033011_SiskiyouCo

COUNTY OF SISKIYOU

Board of Supervisors

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I am here tonight in support of the mining community of Siskiyou County. These are hard working, industrious people with a love of the land. Our county has been hit hard from all sides to stop the people that live here from working. The loss of jobs is growing and is devastating our community. Mining has been a part of our heritage and in times of recession has always provided a source of income for people that are out of work. In resent years not only do people make a living from mining but we have a enjoyed a serge in tourism in the summer from the suction dredge miners that come to enjoy our county.

The EIR that you have prepared does not address the loss of the tourism dollars that suction dredge mining produces, it does not address the closing of camp grounds, stores, mining equipment stores or the loss of sales tax or property taxes that will be lost if miners start to abandon their claims. In this report you use words like May or should with little or no science to support or confirm your assessment that suction dredge mining hurts the fish or the streams. This report is supposed to be unbiased, only examination facts, it cannot be written on assumption, clearly that has not been done.

These reports must be considered and included in the EIR.
I provide you with the following documents that dispute your assumptions.

1. Effects of Suction Dredge Mining written by Joe Cornell
2. Regarding dredging written by Dr. Robert N Crittenden
3. California State Water Resources Control Board Suction Dredge Mining. Mercury study Cladia Wise
4. News release from the U.S. Department of the Interior Mining Operations Have NOT hurt Alaskan Rivers
5. Impact of suction dredging on water quality, Prepared for the US Environmental Protection Agency
6. United States Department of Agriculture Forest Service Comparison of stream material moved by mining operations to natural sediment yield rates.
7. U. S. Army Corps of Engineers U.S. Environmental Protection agency General Permit 88-02P
8. Response of fish to cumulative effects of suction dredge and hydraulic mining written by Peter B. Bayley
9. U.S.G.S. Studies suction dredge mining
10. California Environmental Analysis of Suction Dredging
11. Suction Dredge Mining as a Beneficial Use

Grace Bennett
Siskiyou County Supervisor

Grace Bennett
March 30, 2011

Effects of Suction Dredging

A Summary of Dredging Publications

Written by Joe Cornell

Draft of April 16, 2001

This article is a summary of facts and conclusions found in about two dozen published articles about the effects of suction dredging. The purpose of this study is to present the known facts to the general public. It is expected that only facts and truths can lead to a rational end to the controversies over multiple use of the public lands.

The number of articles directly about effects of dredging are limited. Publications about fish habitat are legion. Most of the articles were garnered from the internet. A few had been around for a long time.

The total of 27 publications contained reports on some 13 separate studies of dredging effects and 7 reviews of accumulated findings and existing regulations. Three older articles discuss effects of sediment from historic mining or sediment in general. One of these, Dr. Wards ODOGAMI Bulletin #10, is also remarkable because the Oregon Dept. of Fish and Wildlife tried to recover and suppress this article some years back. Dr. Ward's conclusions apparently go against some current prevailing doctrines.

No publications were directly ignored, but there are too many related articles in published bibliographies to review them all. The initial deadline for this article was April 23 [2001], the end of the comment period on the local mineral withdrawals. That and the remarkable consistency of the reports permits a public disclosure of findings at this time.

A request to Siskiyou Regional Education Project (SREP) returned no real reference, either for or against. They were specifically asked for photocopies or bibliography of articles about the effects of suction dredging. Their packet contained only local newspaper clippings, some immoderate environmental magazines from Australia promoting "uncivil" acts, and a couple of slick products pushing the Siskiyou National Monument. This is even though they have been known to reference Harvey et al (1995) in public and in court (SREP vs. Rose, 1999).

Reference numbers are keyed to the related bibliography. All studies were by government agencies, universities, and professional organizations. All studies are certainly main-stream and reasonably scientific.

SUMMARY OF DREDGING PUBLICATIONS

Harvey et al (1995)

Harvey et al (1995) is a review of publications and potential problems, as well as recommendations for future management at the watershed level. This seems to be about the only article quoted by immoderate environmentalists. It does record every possible thing that could be used to suggest there might be significant harm. It doesn't come to any conclusion about whether or not dredging should be allowed.

After the over-environmentalistic excesses at the end of the Clinton administration, Harvey et al (1995) can also be viewed in a different light. The study was requested and funded by the Clinton Forest Service. Immoderate environmentalists, those who are trying to end multiple use, seem to think that this article gives them something that the earlier publications didn't. Therefore, this article appears to be a gift to the extremists whose interests were improperly pushed at the end of the Clinton era.

Summary of Conclusions

All statements from the articles are referenced. Your present reporter's comments are not.

Miner's Efforts

A majority of dredge operations studied did not work long periods or disturb large areas of the stream bed.[9] Of the 200 miners studied, only 57 spent more than 500 hours per season.[16] Thus, it appears that dredgers mostly worked afternoons in the summer, even before the setting of the dredging season between hatching and spawning. That's partly because it takes half a day to drive out there and mornings in the mountains can be cool, even in summer.

Water Quality: Turbidity, Sediment, Temperature

Water quality was impacted only during the actual operation of a suction dredge, which generally was only 2 to 4 hours of actual operation.[9] The primary effect of suction dredging was increased turbidity and total filterable solids downstream from the dredge from 30 to 150 meters.[14, 16] Naturally occurring minerals, such as copper and zinc sulfides, may be stirred up from stream bed sediments.[16] **Dredge plumes, although visible, were probably of little direct consequence to fish and invertebrates.[19] Movement rate of suction dredging equals 0.7% of natural rates.[3]**

Deposited sediment decreased exponentially downstream with distances from dredging.[20] Suspended sediment returned to ambient levels 30 to 60 meters downstream.[8, 20] In a few cases, sediment went further downstream than found in other studies because of steep stream gradient and fine sediment.[18] **Maximum sediment concentrations were only a minute fraction of the great loads needed to impact fish feeding and respiration.**[19] **Dredge mining had little, if any, impact on water temperture.**[9]

Fish: Eggs, Young, and Adults

Mortality of fish eggs by dredging ranged by species from 29% to 100% and were generally greater than that of hatchery stock of the same age.[5] Presence of silt during nonerosion periods results in bottom deposition which is damaging to fry production.[17] This is why the dredging season was set between hatching and the next spawning.

There's no doubt that too much sediment is bad for fish eggs. However, dredging can improve permeability and velocity of water in gravel.[11] Intergravel permeability at one site increased, although not significantly; no changes in downstream permeability were noted.[20] **A five-inch dredge could improve the intergravel**

The abundances of several species of aquatic insects and riffle sculpin were adversely affected, but only at and immediately downstream from the dredge site.[8] Due to differences between species… the lack of significant differences between control and dredged stations observed for some taxa is not surprising.[6] The dredging did not significantly reduce the number of invertebrates.(9) Only 7.4% of benthic insects died from going through a dredge.[11] The effects of dredging… were not severe enough to cause differences in mean numbers of invertebrates or in diversity indices.[18]

Effects on the benthic community are highly localized.[6, 8] All settled back to the bottom within 40 feet of the dredge.[11] Impacts on aquatic insect abundance were limited to the area dredged.[20] Most of the recolonization of benthic invertebrates was completed after 38 days.[5]

Impacts of dredging to invertebrates were minimal.[25] Effects of dredging on insects and habitat were minor compared to bed-load movement due to large stream flows during storms and from snowmelt.[18]

Several studies all reported that invertebrates recolonized dredge sites within 30 to 45 days.[5, 14] Substantial recovery of invertebrates occurred rather rapidly, and disturbance occurred only close downstream from the dredge.[16] The 45 day recolonization experiment indicates not only a rapid recovery but also a rapid recovery in the total number of insects over time.[6] Almost all taxa found on cobble substrates take part in the recolonization of sand and gravel areas.[6] Dredging can improve the gravel environment for aquatic insects, as well as fish eggs.[11]

Stream Channel and Banks

Dredging or highbanking of bank materials should be prohibited as this may create turbidity and stream bank instability, unless there is a holding pond.[2] Stream-side vegetation should not be removed.[2] Only a few dredgers undercut banks, thus channelizing the stream, removing vegetation and accelerating bank erosion.[25] Camping in the riparian zone caused some damage.[12] Survey suggested that mining of the streambanks caused more damage than dredging.[12] Moving of large boulders alters the stream bed.[12] Boulders and logs should be replaced, if removed, for fish habitat.[2] **Few miners caused adverse impacts.**[12]

Changes to stream bed were major but localized, such as excavation to bedrock in a hole.[18] Disturbed stream reaches were only a few tens of meters.[8, 14] Stream bed alterations are probably more long-lived on streams with controlled flows than on those with flushing flows.[8, 19] Where flushing flows occur, substrate changes are gone in from one month to one to three years.[8, 16, 17] Holes and piles in the center of the stream are usually gone after one winter.[19] Piles along the banks may linger.[19] This is similar to piles left by historic miners.[19] Pool habitat created at the dredge site may compensate for pool loss immediately downstream.[20]

Natural Variation

Fish and invertebrates displayed considerable adaptability to dredging, probably because the stream naturally has substantial seasonal and annual fluctuations.[6] All measurements of dredge effects turned out to be within the natural variation of the local environment.[24] Stream environments are typically dynamic and variable due to floods, natural inputs of sediment from landslides, and other sources, especially dams.[25] Salmon and steelhead runs were established in past climates much rougher at times than today's, even with mining.[25] That is, in the Ice Age precipitation, landslides, and sediment loads were often much greater than today.[25]

The fish runs did not decline during the first and greater episode of mining.[25] Thus, it's likely that the lesser mining of the 1930's is not the reason for the decline in fish runs at that time.[25] The main

difference between the two times are the dams, industrial wastes, and agricultural withdrawals of the later period.[25]

In the mid-seventies, Willard Street, local historian and author, told your present reporter that the end of the great fish runs of the Rogue River had coincided with the beginning of the agricultural withdrawals, not with mining. In the early 1990's, agricultural withdrawals are oversubscribed and that inforcement is poor, at best.

Cumulative Effects

Cumulative effects of suction dredging have probably not been fully determined, but there is considerable evidence of only localized and temporary effects from multiple dredges.[6, 7, 9, 12] Studied were the effects of six dredges in a 2 km stretch, [6] 40 dredges on an 11 km stretch,[7] up to 24 dredges on 15 km,[9] and 270 dredges in a part of the Sierra Nevada.[12] **Three years of monitoring on the Chugach National Forest found no noticeable impact to water quality from dredges of 6 inches or less.**[10]

"If there were a cumulative effect of dredging, an increasing number of taxa should have declined in abundance after June at downstream stations."[8] No such decline appeared in the data.[8] There is a need for additional study of cumulative effects and other items.[9, 16, 26] **However, no authors declared that effects were serious enough to warrant a change of law and end of dredging rights.**

Conclusions about the Conclusions

Studies to date have not shown any actual effect on the environment by suction dredging, except for those that are short-term and localized in nature.[14, 21] Effects were significant, but localized.[8] The size of the impact zone varies.[8] A six-inch dredge is appropriate where substrate gravel size is large, but a large aperture may be disruptive in a small channel.[11] Suction dredging effects could be short-lived on streams where high seasonal flows occur.[6, 7, 9] **The greatest potential for damage is at low flow.**[15]

Even though cumulative effects and some other questions have not been thoroughly studied, there has been nothing to date to substantiate closure of the small-scale mining operations.[23] **Even with the absence of data, environmental groups were active to close down mining citing unsubstantiated possible discharge violations.**[23] **The effects of suction dredging would appear to be less than significant and not deleterious to fish.**[26]

Regulations and Future Management

Current regulations of size and season appear adequate to protect habitat, with some future adjustments.[18, 25, 27] Suction dredges of larger than 4 inches generally have more than de minimis effects on the aquatic environment and therefore require authorization.[21] The DEI by the State of California stated that, "based on best available data, it is anticipated that the regulations, as amended by the proposed project, will protect fish and other related aquatic dependent resources and will not cause significant effects to the environment or deleterious effects to fish."[26]

Harvey et al (1995), at the request of the Forest Service, reviewed existing studies and recommended analyzing dredging effects by watershed.[27] **California, Idaho, Washington, and Oregon manage dredging with the conclusion that, with mitigations, effects are insignificant.**[27]

17. Shaw and Maga, 1942
18. Somer and Hassler, 1992
19. Stern, 1988
20. Thomas, 1985
21. US Army Corps of Engineers, (1994)
22. US Dept. of Agriculture, (1997)
23. USGS, 1998
24. Wanty et al, 1997
25. Ward, 1938
26. State of California, 1997
27. Harvey et al, 1995

Dr Robert N. Crittenden

Regarding Dredging, sluicing, and panning

Dredging, panning, and sluicing not only improve salmonid habitat but can also create new habitat.

Salmonid eggs and alevins (alevins are tiny newly hatched salmonids which still reside in the interstitial spaces among the gravel of the streambed) need clean gravels through; which interstitial water can flow, providing them with oxygen. Silts and fine sands reduce the porosity of the streambed, thereby, reducing the interstitial flow and the oxygen supply. It can also reduce the amount of interstitial space for alevins. Reduced porosity has been shown to be directly related to reduced survival of salmonid eggs and alevins.

If properly conducted (for example, according to the present guidelines in Washington State — WDW 1987) dredging, panning, and sluicing reduce the amount of fine sand and silt in the streambed and, thereby, improve its porosity. These activities will, therefore, result in better interstitial flow, a better interstitial oxygen supply for eggs and alevins, and more interstitial space for alevins. The net result is improved survival for salmonid eggs and alevins.

Thus, dredging, panning, and sluicing improve existing salmonid habitat and can also create new habitat. These activities should be encouraged.

Habitat for salmonid eggs and alevins — the importance of streambed porosity:

Pink Salmon: As William R. Heard pointed out in his (1991) review "Pink salmon choose a fairly uniform spawning bed in both Asia and North America. Generally these spawning beds are situated on riffles with clean gravel or along the borders between pools and riffles in shallow water with moderate to fast currents. . . . pink salmon avoid spawning in quiet deep water, in pools, in areas with a slow current, or over heavily silted or mud-covered streambeds."

Pink salmon *(Oncorhynchus gorbuscha)* spawning sites may be characterized as being clean gravels. However these sites may also have a few cobbles, a mixture of sand, but relatively little silt (Semko 1954; Kobayashi 1968; Dvinin 1952; Smirnov 1975; and Hunter 1959).

The faster the current, the larger the particle which will be suspended and carried off by it. Hence, a strong current provides some guarantee that silts and fine sands will not plug up the interstitial spaces. The more rapid flow is also turbulent. The eggs and alevins are provided with a good oxygen supply by the turbulent mixing of water into the interstices of the streambed.

The porosity of a streambed and the survival of eggs and alevins has been demonstrated to be directly related to the composition of the streambed, being lower where there are more fine sands and silt (McNeil and Ahnell 1964; Rukhlov 1969; Brannon 1965; Bams 1969).

Chum **Salmon:** In contrast, to pink salmon which preferentially select riffles, chum salmon *(Oncorhynchus ketd)* tend to select sites of upwelling spring water (Kobayashi 1968). These sites often have a lower flow rate than is found at pink salmon sites (Bams 1982; Soin 1954; Sano and Nagasawa 1958). Chum salmon spawning sites may be found directly below a pool which is partially obstructed at its lower end by a gravel bar. The water infiltrates the gravel bar, travels through the bar as ground water, and reemerges into the water column below the bar.

Interstitial flow is as important for the survival of their eggs and alevins, as it is for the pink salmon. However, in this case the oxygen is carried into the groundwater by convection (that is by the net movement of water into and then out of the streambed) rather than by turbulent mixing. However, in some cases turbulent mixing may also be an important factor at chum spawning sites.

Sockeye Salmon: Sockeye salmon *(Oncorhynchus nerka)* spawn either in streams or in areas along lake shores which have underwater springs. There is also a case of beach spawning where turbulence provides the oxygen supply (Olsen 1968). Spring-fed and Beach spawning sites often have lower oxygen levels than stream sites and sockeye eggs have some ecological and physiological adaptations which improve their survival under those slightly reduced oxygen levels. (Smirnov 1950; Soin 1956, 1964). However, their oxygen supply (and, hence, substrate porosity) remain an important factor affecting their survival.

Coho Salmon: Coho salmon *(Oncorhynchus kisutch)* mostly spawn in small steams in areas of gravel of 15 cm or less in diameter (Burner 1951). In some cases Burner found that the spawning sites contained mud, silt, or fine sand, but that this was removed in the nest-building activity. Chamberlain (1907) concluded that coho are the least selective of the salmon species about their spawning site — he found them spawning in almost every stream or river in a very broad range of sites from smoothly flowing to white water and from cobble to muddy His conclusion was also supported by Foerster (1935) and Pritchard (1940).

However coho appear to prefer small streams (Gribanov 1948) and select a site at the head of a riffle where there is a good interstitial flow (Shapovalov and Taft 1954). The porosity of the streambed and the flowrate of the stream are also important factors affecting site selection (Briggs 1953; Gribanov 1948). Survival has been shown to be related to the porosity of the streambed (Tagart 1984).

King Salmon: King Salmon *(Oncorhynchus Tshawytscha)* show strong selectivity for spawning areas with high interstitial flow rates (Vronskiy 1972; Russell et al. 1983). Mike Healey (1991) suggests that of all the salmon species, king salmon may be the most sensitive to reduced oxygen levels during the egg and alevin stages. Their sensitivity to the oxygen level was experimentally demonstrated by Silver et al. (1963). The strong relationship between survival and the percolation rate of oxygenated interstitial water was experimentally demonstrated by Shelton (1955) and demonstrated under field conditions by Gangmark and Broad (1955) and Gangmark and Bakkala (1960).

As Mike Healey (1991) points out, "There is no doubt that percolation is affected by siltation and that siltation in spawning beds causes high mortality (Shaw and Maga 1943; Wickett 1954; Shelton and Pollock 1966).

Caveats: Bear in mind that spawning habitat limitation may not be the mechanism limiting the abundance of any specific stock of salmon. There is an absence of support for the habitat limitation hypothesis, except in a few isolated cases. Nevertheless, the enhancement of habitat and the improvement of survival for eggs and alevins are generally desirable goals.

Also bear in mind that in areas which have no fish, restrictions on dredging, sluicing, or panning aren't needed. An example of such as area is the region of a watershed above an impassible barrier, whether it is a dam, waterfall, or rapid.

In areas which have fish, recreational mining activities should be restricted to times of the year such that eggs and alevins aren't buried under silt and fine sediment while they are still in the gravel. Such regulations are already in place in Washington State.

Effects of dredging, sluicing, and panning on the porosity of the streambed:

Generally these activities involve the removal of sediment material from the streambed or, more often, from a gravel bar. The fine components of the sediment become suspended in the wash water and are carried downstream. The finer the sediment the further it will be carried. However, it will eventually settle, often in a quiet pool area.

What is involved here is the movement of the smaller particles out of a riffle area and into a pool area. Generally this will improve the streambed porosity in the riffle area. Recall that riffles are generally the preferred spawning habitat.

Medium sized particles may deposit in the riffle area. During the next major peak-flow event both the fine sediments and the medium sized particles will often be carried far downstream.

Thus, the effect of mining is to increase the downstream transport rate for fine and medium sediments. The consequence must be that the stream-system as a whole will have fewer of these sediments. This will result in greater streambed porosity. As the literature I have reviewed above shows, for all salmonid species greater porosity results in better survival and more available habitat for eggs and alevins.

In the case where the sediment is removed from a bar, rather than from the streambed, it is necessary to consider a longer time period — Stream courses aren't stationary but move within the confines of the streambanks. Fine sediments in gravel bars will be resuspended in the stream during these natural movements of the stream over the course of several years.

However, if the bars have been mined on a regular basis, their fine and medium particles will already have been removed before the river naturally resuspends them. Gravel bars which are free of silts and fine sand provide habitat. Although these bars may appear dry, there is often water and interstitial spaces below the surface, which can support alevins and redds (that is, nests of eggs) which were laid during high-water.

Recommendation:

The conclusion is that the recreational mining activities of panning, sluicing, and dredging enhance salmonid habitat. These activities should be encouraged. They provide one of the most cost-effective enhancement techniques as they are a beneficial side-effect of private recreation.

Literature Cited:

Bams, R.A. 1969. Adaptations of sockeye salmon associated with incubation in stream gravels. p71-87 in T. G. Northcote (ed.) Symposium, on Salmon and Trout Streams. H.R. MacMillan Lectures in Fisheries. Institute of Fisheries, Univ. of BC., Vancouver B.C.

Bams, R. A. 1982. Experimental incubation of chum salmon *(0. Keta)* in a Japanese style hatchery system. Can. Tech. Rep Fish. Aquat. Sci. 1101: 65 P-

Brannon, E.L. 1965. The influence of physical factors on the development and weight of sockeye salmon embryos and alevins. Int. Pac. Salmon Comm. Prog. Rep. 12: 26 p.

Briggs, J.C. 1953. The behavior and reproduction of salmonid fishes in a small coastal stream. Calif, Dep. Fish Game Bull 94: 62 p.

Burner, C.J. 1951. Characteristics of spawning nests of Columbia River salmon.Fish. Bull. Fish Wildl. Serv. 61: 97-110.

Chamberlain, F.M. 1907. Some observations on salmon and trout in Alaska. Rep. U.S. Bur. Fish. Doc. 627:112 p.

