Garcia River Drilling Mud Spill:

Damage Assessment and Suggestions for
Mitigation, Restoration and Monitoring

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Introduction

The Garcia River flows into the Pacific Ocean at Point Arena, California. The mainstem of the river is approximately 44 miles in length and the watershed area is 114 square miles. The headwater tributaries of the river flow from steep, forested areas while the lower river meanders through agricultural land. The Garcia River once harbored an abundance of chinook salmon (Oncorhynchus tshawytscha). coho salmon (Oncorhynchus kisutch), and steelhead trout (Oncorhynchus mykiss). Today chinook salmon runs are no longer viable, coho salmon are at remnant levels, and only steelhead trout return in significant numbers to tributaries throughout the basin (Monschke in press).

The decline of the fish seems linked with past watershed problems and changes in the stream channel caused by sediment incursions (California Salmon and Steelhead Advisory Committee 1966). But today the riparian zone of the lower river is in its most advanced stage of recovery since earlier this century. Restoration of the Garcia watershed and fisheries resources are being undertaken through a broad based community effort (Monschke in press). Cooperation of the basin's land owners and improved forest practices bode well for restoring the river, but available gene resources for restoring fisheries may be an impediment (Higgins et al. 1992).

A first order unnamed tributary of the lower Garcia River approximately two miles up stream of the river's mouth was impacted by one of the drilling mud spills. The small tributary is the second blue line stream entering the Garcia River from the south. It has not had recent watershed impacts such as timber harvest and flows under a dense canopy of conifers and hardwoods. The water is cool; temperatures measured in the field ranged from 55-57 degrees F. Point Arena mountain beaver (Aplodontia rufa) burrow in the banks of the unnamed tributary and yellow-legged frogs (Rana boylei), red-legged frogs (Rana aurora), and Pacific giant salamanders (Dicamptodon ensatus) were also found in and around the stream (Macedo 1992). California Department of Fish and Game (CDFG) personnel found coho salmon juveniles in the tributary (Macedo 1992). Although no steelhead were found by CDFG immediately after the spill, juveniles may also have been present in the tributary. While the stream may lack surface flow between pools in late summer or during droughts, salmonids can survive well in isolated pools due to optimal water temperatures and high dissolved oxygen.

Moat Creek, a second order tributary of the Pacific Ocean just to the south of Point Arena, was also impacted by drilling mud spills. The stream has approximately five miles of fish habitat but only just over three miles are accessible to anadromous salmonids (CDFG no date). The headwaters arise at an elevation of just under 1000 feet. Headwater stream corridors have a dense canopy of coniferous trees. Water temperatures in pools were 53 degrees F in upper reaches (8/24/92 at 14:30 hrs) and 55-57 degrees F in lower stream segments (8/25/92 at 10:30 hrs.). The stream could be divided into four reaches: headwaters, an alluviated valley reach near the Curly Lane crossing, a higher gradient reach above the Hay Ranch, and a flat reach in agricultural land which extends over one mile up stream of the lagoon.

California Fish and Game file reports (no date) indicate that Moat Creek has an average width of four feet and average pool depth of 18 inches during low flow conditions in summer. Although surface stream flows in riffles may dry up in summer, steelhead and coho salmon use regional short run coastal streams during winter to spawn (Sommarstrom 1984). Juveniles may rear throughout summer in isolated cold pools and some steelhead trout may remain as residents in these habitats. Rainbow trout or juvenile steelhead were found above the spill site on Moat Creek (Macedo 1992). Amphibians in Moat Creek were the same as those found in the unnamed Garcia River tributary with the addition of the rough-skinned newt (Taricha granulosa).

The Spill and Its Impacts

While routing the landward extension of their under sea fiber optic cable, ATT caused significant incursions of drilling muds and cuttings to be introduced into surface waters of Moat Creek and the Garcia River on July 28, 1992. The bentonite clay used as a lubricant for drilling holes for underground cables entered underground fissures in bedrock that contained water and that had subterranean connections with nearby streams. At one Moat Creek site, a hole was accidentally punched through the stream bottom according to OHM crew members working on clean up in the basin. Sandy materials known as drill cuttings also entered the stream channel of Moat Creek (Macedo 1992).

