼ of the NE ¼ Gooding County (Figure 1). Use of both Fluorescein and Rhodamine WT as a tracer is appropriate for this type of geology that exhibits fracture and conduit flow characteristics with high flow velocities and no sediments. The well targeted for dye release is noted in Figure 1 as the “Riddle” well as shown (central lower right side) with a green circle. As with previous tests, the pump will be turned off for 2-3 days after dye release which is also agreeable to the well owner. At least 20 sample locations will be established in the gorge are shown with the labels MG # at points of spring discharge and a one at the Idaho Power Diversion. All of these sites will be monitored with charcoal packets for Phase One of the test. It is about 3,000 feet between the well and the springs in the Gorge and there are no wells in between the dye release well and the springs except the Malad Gorge picnic area well which will be monitored and tested for dye. The closest domestic well to the east is 1,500 feet upgradient and the two domestic wells to the west are cross gradient.

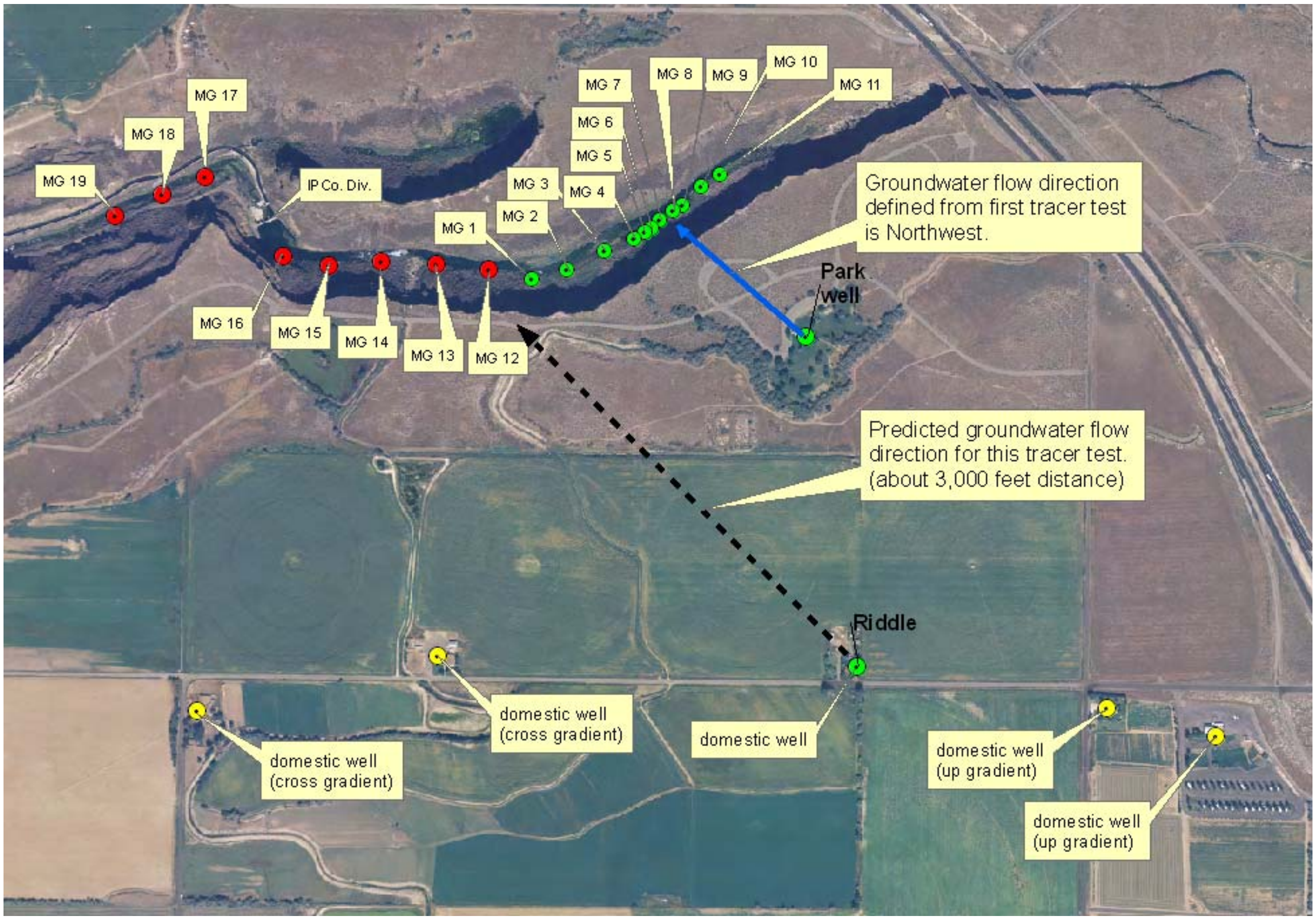

Figure 1. Location map for the second groundwater tracer test at Malad Gorge State Park. All sites with green and red circles will be sampled for the test. The yellow circles denote locations of cross gradient and up gradient domestic supply wells. The black dashed line is the anticipated groundwater flow path direction. The blue line is the groundwater flow direction defined by a previous tracer test. There are no wells in between the dye release well labeled Riddle and the springs in the gorge.

Geologic Conditions and Subsurface Conceptual Flow Model

Water flows along the path of least resistance (high hydraulic conductivity) and the highest flows are expected to be through basalt contact zones with possible 'conduit' type of flow path characteristics. In tandem but at a slower rate, water will also flow both vertically and horizontally through fractures in the massive portion of the basalt from the overlying flow contact zone and diffuse into the low permeability pore spaces. Approximate horizontal groundwater flow velocities are inferred from a previous tracer test in the Malad Gorge State Park well. The total project time period is expected to last one month from start to finish of both Phase One and Two.

The well drilling report shows open borehole (6-inch) with no casing below 198 feet and there is broken basalt within the saturated zone of the aquifer from 210-230 feet (Figure 2). Water level in the well on April 16, 2008 was 178.1 feet below land surface but the dye will be released into the upper level of the broken basalt at 210 feet below land surface. Figure 3 shows the conceptual 2-D model for conditions and dye transport to the springs and river.

