DRAFT

Diamond Lake Management Plan
Oregon Department Fish and Wildlife
Umpqua Watershed
September 4, 2009

Introduction:
Diamond Lake is a natural lake located about 80 miles east of Roseburg in the Cascade Mountains. Originally fishless, the lake has been stocked with rainbow trout (*Oncorhynchus mykiss)* since 1910. Although Diamond Lake lacks adequate spawning habitat to sustain a trout population, the lake is very productive and once trout are introduced the growth rates and survival of the trout are exceptional. Consequently Diamond Lake has been recognized for decades as a premier fishery. Unfortunately this fishery and the lake's ecosystem have been disrupted twice by the invasion of tui chub (*Gila bicolor*). Rotenone was used in 1954 and 2006 to eradicate the chub and restore the fishery and the quality of the lake. The Diamond Lake Restoration Project Final Environmental Impact Statement (FEIS) which was adopted in 2004 was used to select the 2006 treatment for the lake and recommend post-treatment activities (U.S. Dept. Ag. 2004). Per the FEIS, after treatment the Oregon Department of Fish and Wildlife (ODFW) would develop an ecologically sound stocking strategy and new management plan when sufficient information was available for managing the fishery. According to the FEIS (2004) the decision process would take into consideration, "the environmental, biological, economic, and community values of the people of Oregon."

Diamond Lake has operated under various management plans and management directives since 1990. The 1990 Diamond Lake Management Plan (OAR 635-500-0703) was for hatchery production under the Basic Yield alternative of Oregon's Trout Plan. The plan noted that the lake averaged 100,000 angler trips per year, had an average harvest of 2.7 trout per trip, and was annually stocked with about 400,000 fingerling trout. As the fishery declined due to the increasing chub population, management directives allowed the department to switch to an experimental stocking program which used various legal and trophy sized stocks of trout to try to maintain the fishery. Angler numbers dropped to a low of 6,000 and averaged only 22,400 trips per year from 1994 – 2006 prior to treatment. During 2007 and 2008, ODFW operated under a maintenance and experimental stocking strategy per the FEIS. This 2009 plan fulfills the FEIS agreement to develop a post-treatment stocking plan. This proposed plan could modify the existing 1990 plan and retain option (1)(c) of OAR 635-007-0525--"manage for hatchery fish," under the Basic Yield alternative (OAR 635-500-0115).

Overview:
Diamond Lake is in the Cascade Mountain Range at an elevation of 5,191 feet and is part of the Umpqua National Forest. Diamond Lake is fed by three perennial and six intermittent streams and is approximately 3.5 miles long and 1.5 miles wide. It drains to the North Umpqua River via Lake Creek and Lemolo Reservoir. Diamond Lake's water level and flow into Lake Creek is managed by a weir at the mouth of the outlet. The old weir was replaced in 2005 in preparation for drawing the lake down for the 2006

treatment. ODFW has a water right for Diamond Lake and is responsible for maintaining the water level of the lake. During the summer, Diamond Lake stores 5,800 acre-feet of water (permit R-7734, S-4367, S-7800).

Diamond Lake is surrounded by gently sloping forested terrain except for the steep, rocky shoreline on the north end of the lake and the marshy portion of the southern shoreline. Diamond Lake is managed by the U.S. Forest Service (USFS) as a "Special Management Area: MA-2." Consequently, the area is managed for concentrated developed recreation such as resort use, camping, picnicking, boating, fishing, interpretation, and winter sports. A special use permit allows a main resort and marina on the northeast end of the lake and a pizza parlor/store on the south end. There are also three campgrounds around the lake and five boat ramps (Figure 1). On the west side of the lake there are approximately 100 private cabins leased by the USFS as summer homes.