Dvinin, P.A. 1952. The salmon of south Sakkhalin. Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr. 37: 69-108. Translation from Russian by Fish Res. Bd. Can. Transl. Ser. 120.

Foerster, R.E. 1935. Inter-specific cross-breeding of Pacific Salmon. Proc.Trans. R. Soc Can. Ser 3 29(5):21-33.

Gangmark, H.A. and R. G. Bakkala 1960. A comparative study of unstable and stable (artificial channel) spawning streams for incubating king salmon in Mill Creek. CAlif. Fish Game Bull. 46: 151-164.

Gangmark, H.A. and R.D. Broad 1955. Experimantal hatchin of king salmon in Mill Creek, a tributary of the Sacramento River. Calif. Fish. Game Bull. 41:233-242.

Gribanov, V.I. 1948. The coho salmon *(0. kisutch)* — a biological sketch. Izv, Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeangr. 28: 43-101. Translated from Russian in Fish Res. Bd. Can. 25: 825-827.

Healey, M.C 1991. Life History of Chinook Salmon *(O. tshawytscha)* pages 131-393 in C. Groot and L. Margolis *Pacific Salmon Life Histories* UBC PressVancouver, BC 564 p.

Heard, W.R. 1991. Life History of Pink Salmon (Oncorhyncus gorbuscha) pagers119-230 in C.

Groot and L. Margolis *Pacific Salmon Life Histories* UBC PressVancouver, BC 564 p. Hunter, J.G. 1959. Survival and reproduction of pink and chum salmon in a coastal stream. J. Fish. Res. Bd. Can. 16: 835-886.

Kobayashi, H. 1968. Some observations on the natural spawning grounds of pink and chum salmon in Hokkaido. Sci. Rep. Hokkaido Salmon Hatchery 22:7-13. In Japanese with an English summary.

McNeil, W.J. and W.H. Ahnell 1964. Success of pink salmon spawning relative to size of spawning bed materials U.S. Fish and Wildlf. Serv. Spec. Sci. Rep. Fish. 469:15 p.

Olsen, J.C. 1968. Physical environment and egg development in a mainland beach area and an island beach area of Illiamna Lake, p 169-197 in R.I. Burgner (ed.) Further studies of Alaska sockeye salmon. Univ. Wash. Publ. Fish.New Ser. 3.

Pritchard, A. L. 1940. Studies on the age of the coho salmon *(O. kisutch}* and the spring salmon *(0. tschawytscha)* in British Columbia. Proc.Trans. R. Soc. Can. Ser. 3 34(5): 99-120.

Rukhlov, F.N. 1969. Materials characterizing the texture of bottom material in the spawning grounds and redds of the pink salmon *(Oncorhynchus gorbuscha)* in the Sakhalin fish hatcheries in 1976. J. Ichthyol. 20: 110-118.

Russell, L.R. K. R. Conlin, O.K. Johansen, and U. Orr 1983. Chinook salmon studies in the Nechako River: 1980, 1981. 1982. Can. MS. Rep. Fish. Aquat. Sci. 1728: 185 p.

Sano, S. and A. Nagasawa 1958. Natural propogation of chum salmon, *O. keta,* in Memu River, Tokachi, Sci Rep. Hokkaido Salmon Hatchery Translated from Japanese in Fish Res. Bd. Can. Transl. Ser 198.

Semko, R.S. 1954. The stocks of West Kamchatka salmon and their commercial utilization. Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr. 421:3-109. Translated from Russian in Fish Res. Bd. Can. Transl. Ser 288.

Shapovalov, L. and A.C. Taft 1954. The life histories of the steelhead rainbow trout *(Salmo gardneri)* and the silver salmon *(O. kisutch)* wiht special reference to

Waddell Creek, California, and recommendations regarding their management. Calif. Dep. Fish Game bull. 98: 375 p.

Shaw, P.A. and J.A. Maga 1943. The effect of mining silt on yield of fry from salmon spawning beds. Calif. Fish Game 29: 29-41.

Shelton, J.M. 1955. The hatching of chinook salmon eggs under simulated stream conditions. Prog. Fish-Cult. 17: 20-35.

Shelton, J.M. and R. D. Pollock 1966. Siltation and egg survival in incubation channels. Trans. Am. Fish. Soc. 95: 183-187.

Silver, S.J., C.E. Warren, and P Doudoroff 1963. Dissolved oxygen requirements of developing steelhaed trout and chinook salmon embryos at different water velocities. Trans. Am. Fish. Soc. 92: 327-343.

Smirnov, A.I. 1950. Importance of carotinoid pigmentation at the embryonic stages of cyprinids. Dokl. Akad. Nauk SSSR 73:609-612. (In Russian) 1956.

Respriatory significance of the carotinoid pigments in the eggs of salmonids and other representatives of the Clupeiformes. Zool. Sh. 35: 1362-1369. Translated from Russian in Fish. Res. Mar. Ser. (Can.) Transl. Ser 4538.

Smirnov, A. I. 1975. The biology, reproduction, and development of the Pacific salmon. Izdatel'stov Moskovskogo Universiteta, Moscow USSR. Translated from Russian: Fish. Res. Bd. Can. Transl. Ser. 3861.

Soin, S.G. 1954. Pattern of development of summer chum, masu, and pink salmon. Tr. Soveshch. Ikhtiol. Kom. Akad. Nauk. SSSR 4: 144-155. Translated from Russian in Pacific SalmonL selected articles from Soviet periodicals, p42-54. Israel Program for Scientific Translations, Jersalem 1961.

Soin, S.G. 1964. Adaptational features in the development of fish in connection with different feartures of respiration. Vestn. Mosk. Univ. Ser VI Biol. Pochvoed 1964(6), in Russian.

Tagart, J.V. 1984. Coho salmon survival from egg deposition to fry emergence, p 173-181 in J.M. Walton and D.B. Houston (eds.) Proceedings of the Olympic Wild Fish Conference, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA.

Vronskiy, B.B. 1972. Reproductive biology of the Kamchatka River chinook salmon *(O. tshawytscha).* J. Ichthyol. 12: 259-273.

Washington Department of Wildlife 1987. Gold and Fish. 20. p. Wash. Dept. Fish Wildl., Olympia, Wash.

Wickett, W.P. 1954. The oxygen supply to salmon eggs in spawning beds. J. Fish. Res. Bd. Can. 11: 933-953.

Sincerelv

Dr. Robert N. Crittenden
March 2, 1996

State Water Resources Control Board
Division of Water Quality
P.O. Box 100
Sacramento, California 95812-0100
Fax: 916-341-5620

June 15, 2007

Subject: **SUCTION DREDGE MINING**

Dear Board Members,

It has been claimed, at your recent June 12th Board meeting, that reintroduction of mercury in the water traveling through a suction dredge will pose an environmental risk. In the unlikely event that mercury would escape the sluice box recovery system on a suction dredge, it's very nature, would cause it to instantly mix with the other bottom materials moving through the sluice box and cause it to settle deep within the stream or river bottom overburden. The density of mercury is 13.53 grams per cubic centimeter (g/cm^3). The density of gold and lead are, respectively, 19.28 g/cm^3 and 11.34 g/cm^3. Lead, the least dense of the three metals, is routinely found in the cleanup of the dredge sluice boxes which are also collecting lost fishing weights.. That is a very good indicator that the heavier mercury is being captured and held in the sluice box. There is no new harm… but there is the very real benefit to the environment from the removal of the associated mercury and lead.

It has been proven that suction dredges are ideal for the safe recovery of lead and mercury from stream and riverbed sediments. In fact, they do such a good job that rather than disparage the use of suction dredges, it would serve the public good and increase the effectiveness of it's own mission (i.e.; to protect the environment) by encouraging even more suction dredge activity, and providing safe and secure disposal sites for these recovered metals.

Studies and a trial program prove the effectiveness and benefits of the recovery of mercury during suction dredge mining operations. **The US EPA Region 9** (San Francisco, CA office) **has recognized the benefits associated with suction dredger mining as a method of aiding their efforts in environmental cleanup at no cost to the tax payer and have touted the benefits of suction dredgers removing mercury from the environment.**

US EPA REGION 9, MERCURY RECOVERY FROM RECREATIONAL GOLD MINERS

http://www.epa.gov/region09/cross_pr/innovations/merrec.html

The Challenge:

Looking for gold in California streams and rivers is a recreational activity for thousands of state residents. Many gold enthusiasts simply pan gravels and sediments. Serious recreational miners may have small sluice boxes or suction dredges to recover gold bearing sediments. **As these miners remove sediments, sands, and gravel from streams and former mine sites to separate out the gold, they are also removing mercury**.

This mercury is the remnant of millions of pounds of pure mercury that was added to sluice boxes used by historic mining operations between 1850 and 1890. Mercury is a toxic, persistent, and bioaccumulative pollutant that affects the nervous system and has long been known to be toxic to humans, fish, and wildlife. Mercury in streams can bioaccumulate in fish and make them unfit for human consumption.

The Solution:

Taking mercury out of the streams benefits the environment. Efforts to collect mercury from recreational gold miners in the past however have been stymied due to perceived regulatory barriers. Disposal of mercury is normally subject to all regulations applicable to hazardous waste.

In 2000, EPA and California's Division of Toxic Substance Control worked in concert with other State and local agencies to find the regulatory flexibility needed to collect mercury in a simple and effective manner. These groups agreed to test two different mechanisms for collecting mercury during the summer of 2000. One approach was to add mercury to the list of materials that are collected at regularly scheduled or periodic household hazardous waste collection events sponsored by local county agencies.

Another mercury collection approach was to set up collection stations in areas where mercury is being found by recreational miners. One possibility would be to advertise a fixed location where people could bring mercury on a specific date and time. Another was to create a mercury "milk run" where state, local, or federal agency staff would come to locations specified by individuals or organizations such as suction dredging clubs, and pick up mercury that had been collected.

The Results:

In August and September, 2000 the first mercury "milk runs" collected **230 pounds of mercury**. The total amount of mercury collected was equivalent to the mercury load in 47 years worth of wastewater discharge from the city of Sacramento's sewage treatment plant or the mercury in a million mercury thermometers. This successful pilot program demonstrates how recreational **gold miners and government agencies can work together to protect the environment**. In the summer of 2001, State agencies planned to extend the program to six counties and include collection of mercury at summer mining fairs. (US EPA, 2001)

Getting 230 pounds of mercury out of the environment is an achievement that would not have been accomplished without the aide of the suction dredgers. The mining community of today is in my opinion the only group that are in a position with the technology to help out and at a very economical price to the public. Any residual mercury remaining after dredging in a location is that much less to worry about in our nations waterways.

THE 1999 FINAL REPORT FOR THE 40-MILE RIVER STUDY

Heavy Metals

For the unfiltered samples, two metals, copper and zinc, showed distinct increases downstream of the dredge. Total copper increased approximately 5-fold and zinc approximately 9-fold at the transect immediately downstream of the dredge, relative to the concentrations measured upstream of the dredge. For both metals, the concentrations declined to near upstream values by 80 m downstream of the dredge. The pattern observed for total copper and zinc concentration is similar to that for turbidity and TFS, suggesting that the metals were in particulate form, or associated with other sediment particles. Zinc, arsenic, and copper displayed an average value downstream of the dredge that was greater than the average value measured upstream of the dredge (note that samples sizes are low, particularly upstream of the dredge). Copper displayed the greatest change, increasing by approximately 3-fold downstream of the dredge. Dissolved lead concentrations did not appear to be affected by operation of the dredge. **Values of dissolved mercury actually were greater upstream of the dredge, suggesting that any effect of the dredge was likely within the range of natural variation.** (The operator reported observing deposits of liquid mercury within the sediments he was working.) For both dissolved and total concentrations, budgetary limitations precluded multiple sampling across either space or time, thus the results of heavy metal sampling are only indicative of likely conditions. (Prussian, A.M., T.V. Royer and G.W. Minshall, 1999)

Conclusions from the US EPA's commissioned Forty-Mile River study documented that heavy metals in sediments were not a concern and any contaminated sediments containing mercury were not a problem in gold bearing rivers and streams.

An important benefit of suction dredging for gold is that through gravity separation other heavy metals such as mercury are also trapped in the riffles of the sluice box and can be readily collected for disposal or resale.

Mercury Contamination from Historic Gold Mining in California. USGS Fact Sheet FS-061-00 (2005)

MERCURY METHYLATION and BIOMAGNIFICATION

Mercury occurs in several different geochemical forms, including elemental mercury [Hg(0)], ionic (or oxidized) mercury [Hg(II)], and a suite of organic forms, the most important of which is **methylmercury** *(CH_3Hg^+)*. Methylmercury is the form most readily incorporated into biological tissues and most toxic to humans. The transformation from elemental mercury to methylmercury is a complex biogeochemical process that requires at least two steps, (1) oxidation of Hg(0) to Hg(II), followed by (2) transformation from Hg(II) to CH_3Hg^+; step 2 is referred to as **methylation.**

Methylation of mercury is controlled by sulfate-reducing bacteria and other microbes that tend to thrive in conditions of low dissolved oxygen, such as near the sediment-water interface or in algal mats. Numerous environmental factors influence the rates of mercury methylation and the reverse reaction known as demethylation. These factors include temperature, dissolved organic carbon, salinity, acidity (pH), oxidation-reduction conditions, and the form and concentration of sulfur in water and sediments. (USGS 2005)

An important fate of mercury, in contaminated overburden, is to be transported to downstream areas. **This occurs naturally every year during high flow episodes.** However, because the rivers and streams of the Northwest are highly oxygenated, and would be slow in transforming mercury to methyl mercury, there have been few methyl mercury problems reported.

MERCURY IN THE ENVIRONMENT, USGS FACT SHEET 146-00 (October 2000) WHERE METHYL MERCURY IS A PROBLEM

Although mercury is a globally dispersed contaminant, it is not a problem everywhere. Aside from grossly polluted environments, **mercury is normally a problem only where the rate of natural formation of methyl mercury from inorganic mercury is greater than the reverse reaction. Methyl mercury is the only form of mercury that accumulates appreciably in fish.** Environments that are known to favor the production of methyl mercury include certain types of wetlands, dilute low-pH lakes in Northeast and North central United States, parts of the Florida Everglades, newly flooded reservoirs, and coastal wetlands, particularly along the Gulf of Mexico, Atlantic Ocean, and San Francisco Bay. (USGS 2000)

Since none of these areas listed by the USGS are areas that suction dredge mining occur to a large extent and for the fact that methylation occurs in anaerobic sediments under complex conditions effected by many factors including pH and temperature **the likelihood of any major mercury problem is highly unlikely in most gold bearing rivers and streams.**

Suction dredging is used by other agencies as a means to clean up streambed sediments for habitat restoration activities:

NOAA: http://www.photolib.noaa.gov/ habrest/crp_duc.html

DUCK CREEK WATER QUALITY AND ANADROMOUS FISH HABITAT RESTORATION

Duck Creek, a surface water body in Alaska, is impaired by urban runoff from non-point source **pollutants including, heavy metals**, hydrocarbons, iron flocs and excess nutrients. This small coastal stream originates from a spring that drains runoff from Mendanhall Valley, a relatively high residential and business area.

Historically there were runs of nearly 10,000 chum salmon and Coho runs of about 500 fish in Duck Creek. Currently the chum run is extinct and the Coho run consists of only 20 fish. Restoration at Duck Creek involves the development and implementation of bio-remediation methods to restore water quality and anadromous fish habitat in impaired streams.

NOAA scientists attempted to correct the degraded conditions by using high-pressure jet pumps and **suction dredges to remove fine sediment from the streambed.** Researchers also added natural structures to direct stream flow and increase oxygen levels. The removal or replacement of perched culverts that impair fish habitat will also take place to reduce flood hazards. **This project demonstrates the benefits of restoration and the importance of aquatic habitat protection in maintaining healthy aquatic ecosystems.** (NOAA, 2006)

As should be obvious to all, the benefits extremely outweigh any negative concerns of heavy metals in sediments of gold bearing streams and rivers mined using suction dredge techniques.

A recent study was conducted by Washington State Department of Ecology, entitled:

THE EFFECTS OF SMALL-SCALE GOLD DREDGING ON ARSENIC, COPPER, LEAD AND ZINC CONCENTRATION IN THE SIMILKAMEEN RIVER (March 2005).

Their findings were deemed a "*worst-case assessment in several respects*". The study was conducted because ambient arsenic concentrations in the Similkameen River substantially exceed Washington State human health criteria due to natural conditions. The following depicts these findings: (1) Metals concentrations in the effluent and plumes would be subjected to further dilution in the river; (2) Sub-samples for the effluent composites were only taken when the suction hose was in contact with the streambed; (3) Less restrictive water quality criteria would apply at other times of the dredging season when hardness levels are higher; and, (4) Once the effluents are discharged, the metals will partition in to dissolved and particulate fractions. The dissolved fraction is the primary toxicity concern.

It was interesting to note that the Department of Ecology found, ***"The metals concentration measured in gold dredge effluents during the present study were at or below aquatic life criteria"***. Therefore, criteria exceedances would not be anticipated in the Similkameen River, regardless of the number of dredges operating.

A series of dilution calculations were done to estimate what effect multiple dredges would have on metals concentration in the river. As a point of reference, the maximum number of dredges Ecology personnel have observed on the Similkameen is approximately 20, during average September flows. The report estimates that it would take somewhere between 17 and 57 dredges operating continuously (i.e. 24 hours a day) to increase dissolved zinc, lead and copper concentrations by 10%. Further, the report states, *"It would take between approximately 200 and 520 dredges to have the same effects on total recoverable and dissolved arsenic, respectively. In order for zinc, lead, or copper concentrations to be doubled in the river, anywhere from 170 to 570 dredges would need to be operating. Arsenic concentrations in the dredge effluents are too low to cause an increase of that magnitude, regardless of river flow. As demonstrated elsewhere in this report, a 100% increase in the ambient arsenic, copper, lead, or zinc concentrations in the Similkameen River would not result in exceedances of aquatic life criteria."* (Johnson, A. and M. Peterschmidt, 2005)

Results showed that the metals concentrations discharged from small-scale gold dredges are not a significant toxicity concern for aquatic life in the Similkameen and that it would take large numbers of dredges to effect a small change in the river's arsenic levels, even at low-flow conditions. (Johnson, A. and M. Peterschmidt, 2005)

As the scientific literature clearly shows that suction dredging has little effect, if any, on heavy metal contamination that may arise from redistribution of the bottom substrate during normal mining activity. Most importantly, suction dredge miners aid in recapturing mercury and other heavy metals such as lead that otherwise would be continuously transported in heavy winter flows to be relocated further down stream.

I hope you find this information of value and I appreciated the chance to provide it for your consideration in this matter.

LITERATURE CITED

Johnson, A. and M. Peterschmidt, 2005. The effects of small-scale gold dredging on arsenic, copper, lead and zinc concentration in the Similkameen River.

NOAA, 2006: Duck Creek Water Quality and Anadromous Fish Habitat Restoration **http://www.photolib.noaa.gov/ habrest/crp_duc.html**

Prussian, A.M., T.V. Royer and G.W. Minshall, 1999. Impact of suction dredging on water quality, benthic habitat, and biota in the Fortymile River, Resurrection

Creek, and Chatanika River, Alaska, FINAL REPORT. US Environmental Protection Agency, Region 10, Seattle, Washington.

USEPA, 2001. Mercury Recovery from Recreational Gold Miners. http://www.epa.gov/region09/cross_pr/innovations/merrec.html

USGS, 2000. Mercury in the Environment, USGS Fact Sheet 146-00 (October 2000) Environments Where Methyl mercury is a Problem.

USGS, 2005. Mercury Contamination from Historic Gold Mining in California. USGS Fact Sheet FS-061-00 (2005). Charles N. Alpers, Michael P. Hunerlach, Jason T. May, and Roger L. Hothem http://ca.water.usgs.gov/mercury/fs06100.html

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News Release
U.S. Department of the Interior
U.S. Geological Survey
October 27, 1998

CERTAIN MINING OPERATIONS HAVE NOT HURT PRISTINE ALASKAN RIVER

The water quality of the Fortymile River-a beautiful, wild and scenic river in the remote part of east-central Alaska-has not been adversely impacted by gold placer mining operations according to an integrated study underway by the U.S. Geological Survey and the Alaska Department of Natural Resources.

Warren Day, a USGS research geologist from Denver, Colo. will present "Geologic Setting of the Fortymile River Mining District" on October 27 at the annual Geological Society of America meeting in Toronto, Canada at 1:30 p.m. Recent concern over the impact of suction dredge gold placer mining on the water quality of the Fortymile River prompted the collaborative study, with its overall objective focusing on establishing the baseline and background geologic, geochemical, and botanical framework for the lower Fortymile River area.

Day and his colleagues concluded that concentrations of arsenic found in the bedrock are within the ranges of the background soil and stream sediment values. A companion study of the surface water chemical and turbidity data has shown that any variations due to the suction dredging activity fall within the natural variations in the Fortymile River.

The suction dredge placer miners extract gold from the river gravels by sucking the gold-bearing gravels into the floating dredges, pumping the gravel-water mixture across a settling table where the gold concentrates by gravity, then discharging the gold-free gravel and water back into the river.