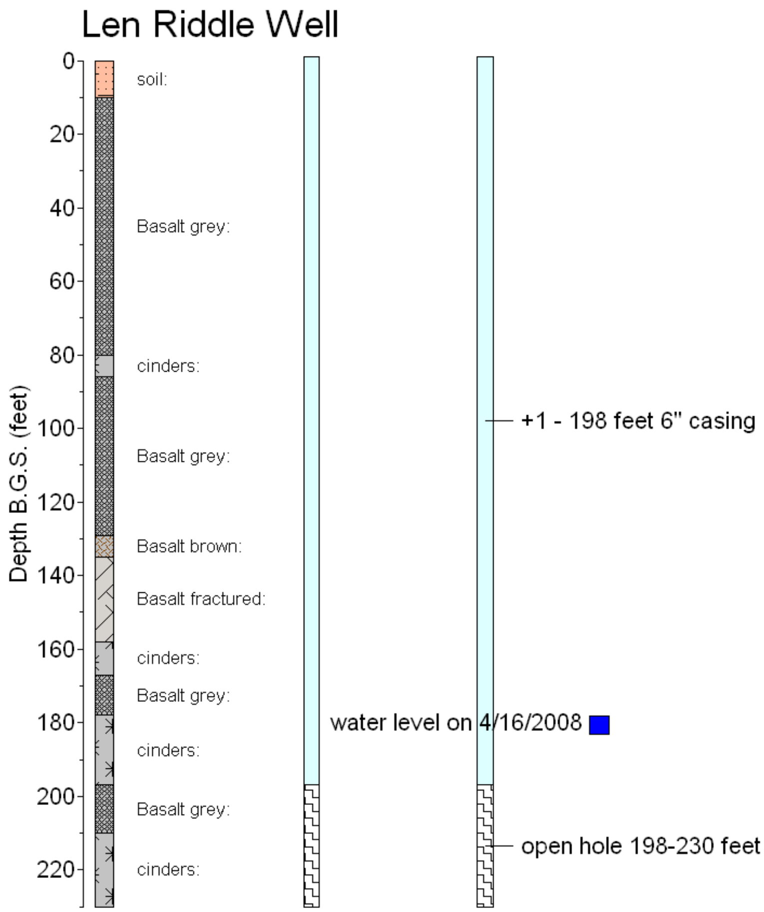

Figure 2. Geology and well construction for the Riddle dye release well. Dye will be released at 210 feet below ground surface through polyethylene tubing.

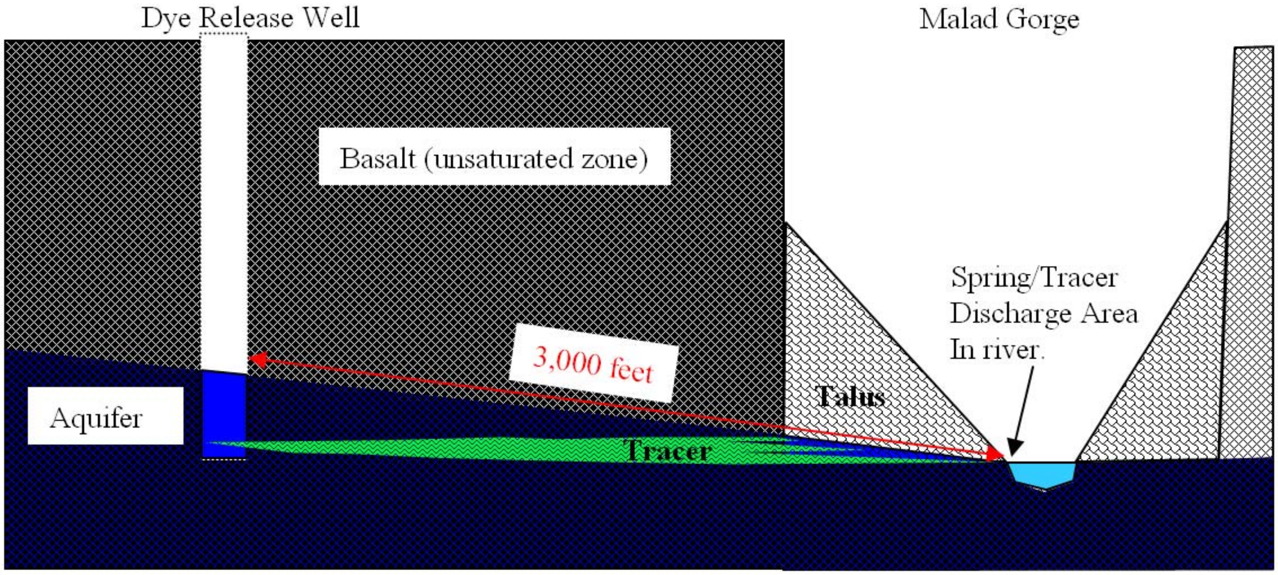

Figure 3. Conceptual 2-D cross section model of the tracer test from the Riddle well to Malad Gorge.

PHASE ONE (Fluorescein with charcoal packets)

Phase One of the project will entail deploying charcoal packets at all of the sample site locations noted in Figure one which will be 20 sites in the Gorge and the Malad Gorge picnic area well. The packets will be retrieved and replaced with fresh packets on a weekly basis until the dye has passed through the system. Water samples will also be collected at each location and frequency and analyzed along with the packets for presence and concentration of dye. Charcoal packets continuously absorb dye as it flows by in the spring water building concentrations in the charcoal as more time elapses even if the water concentration actually decreases. A charcoal packet will be placed near the inlet pipe from the well within the storage tank at the Malad Gorge picnic well and water samples collected too.