Garcia River and Unnamed Tributary: On July 28, 1992, approximately 11,000 gallons of drilling mud, primarily bentonite clay, were spilled into the second lowest blue line tributary of the Garcia River. The stream enters the Garcia River upstream of Windy Hollow Road. Much of the material spilled in the creek passed into the main river. Approximately 2000 feet of the tributary and 2000 feet of the Garcia River were severely impacted by the spill, being coated with a thick viscous mass of clay (Macedo 1992).

Impacts to threatened Point Arena mountain beaver became an immediate concern because they inhabited the valley area below the spill site. Resident red-legged frogs, yellow-legged frogs, and Pacific giant salamanders in the tributary may have been impacted. There was evidence (in Moat Creek) that some of these animals had survived below the spill, probably by leaving the water temporarily. However, loss of invertebrates and other aquatic food resources probably decreased survival of those individuals that avoided initial spill impacts. According to CDFG (Macedo 1992), other species effected by the spill include crayfish (Pacifasticus sp.), sculpin (Cottus sp.), Pacific lamprey larvae (Lampetra tridentata), the western toad (Bufo boreas), and garter snakes (Thamnophis sp.)

A juvenile coho salmon was collected at the lower end of the unnamed tributary (Macedo 1992) and three more juvenile coho were identified during an electrofishing survey of the tributary above the spill site. Coho salmon juveniles have not been found by CDPG personnel anywhere in the Garcia Basin since 1988 (Wendy Jones personal communication). Other juvenile coho may have moved downstream in response to the sediment plume prior to monitoring efforts. Survival of fish flushed from the tributary would be low in the main river because temperatures exceed 70 degrees F, well above the optimum of the species.

Brown and Moyle (1991) in a report to the National Marine Fisheries Service found that coho salmon could be listed as threatened throughout their range in California. Reports from the American Fisheries Society confirm this finding. Nehlsen et al. (1991) listed coho salmon in all small river systems from Ft. Bragg to San Francisco as at moderate risk of extinction. A more detailed AFS regional review of "stocks at risk" found that Garcia River coho salmon were at high risk of extinction (Higgins et al. 1992). Restoration of anadromous salmonid runs are best accomplished using endemic stocks (Helle 1981), so whatever native gene resources remain in the Garcia Basin are of extreme importance. The unnamed tributary may harbor one of the last remnants of native coho that once flourished in the river.

Sampling of aquatic invertebrates was not allowed on the unnamed lower Garcia tributary impacted by the bentonite spill. Results from Moat Creek (see below) would indicate that there was almost total loss of the macroinvertebrate community in areas below the spill.

John Lee analyzed aquatic invertebrates collected from riffle areas on the Garcia River above and below the impact of the spill. The upper site was 250 feet above the diversion of the river away from the unnamed tributary. The lower site was below where Windy Hollow Road crosses the Garcia River. Samples were taken with a standard kick net in a one half square meter area. Samples were preserved in 80% ethyl alcohol and analyzed in the laboratory to the lowest taxonomic level possible, given the limits of current insect identification keys (Merritt and Cummins 1984, Wiggens 1977, Edmunds et al. 1976, Brown 1972, Alan and Edmunds 1963, Usinger 1956). Simpson's Diversity Index was used to give further insight into community structure (Hilsenhoff 1977). The formula for the index is:

$$D = N - 1 \sum_{j}^{i} \frac{n_j(n_j - 1)}{N(N-1)}$$

N = Total number of individuals
n_j = Total number of taxa

The sample from the Garcia River above the spill site had a Simpson's Diversity Index of .8897 while the below spill site had .7665. The sample below the spill site seems to have suffered some loss of diversity as a result of the spill although it was well below the area that was heavily coated. Above the spill site 32 taxa and 1223 individual specimens were present. Below the spill there were 23 taxa and 676 individuals. Tables 1 and 2 show all taxa present at the two sites, their absolute numbers, and frequency of occurrence in the samples.