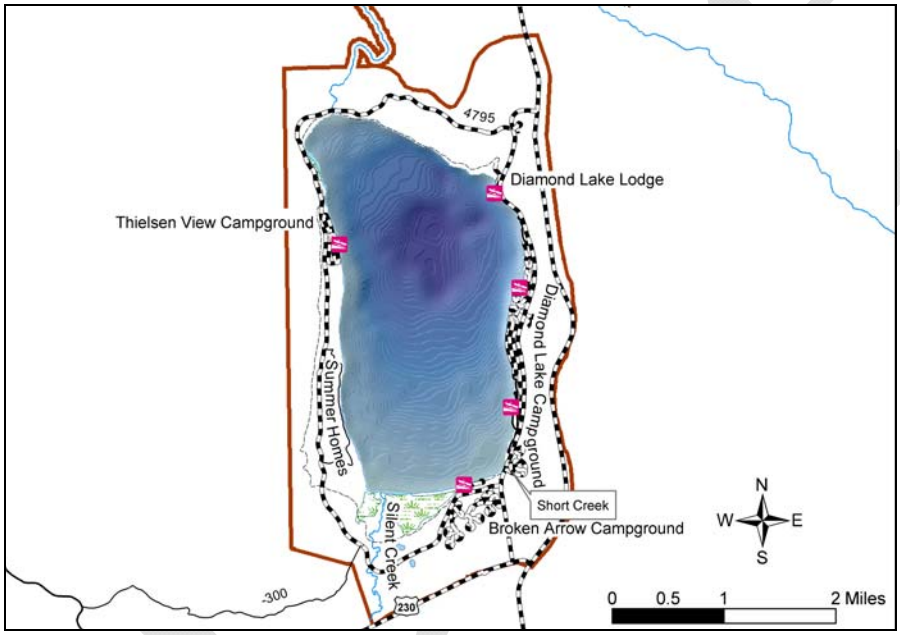

Figure 1. Diamond Lake and associated recreational use areas (FEIS 2004).

Fishery Economics:
Diamond Lake is categorized as a high use destination recreation area of significant economic benefit to southern Oregon by the United States Department of Agriculture (USDA). Open to camping and fishing from late April through October, then snowmobiling, cross country skiing and tubing during the winter; Diamond Lake attracts a variety of recreational users. From 1962 – 1978 the lake attracted 70,500 to 139,500 angler trips per year and averaged 109,800 trips. After chub were discovered and the water quality and trout growth/survival declined, angler numbers dropped to a low of 6,000 and averaged only 22,400 trips per year from 1994 – 2006. The experimental stocking program that was implemented during this time to attract anglers was expensive and focused on the release of legal and trophy-size trout. The 2004 FEIS noted that the reduction of angler trips caused a loss of $4.9 million in annual sales and $1.4 million in labor income in the area (Douglas, Jackson and Klamath counties).

The first year post-treatment (2007), Diamond Lake attracted 72,085 angler trips and generated an estimated $3.76 million dollars in sales and $2.57 million in labor income in the area based on 2006 dollar value. In 2008, the number of angler trips decreased to 41,330. This decline may have been due to a late ice off (Memorial Day weekend), high gas prices and road closures due to fire. The 2004 FEIS had predicted stabilizing at 100,000 angler trips per year. Given the current economy and current angler participation rates, angler trips may range from 65,000 to 85,000 per year. This would still have positive impact on the local economy.

Lake Ecology and Tui Chub Impacts:
Since 1910, when trout stocking began in Diamond Lake, tui chub populations have exploded twice and were subsequently eradicated in 1954 and 2006. During chub invasions, trout survival and growth rates declined. Monitoring conducted between 2001 and 2006, while the chub population was expanding, showed an increase in blue-green algae *Anabaena spp.* phytoplankton cells, an increase in pH, high internal nutrient loading, a decrease in water clarity, and a decrease in benthic organisms. The lake was listed on the Oregon Department of Environmental Quality (DEQ) 303 (d) list for not meeting water quality standards. *Anabaena* blooms led to human health concerns that initiated three health advisory "no water contact" closures and two warnings. At times pH exceeded 9.5 which was above the 6.5 to 8.5 levels preferred by salmonids. High phosphorous levels and internal nutrient loading was believed to be caused by the sheer number of tui chub in the lake—over 95 million. Of the 95 million chub, an estimated 7.6 million were capable of reproducing (Jackson et al. 2004). The smaller chub grazed heavily on the phytoplankton, zooplankton, while the larger chub fed on the benthic organisms—disrupting natural food webs and depleting the food resources of the lake. The pounds of benthic organisms per acre dropped from a 1955 to 1979 average of 115.4 lbs/ac (range 54.7 – 188.0) to 25 lbs/ac between 2004 and 2006. Trout growth rates declined to the point that fingerling stocking was no longer a viable option for maintaining a fishery. The condition factor (ratio that relates fish length and weight to indicate the relative "plumpness") of the trout dropped from an average of 1.43 during 1960 to 1991 (range 1.21 – 1.89), to 1.04 from 1992 – 2004 (range 0.87 – 1.23). Values less than 1 are not desirable and indicate the fish are relatively thin for their length.