Then, 3 pounds of Fluorescein dye will be released at the 210 foot depth of the Riddle well. The dye release will be scheduled to occur when the resident of the house is away on vacation for at least 2 days and maybe 3 days before the pump is turned back on. When the pump is turned back on the water will be tested on site for the presence of dye and the well purged until levels are reduced to below 0.1 ppb. The goal is maintain dye concentrations below 10 ppb in the Malad Gorge picnic well and 100 ppb the springs in the Gorge. Once the dye enters the river it is anticipated it will be below detection limits of the instruments. After the test is over the well will be tested for bacteria by Malad Gorge State Park staff and can be disinfected if necessary. Bacteria were absent in the well water after the last test was completed based on lab analysis.

IDWR staff will analyze water samples and charcoal packets collected from the wells and springs both in the lab calibrated lab fluorometer model TD-700 made by Turner Designs and using a calibrated onsite SCUFA. All water samples will be retained and stored in a refrigerator until the test is completed. QA/QC will be attained by calibrating both field and lab instruments with standards according to the manufactures guidelines and USGS protocol (Wilson et al, 1986). Date analysis and report writing will be performed at the end of the test discussing and describing the results and recommendations for future actions. Copies will be made available.

The Malad Gorge picnic area well can still be used during this trace but the timing of the test will be attempted so that if and when the dye cloud passes by the well it will also correspond to when the well is used or needed least thereby reducing the effects of pumping on the dye movement. It is not anticipated that the dye will flow into the park well because of the offset in geographic position relative the flow paths and the low cone of depression from the short use cycles by the park well in combination with the very high hydraulic conductivity which reduces expansion of the capture zone. The capture zone of this well can only be modeled with a transient flow model, documented hydraulic conductivity and knowledge of the pump cycle frequency, duration and discharge rates. When the Malad Gorge well is turned back on water samples will be tested on site and the well purged until concentration levels are below 0.1 ppb.

PHASE TWO (Rhodamine WT with SCUFA instrument)

The charcoal packet data will not provide an adequate time of travel for calculating the groundwater velocity thus a second test is proposed to release Rhodamine WT dye under the same conditions as the previous test to define the groundwater flow velocity. A determination will be made from Phase One as to the main groundwater flow path based on the highest concentration of dye from charcoal packets and water samples. Then a second test will be implemented using 2 pounds of Rhodamine WT with an in-situ fluorometer placed (Turner Designs SCUFA) at this location which will provide the travel time of the dye and groundwater flow velocity. The Malad Gorge picnic area well will be sampled on a weekly basis as before using both charcoal packets and water samples if dye from the first test is detected in this well. Once again the same procedure will be implemented in regards to the dye release well by not using the pump for several days and sampling the water when the pump is turned back on and purged until concentrations are reduced to 0.1 ppb levels. Once the dye enters the river it is anticipated it will be below detection limits of the instruments. After the test is over the well will be tested for bacteria by Malad Gorge State Park staff and can be disinfected if necessary. Bacteria were absent in the well water after the last test was completed based on lab analysis.

Rhodamine WT is certified by ANSI/NSF for Standard 60 potable water and approved by the EPA as noted by a copy of the certification located in the appendix for use in surface water streams up to 100 ppb. There are no public drinking water intakes in the Malad Gorge River or in the Snake River in this general area. The test will be designed with the goal of a maximum Rhodamine WT resurgent concentration of 100 ppb from the springs.

IDWR staff will analyze water samples and charcoal packets collected from the wells and springs both in the lab calibrated lab fluorometer model TD-700 made by Turner Designs and using a calibrated onsite SCUFA. All water samples will be retained and stored in a refrigerator until the test is completed. QA/QC will be attained by calibrating both field and lab instruments with standards according to the manufactures guidelines and USGS protocol (Wilson et al, 1986). Date analysis and report writing will be performed at the end of the test discussing and describing the results and recommendations for future actions. Copies will be made available.