Table 1. Taxa present at the Garcia River sampling site **above** the spill, including number of organisms and relative abundance. (Orders are in capitals with family and lower taxonomic levels - further indented).

Taxa	Numbers	% Occurrence
EPHEMEROPTERA (Mayflies)		
Oligoneuridae		
Isonychia sp.	177	14.46
Baetidae		
Baetis sp.	137	11.19
Heptageniidae		
I* Rhitroqena sp .	74	6.05
I* Epeorus (Iron) sp.	5	.41
I* Ironodes sp .	1	.08
Heptagenia sp.	4	.33
Cinyqmula sp .	7	.57
Leptophlebiidae		
Paraleptophlebia sp.	1	.08
Ephemerel1idae		
Serratella levis	25	2.04
PLECOPTERA (Stoneflies)		
Pteronarcyidae		
Pteronarcys sp.	21	1.72
Nemouridae		
Malenka sp.	9	.74
Calineuria californica	1	.08
Hesperoperla pacifica	1	.08
Chloroperlidae	10	.82
TRICHOPTERA (Caddisf1ies)		
Ryacophilidae		
Rhyacophila sp.	10	.82
Hydropsychidae		
Hydropsvche sp.	38	3.10
Phi1opotamidae		
Wormaldia sp.	22	1.80
Sericostomatidae		
Gumaqa sp.	41	3.35
Glossomatidae		
I* Glossosoma sp.	1	.08
COLEOPTERA (Beetles)		
Elmidae		
Optioservus sp.	236	19.20
Zaitzevia parvula	133	10.80
Ordobrevia nubifera	22	1.80
Narpus sp.	6	.49
Psephenidae		
Psephenus sp.	1	.08

I* = Indicators species

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Table 1 (Cont.) Taxa present at the Garcia River sampling site above the spill, including number of organisms and relative abundance.

Taxa	Number	% Occurrance
DIPTERA (True Flies)		
Tipulidae		
Hexatoma sp.	15	1.23
Empididae (Hemerodromia?)	2	.16
Chelifera sp.	5	.41
Simuliidae		
Simulium sp.	28	2.29
Chironomidae		
Orthocladiinae	59	4.82
Tanypodiinae	1	.08
Chironominae		
Chironomini	109	8.91
Tanytarsini	22	1.80
Total	1224	

Total Number of Taxa (n) = 32

The ten most abundant taxa of aquatic insects were also plotted from each sample (Figure 1 and Figure 2). Healthy aquatic communities often exhibit "eveness" where many taxa are present in large numbers (Lee 1990, Lauck and Lee 1990). The degree to which all taxa approach the abundance of the most common taxa can be taken as a representation of eveness. The above spill sample also exhibits greater eveness under this criteria when Figures 1 and 2 are contrasted indicating that the lower reach has had some perturbation.

Different species of aquatic invertebrates can be indicators of water pollution or the quality of aquatic habitat (Chandler 1970, Roback 1974, Hillsenhoff 1977). Species present in the above spill sample that are indicators of good habitat quality are noted in Table 1 (I*). Several of these species were present above the spill site but absent below the spill further underscoring impacts from sediment on some community members. For example, Rhitrogena sp., Epeorus (Iron) sp., and Ironodes sp. are indicator species which are present above the spill site but absent at the sampling station below the spill.

Closer scrutiny of taxa present and absent above and below the spill show that insects belonging to the functional group known as "collectors" (Merrit and Cummings 1984) were most severely impacted. These insects have nets which collect food items, straining appendages, or dense setae which were probably clogged by the fine clays that travelled the entire lower length of the Garcia River. Caddisflies (Trichoptera) that use nets for food capture (Hvdropsvche sp. and Wormaldia sp.) were absent from down stream samples.

