Date: March 2, 2004

Subject: Human Health Risk Assessment for the Diamond Lake Restoration Project

To: Sherri Chambers, IDT leader

Introduction

The Umpqua National Forest, in cooperation with multiple state and federal agencies, proposes to use two formulations of the fish toxicant, rotenone, to eradicate unwanted tui chub fish in Diamond Lake. This action is proposed in order to improve both water quality and the trout fishery which have been substantially diminished due to the tui chub population. These rotenone formulations would be applied under two of the four alternatives assessed in the Diamond Lake Restoration Environmental Impact Statement (EIS). This report addresses the risks to human health associated with the use of rotenone which is included only under Alternatives 2 and 3 of the EIS. The risks to human health associated with Alternative 1 (no action) and Alternative 4 (mechanical removal of tui chub) are analyzed in a separate report (Kann, 2003).

Under both Alternatives 2 and 3, the powdered formulation of rotenone, known by its brand name, Pro-Noxfish®, would be applied to Diamond Lake in September when water volume, temperature and chemistry reach conditions considered optimal for achieving a complete fish kill within the lake. Pro-Noxfish® would be administered according to label instructions to reach a target concentration of between 0.025 and 0.10 parts per million (once thoroughly mixed in the lake). For example, based on a predicted water volume of 48,000 acre-feet following the draw down of the lake, mean temperature and pH observed in Diamond Lake in September, and a treatment concentration of 0.10 ppm[1] (the high end of the target concentration range), it is estimated that about 260,000 pounds of powdered Pro-Noxfish® would be needed to eradicate the tui chub population.

Also under Alternatives 2 and 3, the liquid rotenone formulation, known by its brand name, Noxfish®[2], would be applied to two fish-bearing streams that feed into Diamond Lake in September. This product would be applied to attain a target treatment concentration of about 0.10 ppm, once mixed in the stream. It would be applied at drip stations in Silent and Short Creeks located on the south end of the lake (Figure 1). Drip stations would be operated for approximately 17 days in these two creeks where approximately 375 gallons of Noxfish rotenone would be dispensed into the creeks within drawn down area of the lake.

[1] This treatment concentration would be met by applying 2 ppm of the Pro-Noxfish rotenone formulation (Finlayson et al. 2000).

[2] Finlayson et al. (2000) state that liquid rotenone is the only effective formulation of rotenone for treating flowing waters. Noxfish® is the recommended liquid rotenone product for use at Diamond Lake because it *does not* contain Piperonyl Butoxide, an additive in some liquid products that may persist in treated water for several months.