During September 2006, all fish were eradicated from Diamond Lake during the rotenone treatment. Approximately 34 tons of chub were removed from Diamond Lake prior to treatment and 17.4 tons of fish were removed post-treatment in an attempt to minimize some of the potential nutrient loading caused by decaying fish carcasses. Eradicating the chub lowered the internal nutrient loading occurring in the lake.

Fishery Management: 2007 – 2009 Post-Treatment Stocking & Lake Recovery:
Fish stocking resumed in spring of 2007. Per the FEIS and USDA Record of Decision (2004), a conservative stocking approach was used. Since it was unknown to what degree or how quickly the lake might recover, stocking strategies were considered "approximate or predictions." ODFW would manage for maintenance and experimental stocking through 2008. Annual stocking rates were expected to increase in concert with the

recovery of the lake. Adaptive management would be used to adjust actual stocking numbers based on the post-treatment results of lake health monitoring, management decisions and funding. ODFW wanted to provide an attractive fishery and minimize potential impacts to the lake's food chain and water quality. To balance these issues, the number of fish stocked was very conservative especially considering the number of chub which used to occupy the lake. Approximately 85,000 catchable-sized trout were stocked each year in 2007 and 2008 (Table 1). All of the catchable fish except the 2008 Fishwich stock were legal to trophy sized and immediately available to anglers for harvest.

The 2007 fingerling stocking was delayed to mid-June. Traditionally, fingerlings were stocked right after ice off. This stocking delay provided the zooplankton community more time to rebound before receiving any grazing pressure from the fingerlings. The number of fingerlings stocked was far less than the 93 million tui chub <132 mm in length that once occupied the lake. Generally trout 125 mm or greater in length will switch from a zooplankton diet to a benthic diet which includes insect larvae, chironomids, annelids, amphipods and snails. Delaying the fingerling stocking also meant that the fingerlings were already 90 – 100 mm at the time of stocking. With an estimated growth rate of two inches per month, the fingerlings would switch to a benthic diet in less than a month, further reducing grazing pressure on zooplankton. These growth rates were verified by creel data and trap nets set in July and October in 2007 and 2008.

Table 1. Type of rainbow trout, stocking dates, size and number stocked in Diamond Lake during 2007 and 2008.

Type of Trout	**2007: Stocking Dates**	**Number Stocked**	**Size (# per lb)**
Oak Springs (53)	6/12 – 6/13/2007	100,010	Fingerling (46/lb)
Cape Cod (72T)	4/26 – 6/9/2007	21,619	Legal (2.7/lb)
Trout Lodge (103T)	5/4 – 5/23/2007	51,075	Legal (1/lb)
Cape Cod (72T)	5/2 – 5/10/2007	3,619	Trophy (0.2/lb)
Eagle Lake (171)	9/18/2007	6,593	Legal (1.6/lb)
Fishwich (551)	6/12/2007	1,547	Legal (2.3/lb)
	2008: Stocking Dates		
Oak Springs (53)	6/10/2008	200,100	Fingerling (43.5/lb)
Oak Springs (53)	8/12/2008	6,005	Legal (3.3/lb)
Trout Lodge (103T)	5/19 – 6/10/2008	50,942	Legal (1/lb)
Eagle Lake (171)	7/24/2008	14,805	Legal (3/lb)
Fishwich (551)	5/30 & 8/19/2008	7,807	Sub-legal (4.5/lb)
Oak Springs (53)	5/30/2008	6,227	Trophy (0.64/lb)

A similar stocking strategy was used for 2008 (Table 1). Additionally, data on the benthic community, *Anabaena* cell counts, transparency, pH, zooplankton, trout growth rates & condition, plus number of angler trips became available. With the stocking noted above, and data for two years post-treatment, the following has been observed:

- During sampling in October, benthic organisms increased from 25 lbs/ac in 2004 – 2006; to 200.6 lbs/ acre in 2007 and 168 lbs/acre in 2008. The decrease in 2008

was expected since fewer chub carcasses would still be available to enhance the benthic organisms as the carcasses decomposed.