The management of the region and its resources is complex due to the many diverse land-use options. Small-scale, family-owned gold mining has been active on the Fortymile since the "gold rush" days of the late 1880's. However, in 1980, the Fortymile River and many of its tributaries received Wild and Scenic River status. Because of this status, mining along the river must compete with recreational usage such as rafting, canoeing, and fishing.

Violation of mining discharge regulations would close down the small-scale mining operations. No data existed before this study to establish if the mining was degrading the water quality. However, even with the absence of data, environmental groups were active to close down mining on the river citing unsubstantiated possible discharge violations.

This study has found no violations to date to substantiate closure of the small-scale mining operations. The result is a continuance of a way of life on the last American frontier.

Additional information about this study can be found at the following Internet address. This file is in Adobe Acrobat (.pdf) format. If you do not have the Acrobat Reader program, you may download it for free here.

http://greenwood.cr.usgs.gov/pub/fact-sheets/fs-0155-97/fs-0155-97.pdf

As the nation's largest water, earth and biological science and civilian mapping agency, the USGS works in cooperation with more than 2000 organizations across the country to provide reliable, impartial, scientific information to resource managers, planners, and other customers. This information is gathered in every state by USGS scientists to minimize the loss of life and property from natural disasters, to contribute to the conservation and the sound economic and physical development of the nation's natural resources, and to enhance the quality of life by monitoring water, biological, energy, and mineral resources.

This press release and in-depth information about USGS programs may be found on the USGS home page: http://www.usgs.gov

Impact of suction dredging on water quality, benthic habitat, and biota in the Fortymile River, Resurrection Creek, and Chatanika River, Alaska

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FINAL REPORT
June 1999

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Summary

This report describes the results of our research during 1997 and 1998 into the effects of commercial suction dredging on the water quality, habitat, and biota of the Fortymile River and recreational dredging on Resurrection Creek and the Chatanika River. On the Fortymile River, water chemistry, heavy metal concentrations, riverbed morphology, algal (periphyton) standing crop, and aquatic macroinvertebrate abundance and diversity were measured in relation to commercial

suction dredging for both years. The focus of our work on the Fortymile in 1997 was on an 8-inch suction dredge (Site 1), located on the mainstem and a 10 inch dredge located on the South Fork (Site 2a). Our research in 1998 included (1) resampling the 1997 sites on the mainstem and SF Fortymile to determine recovery after one year, (2) sampling a dredge site on the South Fork to examine for possible spatial variability in the effects of large-scale suction dredging on benthic communities (3) sampling a dredge site on the North Fork Fortymile to determine whether impact and recovery differ from conditions on the South Fork and the mainstem, and (4) again sampling unmined sites on the NF and SF to better document suspected background differences between the two forks in terms of macroinvertebrate communities. In all of the suction-mined sites studied, dredges were operated by experienced miners. Sampling was performed at fixed transects above and below the dredge locations. Additional sampling above the confluence of the North and South Forks revealed differences in background conditions in these two main tributaries.

At Site 1, dredge operation had no discernable effect on alkalinity, hardness, or specific conductance of water in the Fortymile. Of the factors we measured, the primary effects of suction dredging on water chemistry of the Fortymile River were increased turbidity, total filterable solids, and copper and zinc concentrations downstream of the dredge. These variables returned to upstream levels within 80-160 m downstream of the dredge. The results from this sampling revealed a relatively intense, but localized, decline in water clarity during the time the dredge was operating. The impact of suction dredging on water clarity and heavy metal concentrations may be greater or lesser than we measured, depending on the type of material the dredge is excavating.

The cross-sectional profiles indicate that the impact of the dredge piles relative to the width of the Fortymile River was small. After one year, dredge piles at Site 1 had largely disappeared following the scouring flows that accompany snow-melt in the Fortymile drainage. However, at Site 2, dredge piles were clearly discernable after one year. Macroinvertebrate abundance and diversity were greatly reduced in the first 10 m below the dredge at Site 1 during 1997, relative to the upstream reference site. For example, macroinvertebrate abundance was reduced by 97% and the number of taxa by 88% immediately below the dredge. The abundance and diversity of macroinvertebrates returned to values seen at the reference site by 80 to 160 m downstream of the dredge. A similar decline in macroinvertebrate abundance and diversity was observed at Site 2a. One year after dredging at both Site 1 and Site 2, recovery of macroinvertebrate diversity appeared to be substantial. The cumulative effect of suction dredging on the biota of the Fortymile is a function of the number of dredges operating concurrently, the size of the dredges, the strategy and effectiveness of their operators, and the rate and extent of re-colonization on the excavated dredge piles.

We compared conditions in the North Fork versus the South Fork of the Fortymile under the hypothesis that the greater background mining activity (of all types) on the SF would result in reduced macroinvertebrate abundance and diversity. We also expected that suction dredging would be relatively less harmful at already impacted sites than at sites that were less disturbed. An increase in macroinvertebrate density was found in the NF, relative to the SF, and this we attributed to the lower variability of benthic organic matter and greater amounts of periphyton standing crop that occurred in the NF. We could discern no natural reason for this difference and therefore attribute this result to the greater disturbance in the SF from all forms of mining, historic and current.

The second component of this project is to examine the effects of recreational suction dredging on smaller streams in Alaska. In 1997, sampling was conducted on a single site on Resurrection Creek, a designated recreational mining stream on the Kenai Peninsula. In 1998, sampling was conducted on the Chatanika River, known to be popular for recreational dredging. The Chatanika River was sampled at a location north of Fairbanks. The results from Resurrection Creek indicated that there was no difference in the macroinvertebrate community between the mining area and the locations downstream of the mining area, in terms of macroinvertebrate density, taxa richness, EPT richness, or food resources. Results from the Chatanika showed slight downstream decreases in macroinvertebrate density, but all other measures remained similar to those of the reference area. In general, our results are in agreement with other studies that have found only localized reductions in macroinvertebrate abundance in relation to small-scale suction dredging.

Part I - Suction Dredging in the Fortymile River

Introduction

This report describes the results of research performed during 1997 and 1998 to determine the possible impacts of commercial suction dredging on the water quality, benthic habitat, and biota of the Fortymile River, Alaska (hereafter, Fortymile). Also described in this report are the impacts by recreational dredging on the Chatanika River and Resurrection Creek. This is the first study of its kind to describe the effects of suction dredge mining on river ecosystems in Alaska.

In stream ecosystems, aquatic macroinvertebrates have become the primary assessment tool for resource managers (see Barbour et al. 1996, Cairns and Pratt 1993). Several characteristics of aquatic macroinvertebrates, as a group, have led to their general acceptance as reliable indicators of ecological condition: (1) they are generally immobile (relative to fish), (2) they consist of a relatively large number of species that, collectively, display a range of sensitivities and responses to various types of habitat degradation, (3) they tend to be ubiquitous throughout streams and rivers, and (4) they are relatively easy to sample and identify. For these reasons, our assessment of the effect of suction dredging on the Fortymile, Chatanika, and Resurrection focused on macroinvertebrates. In addition to aquatic macroinvertebrates, water chemistry, streambed geomorphology, algal (periphyton) standing crop, and benthic organic matter (BOM) standing crop also were measured in relation to suction dredging for both years. The latter two components form the food base for stream herbivores and detritivores and are vital to the production and recovery of aquatic macroinvertebrates. Variations in the sampling method between years are described in the Methods section.

Historically, gold mining occurred throughout the Fortymile basin and several types of operations are still active, including placer mining, hydraulic mining, and suction dredging. Large scale placer mining also occurs in some sections of the Chatanika River and historically in the lower reaches of Resurrection Creek. Our research was limited to investigations on the effects of suction dredging. We addressed two general topics: (1) the effect of relatively large (8-10 inch) commercial suction dredges on ecological conditions in the Fortymile and (2) the general effect of smaller (2-6 inch) recreational suction dredges on benthic habitat and biota in the Chatanika River and Resurrection Creek. Part I of this report presents the results from the Fortymile; Part II describes results of small-scale mining within the recreational mining sites.

Suction dredging typically involves excavating the deeper, largely uninhabited sediments and depositing them on top of the ecologically more important surface substrates. Sorting and re-deposition of substrata moved through a dredge were expected to alter the streambed geomorphology and create "dredge piles" downstream of the dredges. Our effort here was directed toward determining the size (height, width) of the dredge piles, relative to the cross-sectional width of the river. This type of physical disturbance of benthic substrata generally reduces periphyton standing crop, BOM, and macroinvertebrate density. Thus, substrata moved through the dredge were expected to support less periphyton than substrata in undisturbed areas of the river (see Peterson 1996). Abundance and diversity of macroinvertebrates also were expected to be sharply reduced in dredged areas, as physical tumbling of substrata is known to kill and/or dislodge associated organisms (see Resh et al. 1988 for review), in addition to reducing the available food base.

The impact of commercial suction dredging on benthic organisms was evaluated in 1997 on the South Fork and the mainstem Fortymile River (Fig 1.). One site was also sampled in the North Fork near the confluence of the North and South Forks. In addition to resampling the 1997 mainstem and South Fork dredge sites in 1998, we expanded our sampling to include one dredge site on the North Fork and two additional dredge sites on the South Fork. We also sampled three reference sites unaffected by mining activity on the North and South Forks, including the 1997 North Fork Confluence site. Overall, our goals for 1998 were (1) to determine the potential for recolonization of the previous year's dredge spoils, (2) to expand the spatial scale of our sampling by including sites that were dredged early (June), and late (September) in the season, and in different geomorphic settings (inside and outside of a meander bend), (3) to sample dredged sites in a less-disturbed portion of the basin (North Fork) than our other sites, and (4) to compare impact and recovery potentials of dredge mining between more disturbed (South Fork), and less disturbed (North Fork) streams in the same basin.

The research on recreational dredging was designed to assess the potential impacts on the aquatic macroinvertebrate community in streams from geographically diverse locations and streams known to have annually repeated, relatively, intense mining occur in the same location. Several potential sites were examined but most proved to be unsuitable for study because of the absence of discrete areas of concentrated suction dredging confounded by other disturbances. Resurrection Creek contains a section of stream designated for recreational mining activity by the State Department of Fish and Game and the U.S. Forest Service and is located on the Kenai Peninsula in Southcentral Alaska. The Chatanika River has no such designation that we know of, however it appears that mining is restricted to a section of river near Milepost 60 on the Steese Highway. The Chatanika River site is known to receive a sizeable amount of suction dredge activity throughout its available mining season.

Methods

Sampling Design - The majority of our work on the Fortymile in 1997 was conducted at a single site, with an 8-inch suction dredge operated by an experienced miner (hereafter, Site 1). Site 1 was located approximately 13 kilometers (8 miles) upstream of the Taylor Highway-Fortymile River Bridge (approximately 141° 30' W, 65° 17' N; Township 7 south, Range 32 east). Sampling was performed at fixed transects above, within, and below the dredge location (Fig. 2). Work at this site occurred from 14 through 17 August 1997, under baseflow conditions. Less intensive sampling also was conducted above and below a larger (10 inch) dredge located on the South Fork Fortymile also by a veteran miner (Site 2a), and near the mouth of the North Fork Fortymile (NF, Site 4). Sampling at Site 2a and in the NF was performed from 17-18 August 1997 and was restricted to recently dredged piles and un-dredged reference areas because the dredge was not active at the time, due to elevated water levels and turbidity following an intense rainstorm over an extensive part of the basin.

During 1998, we returned to both Site 1 and Site 2a to determine the degree to which the areas dredged in 1997 had recovered relative to the reference areas. At Site 1, the previous year's dredge piles were re-sampled using the same design as in 1997. At Site 2a, the area that had been dredged in 1997 was re-sampled and another location, of different mining history and geomorphic setting, was studied for the first time (2b). During 1998, we also sampled a dredge site located on the NF Fortymile (Site 3) to increase the spatial extent of the study and to determine if the NF and SF respond differentially to effects of suction dredging. Also in 1998 the reference site near the mouth of the NF was resampled and a comparable unmined site on the SF just upstream of the confluence was added for better evaluation of potential SF/NF background differences.

The Before-After-Control-Impact (BACI) approach is a powerful and generally accepted sampling design for detecting environmental impacts (e.g., Smith et al. 1993, Stewart-Oaten et al. 1986, Green 1979). For the present study, a BACI design was used for water chemistry and turbidity sampling at Site 1. Water samples were collected prior to and during dredge operation (Before and After) as well as upstream and downstream of the dredge (Control and Impact). Single measurements' were made at each of ten transects. It was not possible to employ a BACI design for periphyton and macroinvertebrate measurements because of the logistic problems associated with using an actual dredge and the limited amount of time available for sampling under baseflow conditions. Instead, samples at Site 1 were collected upstream and downstream of the dredge while the dredge was in operation. Five macroinvertebrate and periphyton samples were collected at each transect, except the 0 m, 5 m, and 10 m transects. Sampling the 0 m, 5 m, and 10 m transects individually was not practical due to the narrow width of the dredge piles; collection of five samples across their limited width was not possible. Therefore, ten macroinvertebrate and periphyton samples were collected from the 0-10 m area to document conditions immediately below the dredge. At Site 2a, sampling was limited to recent dredge piles located 25, 35, and 70 m below the moored dredge, and a reference transect located 250 m upstream of the dredge. Although the dredge was not in operation during sampling at Site 2a, it had been in operation during the preceding week. Finally, the samples from the reference area at Site 2a were used with similarly collected samples from the mouth of the NF to compare conditions in the two forks of the Fortymile River.

In 1998, five macroinvertebrate and periphyton samples were taken from the reference, mined, 20 m, and 40 m locations at Site 1 to determine the extent of recovery after one year. No mining occurred at Site 1 during the 1998 study period. At Site 2a, samples were taken from the reference, 35 m, and 70 m transects. At Site 2b, slightly downstream of Site 2a, samples were taken from three locations that had been dredged along the inside of a meander bend. Ten samples were taken from an "Upper" location that had been dredged in late September 1997. Five samples were taken from two dredged areas slightly downstream of the upper location that had been dredged within the preceding week. We sampled a single dredge site on the NF that had been dredged with a 10 inch dredge within the previous 10 days of our sampling. Samples were taken at locations that had been dredged, no attempt was made to document the downstream extent of mining disturbance at this site because of inconsistent (patchy) dredge operations by the Site 3 dredge operators. Ten samples were taken from a location not affected by mining in the NF, as well as from each of three transects within the mined area. In addition to the dredged locations within the Fortymile basin, ten samples were taken from unmined locations in both the SF and NF near their junction with the mainstem (Sites 4 and 6). A second NP location was sampled on request by the US Geological Survey after an upwelling of groundwater containing arsenic and other heavy metals was located on the North Fork and is described in detail below. Ten samples were taken from this location and were compared to samples taken from upstream of the upwelling.

Field and Laboratory Methods - The methods used throughout this study are standard and widely accepted techniques in stream ecology. Published reference sources provide detailed instructions regarding these methods (Hauer and Lamberti 1996, APHA 1995, Cuffney et al. 1993, Porter et al. 1993, Platts et al. 1983). These references often provide multiple methods for sampling a given variable. We selected the techniques that were most applicable to our work on the Fortymile; specific details and modifications used on the Fortymile are described below.

Turbidity, the inverse of water clarity, and specific conductance, a measure of the amount of total dissolved mineral salts in the water, were measured on location with portable meters (Hach model 2100P and Orion model 135, respectively) immediately after collection of the water samples. The meters were calibrated on a regular basis, as indicated in the manufacturer's instructions. Water samples for alkalinity and hardness were stored in insulated containers after collection to minimize chemical and biological activity in the water. For analysis, the samples were sent to the Stream Ecology Center, Idaho State University. The alkalinity and hardness of each sample was determined in the laboratory using standard titration methods (APHA 1995).

Samples for total filterable solids were filtered on location within 3 hours of collection. The filters containing the samples were stored in insulated containers to minimize bacterial degradation of filtered organics. Upon completion of the field sampling, the samples were sent for analysis to the Stream Ecology Center, Idaho State University. These samples were analyzed by determining the amount of mass lost on combustion at 550°C for 3 hours. The amount of mass lost on combustion is equivalent to the organic mass of the sample and is referred to as ash-free dry mass (AFDM). Standard procedures were used to determine the AFDM of the samples (APHA 1995). Total settleable solids were measured on-site immediately after sample collector using Imhoff cones; settleable solids were measured only while the dredge was in operation.

Water samples from the Fortymile River were collected for determination of heavy metal concentrations using the "clean hands/dirty hands" procedure as prescribed by the US Environmental Protection Agency. All materials (sample containers, filters, coolers, etc.) and protocols used in the collection of heavy metal samples were provided by US EPA. Samples were sent for analysis to the US EPA laboratory in Manchester, WA. In 1998, macroinvertebrates were collected to examine the potential of these organisms to concentrate heavy metals within their tissues. Macroinvertebrates were collected from four locations: Alder Creek, Polly Creek, and two locations on the NP Fortymile. Alder and Polly creeks are tributaries to the mainstem of the Fortymile; Alder served as the reference site and Polly as a site that has been mined historically and currently experiences some mining activity. On the NF Fortymile, the USGS has identified an area of upwelling groundwater that potentially is a source for dissolved heavy metals in that river. One of the NF Fortymile sites from which macroinvertebrates were collected was located above this possible heavy metal source, the other downstream of it. After collection, the invertebrates were immediately frozen and kept frozen until analysis. Analysis of the metal concentrations within the invertebrate tissues was conducted by James Crock at the USGS, Mineral Resources Program, Denver. To obtain a sufficient mass of tissue for analysis, all individuals from a site were combined; thus the results are based on a single measurement per site. The invertebrates were dried, pulverized, and weighed. The material was then transferred to a Teflon™ vessel and digested in 10 mL of concentrated nitric acid. One mL of the solution was diluted to 10 mL and analyzed using the USGS standard ICP-MS method. Mercury was determined using a cold vapor-atomic fluorescence spectrometry on a separate 1 mL aliquot diluted to 10 mL in sodium dichromate/nitric acid (James Crock, personal communication).

Description of streambed morphology was accomplished by developing cross-sectional profiles (see Platts et al. 1983) of the river at the transects described above (Fig. 2). Distance out from a fixed location on the bank was measured along a (Kevlar) cable stretched taut across the river. At numerous points across the width of the river, the distance from the cable to the water surface and the total water depth were measured.

All macroinvertebrate sampling was done with a Portable Invertebrate Box (PIB) sampler that was modified for use in water deeper than the height of the sampler. The PIB sampler encompassed 0.093 m2 of streambed (the sampler was approximately 30 cm on a side). The sampler was placed into position on the streambed and held in place by one operator while the second operator disturbed the substrata enclosed by the sampler to dislodge the organisms. A removable 250p.m mesh net was attached to the downstream end of the sampler to collect the dislodged organisms. Although designed to be used in deep water, the current velocity of the Fortymile precluded use of the sampler at most deep-water locations, particularly those in the center of the river. At some deep-water locations, SCUBA techniques were used to collect the samples; SCUBA was required for collection of approximately 5% of the samples collected within the sediment plume. In general, all macroinvertebrate samples were collected from nearshore habitats, approximately 2-30 meters from the bank. This is the same distance from the bank in which the dredge was operating.

Following collection, each sample was placed into a labeled plastic bag (Whirl-pak brand) to which approximately 10-15 ml of concentrated formalin was added to preserve the organisms. In the laboratory, the contents of each macroinvertebrate sample were spread-out in a white sorting tray and all organisms removed. The sorting was accomplished with the aid of a dissecting microscope of 10X magnification. The organisms were then identified to the lowest feasible taxonomic level, usually genus, using published taxonomic references, primarily Merritt and Cummins (1996), Wiggins (1996), and Stewart and Stark (1993). A reference collection was established and voucher specimens are located in the Stream Ecology Center, Pocatello at Idaho State University.

Periphyton samples were collected from individual rocks located just upstream of each macroinvertebrate sample. Processing was done immediately after collection of the rock and followed the procedures of Robinson and Minshall (1986). Briefly, the process involved removing all material within an enclosed area (3.14 cm2) from the rock surface. The removed material was then suctioned onto a pre-fired, glass microfiber filter (Whatman GF/F). Filters were frozen with liquid nitrogen in a modified dewar flask (Taylor-Wharton model 3DS) and sent to the Stream Ecology Center, Idaho State University for processing. Periphyton samples were extracted with reagent grade methanol (Holm-Hansen and Riemann 1978) and the 1997 chlorophyll-a content was determined with a spectrophotometer (Gilford Instruments model 2600). The 1998 chlorophyll-a samples were analyzed using a fluorometer in order to detect very low concentrations. Following centrifugation, approximately 3 ml of the sample was removed and used in the chlorophyll-a determination, the remaining material was used for measuring the AFDM of the sample as described above under total filterable solids.