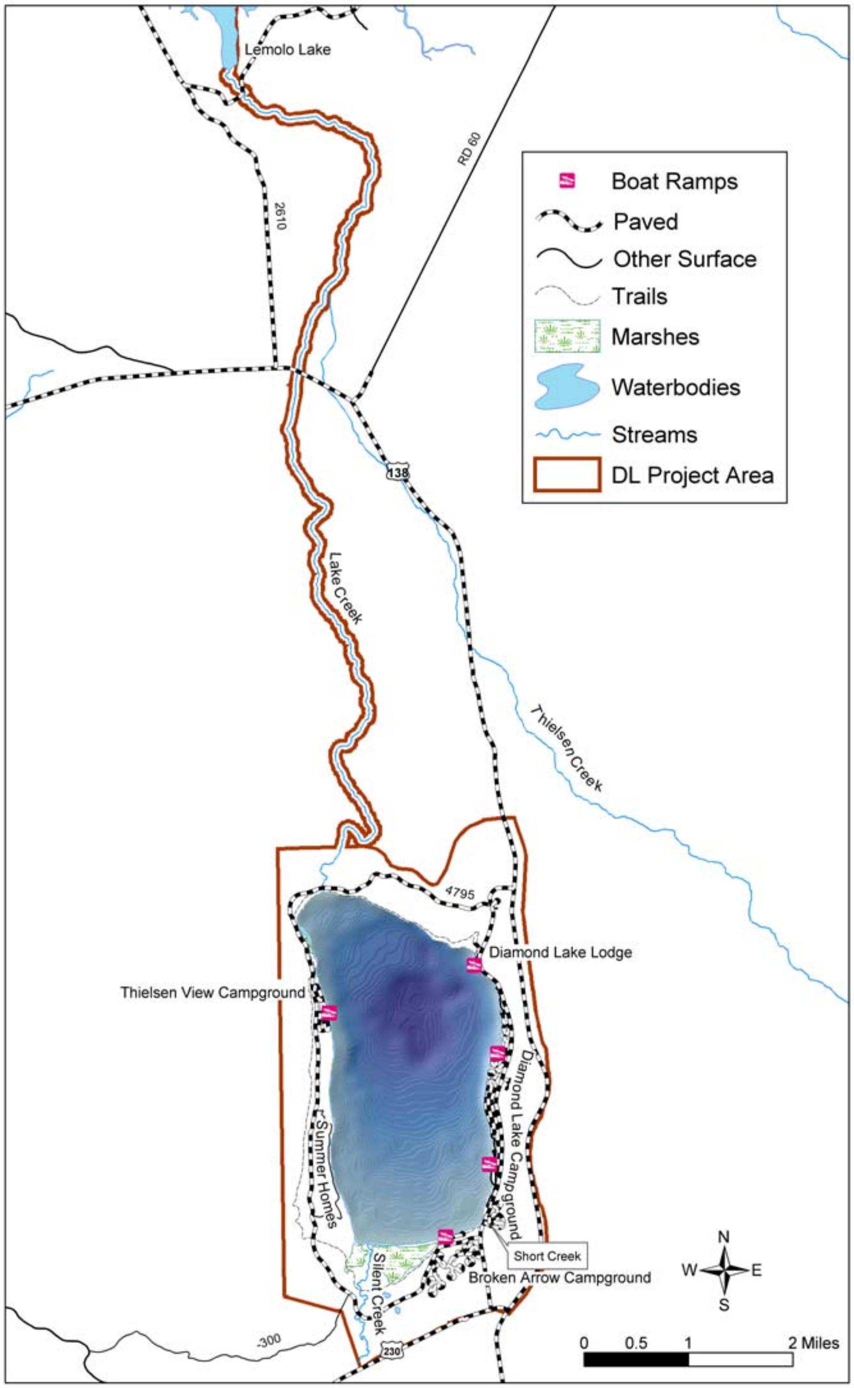

Figure 1. The Diamond Lake Restoration Project Area.

The following site specific mitigation measures have been incorporated into Alternatives 2 and 3 in order to lessen any human health risk associated with implementation of either alternative.

1. Rotenone would be stored at three operational sites: the north end dock facilities, Mt. Thielsen Campground and Broken Arrow Campground where security would be provided 24 hours/day at each site while rotenone is present on site. Rotenone would be stored in the delivery trucks. Enough potassium permanganate (rotenone neutralizer) to neutralize the largest container of rotenone would also be stored on site.

2. Certified pesticide applicators would be responsible for all phases of rotenone application.

3. The two outlets of the lake (Lake Creek and the reconstructed channel) would be closed and locked using control gates so treated water would not escape down the reconstructed canal or Lake Creek.

4. Diamond Lake would be closed to the public during the rotenone application period and only reopened when safety concerns were eliminated. Reopening will be determined by continual monitoring of the assessment wells, the lake water, and the water in lower Lake Creek.

5. The summer home residents who use wells that tap the shallow aquifer (those than 100 feet deep) for domestic water would be notified in advance and required to use the supplied bottled water if rotenone or its other ingredients are detected in the monitoring wells. Monitoring of well water would occur to determine when well use could resume.

6. Bottled water will be supplied to all potentially impacted wells along the western shore of the Lake from Thielsen View Campground to Silent Creek should a detection of rotenone or other added ingredients be detected in any of the Forest Service monitoring wells along the west shore.

7. Diamond Lake outlets (Lake Creek and the reconstructed canal) would remain closed until tests indicated that rotenone, rotenolone[3], and all semi-volatile and volatile organic compounds[4] associated with the chemical treatment had dissipated to non-detectable or trace levels in both the water column and lake bottom sediments (approximately one to two months).

8. The protective equipment listed on the labels of both rotenone formulations and potassium permanganate (should it be used to neutralize spills) would be

[3] Rotenolone is the metabolite (by product) of rotenone (Finlayson et al. 2000).

[4] The liquid rotenone formulation Noxfish® contains inert emulsifiers, solvents, and carriers that are important in ensuring the solubility and dispersion of rotenone in water. Waters treated with Noxfish® may contain rotenone, rotenolone, and volatile (xylene, trichloroethylene, toluene, and trimethylbenzene) and semi-volatile (naphthalene, 1-methyl naphthalene, and 2-methyl naphthalene) organic compounds. These volatile and semi-volatile organic compounds dissipate in treated water before rotenone and rotenolone (Finlayson et al. 2000).

used by all personnel who handle these products. This includes disposable coveralls, gloves, eye protection, face shields, nitrile gloves, and air purifying respirators. Extra amounts of cleansing water and all protective equipment and supplies will be on hand at all times during transport, storage, and application.

9. Community residences and businesses would be notified at least 72 hours prior to the application of rotenone.

10. Community residents would be informed about what they can do to minimize pesticide exposure.

11. A hot line, in cooperation with Douglas County Health Department, would be established to collect reports of any suspected pesticide-related illnesses potentially associated with the project.

12. The potassium permanganate (a rotenone neutralizer) would be kept away from any other oxidizing compounds and any flammable products such as gasoline, oil and alcohol.

13. All of the following detailed plans would be completed according to recommendations and examples provided in the "Rotenone Use in Fisheries Management: Administrative and Technical Guidelines Manual" (Finlayson et al. 2000) prior to project implementation:
    - rotenone application plan,
    - site safety plan,
    - site security plan, and
    - spill contingency plan.

Human Risk Assessment

This risk assessment examines the chance that exposures to the fish toxicant will result in impacts to human health using methodologies widely accepted by the scientific community, regulatory agencies, and the Forest Service. The potential doses of rotenone and its additives that people might receive as a result of implementing either Alternative 2 or 3 of the project are discussed. These doses are compared with doses shown to cause no observed effects in test animals and established guidelines set by the US Environmental Protection Agency (EPA), which regulates such substances.

There are three parts to the risk assessment:

1. Hazard analysis examines the toxic properties of the fish toxicants. Human hazard levels are derived primarily from the results of laboratory experiments on animals, supplemented with information from human poisoning and uncertainty safety factors.
2. Exposure analysis examines the possible exposure pathways to people, estimates any doses that may result from such exposures, and estimates the number of people in the exposed population.