- *Anabaena* cell counts dropped from >20,000 cells/mL in 2006 to well below human health concerns (>16,000 cells/mL) with 413 cells/mL in 2007 and 464 cells/mL in 2008.
- Water clarity as measured by secchi disk depth readings increased from a pre-treatment mean of 1.62m in 2006, to a mean of 6.38m in 2007 and 6.35m in 2008.
- pH went from a mean of 8.5 in 2006 to a mean of 7.6 in 2008.
- The number of edible zooplankton increased post treatment.
- Trout growth rates were similar to the "heydays" of the 1960s, 1970s and 1980s. In 2007 and 2008, fingerlings started being legal sized in August, were about 11 inches long by October, and their condition factors went back up to 1.3 – 1.5.

Overall, lake health improved greatly from 2006 (Figure 2). These various factors which are further described in Eilers (2009), illustrate on a scale of 1 to 10, with 10 being the highest positive score, how Diamond Lake has responded since the removal of tui chub. The lake rebounded from a mean summary score of less than 2 in 2006 to health index scores of nearly 8 and above post-treatment. Adaptive management will continue to be used to improve how these factors are monitored. Instead of a calendar year, factors will be monitored on a "climate" calendar. For example measurements were traditionally taken during June. Due to the late ice-off in 2008, epilimnetic dissolved oxygen and chlorophyll data were measured during a normal post-ice off bloom. However because of the bloom, these values scored low. Conversely in 2007, ice off was in April. By June when these values were measured, the bloom had already subsided so they scored high. This variation can be minimized by standardizing measurements to occur 4 – 6 weeks after ice off.

Similarly in 2008, the lake was 90% ice-free on May 23rd. ODFW stayed with its "calendar year" mid-June stocking of fingerlings. Thus the fingerlings were stocked less than 3 weeks after most of the ice was gone. This action likely impacted the larger species of zooplankton such as *Daphnia* which had less time to multiply before receiving grazing pressure from the fingerlings. In 2009, ice off was May 19th. ODFW used a "climate year" thus stocked fingerlings on June 25 (10,078); June 30 (166,840); July 1 (115,890); and July 7th (53,770), to allow the zooplankton community more time to grow. No legal or trophy sized fish were stocked in 2009.