FLUOROMETRIC FACTS

Bulletin No. 104 Fluorescent Tracer Dyes

Rhodamine WT has been approved as a tracer dye in potable water in the United States (1).

Rhodamine WT is related to rhodamine B, a tracer in common use in the 1960s. It was developed to overcome a disadvantage of rhodamine B, absorption on suspended sediment. The same modification was expected to reduce toxicity, and limited testing bore this out.

Rhodamine WT was an immediate success as a tracer in marine systems and in wastewater. While it was also used in potable water, such use was occasionally forbidden on the grounds that it did not have formal Federal approval for such use. Rhodamine WT is now approved for such use. A brief history follows.

While the EPA has sole responsibility for identifying those substances which may be used a tracers (2), the Food and Drug Administration (FDA) does issue policy statements. The FDA did issue such a policy statement on 22 April 1966 concerning rhodamine B (3). A temporary tolerance limit for ingestion of rhodamine B was set at 0.75 mg per day. Based on normally expensed water consumption, the tolerance would not be exceeded unless the concentration approaches 370 parts per billion (PPB). Noting that 30 PPB may be detected visually in a glass of water, and 10 PPB is visible in larger volume such as a clear reservoir, the FDA pointed out that if the dye is not visible, the tolerance would not be exceeded. The USGS, a large user of fluorescent dye tracers, directed that the concentration should not exceed 10 PPB at the intake of a water supply (4). The visual and instrumental detectability of rhodamine WT, based on active ingredient, is about the same as rhodamine B (rhodamine WT is supplied as a 20% aqueous solution).

Ten parts per billion may not sound like much to the uninitiated, but it is a thousand times the limit of detectability guaranteed by Turner Designs on its Model 10 Series Fluorometers (5). Background fluorescence caused by fluorescent materials in the water being studied usually limits detectability. But even so, measurements can be made to 0.1 part per billion of rhodamine WT (active ingredient), in raw sewage!

On April 10, 1980, Dr. Joseph A. Cotruvo of the U.S. EPA issued a memo stating that the EPA considers rhodamine WT to be equivalent to rhodamine B (1). More recently, the following policy letter was sent to Crompton and Knowles:

United States Environmental Protection Agency
Washington, D.C. 20460
Aug 2 1988

Office of Water Ms. Janice Warnquist Chemical Safety Manager
Crompton and Knowles Corporation

P.O. Box 341 (500 Pear Street)
Reading, Pennsylvania 19603

Dear Ms. Warnquist:

The Criteria and Standards Division (Office of Drinking Water) has reviewed the available data on chemistry and toxicity of Rhodamine dyes. We would not anticipate any adverse health effects resulting from the use of Rhodamine WT as a fluorescent tracer in water flow studies when used with the following guidelines.

-A maximum concentration of 100 micrograms/liter Rhodamine WT is recommended for addition to raw water in hydrological studies involving surface and ground waters.

-Dye concentration should be limited to 10 micrograms/liter in raw water when used as a tracer in or around drinking water intakes.

-Concentration in drinking water should not exceed 0.1 micrograms/liter. Studies which result in actual human exposure to the dye via drinking water must be brief and infrequent. This level is not acceptable for chronic human exposure.

-In all of the above cases, the actual concentration used should not exceed the amount required for reasonably certain detection of the dye as required to accomplish the intended purpose of the study.

The Criteria and Standards Division recommends that Rhodamine B not be used as a tracer dye in water flow studies.

This advisory supersedes all earlier advisories issued by EPA on the use of fluorescent dyes as tracers in water flow studies. This advisory is granted on a temporary basis only.

EPA is terminating its voluntary additives advisory program as announced in the Federal Register (53 FR, 25586, July 7, 1988). A copy of the Federal Register Notice is enclosed for your convenience. All EPA advisory opinions issued within the framework of the additives program will expire on April 7, 1990.