3. Risk analysis combines the hazard information with the dose estimates to predict the health effects to individuals under the given conditions of exposure.

1. Hazard Analysis

Rotenone products have been classified by the US Environmental Protection Agency (EPA) as Category 1 materials which are in the "extremely toxic" range for acute (short-term) toxicity. Laboratory mammals are used to assess the levels of toxicity. The Extension Toxicology Network[5] affiliated with several prominent Universities across the United States summarized the following information from the scientific literature on rotenone toxicity in mammals (ExToxNet, 1996). In acute oral exposure studies, where large doses are fed to test animals over a short time, rotenone was found to be slightly to moderately toxic to mammals. Reported oral LD50 values range from 132 to 1500 mg/kg of body weight in rats. The LD50 is the amount of ingested material that would be lethal to the average laboratory mammal. When 50 percent of the animals in the experiment die, the average lethal dose (LD) is established. Ingested rotenone is believed to be moderately toxic to humans with an oral lethal dose estimated to be between 300 to 500 mg/kg of body weight. Human fatalities are rare perhaps because rotenone is not widely used and because its irritating action causes prompt vomiting (ExToxNet, 1996). Both the liquid and powered formulations of rotenone in their undiluted states are reported to be potentially fatal to humans if inhaled or ingested. Ingestion or inhalation can cause numbness, nausea, vomiting, and tremors.

The rotenone formulations are moderately to highly toxic when inhaled and are therefore considered more toxic when inhaled than when ingested. In rats and dogs exposed to rotenone dust, the inhalation fatal dose was uniformly smaller than the oral fatal dose. Fifty percent of female rats died when exposed to a concentration of 0.045mg/liter of air over a 4 hour period (Prentiss Incorporated, 2000b). A spray of 5% rotenone in water was fatal to a 100-pound pig when exposed to 250 mL of the airborne mixture (ExToxNet, 1996).

In chronic toxicity studies, where non-lethal doses are fed to laboratory animals over extended periods of time, rotenone has been found to have low levels of toxicity when ingested. Dogs fed rotenone for 6 months at doses up to 10mg/kg/day showed reduced food consumption and therefore weight loss. At the highest doses, blood chemistry was adversely affected possibly due to gastrointestional lesions and chronic bleeding (ExToxNet, 1996).

Rotenone formulations proposed for use in Alternatives 2 and 3 are reported to be slightly toxic to non-irritating to the skin from dermal exposure. Dermal exposure to rotenone can cause skin and eye irritation. The lethal dose to rabbits from skin absorption of the powdered formulation was greater than 2,020 mg/kg (Prentiss Incorporated, 2000a).

[5] ExToxNet is a pesticide Information project of cooperative Offices of Cornell University, Oregon State University, the University of Idaho, University of California at Davis, and the Institute for Environmental Toxicology at Michigan State University.

Other toxic effects of rotenone have also been characterized by studies with lab animals and summarized by ExToxNet (1996) and USEPA Integrated Risk Information System (IRIS) (2003). Reproductive toxicity was established in a two generation rat reproduction study conducted by the USFWS in 1983 (IRIS, 2003). Rats fed at 1.88 mg/kg/day (equal to 37.5 ppm) exhibited the lowest effect level for reproductive toxicity while rats fed 0.38 mg/kg/day (equal to 7.5 ppm) exhibited the no-observed effects level. Whether rotenone is teratogenic (causes birth defects) is not known since a feeding study of pregnant rats showed skeletal deformations in rat pups at low doses, but no deformities at higher doses. Rotenone was found not to be mutagenic (cause changes in the genetic material of cells) in treated mice and rats based on several studies at the cellular level. Most rodent studies have revealed no evidence of carcinogenic activity and the prevailing scientific opinion is that rotenone is not carcinogenic (USEPA, 1981 and 1989). USEPA last conducted a comprehensive review of rotenone in 1988 and re-registration is tentatively scheduled for 2006.

A recent study (Betarbet et al, 2000) reported that rats injected with rotenone at 2 to 3 mg/kg body weight each day in the jugular vein for 5 weeks showed symptoms similar to that of Parkinson's disease. Betarbet et al (2000) demonstrated that rotenone is an inhibitor of complex I, one of the five enzyme complexes of the inner mitochondrial membrane involved in oxidative phosphorylation. The findings of Betarbet et al have been debated in the scientific community since other chemicals were administered with the rotenone to enhance tissue penetration and other studies that used realistic exposure pathways (oral, inhalation and dermal) of rotenone have not reported such findings. Meanwhile, neurological research continues to explore the link between Parkinson's disease and pesticide exposures (such as rotenone and others). Although the exact cause of Parkinson's disease is unknown, recent epidemiological studies suggest an association with single gene mutations, toxic exposures or some combination of the two factors (Greenamyre et al, 2003). The USEPA has reviewed this study and is determining the appropriate course of action. The results of this review will help determine what next steps the USEPA will take towards the completion of the rotenone review scheduled for 2006 (USEPA 2003).