Figure 1. Relative abundance of ten most frequent taxa (Garcia R. above spill)

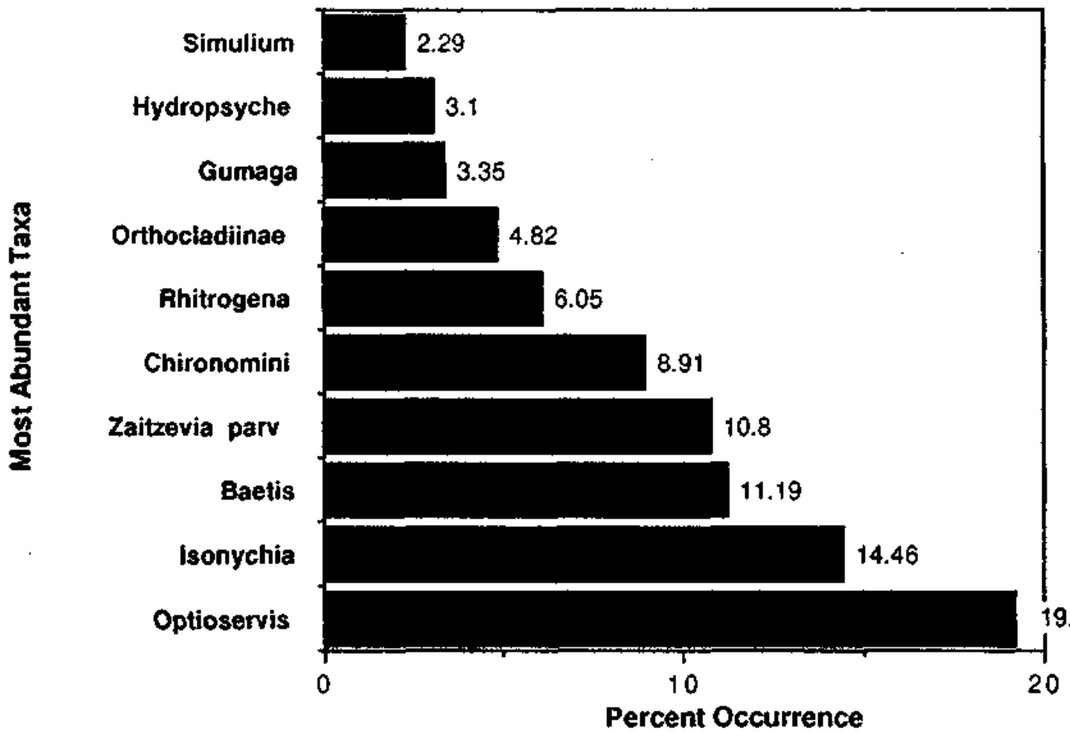

Figure 2. Relative abundance of ten most frequent taxa (Garcia R. below spill)