Our opinion concerning the safety of this tracer dye does not constitute an endorsement, nor does it relate to its effectiveness for the intended use. If this letter is to be used in any way, we require it to be quoted in its entirety.

Sincerely,

Arthur H. Perler, Chief Science
and Technology Branch Criteria
and Standards Division

Enclosure

REFERENCES

1. Cotruvo, J. A., RHODAMINE WT AND B, Memo to P. J. Traina, dated April 10, 1980

2. Letter from A. D. Laumback, FDA, to George Turner, dated 7 June 1977

3. POLICY STATEMENT ON USE OF RHODAMINE B DYE AS A TRACER IN WATER FLOW STUDIES, Department of Health, Education and Welfare, dated 22 April 1966

4. Kilpatrick, F. A., DOSAGE REQUIREMENTS FOR SLUG INJECTIONS OF RHODAMINE BA AND WT DYES, U. S. Geological Survey, Prof. Pater 700-B, B250-253 (1970)

5. FIELD FLUOROMETRY, Monograph available at no charge from Turner Designs

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Biological Considerations

Fluorescein and Rhodamine WT have very low toxicity, biologically degrades and photo degrades when exposed to ultraviolet light. A literature search (see appendix) has been made to ensure that biological risks to humans (Field et al, 1995, Smart 1984), human food sources, and aquatic species such as fish, snails and Daphnia are taken into consideration for the test design and there is no known adverse effects anticipated given the project design. Dye tracing has been performed at locations with endangered species (snails and shellfish), human food sources (trout farms), and salmon spawning beds for over half a century with the approval of the U.S. Fish and Wildlife Service, state agencies and other private and non-profit organizations (Aley, 2008).

Human

Human health and safety are addressed in partial from the MSDS sheets provided in the appendices. The dye is EPA certified to conform to the ANSI/NSF Standard 60 for use in potable public water supplies as set forth by the Clean Water Act (see a copy of the certification in the appendices) and maximum concentrations in surface water at 100 ppb. EPA (1995) states clearly that Rhodamine WT should not exceed 1,000 – 2,000 ppb at the point of groundwater discharge and it would not present an acute toxic threat at or substantially above the recommended 2,000 ppb concentration. Smart (1984) states “Persistent dye concentrations in tracer studies should not cause problems provided they are below 100 ppb”.   After the test, the pump will be turned on and the system flushed until the water is colorless. The water will be tested for residual dye and continued flushing until levels drop to 0.1 ppb. The resurgent concentrations from the springs and in the river will not be a risk to humans since there is no consumption of this water by humans.

Snails

Endangered and non-endangered snails were considered by seeking professional recommendations and information. Tom Aley has performed numerous dye tracer tests at locations where endangered snails are present with the blessing of the U.S. Fish and Wildlife Service (Aley, 2008). A literature search was performed and numerous snail experts contacted about the potential risk. The USGS in 1973 conducted a study which exposed oyster eggs and larvae to Rhodamine WT with no abnormal growth observed. The MSDS documents “no developmental abnormalities or toxicity to oyster larvae at 100,000 ppb” which is an extremely high concentration. Dr. John Stark, who is the director and a professor at Washington State University, stated in regards to snails that Fluorescein should not pose a problem to snails if the concentration is below 300.0 ppm. Rhodamine is in the same family of dyes with similar characteristics. John Stark is an ecotoxicologist who specializes in ecological risk assessment of threatened and endangered species (see Daphnia section below).