Inert Ingredients, Metabolites, and other Chemicals

Chemical manufacturers often add other ingredients to their formulations, called inert ingredients, to enhance effectiveness. The powered formulation, Pro Noxfish® that would be applied to the Lake has no added inert ingredients; it is composed simply of the ground up plant material. The liquid Noxfish® that would be applied to Short and Silent Creeks, contains inert emulsifiers, solvents, and carriers that are important in ensuring the solubility and dispersion of this liquid formulation. Water treated with Noxfish® was found to contain rotenolone (the metabolite of rotenone), and volatile organic compounds (trichloroethylene, xylene, toluene, and trimethylbenzene) and semi-volatile organic compounds (naphthalene, 1-methyl naphthalene, and 2-methyl naphthalene). These volatile and semi-volatile organic compounds naturally breakdown and dissipate in treated water before rotenone and rotenolone (Finlayson et al. 2000).

Five California rotenone projects were monitored for the fate of the compounds of powdered and liquid formulations including inerts in sediments (Finlayson et al, 2001).

Only the naphthalene and methyl naphthalene (associated with Noxfish®) temporarily accumulated in sediments, but this was for a period of less than 8 weeks. The other inert compounds in Noxfish® did not persist in sediments.

Nine California rotenone projects were monitored for the inert ingredients in Noxfish® in surface water (Finlayson et al, 2001). All ingredients were well below the minimum concentrations allowed under maximum contaminant levels (MCLs) for these ingredients in drinking water standards set by the EPA (Finlayson, 2001). Of the seven organic compounds found in Noxfish, trichloroethylene (TCE) is the only carcinogen; the rest are considered noncarcinogens. However, there are inconsistencies in the scientific literature regarding whether naphthalene is carcinogenic. Naphthalene was reported in one source as causing carcinogenic activity in rat nose tissue in an inhalation study (US National Toxicology Program, 2001). The bulk of the toxicology literature however supports that naphthalene is not carcinogenic.

Following application of Noxfish at 1 mg/L, samples collected during application into flowing water did not detect TCE (<0.5 ug/L) or xylene (<0.5 ug/L) except for one sample collected immediately below a drip station at 0.76 ug/L TCE and 0.56 ug/L xylene. Naphthalene and 2-methylnapthalene were detected at concentrations ranges of <0.5 to 57 ug/L and <2 to 50 ug/L, respectively. Table 1 displays the available human health standards set by the EPA for rotenone and other associated chemicals.

Table 1. Human Health Standards, Risk-based Safe Levels, and Detection Limits for Drinking Water

Fish Toxicant Ingredients	Maximum Contaminant Level[1] (ug/L)	Maximum Contaminant Level Goal[1] (ug/L)	Preliminary Remediation Goal[2] (ug/L)	Analytical Detection Limit (ug/L)	Analytical Method
Rotenone	Not Available	Not Available	150	50	SDWA EPA Method 553 (HPLC)
Naphthalene	Not Available	Not Available	6.2	0.5	SWDA EPA Method 524.5
Toluene	1,000	1,000	720	0.5	SWDA EPA Method 524.5
Trichloroethylene	5	Zero	0.028	0.006[3]	USEPA 8260 Mod SIM
Trimethylbenzene	Not Available	Not Available	Not Available	0.5	SWDA EPA Method 524.5
Xylene	10,000	10,000	210	0.1	USEPA 8260 Mod SIM

NOTES:
1 USEPA 2002b Based on safe drinking water standards.

2 USEPA 2002a Based on safe risk-based levels for residential tap water use.
3 Value provided is the MDL instead of the reporting limit. The reporting limit for TCE is 0.05 ug/L using EPA Method 8260 Mod GCMS-SIM.

MCL – maximum contaminate level. The highest level of a chemical allowed in drinking water. It is an enforceable level under the Safe Drinking Water Act.
PRG - preliminary remedial goal. The level of a chemical in drinking water that is not expected to cause any adverse effects for a lifetime of exposure. Lifetime exposure is based on 30 years of exposure for a child and adult drinking 1 and 2 liters, respectively.
Analytical Detection Limit. The level at which a chemical can be accurately and precisely quantified by a certain method.
SWDA – Safe Drinking Water Act. Gives EPA the authority to set drinking water standards. Used in the context of analytical methods developed under the SWDA program for monitoring water quality.
RCRA Resource Conservation and Recovery Act. Used in the context of analytical methods developed under the RCRA program for monitoring water quality.

The possible metabolites of rotenone are carbon dioxide and a more water soluble compound (rotenolone) that is excreted in the urine. Studies indicate that approximately 20 percent of applied oral doses are eliminated from the animals system within 24 hours.

Potassium permanganate is an oxidizer that would be used with this project to neutralize the rotenone formulations in the event of a spill. It has no deleterious effects at the concentrations normally associated with the neutralizing process (Finlayson et al, 2000). However in its concentrated form, it is caustic to mucous membranes in the nose and throat. The required protective clothing and breathing apparatus when handling the concentrated powder would lessen human health risks.

2. Exposure Analysis

Public Exposure Pathways at Diamond Lake

There are only two possible pathways of public exposure to the rotenone formulations proposed in this project—either eating contaminated fish or drinking contaminated water. The other possible exposure pathways, dermal exposure and inhalation exposure, would not be possible for members of the public. No dermal exposure associated with the public swimming in or wading in the treated waters is expected because access to the lake will be restricted to authorized personnel only and swimming will not be allowed until the lake is reopened. In the event swimming is not restricted, the rotenone would not be concentrated enough once it has been mixed in the lake to lead to any concerns regarding dermal exposure (Finlayson et al., 2000). Rotenone product labels state that swimming would be allowed once the product has been mixed into the water according to label instructions. Moreover, no member of the public would have access to the concentrated formulations to receive a meaningful dermal dose. Similarly, no public exposure via inhalation of either rotenone formulation is expected since the work areas where such exposures are possible would be under tight security with no public entry allowed. Airborne drift into adjacent area was found to be 1000 times less than the no observed effect level of the chemical (Finlayson et al, 2000).