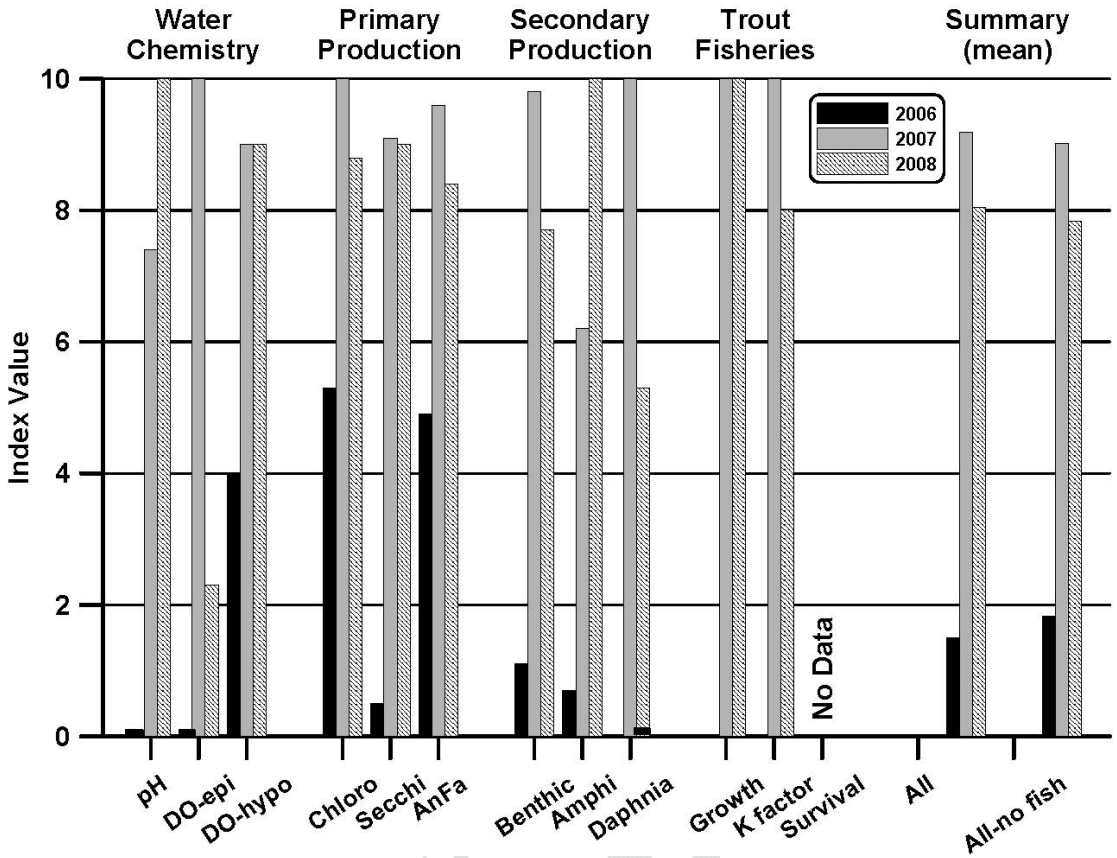

Figure 2. Parameters used to evaluate the health of Diamond Lake from Eilers (2009).

Nonnative Invasive Golden shiners (*Notemigonus crysoleucas*) were discovered in Diamond Lake during a routine trap net survey done in July 2008. ODFW subsequently removed a total of 639 shiners during the remainder of the summer via trap nets and boat electro-shocking. Due to the size of the shiners captured and the lack of any young-of-the-year, it was believed the shiners were placed into the lake after the 2006 rotenone treatment. This theory was tested by comparing otolith (ear bone) analysis of shiners collected at Diamond Lake to those sold at a California bait shop. If both sets of shiners had the same chemical isotopes in their otolith, it would confirm that shiners from Diamond Lake originated from bait shop stock. The otolith analysis (Miller 2009) did not find a similar pattern between the bait shop and Diamond Lake shiners. However, bait shops receive shiners from more than one source and not all sources have been tested. Additionally, the isotope pattern of the otolith did not show a transfer of shiners between 2 water bodies (bait shop water to Diamond Lake). However Miller (2009) noted that given the age of the fish indicated by the growth rings on the shiners tested, it is plausible that some fertile shiners were illegally introduced and reproduced sometime after the rotenone treatment. During the 2008 removal efforts by ODFW, shiners were observed in both spawning and spawned out condition validating that they were in fact capable of reproducing in the lake. In 2009, young of the year golden shiners were collected by boat electro fishing in late July.

Shiners were also illegally introduced into Diamond Lake in 1977 after the 1954 rotenone treatment. Shiner populations never accelerated like tui chub, and the trout fishery, benthic organism density, and trout condition factors remained healthy even after their discovery. Although it is difficult to predict whether or not shiners would have a negative impact this time, Moyle (2002) noted shiners are less successful in establishing large populations in natural lakes and streams than in reservoirs. Predation in natural situations appears to be more limiting than in reservoirs (Moyle 2002). The Eagle Lake trout were stocked into Diamond Lake in 2007 and 2008 in order to provide a piscivorous predator that could prey on shiners in the lake. Eagle Lake trout originated from California and are known to prey on tui chub; therefore it is likely that this stock of trout will prey on shiners. Eagle Lake trout were stocked in Diamond Lake as part of the stocking plan for post-treatment invasive species prevention. The experimental stock of trout created by ODFW from mixing Fish Creek and Mowich Creek broodstock (Fishwich) is another stock being tested in Diamond Lake to see if they have the potential to suppress shiner populations. These fish were stocked as legal or sub-legal sized trout in 2007 and 2008. Additionally about 10,000 Fishwich fingerlings were stocked in 2009. Diet studies are in progress at Diamond Lake to evaluate level of fish predation in these potentially predacious fish stocks.

Diamond Lake Fish Management Strategies:
The 2009 Diamond Lake Management Plan proposes to maintain Diamond Lake as a Basic Yield trout fishery. This Basic Yield management alternative would be a low cost, effective, family-oriented fishery similar to the successful fishery of the 1960s, 1970s and 1980s prior to the last chub invasion. The 2009 plan also includes new elements such as invasive species prevention and control, plus monitoring of the lake to maintain healthy lake ecology and maintain fishery objectives.