Results

Water Chemistry and Clarity

At Site 1, dredge operation had no discernable effect on alkalinity, hardness, or specific conductance in the Fortymile (Fig. 3). Alkalinity ranged from <20 to >50 mg CaCO3/L, regardless of whether or not the dredge was operating. Hardness ranged from approximately 80 to 115 mg CaCO3/L. Both alkalinity and hardness displayed a large amount of variability in the immediate vicinity of the dredge whether or not the dredge was operating. Values of alkalinity and hardness measured at 320 m below the dredge were similar during operation of the dredge to values measured when the dredge was not in use (Fig. 3). Specific conductance showed only slight spatial and temporal variation during our sampling. Values ranged from 131 to 135 µS/cm, with a small decrease immediately downstream of the dredge, when in operation (Fig. 3). Turbidity and total filterable solids (TFS) both displayed an increase below the dredge (Fig. 4). During operation of the dredge, turbidity increased from values around 1 NTU upstream of the dredge to values of approximately 25 NTU immediately downstream of the dredge. The elevated turbidity declined rapidly downstream and by 160 m (525 ft) turbidity had returned to values measured upstream of the dredge. No such increase in turbidity was recorded when the dredge was not in operation. TFS showed a pattern similar to that of turbidity, increasing from 3 mg AFDM/L upstream of the dredge to 46 mg AFDM/L immediately downstream of the dredge (Fig. 4). As with turbidity, TFS did not display an increase downstream of the dredge when the dredge was not operating. Regardless of whether or not the dredge was operating, a longitudinal increase in TFS was measured from 80 m to 320 m downstream of the dredge. At 160 m downstream of the dredge, values of TFS were 28 and 23 mg AFDM/L during operation and non-operation, respectively. Total settleable solids showed a pattern very similar to that observed for TFS (Fig. 5).

During operation of the dredge, specific conductance and turbidity were measured across the width of the Fortymile at 0, 5, 10, 20, and 320 m downstream of the dredge to identify the proportion of the river width affected by the dredge plume. Specific conductance was unaffected by the dredge plume which was located along the right bank, but did decrease near the left bank (Fig. 6). This decrease was most likely due to groundwater and/or a small tributary that joined the Fortymile on the left bank just upstream of the study area.

Unlike specific conductance, cross-sectional measurements of turbidity from within the dredge plume showed a large increase, relative to areas outside the plume (Fig. 7). However, at 320 m downstream of the dredge, cross-sectional variation in turbidity was quite low, ranging from 1.2 to 2.5 NTU. During this sampling, the dredge was operating in close proximity to the right bank. Under these conditions, the plume tended to remain near the right bank and did not extend to the center of the river. In terms of turbidity, approximately 7% of the river width was affected by the dredge plume for a distance of less than 320 m.

Heavy Metals

For the unfiltered samples, two metals, copper and zinc, showed distinct increases downstream of the dredge (Fig. 8). Total copper increased approximately 5-fold and zinc approximately 9-fold at the transect immediately downstream of the dredge, relative to the concentrations measured upstream of the dredge. For both metals, the concentrations declined to near upstream values by 80 m downstream of the dredge. The pattern observed for total copper and zinc concentration is similar to that for turbidity and TFS (see Fig. 4), suggesting that the metals were in particulate form, or associated with other sediment particles. The results of sampling for dissolved heavy metals area are shown in Table 1. Zinc, arsenic, and copper displayed an average value downstream of the dredge that was greater than the average value measured upstream of the dredge (note that samples sizes are low, particularly upstream of the dredge). Copper displayed the greatest change, increasing by approximately 3-fold downstream of the dredge. Dissolved lead concentrations did not appear to be affected by operation of the dredge. Values of dissolved mercury actually were greater upstream of the dredge, suggesting that any effect of the dredge was likely within the range of natural variation. (The operator reported observing deposits of liquid mercury within the sediments he was working.) For both dissolved and total concentrations, budgetary limitations precluded multiple sampling across either space or time, thus the results of heavy metal sampling are only indicative of likely conditions.

Due to the low densities of macroinvertebrates in the dredge plume (and in the Fortymile in general) and the short exposure times, no macroinvertebrates were collected for heavy metal tissue analysis downstream of the suction dredge. However, results from the 1998 analysis of macroinvertebrate tissues suggest that these organisms are capable of concentrating heavy metals at least under conditions of chronic exposure. Although the data are preliminary in nature, several metals showed substantially greater concentration in the invertebrates from Polly Creek (mined) than from Alder Creek (reference), including mercury, zinc, molybdenum, and arsenic (Table 2). Other metals, such as copper and nickel, did not exhibit substantial differences between the two sites. The upwelling area identified by the USGS as a potential source of metals in the NF Fortymile did not appear to be influencing metal concentrations in macroinvertebrates. For the metals listed above, nickel was the only metal that showed a substantial increase (Table 2).

Channel Morphology

Site 1- Cross-sectional profiles were mapped to quantify the extent of the dredge piles relative to the width of the river. At Site 1 only the pile created most recently, 0 m downstream of the dredge, was visible with our profile mapping (Fig. 9). At the transects 5 and 20 m downstream of the dredge the piles were visually obvious due to the light color of the excavated material compared to undisturbed riverbed. However, the piles did not appear as distinct "mounds" in the measurements made at these transects. One year after active dredging occurred, the distinct mounds seen in Figure 8 at the 0 m transect were no longer apparent. There was no discernable dredge pile at the 5 and 20 m areas. Figure 9 is based on detailed mapping along the right bank of the river and is drawn to scale to represent the conditions within the streambed relative to the depth of the river in that area. There is a large width:depth ratio for Site 1 as indicated by Figure 10. Discernable dredging activity can be seen within the first 5 m from the right bank. The area that this particular dredge operation affected was about 6% the width of the river.

Site 2a- In August 1997 partial cross-sectional profiles were measured every 5 meters, beginning slightly downstream of dredging activity and continuing for 110 meters, to map a series of dredge piles along the right bank of the South Fork of the Fortymile (Appendix A). In July 1998 three transects were re-measured to map the change in location of the dredge piles (Fig. 1). The dredge pile at 30 m shows a shift towards the center of the stream, though the overall size remained essentially the same after one year. A profile of the 40 m transect produced similar results. Remaining partial cross-sectional profiles are presented in Appendix A.

Site 2b- In July 1998 a second site on the South Fork was included in our sampling to determine if there are spatial differences in dredging effects on biota. Cross sectional profiles were measured. Full cross-sectional profiles were completed for the "upper" pile in 1998 which had been dredged in September of 1997 (Fig. 12) and partial cross-sections were measured for the upper, middle, and lower locations (Figs. 13 and 14). Easily discernable dredge piles were observed and measured between 0, 5, and 10 m below a reference transect at the upper location for Site 2b. Partial cross-sectional profiles also were measured to determine the longitudinal extent of the upper dredge pile (Fig 13). According to our measurements, the upper dredge pile tapered off at about 35 m. Profiles for the middle and lower dredge areas show another dredge pile beginning between 80 and l00 m. The lower dredge pile begins at about 130 m and continues slightly past 140 m (Fig 14). The middle and lower dredge areas were mined about 7 days prior to our sampling at Site 2b.

Site 3- Cross-sectional profiles also were measured at Site 3 in the North Fork. Entire width profiles were measured every 20 m along this reach (Fig. 15) and partial profiles were measured at various distances between each full profile (Fig. 16). Dredging was active at the 0 m and 10 m locations and between the 40 and 60 m locations. There is a large width:depth ratio for Site 3. Figure 13 shows the size of the dredge piles relative to the entire width of the river for Site 3. The full width profile measured for Site 3 shows distinguishable channel forms where mining activity had occurred within 10 days of our sampling at 20 m, 60 m, and 80 m though the 80 m location may simply be due to natural bed forms. The lack of obvious dredge piles at the 0 m and 40 m locations are most likely because the dredge pile began slightly upstream of these locations. Dredge piles accounted for approximately 15% of the total channel width at Site 3.

The partial profiles show very distinct dredge piles 5 m downstream of mining activity which can be seen nearly 4 m from the right bank. 10 m downstream another relatively distinguishable streambed "rise" is discernable between 4 and 6 m from the right bank. There is no discernable effect on the streambed 15 m downstream of mining activity according to these profiles.

Periphyton Standing Crop

At Site 1, 1997 periphyton AFDM was greatest at the transect upstream of the suction dredge, with a mean value of 1.8 mg AFDM / cm2 (Fig. 17). Periphyton standing crop was reduced by approximately 2-4 fold at the transects downstream of the dredge. The lowest value, >0.5 mg AFDM / cm2, occurred in the first 10 m immediately below the dredge. Unlike other variables, periphyton standing crop did not appear to recover at subsequent transects downstream of the dredge. At the 320 m transect, for example, AFDM was only 50% of the value measured upstream of the dredge. Chlorophyll-a concentrations are reduced to unmeasurable values within the areas dredged and 20 m below the operating dredge. Measured chlorophyll-a concentrations follow the results of periphyton standing crop biomass downstream of the operating dredge. After one year, chlorophyll-a concentrations and periphyton standing crop biomass in the mined area had returned to values near those from the unmined reference location, indicating that periphyton is unaffected by dredging the previous year at this location (Fig 18).

Both periphyton standing crop and chlorophyll-a at Site 2a showed little response to dredging in comparison to the upstream reference location in 1997. In 1998, mean chlorophyll-a concentrations were nearly identical at the reference location to those values in 1997; however, mean chlorophyll-a concentrations were greater at each of the dredged locations in 1998 than in 1997 (Fig 19). Periphyton standing crop in 1998 also increased 2-4 fold in the reference and 25 m locations and increased slightly less in the 70 m and 100 m locations after one year (Fig 19).

At Site 2b, periphyton standing crop biomass averaged between 3 and 4 mg/cm2 for all locations regardless of the year in which they were dredged. However, mean chlorophyll-a was 2.5 times greater in the "Upper" location, which had been dredged late in the previous year, than either of the other two nearby locations that had been dredged in 1998. The Upper location was dredged late in the 1997 mining season but sampled only during 1998. The greater amount of chlorophyll-a in the upper location, compared to the other two (1998) dredge piles is most likely due to the additional time of recovery (Fig. 20).

Comparisons between the NF and SF Fortymile were conducted to document differences in background conditions and the potential for recovery of mined areas in two tributaries with different mining pressures within the same basin. Mean periphyton biomass was three times greater in the NF site (Site 4) than in the SF site (Site 6) in 1997. Mean chlorophyll-a concentrations were 4 times greater in the NF than, in the SF for the same year (Fig 21).

Aquatic Macroinvertebrates

Site 1- The short-term influence of the suction dredge on macroinvertebrates appeared to be limited to the first 20-40 m downstream of the dredge. Two locations were examined upstream of the dredge at Site 1, the first was approximately 80 m upstream and the second approximately 200 m upstream. In terms of water velocity and substrate characteristics, the -200 m site was considerably more similar to the habitat downstream of the dredge than was the -80 m site. For this reason, only the -200 m transect was used as the reference for Site 1.

The abundance of macroinvertebrates at Site 1 was low, relative to large rivers in other parts of North America (e.g., Royer and Minshall 1996). A mean of 270 individuals per m2 was collected at the reference site; approximately 370 individuals per m2 were found at the site 160 m downstream of the dredge (Fig. 22). Diversity averaged 6-7 taxa per sample at the reference site and ranged from 1 to 7 taxa per sample at the sites downstream of the dredge. Taxa within the orders of Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) are considered sensitive to habitat degradation and are used commonly in aquatic bioassessment. The mean number of EPT taxa was 5 per sample at the reference site and ranged from <1 to 5 per sample at the sites downstream of the dredge.

The abundance and diversity of macroinvertebrates at Site 1 was greatly reduced in the first 10 m below the dredge, relative to the reference site. Immediately below the dredge (0-10 m) macroinvertebrate abundance was reduced by 97%, number of taxa by 88%, and number of EPT taxa by 92%, relative to the site 200 m upstream of the dredge. The abundance and diversity of macroinvertebrates returned to values seen at the reference site by 80 to 160 m downstream of the dredge.

The relative abundance of all taxa collected from the Site 1 in 1997 are presented by transect in Table 3. The order Trichoptera was the most abundant, in terms of richness, with seven genera represented. Five genera of Ephemeroptera and two genera of Plecoptera were collected. Two families of Diptera were found, Simuliidae (blackflies) and Chironomidae (midges). Other groups included: one genus of Coleoptera (beetles), Acarina (water mites), Collembolla (springtails), Oligochatea (aquatic earthworms), and Ostracoda. For all transects, 50% or greater of all taxa were members of the Chironomidae and the Ephemeroptera.

The sampling conducted in 1998 indicated substantial recovery at Site 1 from the dredging that occurred in 1997, in terms of macroinvertebrate diversity. Diversity was notably reduced downstream of the dredge in 1997 (see above) but in 1998 the difference in diversity among the four transects was minimal (Fig. 23). For example, at the location 20 m downstream of the dredge macroinvertebrate diversity was approximately 6 taxa in 1997 but 17 taxa in 1998. A similar increase in the number of taxa was observed at all Site 1 transects that were sampled in both 1997 and 1998. Macroinvertebrate density and the number of EPT taxa also increased after one year (Fig. 24).

Site 2a- Sampling in 1997 revealed patterns at Site 2a similar to those observed at Site 1. Macroinvertebrate density at the reference transect was approximately 200 individuals per m2 (Fig. 25). At the transect 25 m downstream of the dredge, density decreased to approximately 20 individuals per m2 and then increased to about 100 individuals per m2 at the transect 70 m downstream of the dredge. The number of taxa at the reference transects was equal for Site 1 and Site 2a and showed a similar downstream pattern at both sites. The number of EPT taxa, however, was considerably less at Site 2a in 1997, although the downstream pattern was the same as that for Site 1. Recovery of macroinvertebrate diversity at Site 2a was nearly complete one year after dredging with approximately 20 taxa at each of the transects (Fig. 26). One year after dredging with a 10 inch dredge at Site 2a, macroinvertebrate density, richness, and number of EPT taxa also had recovered to pre-mining conditions (Fig. 27).

Site 2b- A second site was established on the South Fork of the Fortymile River in 1998 to evaluate the effects of dredging on a nearby site with different water flow and possibly substrate composition. This site was on the inside bank of a meander bend, about 800 m downstream of Site 2a. Site 2b was also used to evaluate the effects of dredging late in the fall on macroinvertebrate composition. In Figures 28 and 29, locations labeled "Upper" represent an area dredged with a 10-inch dredge in late September 1997. Locations labeled "Middle" and "Lower" represent adjacent areas mined within a week of our sampling in July 1998. Comparing Site 2a results with the Upper location of Site 2b revealed that there were in fact differences in macroinvertebrate density between the Upper site of Site 2b and the reference area of Site 2a. Mean macroinvertebrate density at the reference location of Site 2a was 26% of the "Upper" location of Site 2b, 40% of the "Middle" and nearly 30% of the "Lower" locations (Fig 28A). The number of EPT taxa per sample present in the Site 2a reference location were 74% that of the "Upper" location of Site 2b (Fig 29A). Likewise, the number of Diptera present in each sample from Site 2a were 72% those present at Site 2b (Fig. 29B) Diptera comprised between 40 and 80% of the macroinvertebrates per sample at all of our SF sites.

Site 3- We sampled a single dredge site on the North Fork in which a 10-inch dredge was operated by an experienced miner and was actively dredged within 10 days prior to our sampling. This site consisted of three dredged areas, one beginning at the head of our study reach (T0), the second stretching the length between 10 and 20 m from the T0 location (T10), and the third encompassing the distance between 40 and 60 m (T40) from the T0 location. The mined areas at 0 m, 10 m, and 40 m were compared to a reference location in an unmined area of similar substrate type and water velocity. We were not able to determine the distance downstream affected by dredging because of inconsistent dredge operations by the North Fork miners which were caused by relatively high flows over the duration of our sampling. The study reach chosen here allowed us to determine the short term recovery (>10 days) of these dredged areas in the North Fork. Our results suggest that all measures except macroinvertebrate density appeared to fully recover within 10 days since dredging.

Macroinvertebrate density at the reference location averaged about 1600 organisms per m2 while densities within the mined areas averaged between 1200 and 1400 organisms/m2 (Fig. 30A). Macroinvertebrate taxa ranged from 10 to 12 per sample for all locations (Fig. 30B). Mean numbers of EPT taxa ranged from 5 to 6 per sample (Fig. 30C). Diptera, which comprised the majority of the macroinvertebrate community at all of the sites sampled, ranged from 60 to 80% in the NF sites (Fig. 30D).

North Fork/South Fork Comparison - Comparisons between the North Fork and South Fork were made to determine if the South Fork macroinvertebrate populations were depauperate due to degraded water quality from increased mining activity on the South Fork itself and some of its major tributaries. In 1998 we sampled a different reference location on the South Fork (Site 6, see Fig. 1) that was nearly 500 m upstream of its confluence with the North Fork and compared this data with those from an unimpacted reference site several kilometers upstream on the North Fork (Site 5). We also compared this North Fork reference site to a location downstream of an upwelling of heavy metals noted by the USGS near the confluence of the North and South Forks (Site 4).

The upwelling of heavy metals between Sites 4 and 5 appears to have little effect on macroinvertebrate populations in the North Fork. The number of taxa, number of EPT taxa, and overall relative abundance of Diptera are nearly identical for both Sites 4 and 5. Macroinvertebrate density was nearly 2500/m2 downstream of the upwelling and nearly 1500/m2 upstream (Fig 31A). The number of taxa per sample at all locations ranged from 11 to 12 (Fig 31B). The number of EPT taxa ranged from 5 at the NF and SF reference areas, to 6 at the NF confluence area (Fig 31C). Diptera comprised 60 to 80 % of the macroinvertebrates at all locations (Fig 31D).

Although we did not sample the South Fork confluence site in 1997, there may be some degree of yearly variation in macroinvertebrate populations in the South Fork as seen from comparison of reference conditions from Site 2a (see Fig. 26). In the North Fork however, there appears to be less yearly variation in macroinvertebrate populations in the years that we sampled. Even though taxa richness was similar at the NF and 2a sites in both years, the relative dominance of taxa differed among the sites (Fig. 32). There was a greater difference in the taxa abundance of some taxa between years at the SF reference location whereas there is almost no change in the relative dominance of taxa in the NF site. The difference is seen in the shape of the curves. Table 4 shows that the Chironomidae (order Diptera) comprised over 75% of all the macroinvertebrates present in our samples at Site 4 in 1997 and 82% in 1998. Baetis comprised 0.5% in 1998, and 5.5% in 1997. In the SF Diptera comprised about 34% of the macroinvertebrates in 1997 and about 35% in 1998. However, Oligochaeta (Annelida) comprised 32% of the macroinvertebrates in 1998 and only 8% in a 1997. Baetis, a mayfly, comprised 1.3% of the macroinvertebrates in 1998 and 5% in 1997.

Benthic Organic Matter

Benthic organic matter (BOM) is a primary source of carbon and energy for organisms that live on and within the substrate of the river. In general, the amount of BOM found in the Fortymile was lower than values from many streams in the contiguous United States (see Minshall et al 1982), but are similar to other studies from the interior arctic and subarctic Alaska region (for example, see Miller and Stout 1989).

Site 1- In 1998, mean amounts of BOM within the mined area were slightly lower than those found at the reference and downstream (20, 40 m) areas. BOM at the 20 m location is also much more spatially variable than at the other locations (Fig. 33). This increased patchiness may be a result of the downstream redistribution of BOM from upstream dredged areas.

BOM concentrations at Site 2a in 1997 were similar between reference and mined locations, averaging 5 g per m2 at the reference location and 9 and 11 g per m2 at the 35 m and 70 m locations, respectively (Fig. 34). Mean amounts of BOM in 1997 at the reference area was 15% that of 1998. In 1998, mean BOM at Site 2a ranged from an average of 33 g per m2 at the reference area to 25 and 37 g per m2 at the 35 m and 70 m areas, respectively. BOM at Site 2b ranged from 23 g per m2 at the locations mined in 1998 (Middle and Lower areas) and averaged 53 g per m2 at the location mined in the late fall of 1997 (Upper area). These values were similar to those from 1997 for Site 2a, indicating a yearly variation in BOM of between 15 and 30%. BOM from Site 3 averaged between 6 and 7 g per m2, and showed little difference in average amounts between locations (Fig. 35). However, the coefficients of variation in the mined locations showed considerable variability, particularly at the 35 m location.

Mean amounts of BOM in both the NF and the SF confluence locations show considerable differences. At the SF confluence site (Site 6), BOM was more spatially variable and averaged more than twice the amount found at the NF confluence site (Site 4, Fig. 36).

Discussion

The primary effect of suction dredging on water chemistry of the Fortymile River, as detected at Site 1, was increased turbidity, total filterable solids (TFS), and copper and zinc concentrations downstream of the dredge. Turbidity and TFS were substantially elevated downstream of the dredge and the plume of sediment-laden water created by the dredge was visually obvious. But, although the plume was visually dramatic it was spatially confined to within 160 m (= 525 ft.) of the dredge and was restricted to the portion of those days that the dredge was operating. Furthermore, the effect of the plume was limited to approximately 7% of the width of the river. The results from this sampling revealed a relatively intense, but very localized, decline in water clarity during the time the dredge was operating. Wanty et al. (1997) reported turbidity values of 19 NTU 30.5 m (100 ft) downstream of a 10 inch dredge located below Wilson Creek on the North Fork Fortymile River. Values returned to near background levels (3.7 NTU) within the next 30.5 m but remained slightly above background levels (2.2 - 2.3 NTU) as far as 150 m downstream (furthest sampling transect). Turbidity values downstream of an 8-inch dredge operating in the same vicinity were lower because less sediment was being disturbed and the sediments were coarser and hence settled more rapidly. The 19 NTU at 30.5 m is comparable to the value we found at 20 m at Site 1.