It would be extremely unlikely that members of the public would have access to dead or dying fish in order to unwitting consume any contaminated fish and receive a dose of the toxicant. This is because Diamond Lake would be closed to public entry during the 2 to 3 week treatment period; public awareness of the closure would be heightened well in advance of the treatment; and because warning signs would be affectively posted throughout the area. Fish in Diamond Lake are expected to be rapidly killed by the treatment within a 2 to 3 week period. Should anglers gain access to the lake and ignore the warnings, live fish caught may contain high amounts of rotenone and dead fish caught have the risk of salmonella and other bacteriological poisonings. Most dead fish that are not collected and removed will sink to the bottom within several days, decompose, and release nutrients back into the water. No fish would be restocked into Diamond Lake until well after all toxic residues are gone.

The primary pathway for members of the public to be exposed to rotenone is by drinking well water. This pathway presents more risk than the consumption of tainted fish because the water would essentially look and smell normal a few days following the application. The water in the lake itself presents the greatest risk to potential water drinkers, while waters downstream of the lake present little to no risk of public exposure. The risk of consuming contaminated water would be prevented by supplying drinking water to well users if rotenone or other added ingredients are detected in any of the monitoring wells. Based on the groundwater transport and modeling assessment, the Forest Service monitoring wells are adequate to intercept any rotenone or other added ingredients far in advance of transfer to a domestic well.

The consumption of contaminated surface water out of Diamond Lake by visiting members of the public is unlikely given the closure to public entry, the heightened public awareness, and the warning signs that would be in place throughout the area. These mitigation measures would remain in force until all risk of exposure is eliminated.

The potential for contamination of the groundwater is lessened somewhat however, due to the strong tendency of rotenone to attach to soil particles and organic sediment such as that found in the Lake bottom. The lake sediments are expected to rapidly capture and hold the chemical, essentially "filtering" it out of the water column as the water from the lake enters the groundwater environment. The proportion of the rotenone that may actually remain in solution would be the amount available to contaminate groundwater. That proportion is estimated to be only about 10% (Breeden, 2003).

The primary concern for public consumption of tainted drinking water is associated with the domestic water users of the Diamond Lake area—primarily the users of shallow wells that service the summer homes on the west shore of the lake (Figure 1). A study conducted by the Forest Service of the potential for groundwater contamination was done for this project (Breeden, 2003). A total of 16 monitoring wells were installed to investigate groundwater movements around the lake (see

Figure 1). The study showed that the shallow aquifer on the north and northwest shores of Diamond Lake, which supplies most of the domestic wells in that area, can be expected to receive groundwater originating from the Lake during the fall and winter months. If treated water from the lake does in fact enter the shallow aquifer that supplies the west shore domestic users, then health risk could potentially exist for as long as 8 weeks or until the toxicant fully breaks down.

There are 102 summer homes located on west shore of Diamond Lake (Figure 2) and all but about 20 are serviced by wells tapped into the shallow aquifer that is susceptible to contamination from treated lake water. Those summer home wells not at risk, are the deeper wells, typically greater than 60 to 100 feet deep that tap into the deep aquifer. The Forest Service Thielsen View campground, also located on the west shore of Diamond Lake (with 60 camp sites), is also serviced by a well located in the shallow aquifer where contamination from the lake is possible. The Oregon Department of Fish and Wildlife maintains a small work facility at the Lake Creek outlet. The drinking water for this facility comes from Lake Creek which will be dry during the period of concern so no exposure from the drinking water at this location is possible.

The above exposure concerns associated with well contamination have been addressed as mitigation measures in both Alternatives 2 and 3 that propose rotenone use. During the months of September and October of the treatment year, the Forest Service Thielsen View campground would be closed and the well shut down to render this well water inaccessible until all danger of public consumption is gone. Drinking water for the ODFW work facility will be supplied from bottled water. Monitoring of the two Forest Service monitoring wells located near the summer homes would be on-going through the life of the project to assess whether drinking water wells are being impacted by rotenone or other inert ingredients.

Most of the 102 summer homes would have limited occupancy given the fact that they are all second homes and due to the inconvenience of needing to use alternative water supplies during this period. The biggest concern for public consumption of contaminated well water would be from west shore domestic users whose wells are less than 100 feet deep that might choose to ignore the Federal order listed in the code of the Federal Register[6] (CFR) to cease use of their wells. The number of people who may potentially be exposed to rotenone from drinking out of contaminated wells might be anywhere from 1 to 100 people.

In contrast, domestic water users on the east shore of Diamond Lake are not at risk of consuming tainted water. These users include campers at the Forest Service Diamond Lake campground (with 240 camp sites) and Broken Arrow campground (with 140 camp sites), the Diamond Lake Lodge, the South Shore Pizza Parlor, and all the associated visitors and residents of those facilities. The east shore domestic water users receive water from snow-melt springs by Two Bear Creek, located well above the elevation of the lake where rotenone contamination is impossible. The two large Forest Service campgrounds on the east shore are serviced by wells that tap the deep aquifer. These wells, at about 250 feet and 200 feet in depth, penetrate into the deep aquifer that is protected by an impermeable layer of hard rock. This impermeable layer of andesite

[6] A CFR closure is published in the Code of Federal Register. This allows Law enforcement personnel to issue citations when the code is violated.

bedrock would not allow any seepage of contaminated lake water into this deep aquifer where these two campground wells are located (Breeden, 2003).