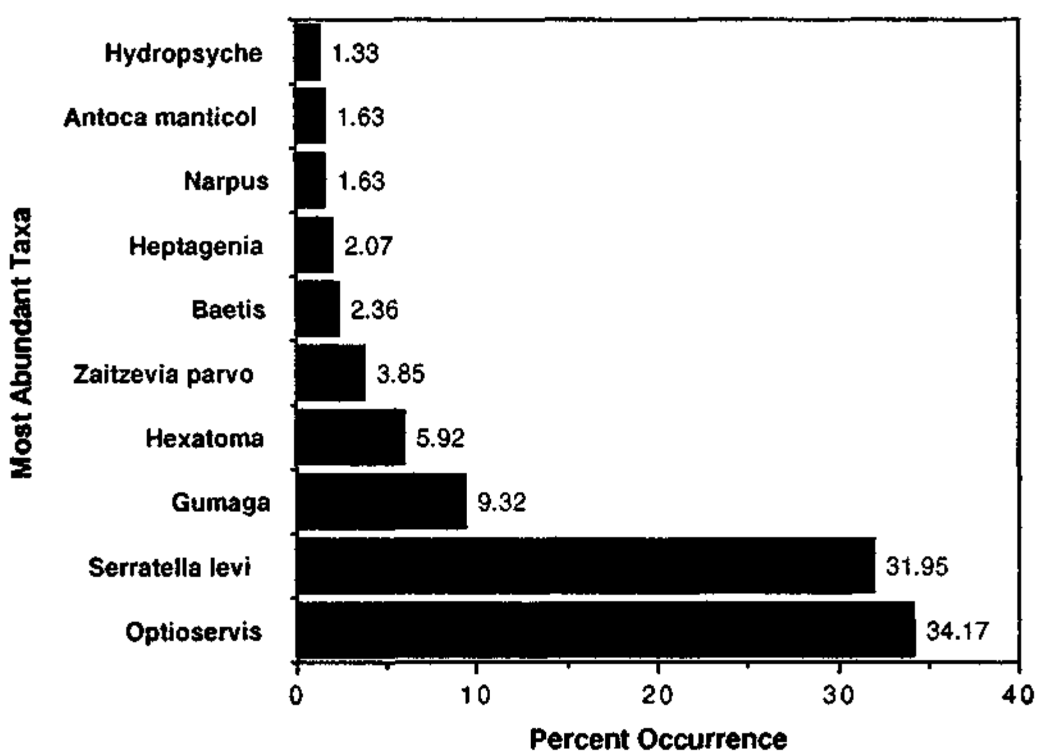

Table 2. Taxa present at the Garcia River sampling site below the spill, including number of organisms and relative abundance. (Orders are in capitals with family and lower taxonomic levels further indented).

Taxa	Number	% Occurrance
EPHEMEROPTERA (Mayflies)		
Ephemerellidae		
Serratella levis	215	31.95
Baetidae		
Baetis sp.	16	2.36
Heptageniidae		
Heptaqenia sp.	14	2.07
Leptophlebiidae		
Paraleptophlebia sp.	1	.15
Tricrythidae		
Tricorythodes sp.	1	.15
PLECOPTERA (Stoneflies)		
Nemouridae		
Malenka sp.	1	.15
Chloroperlidae		
Sweltsa sp.	9	1.33
TRICHOPTERA (Caddisflies)		
Ryacophilidae		
Rhyacophila sp.	1	.15
Hydropsychidae		
Hydropsyche sp.	9	1.33
Sericostomatidae		
Gumaqa sp.	63	9.32
COLEOPTERA (Beetles)		
Elmidae		
Optioservus sp.	231	34.17
Zaitzevia parvula	26	3.85
Ordobrevia nubifera	3	.44
Narpus sp.	11	1.63
Dytiscidae		
Oreodytes sp.	4	.59
DIPTERA (True Flies)		
Tipulidae		
Hexatoma sp.	40	5.92
Antocha monticola	11	1.63
Chironomidae		
Orthocladiinae	3	.44
Tanypodinae	5	.74
Chironominae		
Chironomini	6	.89
Tanytarsini	2	.30
Tanydaridae		
Protanyderus sp.	1	.15
Total Specimens	676	

Total Number of Taxa (n) = 23

CDFG (Macedo 1992) also found impacts due to fine clays downstream as well as direct smothering of aquatic invertebrates in the heavily impacted areas. **The degree to which impacts on the invertebrate community translate into reduced carrying capacity for the river's fishes is impossible to calculate.**

Moat Creek: On Monday (8/24/92), damage on Moat Creek in the area of the spill on the Whitmore Ranch was assessed. Rainbow trout had been sighted in this area (Macedo 1992a) and it is likely that both resident and steelhead juveniles were severely impacted by the spill. There was evidence that drilling muds and cuttings had entered the stream channel at several places. Aquatic invertebrates were sampled in this upper reach using a kicknet. Methods used on the Garcia River were not appropriate for Moat Creek sampling due to low flows. Specimens were collected in a   from riffles and pools to determine what species were present in un-impacted reaches (Table 3). The high incidence of indicator species (I*) in this reach confirms observations that this reach is high quality aquatic habitat (Chandler 1970, Roback 1974, Hillsenhoff 1977).

The lower gradient reach near the Curly Lane bridge visited on the same day showed major impacts from drilling muds and subsequent clean up activities. Crews were actively engaged in flushing the stream channel and dredging drilling muds and cuttings from the stream bed with buckets. Surface flows between pools were lacking in this reach. The macroinvertebrate community was almost completely wiped out and only four specimens were found in sweeps of the drift net through pools. Rough skinned newts and Pacific giant salamander larvae were found in pools that still were coated with a layer of clays that remained after clean up.