Wanty et al. (1997) examined dissolved metal concentrations 60.8 m (200 ft) downstream of a 10-inch and an 8-inch dredge and found no difference between the sides and center of the dredge plume. In our study, dissolved metals displayed no clear pattern in relation to the dredge suggesting the increased concentrations of total copper and total zinc at Site 1 were likely a result of metals associated with the sediments excavated by the dredge. As the metal-laden sediments were transported downstream and deposited on the riverbed, total copper and zinc concentrations declined. By 80 m downstream of the dredge, copper and zinc concentrations were similar to those measured upstream of the dredge (see Fig. 8). These results suggest the need for examining heavy metal accumulation on the riverbed, rather than instantaneous measures of heavy metal concentrations in the water column. The examination of heavy metal concentrations in aquatic macroinvertebrates indicated that at some locations, such as Polly Creek, the chronic effects of mining may be reflected in the physiological condition of the biota. However, the degree to which metals within the tissues of the macroinvertebrates may influence life-history or other biological traits is unknown.

United States Department of Agriculture
Forest Service
Siskiyou National Forest
200 NE Greenfield Road
Grants Pass, OR 97526-0242

Reply to: 2800
Date: October 16, 1995

Subject: A comparison of stream materials moved by mining suction dredge operations to the natural sediment yield rates

To: The Record

A question that has frequently been asked is how much material is moved by annual mining suction dredge activities on the Siskiyou National Forest and how does this figure compare with the natural movement of such materials by surface erosion and mass movement? At the conclusion of the 1995 summer suction dredge season, the responsible minerals personnel on each Ranger District of the Siskiyou National Forest were asked to make a quantitative estimate of the number of cubic yards of material that was moved over the season by suction dredge operations. The estimates were based on on-the-ground observations carried out over the summer. Quantities of moved material ranged from 23 to 1920 cubic yards per district with a Forest total of 2413 cubic yards for the season.

Three documents were examined to determine a reasonable estimate of natural sediment yield rates. A published 1985 study by Michael P. Ainaranthus et al entitled "Logging and Forest Roads Related to Increased Debris Slides in Southwestern Oregon" found that natural erosion rates for debris slides in the Klamath Mountains of southwest Oregon averaged about 0.5 cubic yards per acre per year. This same study found that erosion rates on roads and landings were 100 times those on undisturbed areas, while erosion on harvested areas was seven times that of undisturbed areas. In another study (unpublished) done in 1988 by Jon Vanderheyden et al entitled "Siskiyou National Forest Silver Fire Recovery Process Paper", surface and channel erosion rates were estimated and then an estimate of total natural erosion rates was made by summing a debris slide rate with surface and channel rates. The debris slide rate was developed for the Siskiyou National Forest from an inventory that examined landslide activity between 1956 - 1976 on 137,000 acres of the Forest. This 1985 study estimated that baseline sediment yield (total natural erosion rate) in the Silver Creek basin averaged about 14.2 tons per acre per decade. For the Indigo Creek basin sediment yield averaged 8.0 tons per acre per decade. Putting these figures on an annual basis and using a generally accepted average of 1.5 tons per cubic yard of material would produce sediment yields of 0.95 and 0.53 cubic yards per acre per year for Silver and Indigo Creeks respectively. The Siskiyou National Forest Land and Resource Management Plan of 1989 estimated that the average natural sediment yield rate for the Forest from both mass movement and surface erosion was 0.5 tons per acre per year. This figure equals about 0.33 cubic yards per acre per year and is the most conservative of the natural sediment yield figures found in the literature readily available.

There are 1,092,302 acres on the Siskiyou Natural Forest. Using a factor of 0.33 cubic yards per acre per year times 1,092,302 acres will produce a very conservative estimate that 331,000 cubic yards of material move each year from natural causes compared to the 2413 cubic yards that was moved by suction dredge mining operations in 1995 on the Siskiyou. This would be a movement rate by suction dredge mining that equals about 0.7% of natural rates.

/s/ Michael F. Cooley
MICHAEL F. COOLEY
Recreation, Lands and Minerals Staff Officer, Siskiyou National Forest

In 1993 the U.S. Army Corps of Engineers (Corps) and U.S. Environmental Protection Agency (EPA) were subject to a court decision that forced them to issue new rules regarding suction dredging in Alaska. A challenge to this decision resulted in a new decision in May 1999 that the Corps, at least, was not required to regulate suction dredging in most cases. Unfortunately, the same decision states that because of another court decision, Rybachek v. EPA, 904 F.2d 1276 (9th Cir. 1990) resuspension of materials by placer miners as part of gold extraction operations is an "addition of a pollutant" under the CWA (Clean Water Act) subject to EPA's regulatory authority. The final result of all this legal action is that the Corps issued General Permit 88-02P for Alaska that covers most suction dredge activities automatically

The main reason this SPECIAL PUBLIC NOTICE 94-10 is presented here is to show the Corps finding of de minimis (i.e., inconsequential) effects on aquatic resources for suction dredges with nozzle openings of 4 inches or less. This is an official recognition of what suction dredgers have long claimed; that below a certain size, the effects of suction dredging are so small and so short-term as to not warrant the regulations being imposed in many cases. The U.S. Environmental Protection Agency (EPA), in particular, has ignored this concept, although numerous studies, including the EPA's own 1999 study of suction dredging, repeatedly and consistently support the Corps finding de minimis effects. The reports consistently find no actual impact of consequence on the environment, and so almost always fall back to the position that "potential for impact exists".

However, showing potential for harm, and showing that actual harm exists are two different things, and the studies to date have not shown any actual effect on the environment by suction dredging except for those that are short-term and localized in nature. Current regulatory efforts are proceeding despite this lack of evidence showing that harm to the environment is taking place. The regulatory agencies should be consistently and continually challenged by the dredging community to produce sound, scientific evidence that support their proposed regulations. To regulate against a "potential for harm", where none has been shown to exist, is unjustifiable and must be challenged.

Public Notice
US Army Corps of Engineers

Alaska District Regulatory Branch
Post Office Box 898
Anchorage, Alaska 99506-0898

Date: 13 SEPTEMBER 1994
Identification No.: SPN 9410
In reply refer to above Identification Number

SPECIAL PUBLIC NOTICE 94-10

APPLICATION OF THE "EXCAVATION RULE" TO RECREATIONAL PLACER MINING ACTIVITIES IN ALASKA FOR THE PURPOSE OF THE CORPS' SECTION 404 REGULATORY PROGRAM

Changes to regulations of the U.S. Army Corps of Engineers (Corps) and U.S. Environmental Protection Agency published August 25, 1993, in the FEDERAL REGISTER (FR) at 58 FR 45008 are affecting regulation of recreational placer mining activities in Alaska. The new regulations, referred to as the "excavation rule" became effective on September 24, 1993, and were described in a joint Alaska District Corps the United States and Environmental Protection Agency, Region X, Special Public Notice (93-15) dated September 17, 1993.

The Department of the Army (DA) exerts regulatory jurisdiction over waters of the United States, which includes wetlands, pursuant to Section 404 of the Clean Water Act. For regulatory purposes, the Corps defines waters of the United States as those waters below the high tide line of any tidal water body (ocean, estuary, etc.), and those waters below the ordinary high water mark of non-tidal water bodies (creeks, rivers, ponds, lakes, etc.). Wetlands are defined as those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. The law requires that any individual or entity that proposes to discharge dredged and/or fill material into or excavate material from wetlands or other waters of the United States must obtain a DA permit (sometimes called "404 permits") prior to conducting the work. Under the new regulations, this means that recreational placer mining by means of suction dredging, hand mining, or other excavation in non-navigable waters now requires DA authorization.

The preamble for the new regulations stated that some excavation activities may generally (except in extraordinary situations) have <u>de minimis</u> (i.e., inconsequential) effects on aquatic resources including their associated functions and

values and therefore would not degrade or destroy waters of the United States and would not be regulated.

The Alaska District Corps has reviewed recreational placer mining using suction dredges and hand mining (pick and shovel, panning, etc.) activities in light of the new "excavation rule" and has determined, except in extraordinary circumstances, that recreational suction dredge mining using an intake nozzle size equal to or less than 4 inches and hand mining in waters of the United States would have de minimis effects on the aquatic environment, provided the State of Alaska Department of Fish and Game requirements for fish-bearing waters are met. Therefore, these activities, as described above, will generally not be regulated by the Corps and no permit is required. However, the Alaska District Corps retains the discretion to require authorization on a case-by-case basis. (emphasis added)

The fact that no authorization or permit is required from the Corps for recreational placer mining, as described above, does not relieve any miner from the necessity to obtain any other permits or authorizations required by other entities. Consequently, the Alaska Department of Fish and Game and any applicable land management agency (Bureau of Land Management, National Park Service, U.S. Forest Service, Alaska Department of Natural Resources, etc.) should be contacted prior to conducting recreational placer mining to identify any possible requirements or restrictions on mining activities.

OPERATION OF LARGER SUCTION DREDGES

Operation of suction dredges with an intake nozzle size greater than 4 inches generally has more than de minimis effects on the aquatic environment and therefore requires authorization from the Corps under Section 404 of the Clean Water Act. At the current time, an individual DA permit is required for these activities, unless the mining is "ongoing" and a request for the operation to be grandfathered was received by August 25, 1994 (as described in the excavation rule published on August 25, 1993)

GRANDFATHER PROVISION OF THE "EXCAVATION RULE". Section 404 authorization is not required for discharges of dredged material associated with ditching, channelization, or other excavation activities in waters of the United States, including wetlands, where such discharges were not previously regulated and where such activities had commenced or were under contract to commence prior to August 25, 1993, and where such activities were completed before August 25,

1994. The Corps retains the authority to grant, on a case-by-case basis, an extension of this 12-month grandfather provision subject to the following conditions:

1. The excavation activity is of the type that occurs on an "ongoing" basis, either periodic or continuously (e.g., mining operations);

2. The discharger had submitted to the Corps, within the 12-month period between August 25, 1993, and August 25, 1994 , an individual permit application seeking a Section 404 authorization for such excavation activity; and

3. In no event can the grandfather provision be extended beyond August 25, 1996.

**Note: The deadline for filing an extension for an operation under the grandfather provision of the excavation rule was August 25, 1994. All rights under the grandfather provision were forfeited if an application was not submitted by that date. The Alaska District Corps has accepted the 1994 State of Alaska Annual Placer Mining Applications (APMAs) on file for the purpose of reserving grandfathering rights in accordance with the excavation rule. Any placer miner conducting excavation activities that have not been determined to have de minimis effects, as described above, must contact us at the address below and specify in writing those excavation activities in the 1994 APMA that they wish to continue as an "ongoing" operation. Interested parties should contact us by March 31, 1995, if they intend to do so.

As stated, currently all suction dredge operations, with an intake nozzle diameter greater than 4 inches, that do not qualify for or have forfeited their grandfather rights, require Corps authorization before proceeding. The Alaska District is in the process of modifying its placer mining general permit (GP 88-02M) to include suction dredge mining operations. At this time, we have not determined if there will be a size limitation to suction dredges that would be covered under the modified placer mining general permit. However, the Corps anticipates that many suction dredge mining operations may qualify for the modified general permit. A Special Public Notice advertising and requesting comments on the proposed placer mining general permit (GP 88-02M) changes will be issued in the near future.

FOR FURTHER INFORMATION

Additional information may be obtained by contacting the Corps at (907) 753-2712, or toll-free in Alaska at (800) 478-2712, or at the following address:

U.S. Army Corps of Engineers
Alaska District Regulatory Branch
Post Office Box 898
Anchorage, Alaska 99506-0898

BY AUTHORITY OF THE SECRETARY OF THE ARMY:

Date: 13 Sep 94

Peter A. Topp
Colonel, Corps of Engineers
District Engineer

Response of fish to cumulative effects of suction dredge and hydraulic mining in the Illinois subbasin, Siskiyou National Forest, Oregon*

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April, 2003

* Final report from a study, Cumulative effects of mining activities on the Siskiyou National Forest,
based on a Cost-Reimbursable agreement between the USDA Forest Service, Siskiyou National
Forest and Oregon State University under the provisions of the National Agricultural Research,
Extension and Teaching Policy Act of 1977 (Pub.L. 95-113), as amended by the Food Security Act
of 1985 (7 U.S.C., 3319a Pub. L. 99-198).

Contents

"Truth, like gold, is to be obtained not by its growth, but by washing away from it all that is not
gold."
- Leo Tolstoy

Abstract:

Potential cumulative effects of suction dredge mining (SDM) was assessed in combination with
early hydraulic mining and other independent variables reflecting land-uses on fish in the Illinois
subbasin. Fish response data were from 59 reaches sampled by summer snorkeling under the
SMART program. Responses utilized were pool densities of salmonids over one year old, of
young-of-the-year salmonids, and a stream habitat measure, width-to-depth ratio. Intensity of
suction dredge mining was estimated from a directed survey that censused the quantity of sediment
proposed to be moved per unit stream length in each 640-acre Section. The potential cumulative
effect for each explanatory variable was estimated by summing the inverse distance of each
corresponding pixel in each drainage defined by the location of each fish sample. Cumulative SDM
was found to be non-significant (tested at P=0.05, with significance of coefficient always >0.5)
for each of the three response variables tested in a general linear model. However, early hydraulic
mining was found to have a significant negative effect (P=0.03) on observed density of salmonids
over one year old.

1. Introduction

The activities of suction dredge mining (SDM) in streams of the Siskiyou National Forest have
attracted the attention of environmental organizations, many of whom oppose such activity in the
Forest, particularly in the Kalmiopsis Wilderness. This opposition has been met with similarly
well-organized miners who wish to retain their claims. The U.S. Forest Service has responded
with a set of guidelines for miners to minimize environment effects of their activities, and an EIS
has been prepared.

The ingredient that is lacking in this process is scientific information and analysis that accounts

for suction dredge mining and other potential confounding effects on stream biota, including early
hydraulic mining (HM). This report describes a first analysis of existing, recent data which

accounts for cumulative effects of suction dredge mining, early hydraulic mining, and other
activities as reflected by land-use on measures of fish populations and habitat in the Illinois
subbasin (Fig. 1).

1.1 Acknowledgements

The following colleagues are thanked for their help during this project: John Bolte, Randall
Frick, Steve Jacobs, Kevin Johnson, John Nolan, Tom Atzet, Bonnie Howell, Karen Honeycutt,
Edmund Hall, Margaret McHugh, Dan Delany, Roger Mendenhall.

1.2 Background

Suction dredge mining (SDM) involves pumping streambed material via a pipe, passing it over
a sluice box to sort out any gold, and discarding the tailings downstream (Fig. 1).
There have been several studies on local effects on stream biota of SDM that have been
reviewed from scientific (Harvey and Lisle 1998) and policy (Bernell et al. 2003) points of view.
Rather than repeat the details of these excellent reviews, I summarize here the key issues as they
may pertain to the area of study.
There have been several localized effects of SDM documented depending on where and at what
time of the year it is carried out. These have included entrainment and subsequent mortality of fish
larvae, fish eggs, or invertebrates and the use of unstable tailings for spawning by some salmonids
(Harvey and Lisle 1998). There are potential effects due to a plume of suspended fine sediment
downstream that does not normally occur during summer flows, due to the physical disturbance of
riparian habitat or stream banks, effects due to site access by vehicles, and to the inevitable spills of
fuel or oil. Harvey and Lisle (1998) opine that "effects of dredging commonly appear to be minor
and local", but stress that cumulative effects of several operations at larger scales have not been
investigated. This is one reason this study has been undertaken.
In a comprehensive policy review of recreational placer mining in Oregon Scenic Waterways,

Bernell et al. (2003) deduce from the literature, stakeholders, and government agencies that the most effective control to prevent potential effects of poor mining practice is self-control, which requires more investment in education and compliance.

Because most SDM activity (e.g., Fig. 1) in the Rogue basin and the Siskiyou National Forest was concentrated in the Illinois River drainage, the study described here was limited to the drainage of that subbasin (Fig. 2).

2. Approach

Designing and executing a study specifically for this purpose would not only require fish sampling during several years, but also a parallel labor-intensive process of tracking and measuring current mining activities in an extensive and challenging landscape. Existing mining claims provide an unreliable measure of potential impact because most claims are not active during any one season, and those that are vary considerably in mining intensity. Therefore, a study based on a new sampling design was beyond the resources available and would not be timely for required management decisions.

Fortunately, two factors coincided to make this study possible. First, a survey of SDM was completed in 1999 (Kevin L. Johnson, Area Mining Geologist, USFS, Grants Pass, OR) that included a measure of the intensity of mining as quantity of sediment moved. Secondly, independent fish survey data were available from the SMART program of USFS (USFS 2001), and ODFW salmon spawning survey data (provided by Steven Jacobs, ODFW Hwy 34 lab., Corvallis, pers. comm.) described in www.streamnet.org.

However, merely combining fish and suction dredge mining data sets alone would not provide sufficient information for a valid analysis, because the study was observational rather than a fully controlled experiment (Diamond 1986). In order to account for any significant influence of other differences among riverscapes and avoid potential confounding with any SDM effects, other 'nuisance' variables were required to represent those potential effects.

Rationales for determining the response and potential effects for the derivation of explanatory variables are described below.

3. Methods: Response variables

For the purposes of this study, a response variable representing fish or fish habitat in a stream needs to (1) be sensitive to habitat change that includes potential effects of SDM, (2) have a sufficient range of values, (3) not be dominated by zero values to prove statistically intractable, (4) be measurable with consistent bias among sample sites, (5) be from a survey with independent and random - or at least representative - samples of consistent protocol, and (6) be from samples that are independent.

A fish habitat variable was used that satisfied the relevant conditions. Regarding fish responses

and (4), all fish sampling methods are biased, but the important issue here is that the protocol and sampling conditions beyond the protocol do not produce a variable bias that may be related to the potential causal effects being tested. Two existing surveys satisfied the foregoing conditions:

3.1 ODFW Spawning anadromous salmonid surveys:

In a given stream and year, replicate counts of visible spawning or spawned anadromous salmonids are made by trained personnel during the spawning season, producing "Adult Return-Peak" and "Adult Return-Estimates of Spawning Population" estimates by species, stream reach and year. The "Adult Return-Estimates of Spawning Population" estimates are made by an integration of all counts during the season ('area-under-the-curve' method, English et al. 1992)) over a defined length of stream. These spawning population totals, estimated by ODFW, were expressed as number of adults on a per-stream-kilometer basis for coho salmon, chinook salmon, and all anadromous species combined (that also includes some steelhead).

Data from 1995 through 2000 were obtained from 53 sites (stream reaches) that had been randomly selected in the Illinois subbasin (Fig. 3), in which a subset of those sites had been sampled each year.

3.2 Summer snorkeling counts by SMART program

USFS's SMART (Stream Management, Analysis, Reporting, and Tracking database) has included sampling of reaches in the system during two phases: 1989-1995 and 1996 to the present. Data from the second phase, in which training and recording were more rigorous, were utilized from 1996-1999. Ranger District biologists were required to sample all fish bearing streams within 10 years, and the design protocol required that each stream was to be randomly selected for sampling in a given year.

Summer, daytime snorkel counts by species, with breakdowns for salmonids into size or age groups, were made in a reach from successive pools and riffles progressing upstream.

Considerably fewer fish were observed in riffles than in pools. Riffle counts were not included because in summer it is difficult to obtain representative snorkel counts in many riffles due to shallow, turbulent water and coarse substrates.

Sixty-one samples were taken from reaches during the second phase which began in 1996. Of these, two samples were taken from one reach in different years. One of these was eliminated by coin toss. A second reach was eliminated because only one riffle was sampled for fish. Therefore 59 independent reaches were retained for the analysis (Fig. 4). These reaches averaged 3.3 km

(range 0.8 - 9.4) long. A mean of 10 pools per reach (range 1-23) was sampled for fish.

Physical measurements of pools and riffles were taken directly every 10th pool (minimum of 10 pool-riffles measured when available).

Mean pool width varied between 5.6 ft (1.7 m) and 37.4 ft (11.4 m), and averaged 17.7 ft (5.4 m). Measurements of remaining habitat units were estimated by identified crew members, estimates that were calibrated with measurements every 10th pool (Appendix 1). Basin drainage areas corresponding to each sample (downstream end of reach) varied from 584 to 51,500 acres (236 to 20,840 Ha).

Only fish data from pool observations were included because it is difficult to maintain consistency when attempting quantitative observations in riffle and other habitat types during low summer conditions. The species breakdown of fish taxa observed in pools in shown in Fig. 5, along with the frequency of presence in all pools and reaches sampled. A total of 610 pools were sampled among the 59 reaches. All reaches contained fish, and a zero fish count was only record for one pool. Sampled pool frequencies (every 10th pool) varied from 1 to 27 pools per reach.

Total reach lengths varied from 0.6 to 6.3 miles. Young-of-the-Year (YOY or O+) salmonids were observed in 502 pools and 58 reaches, while older salmonids were observed in 434 pools and 58 reaches.