Fish

Two potential issues, native or indigenous populations and commercial production are addressed in regards to fish. The MSDS documents that the LC50 for Rainbow Trout at 96 hours of 320,000 ppb which is an extremely high concentration. Dye tracing has been approved by federal regulatory agencies (EPA, 1995) and performed in streams and rivers for over half a century at locations that include sensitive environments and endangered species such as in Salmon spawning beds with no problems or issues (Aley, 2008). A USGS study in 1973 exposed trout and salmon smolts to Rhodamine WT at a concentration of 10,000 ppb for 17.5 hours then increased the concentration to 375,000 for an additional 3.5 hours with no ill effects to the trout or salmon. The fish remained healthy in dye free water a month after the test was completed. Resurgent dye concentrations are expected to be very low ranging from 0.1-100 ppb from the springs and diluted after mixing with additional river water near the spring area above the upper IPCo. diversion structure. Even more dilution will occur downstream from more spring discharge into the river where it is anticipated concentrations of dye will be at or below the minimum detection limits. The endemic species of Shoshone Sculpin are present in the lower Malad River below the Highway 30 Bridge (Bowler, 1992 and personal communication with Malad Gorge staff, 2008). The dye is expected to be below detection limits by the time it flows through this section from the effects of dilution, biological degradation, ultraviolet light degradation, and absorption onto concrete and rock substrate.

Daphnia

Daphnia are small, planktonic crustaceans, between .2 and 5 mm in length (Figure 5). *Daphnia* are members of the order Cladocera, and are one of the several small aquatic crustaceans commonly called water fleas because of their saltatory swimming style (although fleas are insects and thus only very distantly related). They live in various aquatic environments ranging from acidic swamps to freshwater lakes, ponds, streams and rivers (Wikipedia, 2008).

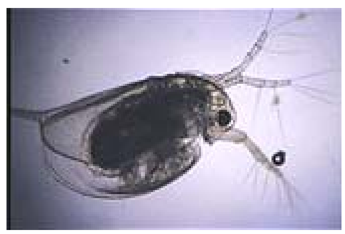

Figure 5. Photo of Daphnia crustacean (Wikipedia, 2008).

The MSDS documents the LC50 for Daphnia Magna at 170,000 ppb which is an extremely high concentration. Dr. John Stark was contacted by IDWR staff (personal communication) and discussed the risk of Fluorescein dye to both snails and Daphnia. Although this test will use Rhodamine WT, it is still in the same family of dyes with similar low risk factors and therefore useful to compare. Dr. Stark is an ecotoxicologist who specializes in ecological risk assessment of threatened and endangered species. He runs the WSU Salmon toxicology research laboratory and has recently started work on the effects of pesticides on endangered butterfly species. Stark is also a population modeler and has developed population-level risk assessments based on matrix models and differential equation models.

John D. Stark
Director, WSU Puyallup Research & Extension Center
and Professor, Ecotoxicology Program
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Puyallup, WA 98371-4998
http://entomology.wsu.edu/Profiles/stark.html

Phone: (253) 445-4519
E-Mail: starkj@wsu.edu

Dr. Stark provided a professional paper (Walthall and Stark, 1999) that addresses the risk of dyes to Daphnia and the research paper concluded there is little or no issues with Fluorescein dye concentrations below 337 (278±403) mg/liter (ppm) and the resurgent dye concentration is expected to be several orders of magnitude less in concentration within the range of 0.1-100 ppb.

Appendix of Information Used for Proposed Implementation

1. List of References
2. Certification of Approval for use in Potable Water & Safety Reference
3. Material Safety Data Sheet for Rhodamine WT
4. Flourometric Facts Bulletin – Rhodamine WT
5. Technical Data Bulletins
6. USGS Report (title page only) “Fluorometric Procedures for Dye Tracing”
7. Groundwater Tracing Handbook by Thomas Aley
8. Reference: Groundwater Tracer Tests at Hagerman Fossil Beds N.M. 2001
9. Reference: Hydrologic Study of the Deer Gulch Basalt 2005
10. Reference: Tracer Tests in Columbia River Basalts 1998
11. Resume of Thomas Aley – author of Groundwater Tracing Handbook by Ozark Underground Laboratory.
12. USGS Rhodamine WT Reader Information Sources