The steep gradient reach below the Curly Lane crossing was not sampled but Macedo (personal communication) found ample pool habitat for juvenile steelhead. Unfortunately, these pools had also been filled in with drilling muds. Aquatic invertebrate samples taken in isolated pools one half mile up from Highway 1 on the Hay Ranch showed no living aquatic invertebrates except one beetle larvae (Aqabus sp.). Samples taken in a pool 100 feet upstream of Highway 1, where water flushed downstream was being pumped out, did have some insect fauna (Table 4) and sticklebacks (Gasterosteous aculeatus). The macroinvertebrates were species capable of withstanding low dissolved oxygen and the stickleback were gasping at the surface when collected. The lowest pool sampled in Moat Creek was 15 feet upstream of the Highway 1 bridge and contained similar fauna to the pool 100 feet upstream (Table 5). Later operations caused even these pools and the lagoon of Moat Creek to dry up (Macedo personal communication).

Table 3. Moat Creek invertebrate fauna from **above** spills.

	EPHEMEROPTERA (Mayflies) Baetidae	
	Baetis sp.	4
	Heptageniidae	
I*	Ironodes sp.	8
	Cinygmula sp.	10
	Leptophlebiidae	
	Paraleptophlebia sp.	3
	PLECOPTERA (Stoneflies)	
	Perlidae	
	Calineuria californica	7
I*	Hesperoperla hoguei	11
	Nemouridae	
I*	Soyedina sp.	4
	Chloroperlidae	
	Sweltsa sp.	2
	Peltoperlidae	
	Soliperla sp.	1
	Leuctridae	1
	TRICHOPTERA (Caddisf1ies)	
	Limnephilidae	
	Psychoqlypha sp.	4
	Ryacophilidae	
	Rhyacophila sp.	5
	Odontoceridae	
	Namamyia plutonis	1
	Hydropsychidae	
	Parapsyche sp.	7
	Uenoidae	
	Farula sp.	32
	Lepistomatidae	
	Lepidostoma sp.	2
	Calamoceratidae	
	Heteroplectron californica	12
	COLEOPTERA (Beetles)	
	Elmidae	
	Lara sp.	2
	Heterlimnius sp.	6
	Dytiscidae	
	Agabus sp.	2
	DIPTERA (True Flies)	
	Tipulidae	
	Hexatoma sp.	1
I*	Rhabdomastix sp.	1
	Empididae	
	Chelifera sp.	2
	Simuliidae	
	Simulium sp.	1
	Chironomidae	
	Orthocladiinae	4
	Tanypodiinae	1
I*	Ptychopteridae (Ptychoptera)	2

I* = Indicators species

Table 4. Invertebrates present in Moat Creek (below spill site) 100 feet above Highway 1.

EPHEMEROPTERA (Mayflies)	
Leptophlebiidae	
Paraleptophlebia sp.	73
TRICHOPTERA (Caddisf lies)	
Ondontoceridae	
Nerophilus californicus	18
COLEOPTERA (Beetles)	
Dytiscidae	
Aqabus sp.	1
MEGALOPTERA (Dobsonfly)	
Sialidae (Sialis sp.)	23
ODONATA (Dragonfly)	
Aeshnidae (Aeshna sp.)	1
Isopoda	
Gnorimosphaerona oreqonensis	14
Ascellus sp.	3
Amphipoda	
Anisoqammaris sp .	290
Total Taxa Present = 7 Total specimens =	**423**

It is obvious that Moat Creek was the most severely impacted stream and suffered an almost total loss of its invertebrate community. The distribution and abundance of steelhead trout or coho salmon in Moat Creek is unknown but any of these fish below the spill site would have been killed or flushed from the stream. A grey cloud was noticed by local citizens off the mouth of Moat Creek during the initial period of the spill (Alan Levine personal communication. Bentonite clays contain a high amount of barium which can block metamorphosis of red abalone larvae (Morse 1985). It is possible that drilling muds entering the ocean off the mouth of Moat Creek may have had some negative effects this species.