Only Rainbow trout (which may have included juvenile steelhead which are the same species), occurred consistently throughout the reaches. Statistical analysis would be difficult for other species because of large numbers of zero observations. Because all salmonids are sensitive to higher temperature and restricted habitats during summer and low flows, it was decided to represent all native salmonid species in response variables. However, because of different behaviors and habitat preferences among YOY and older salmonids, these were analyzed as two separate responses. It is easy for trained snorkelers to distinguish between YOY and older salmonids because of their size difference.

The response variable was expressed in density form as the number of a defined fish group (young-of-year or older salmonids) observed per 1000 m^2 of pool area. The number of fish are summed over all pools snorkeled:

Fish Response = S(# fish observed in pool, i)/S(surface area of pool, i)

Methods and results of corrected estimates of pool dimensions, based on SMART calibration data, used to estimate pool area are described in Appendix 1.

3.3 Fish habitat

One of the most useful measures of fish habitat is the dimensionless variable, width-to-depth ratio, based on wetted stream habitat dimensions. Streams that are deep for their width (i.e., low width-to-depth ratio) tend to provide more habitat for fish, especially salmonids during summer (Scarnecchia and Bergersen 1987; Kozel and Hubert 1989). Natural differences in the ratio do exist due to differences in sediment type, transport, and deposition, and also whether the reach channel is constrained geomorphically. However, degradation of streams through riparian forest removal, changes in hydrology, and transport of sediment generally tends to widen streams at the cost of mean depth, a process that is consistent with reduction of overhanging bank habitat and

bankside vegetation. Maximum depth of pool or riffle was measured for all sampled habitats,
therefore this depth measure was used instead of the strongly correlated mean depth that was
estimated for less than half of sampled habitats. The mean ratio for a reach was estimated by
calculating the mean of all pool and riffle width-to-depth ratios.
Width-to-depth ratio averaged 9.2, and ranged from 5.4 to 15.5 for the same 59 reaches sampled in the SMART program that contributed to the fish response data (Fig. 4).
All response variables were checked for quality and internal consistency, but were not compared to explanatory variables until an independent set had been derived from the latter as
described in Sections 4, 5.1, and 5.2.

4. Methods: Potential effects on fish populations

The primary potential effect represents the object of this study, suction dredge mining (SDM). The 1999 survey of SDM included (1) a census of the proposed amount of sediment that
miners were anticipating that they would transfer downstream during the summer season, and (2)
an extensive field sample of the mining activity in which the actual amount of sediment moved was
measured. Notwithstanding some individual differences in between expected and actual quantities
moved, there was a good correlation from 48 samples ($r= 0.600$, $P<0.00001$, Fig. 6). Because it
was essential to have a measure of cumulative effects from all SDM operations, the measure of the
estimated (proposed) amount to be moved was adopted, because this resulted from a census during
the 1999 season. This was also considered to be more appropriate because fish responses were
measured over a 5-year period, and proposed SDM that did not occur during 1999 could have
occurred during other years.

The proposed measure adopted was expressed as the quantity of sediment moved per unit length of stream in segments that were contained in 640-acre (close to 1-mile square) Sections.
Derivation of potential cumulative effect of several processes in a given drainage is described
below under Cumulative Effects.
Any effect on the fish response from causes other than SDM could potentially confound interpretation. These 'nuisance' variables include early hydraulic mining (HM) and several
land-use effects.

HM mostly occurred in 1860-1910 (Fig. 7), but was included because it had a long-lasting visible effect on the surface geology, soils, and vegetation of riparian zones (e.g., Fig. 8). HM peaked in the early 1900's but continued to occur sporadically until as recently as a single operation on Althouse Creek in the mid 1980's (John R. Nolan, USFS, Pers. comm.).

Also land use varied, with forest type, degree of deforestation, urban, and agriculture uses differing among drainage areas sampled for fish. For quantifying the relative effect of these land uses, the best available source covering the whole basin was the Western Oregon Digital Imagery Project (WODIP: Nighbert et al. 2000). That project classified the region into 25-by-25-m pixels representing 49 land-use types, largely on the basis of satellite imagery and ground truth information. Their very detailed forest classification included estimates of mixed or single stands of hardwoods and conifers, four tree size classes, and canopy cover down to 10% intervals. These distinctions were far too fine to indicate differences among basins statistically in this study, so a reduced set of forest and other land-use components was derived that did not involve the elimination of pixels (Fig. 9). In addition a road cover image was obtained through U.S. Forest Service, Grants Pass, which was merged with the simplified WODIP land-use cover .

Water-use effects on hydrology from dams is negligible in the basin, and water abstraction effects would be related to the potential agricultural and urban influence already being measured.

The foregoing data sources were analyzed as follows.

5. Analysis and results:

Before performing a definitive statistical analysis (5.3), an appropriate method for encoding potential influence to derive explanatory variables is described (5.1), followed by the process to derive an independent set of those explanatory variables (5.2).

5.1 Rating potential influence of explanatory variables

The fish sampled at a given location are mostly influenced by habitats in their home range, which is roughly of the same order as the reach lengths sampled. However, these habitats are primarily influenced by natural and anthropomorphic activities upstream. What is the most rational way of measuring potential influence stream and land-use types?

The traditional approach is simply to sum the number of pixels corresponding to each

classification, with each sum being the explanatory variable representing the potential influence of
each classification (Fig. 10 A). This process provided equal weights to each pixel, so a land-use at
the periphery of the drainage basin would be deemed equally influential as one of similar area
adjacent to the sample point. This scoring procedure was unrealistic for assessing effects on a
stream reach. Given the importance of riparian zones on streams, a stream buffer zone approach
(Fig. 10B) became popular, but the distance from the stream (buffer width) beyond which land-use
effects were rated at zero has become a controversial issue. Moreover, a land or stream use in the
buffer zone was still considered to have the same effect whether it was close or distant from the
sampled reach.

A solution to the foregoing problems is to weight each land-use (including mining use) according to some inverse function of its distance, as the water flows, to the sample location ('pour
point'). A rationale for utilizing an inverse-distance weighting method is derived (Appendix 2) and
illustrated (Fig. 11). This process produces an explanatory variable datum that represents a
cumulative measure of the potential impact on each sampled reach from all sources of each
candidate effect in the drainage associated with that sample.

Explanatory variables for all land-use types, including SDM and hydraulic mining (HM) activities along the stream corridor, were converted where necessary to raster (25-m pixel) images.

A recent 10-m resolution DEM was used to develop a 25-m raster image indicating flow path
directions over the entire landscape, a process that also defines the drainages basins corresponding
to each fish sample. The process, developed by John Bolte (Department of Bioresources, Oregon
State University), utilizes a program (ZOI) that interfaces with the flow direction cover map to
derive sums of inverse-distance weighted values for each classification in each drainage basin
ARC-INFO GIS software (Bayley et al. 2001; Kehmeier et al. in submission).

The two mining activities were coded as follows. The proposed cubic yards of sediment to
be moved (see above) by Suction dredge mining (SDM) in 1999 was expressed on a per unit

stream length (cu. yds/1000 ft of stream) in each Section where this mining was involved. This measure of intensity of mining was converted to classes and assigned to pixels in a rasterized GIS

image (Figs. 2,3). The process outlined above weighted each pixel by the measure of mining intensity in addition to its inverse distance from the sampled reach.

The stream reaches where early hydraulic mining (HM) occurred was mapped by John Nolan and Roger Mendenhall (USFS, Grants Pass, OR). They assigned one of four ranks to each reach to describe the visual effects (e.g. see Fig. 8) that reflected the intensity of this mining activity independently of other activities. These rankings were assigned intensities of 1 through 4 that were applied to classes in a similar manner as SDM. Different units for different mining effects do not matter in a linear statistical analysis; what is important is to reflect the relative intensity and cumulative effect of each mining activity in each drainage.

Figure 12 provides an example of a combined image with drainage basins corresponding to three SMART fish samples, with corresponding calculations of inverse distance weights of aggregated land-uses (see next section). This process does not eliminate any land or water use in the drainage, but weights each pixel of each classification according to the inverse of its distance to the fish response measured.

5.2 Deriving a set of independent explanatory variables

Any statistical analysis that investigates the significance and magnitude of a potential influence requires that the explanatory variable representing that influence is independent of potentially confounding variables. A fair assessment of whether correlations are insufficiently correlated among a set of candidate variables must account for the multiple testing effect. Consequently Bonferroni adjustments were made to the overall alpha value of 0.05 used as a rejection criterion.

Because the response variables involved two surveys with separate sets of drainages that required separate statistical modeling, a multiple correlation test was performed on the explanatory variables of each data set. Fig. 13 shows the Pearson correlation matrix for all cumulative-effect, explanatory variables for the 53 drainages corresponding to the ODFW salmon spawning samples.

Even though Bonferroni corrections (at P=0.05) were used, there is a serious problem because of the highly significant correlation between the SDM and HM cumulative effects (Fig. 14). Because subsets of the sites were sampled during different years, the explanatory variables of those subsets were separately analyzed. However, the significant correlation among the mining types persisted.
Although there is some overlap between the types, this persistence was partly attributed to lack of proximity to upstream mining of a large proportion of the sites (Fig. 3).
Therefore, an analysis of the salmon spawning response could not proceed, because it

would not be possible to distinguish between the mining activities any effects that may be indicated statistically. Impasses such as this are not uncommon when trying to impose a sampling design on existing data, and do not reflect the quality of the information in the data set.
The Pearson correlation matrix for all explanatory, cumulative-effect variables for the 59 SMART drainages is shown in Fig. 15. Here, fortunately, there were no significant (again, Bonferroni at P=0.05) correlations between SDM and any other explanatory variables. While it is not incorrect to proceed with analyses relating this set to the fish response, there are redundancies among several of the remaining 'nuisance' variables that will unnecessarily consume degrees of freedom. Also, some cover types were sparse and did not vary much among drainages (Fig. 16).
There were three clusters of strongly interrelated variables that generally represented decreasing degrees of vegetation cover and, to a large extent, human disturbance: (1) agriculture, urbanization, and roads, (2) forest with less than 50% canopy, non-forest vegetation, and barren, and (3) forest with greater than 50% canopy.
The cumulative-effect variables representing these three land-use cover types, and those for the two mining activities, produced a much cleaner correlation matrix (Fig. 17). Because no land-use types from WODIP have been eliminated, and all their areas add to 100% in each drainage, there will clearly not be independence in any set. In this case, a strong negative correlation exists between set (2) and (3) (Fig. 18), indicating that one cumulative variable should

be dropped. In this case, a weak correlation was indicated between variable (2) and (1), so variable
(2) was eliminated, leaving a set of four variables (Urban-Ag-Roads (1), Forest >50% (3), HM
(4), and SDM (5)) that were uncorrelated at the Bonferroni-corrected 5% level. This set of
explanatory variables was used in the statistical analyses described below.

5.3 Linear statistical analyses

The response variable is a count of fish in a given sampled area. The fish may or may not be randomly distributed in that area. Expressing the error distribution according to the negative
binomial model (White and Bennetts 1996), accounts for any additional variance, $2/$, (= mean, = constant) to that corresponding to a random error as in a Poisson distribution.
The linear statistical model fit to the SMART data set was:

(1) $Y = exp(0 + 1x1 + 2x2 + 3x3 + 3x3 + 12\,x1x2 + 13\,x1x3 \ldots\ldots + 34\,x3x4)$

where Y = number of fish per 1000 m_2 of total pool area sampled in the reach

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(juvenile + adult native salmonids greater than 1 year old or YOY salmonids),

$_0$ = fitted constant,

= fitted coefficients with non-zero subscripts corresponding to the following variables:

x_1 = 'Urban-Ag-Roads' cumulative effect,

x_2 = 'Forest >50%' cumulative effect,

x_3 = Hydraulic mining (HM) cumulative effect,

x_4 = Suction dredge mining (SDM) cumulative effect,

x_ix_j = all first order interaction terms between ith and jth variables ($i\,j$),

with the error corresponding to the variance function of the negative binomial distribution:

(2) $var\ (Y)$ =

where = mean of count, Y

variance additional to Poisson (random) variance

= fitted constant

An S-Plus routine that fits the constant in the negative binomial model jointly with the model coefficients with an iterative procedure (Venables and Ripley 1999) was used to compute the
general linear models. In the case of the stream width-to-depth ratio response, a simple Normal
linear statistical model (regression) was applied.

In this study the principal interest is in whether the coefficient, 4, that estimates the magnitude and sign of any effect of Suction dredge mining (SDM), is significantly different from
zero, providing that the SDM variable, x_4 , is not part of a significant interaction with another
explanatory variable. Other explanatory variables need to be included because interactions with
them may confound our interpretation. If the model does not indicate significant interactions, those

terms are removed and the reduced model is refitted. The modelling process was repeated after dropping non-significant ($P > 0.05$) interactions. Non-significant main effects (*i*) were not dropped if they were part of a significant interaction.

5.4 Results

With the models on native salmonids greater than one year old, no significant first order interactions remained after the elimination procedure. Fig 19A illustrates a later model run with an interaction term between the two mining activities, Fig. 19B show a run with only main effects, and Fig. 19C shows a model with the least significant ($P > 0.5$) effect, suction dredge mining, removed. Only the cumulative effect of hydraulic mining (HM) indicated a modest significance (at

$P = 0.03$) among the main effects. It's sign was negative, indicating that the greater the severity of this activity had been, the greater the reduction in salmonids over 1 year old.

Model diagnostics are critical to assess the appropriateness of the statistical procedure and assumptions. Theoretically, deviance residuals are expected to be approximately normal (Pierce and Schafer 1986), so models producing large departures should be viewed with suspicion. A normal probability plot of the deviance residuals suggested reasonable conformity (Fig. 20). A second issue is the independence of the data used. Although the inverse distance weighting effect gave more emphasis to land-uses occurring closer to the sample site, drainage areas of several sample points overlapped to varying degrees. Also the longitudinal movement of fish populations among adjacent sites sampled in the same year may be sufficient to render the samples non-independent statistically. Therefore, spatial autocorrelation among samples could occur to a degree that the key assumption of independence of samples would be questioned. To this end, the SMART samples were ordered according to proximity 'as the fish swims' and the corresponding deviance residuals from the model (Fig. 19C) tested for spatial autocorrelation. The mean correlation among the consecutively placed samples was 0.14 with a standard error of 0.13, so autocorrelation was not close to being significant.

As a matter of interest, Fig. 21 indicates through examples the predicted increase in

salmonid density in summer pools that would be expected to occur if the prevailing negative effects
on habitat of hydraulic mining did not exist.
Testing the Salmonid young-of-the year (YOY) response with similar models did not produce any significant coefficients of explanatory variables or their interactions. Similarly the
stream width-to-depth ratio response using simple linear models produced no significant effects. In
both cases SDM coefficients were in fact positive but not remotely significant at P>0.5.

6. Discussion and Conclusions

Analyses of observational field data sets can never be expected to produce strong results compared with laboratory or field experiments (Diamond 1986; Rose 2000). This is particularly
true when the sampling study has not been designed to test the specific variable of interest.
However, there are not realistic alternatives because this variable, suction dredge mining, cannot be
controlled or easily measured over a sufficiently larger number of drainages to provide a design
robust enough to account for confounding factors and provide enough statistical power.
The statistical analyses did not indicate that suction dredge mining has no effect on the three

responses measured, but rather any effect that may exist could not be detected at the commonly
used Type I error rate of 0.05. The fact that the analysis was able to detect a negative effect of
another mining process, HM, on native salmonids, is an indication of the long-lasting effect that
hydraulic mining has had on the environment, particularly on riparian zones and floodplain
sections in geomorphically unconstrained reaches (Fig. 8).
The reader is reminded of the effect of scale. Localized, short-term effects of suction dredge mining have been documented in a qualitative sense. However, on the scales occupied by
fish populations such local disturbances would need a strong cumulative intensity of many
operations to have a measurable effect. Local information reveals that most suction dredge miners
more or less adhere to guidelines that have recently been formalized by the Forest Service (Kevin
L. Johnson and John Nolan, pers. comm.) and generally in the Oregon (Bernell et al. 2003), but
there are individual cases where egregious mismanagement of the immediate environment has

occurred, particularly with respect to damaging river banks in various ways. This analysis cannot
account for individual transgressions, and a study to do so at an appropriate scale would be very
expensive if feasible.

Given that this analysis could not detect an effect averaged over good and bad miners and that a more powerful study would be very expensive, it would seem that public money would be
better spent on encouraging compliance with current guidelines than on further study.

7. References

Bayley, P. B., J. Bolte, and J. Kehmeier. 2001. Effects of agricultural land-use on native fish in
the Willamette basin. Final Report for NRICGP-CSREES Award No. 97-35101-4319 ORE00904. February 2001. Fisheries & Wildlife Dept., Oregon State University, Corvallis, OR.

Bernell, D., J. Behan, and B. Shelby. 2003. Recreational placer mining in the Oregon Scenic
Waterways System. An assessment for the Oregon Parks and Recreation Department, INR Policy
Paper 2003-01. Institute for Natural Resources, Oregon State University, Corvallis, OR.

Diamond, J. 1986. Overview: laboratory experiments, field experiments, and natural experiments.
Chapter 1. Pages 3-22. *In* J. Diamond and T. Case, editors. Community Ecology. Vol. 15 Harper
& Row, New York.

English, K. K., R. C. Bocking, and J. R. Irvine. 1992. A robust procedure for estimating salmon
escapement based on the area-under-the-curve method. Canadian Journal of Fisheries and Aquatic
Sciences 49: 1982-1989.

Harvey, B. C., and T. E. Lisle. 1998. Effects of suction dredging on streams: a review and evaluation strategy. Fisheries (Bethesda) 23: 8-17.

Kehmeier, J., J. Bolte, and P. B. Bayley. in submission. Quantifying the impacts of land use on
stream conditions using an inverse flow distance method.

Kozel, S. J., and W. A. Hubert. 1989. Testing of habitat assessment models for small trout
streams in the Medicine Bow National Forest, Wyoming. North American Journal of Fisheries
Management 9: 458-464.

Nighbert, J., J. O'Neil, A. Byrd, and K. C. Kroll. 2000. WODIP guidebook. Western Oregon
Digital Image Project (WODIP). The Bureau of Land Management (Prepared for BLM-OSO by
AverStar, Inc.). January 2000. www.or.blm.gov/gis/projects/vegetation/wodip/index.asp.

Pierce, D. A., and D. W. Schafer. 1986. Residuals in generalized linear models. Journal of the
American Statistical Association 81: 977-986.
Rose, K. A. 2000. Why are quantitative relationships between environmental quality and fish
populations so elusive? Ecological Applications 10: 367-385.
Scarnecchia, D. L., and E. P. Bergersen. 1987. Trout Production and Standing Crop in Colorado
's Small Streams, as Related to Environmental Features. North American Journal of Fisheries
Management 7: 315-330.
USFS. 2001. Stream Inventory Handbook. Level I and II. Version 2.1. U.S. Forest Service.
Pacific Northwest Region 6. Medford, OR.
Venables, W. N., and B. D. Ripley. 1999. Modern applied statistics with S-PLUS. 3rd ed.
Springer, New York.
White, G. C., and R. E. Bennetts. 1996. Analysis of frequency count data using the negative
binomial distribution. Ecology 77: 2549-2557.

Appendix 1. Estimation of pool dimensions from SMART calibrations.