Figure 2. Location of the summer homes (shown as small black boxes on the west shore) and the Forest Service Monitoring Wells (MW) installed to assess ground water

conditions for the Diamond Lake Restoration Project.

Public Exposure Pathways Downstream of Diamond Lake

The draw down of the lake would result in no surface water flowing out of the lake at its only natural outflow, Lake Creek, or at the constructed drainage canal plumbed into Lake Creek. The draw down would occur during the winter months prior to the proposed September treatment. By September of the year of treatment, during the lowest flows of the year, the lake level is expected to be about 8 feet in elevation below the Lake Creek outlet. The chance of a fall rainstorm large enough to rewater the lake causing contaminated water to flow out of the Lake, is extremely low. More than 12 inches of rain would need to fall to rewater the lake. Based on historic weather data, there is only a very small chance of that occurring during a 30 day period from early October to early November (Hofford, 2003).

Both Alternatives 2 and 3 include a mitigation measure requiring the closure of these two outlets with headgate structures until tests indicated that rotenone, rotenolone[7], and all semi-volatile and volatile organic compounds[8] associated with the chemical treatment had dissipated to non-detectable or trace levels in both the water column and lake bottom sediments (approximately one to two months). The rotenone and its byproducts including the inert ingredients found in the liquid formulation, would be fully broken down prior to any downstream delivery of surface waters and associated sediments. Therefore, no downstream public exposure associated with surface water consumption is expected in Lake Creek or Lemolo reservoir, 12 miles downstream of Diamond Lake.

The Forest Service also investigated the potential of contaminated groundwater to discharge into Lake Creek. In September 2003, the Forest Service conducted a groundwater seepage study along a six mile length of Lake Creek. The results of this study showed that Lake Creek received no appreciable increase in flow due to groundwater discharge into the creek. No contamination of Lake Creek and its downstream areas, including Lemolo reservoir from the groundwater aquifer is expected. Groundwater discharge at a location further downstream of the six mile study area was not examined. However, the longer travel time to any potential discharge locations further downstream, the tendency for rotenone to bind with soil particles at the bottom of the lake, and the tendency for the rotenone to breakdown over time, all make the potential of groundwater contamination of downstream water bodies such as lower Lake Creek and Lemolo reservoir very remote.

The required preventive measure under both Alternatives 2 and 3, of monitoring the waters of Diamond Lake and Lake Creek following the rotenone treatment will confirm whether or not any downstream waters contain any trace of the toxicant. If any residues are detected, the exposure to members of the public through drinking water

[7] Rotenolone is the metabolite (by product) of rotenone (Finlayson et al. 2000).

[8] The liquid rotenone formulation Noxfish® contains inert emulsifiers, solvents, and carriers that are important in ensuring the solubility and dispersion of rotenone in water. Waters treated with Noxfish® may contain rotenone, rotenolone, and volatile (xylene, trichloroethylene, toluene, and trimethylbenzene) and semi-volatile (naphthalene, 1-methyl naphthalene, and 2-methyl naphthalene) organic compounds. These volatile and semi-volatile organic compounds dissipate in treated water before rotenone and rotenolone (Finlayson et al. 2000).

from wells around the reservoir would be minimized by public notification, warning signs, supplied bottled water, and/or potential closures that would be put into effect. In the very remote case that the water supplies from Lake Creek and/or Lemolo are threatened, actions to minimize exposure will be taken.

Exposure of Application Worker

The most likely individuals to be exposed to rotenone formulations proposed for this project are the application workers who will be involved in removing the concentrated formulations from their original containers, diluting, and mixing the formulations, filling application containers, and applying the rotenone out of boats in the lake and at drip stations in Silent and Short Creeks. At each step, the risk of accidental exposure is present. The primary exposure pathway would be via inhalation of the powdered formulation, Pro-Noxfish®, when rotenone become airborne once removed from its container and handled. The primary exposure pathway for the liquid Noxfish® would be inhalation or dermal exposure during handling. The same exposure pathways would be possible during any unanticipated spills. Prevention measures in place under Alternatives 2 and 3 to substantially limit the risk to application workers include:

- A 24 hours/day security effort where the rotenone is stored.
- Enough potassium permanganate (rotenone neutralizer) would be on-hand to neutralize the largest container of rotenone stored on site.
- Certified pesticide applicators would be responsible for all phases of rotenone application.
- The protective equipment listed on the labels of both rotenone formulations will be used by all personnel who handle these products. This includes disposable coveralls, gloves, eye protection, nitrile gloves, and air purifying respirators. Air purifying respirators provide a 10 to 50 fold protection factor. Extra replacements will be available at all times during the implementation phase.
- All of the following detailed plans would be completed according to recommendations and examples provided in the "Rotenone Use in Fisheries Management: Administrative and Technical Guidelines Manual" (Finlayson et al. 2000) prior to project implementation: rotenone application plan, site safety plan, site security plan, and a spill contingency plan.

3. Risk Analysis

The risk analysis compares the dose levels from the exposure analysis section with the toxic effect levels described in the hazard analysis section and the existing guidelines set for rotenone by the US Environmental Protection Agency. The EPA has concluded that the use of rotenone for fish control does not present a risk of unreasonable adverse effects to humans (USEPA, 1981 and 1989).