Per the OAR's guiding this trout management alternative, the primary management components are:

- fingerling stocking will provide the major fish production for the lake;
- the fishery would be of a consumptive nature without special regulations, and
- the productive capacity of the waters will be maintained or enhanced.

Per this 2009 plan, the ODFW would also include in the OAR's:

- Legal and trophy sized rainbow trout may be stocked to enhance the trout fishery or if necessary to balance the lake's ecosystem.
- Conduct fishery monitoring and evaluations necessary to maintain fishery objectives and healthy lake ecology.
- Provide for the prevention and control of illegally introduced fish species.

To implement the OAR's, ODFW will use available information from three standards to evaluate lake health and fishery objectives. This information will help ODFW use adaptive management strategies to plan stocking rates and stock sizes for Diamond Lake. The standards include: water quality, biological indices, and a stocking model. To meet water quality objectives, ODFW will follow the DEQ standards set forth in the Diamond Lake TMDL report (2006). Generally these water quality goals would seek pH values of

8.5 or less, average chlorophyll algae of equal to or less than 0.01 mg/L and *Anabaena flos-aquae* safe for water contact recreation at less than 15,000 cells/mL (TMDL 2006, Eilers 2009). Modeling conducted for the TMDL (2006) report stated that the lake could potentially support 440,000 trout and still meet water quality goals.

The biological indices established by Eilers (2009) look at a variety of parameters (Figure 2). These factors include water quality attributes as well as data on trophic levels of the lake, and trout condition and growth. To meet the DEQ water quality standards noted in Figure 2 the pH would need to score 5 or higher, while chlorophyll would need to score 6 or higher and *Anabaena* would need to score 6.5 or higher. Additionally, the ODFW will look at other parameters in this index such as benthic organism densities, water clarity, dissolved oxygen (DO), and the fish health factors to help maintain the lake's productivity and health. Most historic values would have scored a minimum of 6 or better. Thus, an average score of 6 or more indicates a healthy lake which meets also meets DEQ's requirements. Trends in scores between years will be evaluated to determine appropriate stocking levels.

ODFW will also use an accounting-type stocking model to evaluate stocking rates, survival, and harvest to predict excess fish and avoid internal nutrient loading or stress to the food chain. The goal is to have harvest nearly equal the number of one-year old fish available to avoid internal nutrient loading or stress to the food chain. For example, data from the 1960s, 1970s, and 1980s showed that both the lake and the fish were healthy when approximately 400,000 fingerlings were stocked per year, 70% of the fingerlings survived to be one year old (280,000 trout = 92 lbs of fish/surface acre), and there were about 100,000 angler trips per year with an average harvest of 2.7 fish (270,000 trout = 89 lbs of fish/surface acre). Approximately 280,000 fish were available at the start of the angling season and 270,000 fish harvested. Thus there was little excess and the poundage of trout left in the lake at the end of the season was <100 lbs/surface acre. By modeling the number of fish stocked, survival, harvest, and the number/pounds of fish left at the end of the season, the model can determine whether or not stocking rates need to be adjusted to reach an equilibrium. Various stocking and harvest scenarios can also be tested to predict suitable stocking rates.

Implementation:
Balance stocking to meet recreational fisheries goals and lake health goals:

- Stock fingerling trout for the primary fishery production program. Adaptive management will be used for setting stocking rates but the number could range from 0 to over 400,000 fingerlings. This is below the DEQ level of 440,000. Stocking rates or the size of trout at stocking will be based on trout harvest, trout growth rates and condition factor, and modeling outputs. Information from monitoring and evaluation of lake health parameters such as DO, pH, water clarity, and benthic organism density will also be incorporated into stocking decisions when data is available.

- Allow for the option of stocking legal sized or trophy trout if desired to enhance recreational opportunity or if necessary to balance the lake's ecosystem.
- Fingerling stocking will be delayed to until 4 – 6 weeks after annual ice off.
- Continue to periodically stock predacious trout to limit the expansion of invasive fish species.
- Work cooperatively with Diamond Lake Resort, the USFS and other interested partners to promote fishery participation to achieve angler participation rates of 50,000 – 100,000 angler trips per year in order to meet trout harvest goals to avoid stressing the lake's ecosystem.
- Continue working with the Diamond Lake/SW Oregon Invasive Species Prevention Committee to conduct invasive species education, monitoring, and enforcement activities. Activities include: interpretive brochures and signs, surveys, boat checks, working with tournaments on prevention measures, and law enforcement support. Monitoring activities include trap netting, electroshocking, visual observations and public contact.