Each set below is a regression result for habitat length and width from a specific MasterKey
(stream) and observer combination. The linear regression models are:

Ln(HAB_LEN) = LHAB_LEN = CONSTANT + LEST_LEN*(Ln(EST_LEN))
Ln(HAB_WID) = LHAB_WID = CONSTANT + LEST_WID*(Ln(EST_WID))
where HAB_LEN = measured habitat length at water surface,
EST_LEN = independent visual estimate of habitat length at water surface,
CONSTANT, LEST_LEN, LEST_WID = fitted coefficients
HAB_WID = measured mean habitat width at water surface,
EST_WID = independent visual estimate of mean habitat width at water surface.
Therefore, Pool area = HAB_LEN*HAB_WID.

```
"Observer ID_Masterkey"
VARIABLE COEFFICIENT STD ERROR STD COEF TOLERANCE T P(2 TAIL)
```

```
"B16110300055"
```



```
DEP VAR:LHAB_LEN N: 39 MULTIPLE R: 0.985 SQUARED MULTIPLE R: 0.971
CONSTANT 0.160 0.132 0.000 . 1.213 0.233
LEST_LEN 0.986 0.028 0.985 1.000 35.269 0.000
DEP VAR:LHAB_WID N: 39 MULTIPLE R: 0.931 SQUARED MULTIPLE R: 0.867
CONSTANT 0.437 0.193 0.000 . 2.266 0.029
LEST_WID 0.886 0.057 0.931 1.000 15.523 0.000
"C13110300057"
DEP VAR:LHAB_LEN N: 20 MULTIPLE R: 0.991 SQUARED MULTIPLE R: 0.982
CONSTANT 0.043 0.141 0.000 . 0.307 0.763
LEST_LEN 1.011 0.032 0.991 1.000 31.201 0.000
DEP VAR:LHAB_WID N: 20 MULTIPLE R: 0.753 SQUARED MULTIPLE R: 0.566
CONSTANT 0.924 0.419 0.000 . 2.205 0.041
LEST_WID 0.704 0.145 0.753 1.000 4.850 0.000
```

```
"C13110300058"
DEP VAR:LHAB_LEN N: 20 MULTIPLE R: 0.991 SQUARED MULTIPLE R: 0.982
CONSTANT 0.043 0.141 0.000 . 0.307 0.763
LEST_LEN 1.011 0.032 0.991 1.000 31.201 0.000
DEP VAR:LHAB_WID N: 20 MULTIPLE R: 0.753 SQUARED MULTIPLE R: 0.566
CONSTANT 0.924 0.419 0.000 . 2.205 0.041
LEST_WID 0.704 0.145 0.753 1.000 4.850 0.000
"C13110300059"
DEP VAR:LHAB_LEN N: 20 MULTIPLE R: 0.991 SQUARED MULTIPLE R: 0.982
CONSTANT 0.043 0.141 0.000 . 0.307 0.763
LEST_LEN 1.011 0.032 0.991 1.000 31.201 0.000
DEP VAR:LHAB_WID N: 20 MULTIPLE R: 0.753 SQUARED MULTIPLE R: 0.566
CONSTANT 0.924 0.419 0.000 . 2.205 0.041
LEST_WID 0.704 0.145 0.753 1.000 4.850 0.000
"D05110500019"
DEP VAR:LHAB_LEN N: 44 MULTIPLE R: 0.995 SQUARED MULTIPLE R: 0.989
CONSTANT -0.100 0.066 0.000 . -1.515 0.137
LEST_LEN 1.037 0.017 0.995 1.000 62.325 0.000
DEP VAR:LHAB_WID N: 44 MULTIPLE R: 0.970 SQUARED MULTIPLE R: 0.941
CONSTANT -0.082 0.113 0.000 . -0.722 0.474
LEST_WID 1.028 0.040 0.970 1.000 25.768 0.000
"D06110500022"
DEP VAR:LHAB_LEN N: 18 MULTIPLE R: 0.995 SQUARED MULTIPLE R: 0.991
CONSTANT -0.011 0.100 0.000 . -0.107 0.917
LEST_LEN 1.001 0.024 0.995 1.000 41.996 0.000
DEP VAR:LHAB_WID N: 18 MULTIPLE R: 0.983 SQUARED MULTIPLE R: 0.966
CONSTANT 0.175 0.108 0.000 . 1.626 0.123
LEST_WID 0.939 0.044 0.983 1.000 21.381 0.000
"D06110500023"
DEP VAR:LHAB_LEN N: 47 MULTIPLE R: 0.991 SQUARED MULTIPLE R: 0.981
CONSTANT 0.103 0.091 0.000 . 1.135 0.262
LEST_LEN 0.979 0.020 0.991 1.000 48.780 0.000
DEP VAR:LHAB_WID N: 47 MULTIPLE R: 0.981 SQUARED MULTIPLE R: 0.963
CONSTANT -0.028 0.092 0.000 . -0.308 0.760
```



```
LEST_WID 1.013 0.030 0.981 1.000 34.104 0.000
"B16110500024"
DEP VAR:LHAB_LEN N: 411 MULTIPLE R: 0.994 SQUARED MULTIPLE R: 0.987
CONSTANT 0.053 0.024 0.000 . 2.239 0.026
LEST_LEN 0.996 0.006 0.994 1.000 177.376 0.000
DEP VAR:LHAB_WID N: 411 MULTIPLE R: 0.974 SQUARED MULTIPLE R: 0.948
CONSTANT 0.050 0.031 0.000 . 1.608 0.109
LEST_WID 0.984 0.011 0.974 1.000 86.759 0.000
"B16110500025"
DEP VAR:LHAB_LEN N: 411 MULTIPLE R: 0.994 SQUARED MULTIPLE R: 0.987
CONSTANT 0.053 0.024 0.000 . 2.239 0.026
LEST_LEN 0.996 0.006 0.994 1.000 177.376 0.000
DEP VAR:LHAB_WID N: 411 MULTIPLE R: 0.974 SQUARED MULTIPLE R: 0.948
CONSTANT 0.050 0.031 0.000 . 1.608 0.109
LEST_WID 0.984 0.011 0.974 1.000 86.759 0.000
"B16110500026"
DEP VAR:LHAB_LEN N: 411 MULTIPLE R: 0.994 SQUARED MULTIPLE R: 0.987
CONSTANT 0.053 0.024 0.000 . 2.239 0.026
LEST_LEN 0.996 0.006 0.994 1.000 177.376 0.000
DEP VAR:LHAB_WID N: 20 MULTIPLE R: 0.999 SQUARED MULTIPLE R: 0.999
CONSTANT 0.021 0.021 0.000 . 0.998 0.331
LEST_WID 0.991 0.008 0.999 1.000 119.981 0.000
"B16110500027"
DEP VAR:LHAB_LEN N: 411 MULTIPLE R: 0.994 SQUARED MULTIPLE R: 0.987
CONSTANT 0.053 0.024 0.000 . 2.239 0.026
LEST_LEN 0.996 0.006 0.994 1.000 177.376 0.000
DEP VAR:LHAB_WID N: 411 MULTIPLE R: 0.974 SQUARED MULTIPLE R: 0.948
```

```
CONSTANT 0.050 0.031 0.000 . 1.608 0.109
LEST_WID 0.984 0.011 0.974 1.000 86.759 0.000
"B16110500043"
DEP VAR:LHAB_LEN N: 411 MULTIPLE R: 0.994 SQUARED MULTIPLE R: 0.987
CONSTANT 0.053 0.024 0.000 . 2.239 0.026
LEST_LEN 0.996 0.006 0.994 1.000 177.376 0.000
DEP VAR:LHAB_WID N: 35 MULTIPLE R: 0.943 SQUARED MULTIPLE R: 0.889
CONSTANT 0.231 0.203 0.000 . 1.143 0.261
LEST_WID 0.945 0.058 0.943 1.000 16.285 0.000
"B17110500030"
DEP VAR:LHAB_LEN N: 411 MULTIPLE R: 0.994 SQUARED MULTIPLE R: 0.987
CONSTANT 0.053 0.024 0.000 . 2.239 0.026
LEST_LEN 0.996 0.006 0.994 1.000 177.376 0.000
DEP VAR:LHAB_WID N: 411 MULTIPLE R: 0.974 SQUARED MULTIPLE R: 0.948
CONSTANT 0.050 0.031 0.000 . 1.608 0.109
LEST_WID 0.984 0.011 0.974 1.000 86.759 0.000
"B17110500033"
DEP VAR:LHAB_LEN N: 411 MULTIPLE R: 0.994 SQUARED MULTIPLE R: 0.987
CONSTANT 0.053 0.024 0.000 . 2.239 0.026
```



```
LEST_LEN 0.996 0.006 0.994 1.000 177.376 0.000
DEP VAR:LHAB_WID N: 411 MULTIPLE R: 0.974 SQUARED MULTIPLE R: 0.948
CONSTANT 0.050 0.031 0.000 . 1.608 0.109
LEST_WID 0.984 0.011 0.974 1.000 86.759 0.000
"B17110500034"
DEP VAR:LHAB_LEN N: 411 MULTIPLE R: 0.994 SQUARED MULTIPLE R: 0.987
CONSTANT 0.053 0.024 0.000 . 2.239 0.026
LEST_LEN 0.996 0.006 0.994 1.000 177.376 0.000
DEP VAR:LHAB_WID N: 411 MULTIPLE R: 0.974 SQUARED MULTIPLE R: 0.948
CONSTANT 0.050 0.031 0.000 . 1.608 0.109
LEST_WID 0.984 0.011 0.974 1.000 86.759 0.000
"B17110500055"
DEP VAR:LHAB_LEN N: 411 MULTIPLE R: 0.994 SQUARED MULTIPLE R: 0.987
CONSTANT 0.053 0.024 0.000 . 2.239 0.026
LEST_LEN 0.996 0.006 0.994 1.000 177.376 0.000
DEP VAR:LHAB_WID N: 411 MULTIPLE R: 0.974 SQUARED MULTIPLE R: 0.948
CONSTANT 0.050 0.031 0.000 . 1.608 0.109
LEST_WID 0.984 0.011 0.974 1.000 86.759 0.000
"B18110500043"
DEP VAR:LHAB_LEN N: 21 MULTIPLE R: 0.995 SQUARED MULTIPLE R: 0.990
CONSTANT 0.065 0.102 0.000 . 0.644 0.527
LEST_LEN 1.002 0.023 0.995 1.000 43.145 0.000
DEP VAR:LHAB_WID N: 21 MULTIPLE R: 0.897 SQUARED MULTIPLE R: 0.804
CONSTANT 0.043 0.340 0.000 . 0.127 0.900
LEST_WID 0.979 0.111 0.897 1.000 8.822 0.000
"B19110500046"
DEP VAR:LHAB_LEN N: 411 MULTIPLE R: 0.994 SQUARED MULTIPLE R: 0.987
CONSTANT 0.053 0.024 0.000 . 2.239 0.026
LEST_LEN 0.996 0.006 0.994 1.000 177.376 0.000
DEP VAR:LHAB_WID N: 411 MULTIPLE R: 0.974 SQUARED MULTIPLE R: 0.948
CONSTANT 0.050 0.031 0.000 . 1.608 0.109
LEST_WID 0.984 0.011 0.974 1.000 86.759 0.000
"D05110500028"
DEP VAR:LHAB_LEN N: 21 MULTIPLE R: 0.990 SQUARED MULTIPLE R: 0.981
CONSTANT -0.175 0.115 0.000 . -1.526 0.143
LEST_LEN 1.063 0.034 0.990 1.000 31.362 0.000
DEP VAR:LHAB_WID N: 21 MULTIPLE R: 0.940 SQUARED MULTIPLE R: 0.883
CONSTANT 0.380 0.140 0.000 . 2.718 0.014
LEST_WID 0.811 0.068 0.940 1.000 11.981 0.000
"D06110500029"
DEP VAR:LHAB_LEN N: 24 MULTIPLE R: 0.997 SQUARED MULTIPLE R: 0.994
CONSTANT -0.060 0.073 0.000 . -0.824 0.419
```

LEST_LEN 1.019 0.018 0.997 1.000 58.080 0.000
DEP VAR:LHAB_WID N: 24 MULTIPLE R: 0.945 SQUARED MULTIPLE R: 0.892
CONSTANT -0.370 0.242 0.000 . -1.527 0.141
LEST_WID 1.106 0.082 0.945 1.000 13.502 0.000

"D06110500031"
DEP VAR:LHAB_LEN N: 23 MULTIPLE R: 0.997 SQUARED MULTIPLE R: 0.994
CONSTANT 0.040 0.066 0.000 . 0.597 0.557
LEST_LEN 1.001 0.016 0.997 1.000 61.503 0.000
DEP VAR:LHAB_WID N: 23 MULTIPLE R: 0.968 SQUARED MULTIPLE R: 0.938
CONSTANT 0.038 0.143 0.000 . 0.268 0.791
LEST_WID 0.989 0.056 0.968 1.000 17.793 0.000
"D06110500032"
DEP VAR:LHAB_LEN N: 20 MULTIPLE R: 0.998 SQUARED MULTIPLE R: 0.996
CONSTANT -0.026 0.058 0.000 . -0.444 0.663
LEST_LEN 1.008 0.014 0.998 1.000 71.231 0.000
DEP VAR:LHAB_WID N: 20 MULTIPLE R: 0.954 SQUARED MULTIPLE R: 0.910
CONSTANT -0.117 0.198 0.000 . -0.594 0.560
LEST_WID 1.044 0.077 0.954 1.000 13.503 0.000
"D06110500060"
DEP VAR:LHAB_LEN N: 22 MULTIPLE R: 0.982 SQUARED MULTIPLE R: 0.965
CONSTANT 0.028 0.170 0.000 . 0.164 0.871
LEST_LEN 1.002 0.043 0.982 1.000 23.580 0.000
DEP VAR:LHAB_WID N: 22 MULTIPLE R: 0.922 SQUARED MULTIPLE R: 0.851
CONSTANT 0.277 0.218 0.000 . 1.269 0.219
LEST_WID 0.891 0.083 0.922 1.000 10.673 0.000
"D06110500061"
DEP VAR:LHAB_LEN N: 22 MULTIPLE R: 0.997 SQUARED MULTIPLE R: 0.995
CONSTANT 0.024 0.063 0.000 . 0.378 0.710
LEST_LEN 0.998 0.016 0.997 1.000 61.761 0.000
DEP VAR:LHAB_WID N: 22 MULTIPLE R: 0.971 SQUARED MULTIPLE R: 0.944
CONSTANT 0.077 0.129 0.000 . 0.595 0.558
LEST_WID 0.968 0.053 0.971 1.000 18.297 0.000
"D06110500062"
DEP VAR:LHAB_LEN N: 22 MULTIPLE R: 0.986 SQUARED MULTIPLE R: 0.972
CONSTANT 0.162 0.141 0.000 . 1.147 0.265
LEST_LEN 0.973 0.037 0.986 1.000 26.459 0.000
DEP VAR:LHAB_WID N: 22 MULTIPLE R: 0.986 SQUARED MULTIPLE R: 0.972
CONSTANT -0.013 0.094 0.000 . -0.143 0.888
LEST_WID 1.006 0.038 0.986 1.000 26.320 0.000
"D06110500063"
DEP VAR:LHAB_LEN N: 20 MULTIPLE R: 0.980 SQUARED MULTIPLE R: 0.961
CONSTANT 0.243 0.168 0.000 . 1.447 0.165
LEST_LEN 0.952 0.045 0.980 1.000 21.088 0.000
DEP VAR:LHAB_WID N: 19 MULTIPLE R: 0.897 SQUARED MULTIPLE R: 0.804
CONSTANT 0.370 0.221 0.000 . 1.670 0.113
LEST_WID 0.820 0.098 0.897 1.000 8.350 0.000
"D06110500064"
DEP VAR:LHAB_LEN N: 26 MULTIPLE R: 0.997 SQUARED MULTIPLE R: 0.994
CONSTANT 0.017 0.062 0.000 . 0.278 0.783
LEST_LEN 1.002 0.016 0.997 1.000 62.348 0.000
DEP VAR:LHAB_WID N: 26 MULTIPLE R: 0.911 SQUARED MULTIPLE R: 0.830

CONSTANT 0.017 0.188 0.000 . 0.090 0.929
LEST_WID 0.986 0.091 0.911 1.000 10.820 0.000
"D06110500065"
DEP VAR:LHAB_LEN N: 28 MULTIPLE R: 0.992 SQUARED MULTIPLE R: 0.985
CONSTANT 0.094 0.092 0.000 . 1.029 0.313
LEST_LEN 0.991 0.024 0.992 1.000 41.150 0.000
DEP VAR:LHAB_WID N: 28 MULTIPLE R: 0.962 SQUARED MULTIPLE R: 0.926CONSTANT

```
0.024 0.144 0.000 . 0.170 0.866
LEST_WID 0.998 0.055 0.962 1.000 18.048 0.000
"D07110500056"
DEP VAR:LHAB_LEN N: 411 MULTIPLE R: 0.994 SQUARED MULTIPLE R: 0.987
CONSTANT 0.053 0.024 0.000 . 2.239 0.026
LEST_LEN 0.996 0.006 0.994 1.000 177.376 0.000
DEP VAR:LHAB_WID N: 411 MULTIPLE R: 0.974 SQUARED MULTIPLE R: 0.948
CONSTANT 0.050 0.031 0.000 . 1.608 0.109
LEST_WID 0.984 0.011 0.974 1.000 86.759 0.000
"D08110500066"
DEP VAR:LHAB_LEN N: 39 MULTIPLE R: 0.998 SQUARED MULTIPLE R: 0.996
CONSTANT -0.019 0.049 0.000 . -0.393 0.696
LEST_LEN 1.000 0.010 0.998 1.000 97.917 0.000
DEP VAR:LHAB_WID N: 39 MULTIPLE R: 0.969 SQUARED MULTIPLE R: 0.939
CONSTANT 0.469 0.108 0.000 . 4.355 0.000
LEST_WID 0.853 0.036 0.969 1.000 23.924 0.000
"D10110500085"
DEP VAR:LHAB_LEN N: 411 MULTIPLE R: 0.994 SQUARED MULTIPLE R: 0.987
CONSTANT 0.053 0.024 0.000 . 2.239 0.026
LEST_LEN 0.996 0.006 0.994 1.000 177.376 0.000
DEP VAR:LHAB_WID N: 411 MULTIPLE R: 0.974 SQUARED MULTIPLE R: 0.948
CONSTANT 0.050 0.031 0.000 . 1.608 0.109
LEST_WID 0.984 0.011 0.974 1.000 86.759 0.000
"D10110500086"
DEP VAR:LHAB_LEN N: 411 MULTIPLE R: 0.994 SQUARED MULTIPLE R: 0.987
CONSTANT 0.053 0.024 0.000 . 2.239 0.026
LEST_LEN 0.996 0.006 0.994 1.000 177.376 0.000
DEP VAR:LHAB_WID N: 38 MULTIPLE R: 0.995 SQUARED MULTIPLE R: 0.990
CONSTANT 0.028 0.041 0.000 . 0.685 0.498
LEST_WID 0.987 0.016 0.995 1.000 60.364 0.000
```

The following bias corrections, based on observers who had consistently valid calibrations across streams, were used in reaches where unsatisfactory calibration data sets were encountered. Those were deemed unsatisfactory because they had identical values for estimates and measurements of pool length and depth, and comprised 42% of all data.

```
DEP VAR:LHAB_LEN N: 411 MULTIPLE R: 0.994 SQUARED MULTIPLE R: 0.987
CONSTANT 0.053 0.024 0.000 . 2.239 0.026
LEST_LEN 0.996 0.006 0.994 1.000 177.376 0.000
```



```
DEP VAR:LHAB_WID N: 411 MULTIPLE R: 0.974 SQUARED MULTIPLE R: 0.948
CONSTANT 0.050 0.031 0.000 . 1.608 0.109
LEST_WID 0.984 0.011 0.974 1.000 86.759 0.000
```

Appendix 2. Rationale for representing the effect of a land-use on a stream reach.

It is intuitive that the greater the distance a land-use is from the location of a measured response, the lesser will be its potential impact. An analogy is provided by the simple inverse square distance law of light intensity: The intensity from a point source of light is inversely related to the distance from the source. The intensity, I_1, at distance r_1 changes to I_2 at greater distance r_2

according to the increasing surface area of a sphere of radius r with the light source at the center:

$$I_1 4\pi r_1^2 = I_2 4\pi r_2^2$$

If the inner sphere 1 is unit distance (say one pixel from the source) , then the intensity I_2 at distance r_2 is reduced relative to I_1 thus:

$I_2 / I_1 = 1/r_2^2$; hence the inverse square law.

However, this represents a decay in energy intensity in three dimensions. While at that extreme one could envisage loss in the effect of intensity of a land-use in three dimensions (e.g., a pollution effect dissipating outwards and downwards into the water table), one can also envisage some effects (e.g. the distribution of large wood, which decays very slowly, down a stream from a riparian source) as being one-dimensional. Between these extremes, the predominantly two-dimensional nature of landscapes at the scale of drainages containing 2nd to 4th order streams probably mediates the decay of most processes over distance, even when considering the relatively shallow layers of groundwater or hyporheic zones. Therefore, the decay of intensity in two dimensions would be equivalent to that of a light source in a circle of perimeter $2\pi r$:

$$I_1 2\pi r_1 = I_2 2\pi r_2$$

or $I_2 / I_1 = 1/r_2$

Hence the inverse rule that has been adopted in this analysis (Fig. 11).

The software, ZOI, produces inverse and inverse square measures. It also produces separate measures for instream and out-of-stream distance components from each pixel. While theoretical arguments can be made for combinations of these alternatives there are statistical limitations.

First, splitting the distance into instream and out-of-stream components doubles the number of coefficients that need to be fitted in the statistical analysis. This reduces degrees of freedom, and therefore power, and also increases the probability of lack of independence among variables or significant interactions between them. To attempt to resolve these issues a designed, stratified study covering many more drainages than in this study would be necessary.

Second, while it is tempting to repeat the statistical analysis using alternative derivations of

effects (such as inverse and inverse squared variables), this compromises the meaning of the
adopted error rate (e.g., the conventional 5% alpha level). In other words, unless one takes the
required penalty of lowering the effective significance level to account for multiple testing, one can
be accused of undertaking a 'fishing expedition' with the data set.

Fig. 1. Typical suction dredge mining activities.
(photographs by Kevin L. Johnson)

10 Miles
16 Km
N
Suction dredge mining 1999
Hydraulic mining
CJ

Fig. 2. Illinois river subbasin and location, showing reaches where suction dredge mining activities
and early hydraulic mining occurred. Black line shows boundary of the Siskiyou National Forest.
CJ Cave Junction
Oregon

10 Miles
16 Km
N
Suction dredge mining 1999
Hydraulic mining
ODFW Spawning samples

Fig. 3. Locations of ODFW Salmonid spawning stations from 1995-2000 (downstream starting points of reaches sampled) in Illinois subbasin, and reaches where suction dredge mining activities
and early hydraulic mining occurred. Black line shows boundary of the Siskiyou National Forest.