The risk of toxicity to humans is characterized for threshold effects and non-threshold effects. Threshold effects occur when a certain level or dose is obtained that triggers an effect. All toxic effects such as local toxicity (toxic effect at the location of exposure (e.g. skin, eye), systemic toxicity (requiring the absorption and distribution of toxins distant from its entry point, where effects occur), and reproductive effects, are assessed with dose thresholds. Only cancer is considered a non-threshold effect. A non-threshold effect can potentially occur when any dose has some possibility of causing cancer, no matter how small the dose.

Risk to the Public

The US Environmental Protection Agency (EPA) has not established an allowable maximum contaminant level[9] (MCL) of rotenone for public water suppliers. However, EPA Region 9 does establish a preliminary remedial goal[10] (PRG) for long-term residential use of 150 ug/L. In addition, other additives to the Noxfish include xylene, trichloroethylene, toluene, and trimethylbenzene and semi-volatile naphthalene, 1-methyl naphthalene, and 2-methyl naphthalene. Table 1 provides a list of safe levels for residential use of these chemicals along with the detection limits used in the monitoring of these chemicals. Bottled water will be supplied to all potentially impacted wells (Figure 1) along the western shore of the Lake from Thielsen View Campground to Silent Creek should a detection of rotenone or other added ingredients be detected in any of the Forest Service monitoring wells along the west shore. Supplied drinking water will only be ceased once it is determined that no detectable levels of rotenone or Noxfish additives are below detectable levels. If monitoring wells or domestic wells sampling detect any of these chemicals above the USEPA Tap Water PRG, users will be advised of their risks and discontinuance of well use may be enforced. Through temporary closure of Diamond Lake to the visiting public and temporary discontinuance of well use where appropriate, oral exposures would be significantly minimized or eliminated.

Dermal contact of contaminants potentially in the groundwater while bathing or showering is not predicted to be a significant exposure pathway. Concentrations of rotenone in the lake are projected to be around 0.1 milligram of rotenone per liter of treated lake water (mg/L) which is below the safe level for tap water use established by the EPA (0.15mg/L). For the chemicals of concern, dermal contact risk would be considered insignificant until well water concentrations exceeded tap water PRGs.

The actual hazard to human health associated with accidentally or otherwise drinking water directly from Diamond Lake following the treatment is low. The worst-case concentration of rotenone to occur in the lake immediately after application is 0.10mg/L which is below the PRG safe level of 0.15 mg/L. The safe level is protective of children and adults drinking 1 and 2 liters of water per day, respectively, for 350 days per year for 30 years. Risks from inert ingredients are difficult to predict but are likely very low given the large dilution.

[9] An allowable maximum contaminate level is defined by the EPA as the highest level of a chemical allowed in drinking water. Considers cost, treatment technology, availability and reliability of analytical methods.

[10] A preliminary remedial goal is defined by the EPA to be the level of a chemical in drinking water that is not expected to cause any adverse effects for a lifetime of exposure. Purely based on acceptable risk and does not take into cost, treatment technology, and analytical methods into consideration.

Application workers

Risk to application workers is minimized through ensuring adequate safety measures are taken to minimize exposure. By completing the rotenone application plan, site safety plan, site security plan, and a spill contingency plan, risk to site personnel including Forest Service Staff and certified application workers will be substantially reduced to safe levels or eliminated.

Direct Effects To Human Health

General Public and Application Workers

For the general visiting public, no exposure to the fish toxicant is expected, therefore no direct effect to the health of the visiting public is expected under either Alternatives 2 or 3. For members of the public who live at Diamond Lake there is a risk of exposure with the possible consumption of contaminated water from the wells on the west side of the lake. Concentrations of rotenone in drinking water are not predicted to be measurable or significant. This is because of the very dilute levels of rotenone that would exist in the lake (up to 0.10 ppm or mg/L) and the low likelihood of any serious illness from consuming contaminated water if people were to ignore the warnings and closures or not drink the bottled water provided. Moreover, since rotenone breaks down rapidly in sunlight, and since it is strongly bound to lake sediments, the concentrations that may actually show up in well water is expected to be substantially lower than the concentration in the lake itself. If summer home owners were to drink the dilute concentration over the course of several days, illness is possible but not likely.

Application workers are most at risk of receiving a dose and becoming sick from this project. If spills on the skin or splashes into eyes, or accidental inhalation occurs and such exposures are not washed off as required or if the victim is not moved to an area of fresh air as required, then application workers could become temporarily ill. In an extreme case of high exposure, death could occur. These potential direct effects to human health are expected to be minimized and/or avoided all together by following the prudent industrial handling practices required by law and as mitigation measures of this project.

Indirect Effects to Human Health

The water in Diamond Lake is rich in nutrients (nitrogen and phosphorus) largely due to an overabundance of fish. Nutrient rich waters can lead to downstream public health concerns when such waters are consumed. Both Alternative 2 and 3 would send nutrient rich waters to downstream areas during the winter draw down period. However, these draw down waters would be delivered during the cooler, wetter winter months of the year when proliferation of plant growth (typically associated with a nutrient flux) is less likely and when the dilution of the lake water would be maximized. Due to the timing of the draw down, no indirect effects to human health associated with downstream water consumption are expected.