Management Considerations:
Again, ODFW will weigh its stocking decisions in concert with DEQ standards, available biological indices and modeling outputs. Adaptive management will be used as ODFW learns how to better monitor or evaluate the various factors. Monitoring and fingerling stocking will be shifted from a calendar year timing to following the natural climate and bio-rhythms of the lake. A "best available science" approach will be used to incorporate new monitoring techniques or modeling applications as they become available.

Stocking plans will also consider the use of legal or trophy sized trout for enhanced angling opportunity or to assist balancing the lake's ecosystem. For example, catchable sized trout (including predacious stocks) could be used to replace some fingerlings if the zooplankton community was stressed. Delaying the fingerling stocking would allow the zooplankton community to grow after ice off. It also means that the fingerlings would switch to a benthic diet in less than a month, further reducing pressure on zooplankton communities. Due to their fast growth rate, the fingerlings would also out-grow the size preferred by predacious fish within a month. Fish such as golden shiners will generally be less than five-inches long for over a year and thus will be more available for consumption by predacious fish. Unfortunately stocking the lake with predacious fish could encourage some people to illegally fish with live bait fish. Thus although ODFW will continue to stock predacious stocks, publicity will be minimized to avoid attracting the use of live bait. Invasive species education and law enforcement efforts will also continue to protect the lake. DFW will also continue monitoring for invasive species and implement removal techniques based on available funding and staff.

ODFW will annually assess fish populations in Diamond Lake, including species composition, abundance, fish health and productivity (growth rate, condition factor). The recreational fishery will also be monitored as funding and staffing are available in order to determine harvest rates, angler catch rates, angler demographics, and angler opinions and attitudes on the Diamond Lake trout fishery. This information will be used to

encourage 50,000 – 100,000 angler trips per year and a harvest high enough to be in balance with the lake's ecosystem.

Summary:

The 2009 Diamond Lake Management Plan seeks to balance a Basic Yield, recreational hatchery trout fishery with the ecosystem of Diamond Lake. Historically, from 1960 to 1991, the condition factor of the trout averaged 1.43, benthic density averaged 115.4/acre (1955 – 1992), the lake was known for its clarity (anecdotal) and *Anabaena* levels were below human health concerns. The growth rate of the trout during this time suggests that phytoplankton, zooplankton, and benthic communities were healthy enough to support an annual stocking of 400,000 fingerlings with a harvest of about 270,000 trout. This plan seeks to achieve a similar fishery, but provides a cautious fish stocking approach and additional conservation measures to help maintain the various trophic communities and predict conditions to continue to maintain both the fishery and the ecosystem.

Literature Cited:

Eilers, J. M. 2009. Water Quality & Biological Response to Rotenone Treatment in Diamond Lake, Oregon. Report to the Oregon Department of Fish and Wildlife, Roseburg, Oregon. 102 pp.

Jackson, L. S., D. H. Jackson, and D. W. Loomis. 2004. Analysis of Tui Chub Data Collected at Diamond Lake. Oregon Department of Fish and Wildlife, Roseburg, Oregon.30 pp.

Miller, J. A. 2009. Otolith elemental composition of golden shiners (*Notemigonus crysoleucas*) collected in Diamond Lake, Oregon in 2008. Report to the Oregon Wildlife Heritage Foundation, Portland, Oregon. 14pp.

Moyle, P. B. 2002. Inland Fishes of California. Revised. Univ. of California Press. 164 – 166.

Oregon Department of Environmental Quality. 2006. Umpqua Basin TMDL; Diamond Lake TMDL. Chapter 6: Diamond Lake and Lake Creek aquatic weeds, dissolved oxygen and pH TMDL:6-1 to 6-15.

Oregon Department of Fish and Wildlife. 1996. Diamond Lake fish management issues. August, 1996, 44 p.

United States Department of Agriculture, Umpqua National Forest November. 2004. Diamond Lake restoration project, final environmental impact statement. 579 pp. plus appendixes.

USDA Umpqua National Forest December 2004. Record of Decision: Diamond Lake Restoration Project. 31 pp.