10 Miles
16 Km
N
Suction dredge mining 1999
Hydraulic mining
SMART fish samples

Common name	Scientific name	Total No. individuals observed	No. Pools species was observed	No. reaches species was observed
Rainbow trout*	Oncorhynchus mykiss	5368	531	55
Coastal cutthroat trout	Oncorhynchus clarki	335	127	34
Coho salmon	Oncorhynchus kisutch	21	9	4
Brook trout*	Salvelinus fontinalis	5	5	1
sculpins **	Cottus spp.	257	33	16
Redside shiner	Richardsonius balteatus	93	4	2

Northern pikeminnow Ptychocheilus oregonensis 84 8 3
Aggregate values 6163 610 59
Total number of units sampled 611 59
* introduced species **enumerated in about half of pools sampled
Fig. 5. Numbers of fish observed by species, and numbers of pools and reaches in which separate
species and all taxa were observed from 59 SMART summer snorkeling reaches visited from 1996-1999. Fish observed in non-pool habitats were excluded here and from the analysis.

Fig. 4. Locations of SMART summer snorkeling stations from 1996-1999 (downstream starting points of reaches sampled) in Illinois subbasin, and reaches where suction dredge mining activities and early hydraulic mining occurred. Black line shows boundary of the Siskiyou National Forest.

0 50 100 150 200
0
10
20
30
40
50
CU. YDS APPLIED FOR
CU. YDS MOVED
Fig. 6. Sediment moved by independent suction dredge mining operations in 1999. [x-axis = amount estimated prior to season; y-axis = amount moved downstream during season. Least squares regression line shown]
(source: Kevin Johnson, USFS, Grants Pass, OR)
48 samples, r = 0.60

Fig. 8. Sucker Creek floodplain in 2001 that was subject to 19th Century hydraulic mining.
Fig. 7. Examples of late 19th Century hydraulic mining (photograph at left by Nome 1900)
P. B. Bayley

Urban/Agriculture
Non-forest vegetation
Barren
Conifer forest <50% cover
Mixed forest <50% cover
Hardwood <50% cover
Conifer forest >50% cover
Mixed forest >50% cover
Hardwood >50% cover
Roads
Suction dredge mining 1999

Hydraulic mining
ODFW Spawning samples
SMART fish samples
10 Miles
16 Km
N
Fig. 9. WODIP classification of land-cover types in the Illinois subbasin, fish sample locations, and
reaches where suction dredge mining activities and early hydraulic mining occurred. (Roads are are
too fine to be observable at this scale.) Black line shows boundary of the Siskiyou National Forest.

Sample location ("Pour Point")
that defines drainage basin
Score = 2 Score = 4
A B
Fig. 10. Examples of scoring land-use classifications for potential influence on a stream sample (A) All pixels for a given classification in the drainage basin summed, (B) Only pixels falling within a defined buffer zone arounf permanent stream are summed.

Distance, d, from pixel to sample point,
as the water flows
Influence proportional to 1/Distance
Total potential influence score =
1
d1
1
d2
1
d3
1
d4
+ + +
Sample
(Pour Point)
Fig. 11. Example of scoring land-use classifications for potential influence on a stream sample in which all pixels for a given classification are weighted by their inverse distance to the sample location and summed (dotted lines show flow paths overland from off-channel pixels determined by a flow map derived from a 10-m DEM (Digital Elevation Map)).

1/Distance weights (Percent coverage in basin)
Stream Ag-Urban <50% >50% Hydraulic Dredge
-Roads Forest Forest Mining Mining
Days Gulch 4.7 (5.2) 68 (49) 27 (46) 14 (1) 7.5 (12)
Fiddler Gulch 2.4 (3.2) 63 (46) 35 (51) 36 (11) 0 (0)
Fiddler Gulch (upper) 3.8 (4.3) 28 (29) 69 (67) 27 (3.4) 0 (0)

Fig. 12. Example of distribution of original land-use and mining classifications (25-by-25-m pixels), showing
three SMART fish sampling locations in Josephine Creek basin, and explanatory variable results. Table
shows inverse distance weighting measures for aggregated land-use and mining classifications, which were
the explanatory variable values used, in the three drainages. (Percent coverage values based on sums of
pixels are shown in parentheses for comparison)

Urban/Agriculture
Non-forest vegetation
Barren
Conifer forest <50% cover
Mixed forest <50% cover
Hardwood <50% cover
Conifer forest >50% cover
Mixed forest >50% cover
Hardwood >50% cover
Roads
Suction dredge mining (SDM) 1999
Hydraulic mining
SMART fish samples
Drainage basin boundaries (sketched)

0 1
0
1
2

Cumulative effect of sediment transport by suction
dredge mining
Cumulative effect of hydraulic mining
r = 0.67, p<0.001

Forest <50% canopy Forest >50% canopy Suction
Urban Non-For Barren Conifer Mixed Hwood Conifer Mixed Hwood Roads Hydraul Dredge
-Ag _Veg Mining Mining
Urban-Ag 1.000
Non-For_Veg 0.12 1.000
Barren 0.152 0.770*** 1.000
Con_For<50% 0.019 0.710*** 0.667*** 1.000
Mix_For<50% 0.282 0.405 0.399 0.422 1.000
Hwd_For<50% -0.510**-0.519** -0.443 -0.504** -0.757*** 1.000
Con_For>50% -0.469* -0.893*** -0.758*** -0.759*** -0.527** 0.659*** 1.000
Mix_For>50% -0.464* -0.790*** -0.770*** -0.572** -0.353 0.569** 0.824*** 1.000
Hwd_For>50% -0.333 -0.577*** -0.501** -0.585*** -0.444 0.743*** 0.595*** 0.632*** 1.000
Roads -0.300 0.015 -0.157 0.076 -0.399 0.179 0.051 -0.019 -0.100 1.000
HM -0.210 0.055 0.257 0.298 0.019 -0.189 -0.043 -0.099 -0.280 0.334 1.000
SDM -0.203 0.133 0.406 0.366 -0.121 -0.045 -0.142 -0.179 -0.225 0.442 0.670*** 1.00

Fig. 13. PEARSON CORRELATION MATRIX of cumulative effects of drainages defined by 53 ODFW salmon spawning
samples. Bonferroni-corrected probabilities: * P<0.05, ** P<0.01, **P<0.001.
(Urban-Ag = Urban and agriculture areas combined; Non-For_Veg = Non-forest vegetation; HM = Hydraulic mining; SDM = Suction
Dredge Mining)

Fig. 14. CORRELATION between cumulative
effects of Hydraulic mining and
Suction Dredge Mining from drainages
defined by 53 ODFW salmon spawning

samples.

Forest <50% canopy Forest >50% canopy Suction
Urban Non-For Barren Conifer Mixed Hwood Conifer Mixed Hwood Roads Hydraul Dredge
-Ag _Veg Mining Mining
Urban-Ag 1.000
Non-For_Veg -0.022 1.000
Barren -0.070 0.825** 1.000
Con_For<50% 0.025 0.835** 0.890** 1.000
Mix_For<50% -0.178 0.530** 0.442* 0.509** 1.000
Hwd_For<50% -0.081 0.157 0.072 0.155 0.078 1.000
Con_For>50% 0.009 -0.947** -0.875** -0.927** -0.634** -0.217 1.000
Mix_For>50% 0.060 -0.647** -0.759** -0.640** -0.098 0.239 0.575** 1.000
Hwd_For>50% 0.017 -0.427* -0.482** -0.497** -0.115 0.377 0.364 0.473* 1.000
Roads -0.063 -0.303 -0.352 -0.433* -0.340 -0.448* 0.333 0.015 0.080 1.000
HM -0.117 -0.111 0.022 -0.017 -0.066 -0.309 0.118 -0.079 -0.343 0.039 1.000
SDM -0.045 -0.049 0.034 -0.011 -0.112 -0.145 0.078 -0.106 -0.113 -0.057 0.255 1.00
Fig. 15. Pearson correlation matrix of cumulative effects of drainages defined by 59 SMART samples. Bonferronicorrected
probabilities: * P<0.05, ** P<0.01, **P<0.001.
(Urban-Ag = Urban and agriculture areas combined; Non-For_Veg = Non-forest vegetation; HM = Hydraulic mining; SDM = Suction
Dredge Mining)
0
20
40
60
80
100
%
Urban/Agriculture
Non-forest vegetation
Barren
Conifer forest <50% cover
Mixed forest <50% cover
Hardwood <50% cover
Conifer forest >50% cover
Mixed forest >50% cover
Hardwood >50% cover
Roads
Fig. 16. Proportions of WODIP-based explanatory variables, by area of drainage occupied, from drainages defined by
59 SMART fish samples. (Samples ordered on x-axis by increasing canopy >50% of all forest to illustrate ranges of
explanatory variables. The legend identifies the variables in the same order as shown on the graph).

Urban Forest <50% canopy Suction
+ Agric. + Non-For_Veg Forest >50% Hydraulic Dredge
+ Roads + Barren canopy Mining Mining
(1) Urban-Ag-Roads 1.00
(2) For.<50%+Non-For.+Barren -0.401* 1.00
(3) Forest >50% canopy 0.299 -0.994*** 1.00

(4) Hydraulic Mining 0.019 -0.061 0.059 1.00
(5) Suction D. Mining -0.064 -0.031 0.040 0.255 1.00
Urban-Ag-Roads
Forest<50%
+Non-Forest veg.
+Barren
Forest >50%
0
20
40
60
80
100
%
Fig. 17. PEARSON CORRELATION MATRIX of reduced set of cumulative effects of drainages defined by 59
SMART samples. Bonferroni-corrected probabilities: * P<0.05, ** P<0.01, **P<0.001. [see text for (1), (2),
etc.,].
(Urban-Ag-Roads = Urban, agriculture and road areas combined;
For.<50%+Non-For.+Barren = +Forest less than 50% canopy, Non-forest vegetation, and barren areas combined)
Fig. 18. Proportions of reduced WODIP-based explanatory variables, by area of drainage occupied, from
drainages defined by 59 SMART fish samples.

(A) Model: Response: Density of Salmonids ³ 1yr-old
Explan. vars.: Ag-Urban-Roads + Forest>50% + Hydraulic Mining
+ Suction Dredge Mining + Hydraulic Mining*Suct.Mining
Coefficients:
Value SE t-value
(Intercept) 4.04
Ag-Urban-Roads -4.96 5.65 -0.88
Forest>50% 0.39 0.73 0.53
Hydraul.Mining -0.40 0.19 -2.04#
Suct.Mining -0.33 0.29 -1.16
Hydraul.*Suct.Mining 0.25 0.23 1.06
(B) Model: Response: Density of Salmonids ³ 1yr-old
Explan. vars.: Ag-Urban-Roads + Forest>50% + Hydraulic Mining
+ Suction Dredge Mining
Coefficients:
Value SE t-value
(Intercept) 3.86
Ag-Urban-Roads -5.45 5.68 -0.96
Forest >50% 0.66 0.68 0.97
Hydraul.Mining -0.36 0.19 -1.90
Suct.Mining -0.05 0.08 -0.56
(C) Model: Response: Density of Salmonids ³ 1yr-old
Explan. vars.: Ag-Urban-Roads + Forest>50% + Hydraul.Mining
Coefficients:

Value SE t-value
(Intercept) 3.85
Ag-Urban-Roads -5.46 5.67 -0.96
Forest >50% 0.68 0.67 1.00
Hydraulic Mining -0.38 0.18 -2.13# (P=0.03)

Fig. 19. General linear model results using negative binomial fits to 59 SMART fish samples on the
density of Native Salmonids ^{3}1yr-old (* = interaction between two variables; # signidicant coefficient at P<0.05; see text for refs. to A, B, and C).

Predicted density if
Hydraulic Mining had ....
existed as or, not Predicted
recorded, occurred change
Althouse Creek (lower) 30 52 71%
Josephine Creek (mouth) 30 45 50%
Days Gulch (mouth) 39 43 12%
Model: Density of Salmonids ^{3} 1yr-old (#/1000 m2)
= exp(3.85-5.46*Ag-Urban-Roads + 0.68*Forest>50% - 0.38*Hydraul.Mining)

Fig. 20. Normal probability plot of deviance residuals from model in Fig. 19C.

-2 -1 0 1 2
-2 -1 0 1 2
Quantiles of Standard Normal
Deviance Residuals

Fig. 21. Predicted change in salmonid density (older that YOY) in selected streams if hydraulic mining effect had not occurred.

USGS

Department of the Interior
U.S.Geological Survey
USGS Fact Sheet FS--154-97
October 1997

Studies of Suction Dredge Gold-Placer Mining Operations Along the Fortymile River, Eastern Alaska

The U.S. Geological Survey (USGS) and the Alaska Department of Natural Resources (AKDNR) are investigating the environmental geochemistry of the Fortymile River drainage area in eastern Alaska. This river is designated a Wild and Scenic Corridor by the Alaska National Interest Lands Conservation Act. Current users of the river include placer mine operators, as well as boaters and rafters. Along the North Fork Fortymile River, and just below its confluence with the South Fork (fig. 1), mining is limited to a few small suction dredges which, combined, produce as much as a few hundred ounces of gold per year. In this area, some potential environmental concerns have been raised associated with the mining activities, including increased turbidity of the river water; adverse impact on the overall chemical quality of the river water; and potential additions of specific toxic elements, such as arsenic, to the river during mining operations.

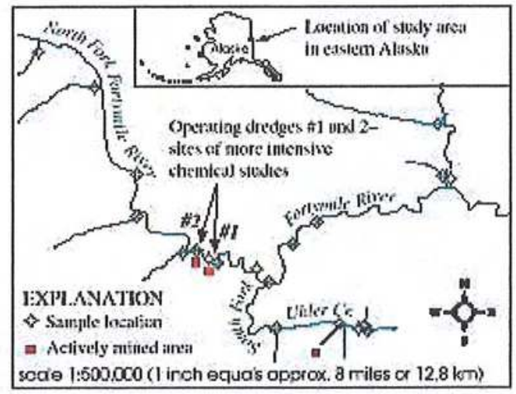

Figure 1. Schematic map of the Fortymile River study area. The town of Chicken lies about 20 miles (32 km) to the south.

A cooperative effort between the USGS and the AKDNR was initiated to provide data to address these concerns as well as regional geochemical data. In June 1997, field measurements were made for pH, turbidity, electrical conductivity (a measure of the total dissolved concentrations of mineral salts), and stream discharge for the Fortymile River and many of its tributaries. Samples were collected at the same time for chemical analyses, including trace-metal analyses, in the USGS laboratories in Denver, Colorado. This Fact Sheet summarizes some of the results of this ongoing study, especially in regard to the suction dredge mine sites.

TURBIDITY SURVEYS

Two sites were studied where suction dredges were operating in the North Fork Fortymile River, as shown on figure 1. Samples were collected on a grid extending downstream from the dredges as they were

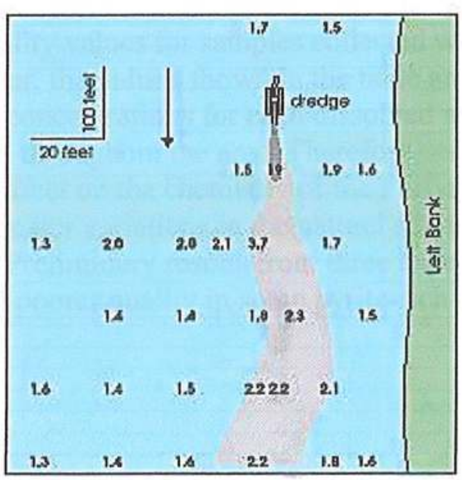

Figure 2. Results of turbidity survey behind an operating 10-inch suction dredge (site #1 on fig. 1). All numbers shown are in NTU, or nephelometric turbidity units; the standard unit of turbidity. The right bank of the river is off the edge of the figure. The approximate shape of the plume is shown in gray. Note that the figure is exaggerated 5x horizontally, so the plume is actually much narrower than it appears in the figure. To comply with State regulations, dredges may not increase the turbidity of the river by more than 5 NTU, 500 feet behind the dredge.

California Environmental Analysis of Suction Dredging

The State of California explained in its environmental analysis of suction dredging:

"In streams carrying heavy sediment loads, the substrate often becomes compacted. The result is a highly-embedded and nearly 'cement-hard' substrate which provides poor fish spawning and rearing conditions. Suction dredging in such stream areas may break up compacted substrate and mobilize the fines . . .". (See MER40.)

This study corroborated the findings of numerous prior cumulative impact studies. (*See, e.g.,* MER24 ("The only attempt to measure cumulative effects of dredging on fish and invertebrates (Harvey 1986) suggested that a moderate density of dredges does not generate detectable cumulative effects"); MER30 (thirty-five years of personal observations); MER32 (six 6" dredges on 2 km stream and 40 dredges on 11 km stretch "had no additive effects"); MER33 (no cumulative effects from twenty-four 3" to 6" dredges along 15 km stretch); MER34-35(California state EIS finds no significant effects); MER36 (U.S. Army Corps of Engineers study provides "official recognition of what suction dredgers have long claimed: that below a certain size [4 inches], the effects of suction dredging are so small and so short-term as to not warrant the regulations being imposed in many cases", finds *de minimus* impact on aquatic resources).

Suction Dredge Mining as a Beneficial Use.

INTENT: the intent of the Mining Laws and the continuing intent of Congress are simple and self-evident:

- The general policy of the mining laws is to promote widespread development of mineral deposits and to afford mining opportunities to as many persons as possible. (30 USC 22.50) (emphasis added)

and;

> The Congress declares that it is the continuing policy of the Federal Government in the national interest to foster and encourage private enterprise in (1) the development of economically sound and stable domestic mining, minerals, metal and mineral reclamation industries, (2) the orderly and economic development of domestic mineral resources, reserves, and reclamation of metals and minerals to help assure satisfaction of industrial, security and environmental needs... For the purpose of this Act 'minerals' shall include all minerals and mineral fuels including oil, gas, coal, oil shale and uranium. (Mining and Minerals Policy Act of 1970) (emphasis added)

The state of Oregon has declared the development of mineral resources to be a beneficial use.

ORS 541.110
Use of water to develop mineral resources and furnish power. The use of the water of the lakes and running streams of Oregon for the purpose of developing the mineral resources of the state and to furnish electric power for all purposes is declared to be a public and beneficial use and a public necessity.

News Release

Washington State Department of Ecology News Release - September 17, 2007

07-263

Small-scale miners help remove mercury from the environment

YAKIMA - Modern-day miners have teamed up with the Washington Department of Ecology (Ecology) to remove mercury left in streams and rivers from gold rush days. Turn-of-the-century miners left behind a legacy of mercury contamination that the modern-day prospectors are helping to clean up.

Old-time miners would pour mercury directly into sluice boxes and other mining equipment to capture the fine particles of gold. It often spilled into river gravel where modern miners, who don't use mercury, find it while they are prospecting and remove it from the environment.

Over the past four years, the Resources Coalition and other small-scale miners associations have turned in 127 pounds of mercury and 8 pounds of lead for safe disposal. This year, Ecology staff attended miners' rallies in Oroville and Monroe, providing a convenient opportunity for proper disposal of lead and mercury.

"That is 127 pounds of mercury no longer contaminating Washington's waterways or being accidentally spilled," explained Brian Dick, a manager with Ecology's hazardous waste and toxics reduction program. "The miners have responded with great enthusiasm and have worked with Ecology to get the word out to their members about our collection program."

In Washington, small-scale miners are allowed to prospect for gold in streams under rules described in the Gold and Fish pamphlet. More information about the Gold and Fish pamphlet is available online at:
http://www.wdfw.wa.gov/hab/goldfish/goldfish.htm.

Mark Erickson, with the Resources Coalition said, "Our members care about the environment and are happy to help remove legacy mercury and lead from Washington's rivers and streams."

Mercury is a naturally occurring metallic element. A neurotoxin, mercury can damage nerve tissue in animals and humans who are exposed to it. Mercury spills are dangerous, difficult and costly to clean up. In May of 2007, two Yakima teens playing with mercury they found in a nearby storage shed caused over $265,000 in property damage. One of the teens was hospitalized as a result of mercury exposure.

There is a national effort to reduce the use of mercury. In 2003, the Washington Legislature passed the Mercury Education and Reduction Act, initiating a program to reduce the use of mercury in consumer products and safely dispose of them. For decades, mercury has been used in a variety of household, medical, and electrical products, as well as in industrial applications.

More information on the state's mercury reduction efforts and information on how to safely dispose of mercury containing products may be found online at http://www.ecy.wa.gov/mercury/ or call 1-800-RECYCLE.

Mining produces wealth.

The miner who digs a fortune out of the ground has the satisfaction of knowing that he has not robbed a soul, even though becomes a thousand times a millionaire. Then, too, there is another factor to take into consideration. The man who makes his fortune on the board of trade or the stock exchange, or in building a gigantic business, adds nothing to the store of the world's available wealth. The world, in other words, is no richer because he is richer. He is richer rather because someone else is poorer. The miner, on the other hand, whether he digs out $10 or $100,000, adds that much to the world's wealth, and with the added wealth he contributes just that much to the possible amount of the world's comforts and pleasures.

As I look at the matter, there are a few producers of wealth. The many live on the few. The only man comparable to the miner is the farmer. He gets what he has directly from nature, but he produces a perishable wealth. While he meets a want, his contribution to the world's wealth, therefore, is not permanent, like the miner's. The gold miner is today the king of wealth of the country, and I honor him above all others. It is no dishonor; it needs no apology to emulate his example or assist him in his efforts. There is the whole story in a nutshell.

The Reverend Robert McIntyre