Following the draw down and rotenone treatment, the lake is expected to have increased nutrient loads from the decomposition of dead fish and nutrient rich suspended sediments generated by wave action and the other connected activities that would occur when the lake level is 8 feet in elevation lower than normal. Moreover, because zooplankton populations would be killed by rotenone a short-term increase in phytoplankton abundance is expected along with the water quality problems associated with algae proliferation. Once the lake begins to finally spill into Lake Creek, these short-term interactions may function together to decrease water quality downstream in Lake Creek and Lemolo reservoir. Alternatives 2 and 3 could result in a short-term indirect effect to the health of potential downstream users of Lake Creek with an increased risk of water borne pathogens and associated illness. This short-term potential indirect effect is not expected to be a risk within or downstream of Lemolo reservoir because by the time the nutrient-rich waters reach the reservoir, there would be substantial dilution from small tributaries and from the North Umpqua River that mixes with Lake Creek in Lemolo.

With eliminated or substantially reduced populations of tui chub, Diamond lake would have lower levels of nutrients, thus lower downstream eutrophication in Lake Creek and Lemolo Reservoir. Alternatives 2 and 3 have the greatest potential to result in indirect long-term beneficial effects to downstream water quality and the health of the people who may potentially drink from these downstream waters.

Cumulative Effects to Human Health

Other pesticides have been used in the project area in the past. Table 9 shows that the herbicides Cimizine, 2,4-D and Trichlopyr were sprayed along the road shoulders of highway 138 to clear vegetation between 1980 and 1983. The herbicide picloram was used in the project area when it was spot applied to individual plants or groups of spotted knapweed at several locations using a backpack sprayer along highway 138 near Diamond Lake and near the south entrance to Diamond Lake. From the mid 1960's to 1982 the pesticide malathion was applied multiple times each summer to kill mosquitoes at the south shore marsh and various other areas around the lakeshore. Of the above pesticides, only the use of picloram to spray scattered groups of spotted knapweed is reasonably foreseeable in the future in the immediate vicinity of Diamond Lake. The small amount of picloram used in 2003 and expected to be used over the next few years in the vicinity of the project has little chance of entering surface or ground water given the extremely small amounts needed to spray the scattered plant populations and the time of year that spray has been and would continue to be applied (dry summer months, Umpqua National Forest Noxious Weed Environmental Assessment). Moreover, the other pesticides used in previous decades (1960-1980's) have essentially no chance of resulting in any additive cumulative effect to human health over and above any exposure to either rotenone or algae toxins because the previously used pesticides would have disappeared by now.

A multitude of past, present, and reasonably foreseeable projects and activities use various forms of petroleum products that can be harmful to human health. These past and on-going activities and projects include things like timber sales, forest fuels reduction projects, forest thinning, hazard tree removal, campground maintenance and improvement, highway construction and reconstructions, paving projects, facility construction and reconstruction, and marina operations and boating (Tables 9, 10 and 11). Any of these that have taken place, or are on-going, or that will occur during the implementation of either alternatives 2 or 3, within the watershed of Diamond Lake, could potentially deliver petroleum-type toxicants to surface water and groundwater of the Lake. This possibility is heightened if substantial spills were to occur in association with any of the projects.

Some of the inert ingredients of the liquid rotenone formulation (trichloroethylene, naphthalene, and xylene) are also present in the fuel of motor boats, and as a result are commonly found in lakes where motorized activities occur. Prior to breakdown of these inert ingredients in Noxfish, there is a potential of an additive effect from these compounds from both the Noxfish and the boat use (during the application and mixing of the powered rotenone that does not contain any inert ingredients). Added together, from both sources, these inert ingredients could potentially reach higher concentrations than if no boats were used in the Lake. However, Finlayson (2000) reported that concentrations of these compounds in water immediately following treatments using Noxfish were low and presented no health risks. Since the Noxfish would only be applied to two fish bearing streams that feed into Diamond Lake and since most of the rotenone used under Alternative 2 and 3 would be the powdered formulation lacking any other ingredients, the likelihood of additive effects is very low. If it did occur it would last a short time over a few weeks, because trichloroethylene, naphthalene, and xylene all break down within about three weeks time (Table 2). Those most at risk of an additive effect would be the application workers involved in implementing either Alternative 2 or 3.

Table 2. Persistence of rotenone and other organic compounds in water and sediment impoundments treated with 2 mg/L rotenone formulation (Source: Finlayson et al. 2000, p. 192-193).

Compound	Initial water concentration (µg/L)	Water persistence	Initial sediment concentration (µg/L)	Sediment persistence
Rotenone	50	<8 weeks	522	<8 weeks
Trichloroethylene	1.4	<2 weeks	ND*	
Xylene	3.4	<2 weeks	ND	
Trimethylbenzene	0.68	<2 weeks	ND	
Napthalene	140	<2 weeks	146	<8 weeks
1-m-napthalene	150	<3 weeks	150	<4 weeks
2-m-napthalene	340	<3 weeks	310	<4 weeks
Toluene	1.2	<2 weeks	ND	

*ND = Below detection limits

Given long-term exposure to various forms of toxicants in the environment, it is conceivable that human health could be incrementally compromised by long-term exposure to these products in the waters of Diamond Lake. This could potentially result in cumulative effects to human health when added to the effects from toxins potentially received as a result of any of the alternatives associated with this project. Yet there is no scientific literature to support this hypothesis.

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