The Effectiveness of Clean Up Efforts

The clean up operations seemed well organized under the direction of the California Department of Fish and Game. ATT supplied over-sight personnel from the California Department of Parks and Recreation and sufficient man power and equipment to carry out the mandate of CDFG. The strategy of deflecting flows of the main Garcia River away from the mouth of the unnamed tributary allowed more complete removal of bentonite from the stream channel before it moved down stream. It also limited damage from downstream drift of fine sediment resulting from clean up operations.

Table 5. Moat Creek invertebrate community in pool 15 feet upstream of Highway 1 bridge **below** spill site.

EPHEMEROPTERA (Mayflies)	
Leptophlebiidae	
Paraleptophlebia sp.	97
ODONATA (Dragonfly)	
Aeshnidae (Aeshna sp.)	2
HEMIPTERA	
Gerridae	
Gerris sp.	4
Isopoda	
Gnorimosphaerona oreqonensis	3
Ascellus sp.	1
Amphipoda	
Anisoqammaris sp.	31
Total Taxa = 6 **Total Specimens**	**= 137**

Flushing the unnamed tributary and Moat Creek with water to remove drilling muds was probably prudent but did cause more immediate damage. Dredging Moat Creek seemed to be the best course of immediate action because the streams ability to scour deposits of bentonite several feet deep was unknown. Clean up crews, however, may have destabilized stream banks and disrupted armoring of the stream bed in certain areas.

Mitigation, Restoration, and Monitoring

While AT&T may have acted in good faith after the spill to help control damages, on site and off site impacts occurred. The spill on the Garcia River tributary negatively effected one of the last remaining coho salmon populations in the basin. The aquatic invertebrate community was also harmed on the lower main Garcia River, the area of highest productivity for older age juvenile steelhead. The extent of the damage to these steelhead, which have the highest chance of returning as adults, due to decreased carrying capacity of the river cannot be quantified. Moat Creek suffered almost complete extermination of its aquatic community as a result of spills. **Since damages have been incurred that cannot be mitigated on site at this time, AT&T should support longer term restoration and monitoring efforts for the Garcia River and Moat Creek.**

Funding requests that follow will be split into two separate sections: the Garcia River watershed and Moat Creek. The Garcia River has been the subject of on-going studies and restoration efforts (Monschke in press). Conversely, small coastal streams such as Moat Creek are poorly studied. To gauge the recovery of Moat Creek, a second stream with similar watershed area and land use history will be needed for comparison in a monitoring program.

Garcia River Watershed

The actions for mitigation, restoration and monitoring in the Garcia River Basin draw in part on the draft Garcia River Watershed Enhancement Plan (Monschke in press). The suggestions here are not to be considered in lieu of funding requests being formulated by Jack Monschke and submitted separately to AT&T. Actions called for below reflect the author's background in salmon and steelhead restoration and a broad familiarity with the scientific literature. Experts in various disciplines were also consulted as to what actions were most appropriate to restore the river and to monitor its health. Cost estimates are listed in the budget at the end of the document.

Sediment Studies: The Garcia River watershed is comprised of very unstable soil types and has a history of intensive land use. High sediment yield from disturbed watersheds in northwestern California and southwest Oregon has been linked to declines or losses of fisheries resources (Nawa et al. 1991, Higgins et al. 1992). While logging practices and road building standards have improved substantially over the last 20 years, old roads and landings may still pose a very high erosion risk. Erosion potential in future storm events must be minimized if Garcia River salmon and steelhead are to be restored. A full inventory of sediment sources is also necessary to judge whether it is prudent to use structural treatments in the stream channels. Such structures could be buried or rendered ineffective if large amounts of sediment are transported in future flood events.

Dr. William Weaver and Danny Hagans of Pacific Watershed Associates (Attachment #1) advised the author on how erosion risk might be assessed in the Garcia watershed and what actions might be taken to reduce that risk. Pacific Watershed Associates has extensive experience in erosion and sediment source inventories throughout northern California for Indian Tribes, the U.S. Forest Service, private timber companies, and fisheries restoration programs. The methods of how such an assessment would be performed can be found in Attachment #2 ("Watershed Assessments for Erosion Control, Erosion Prevention and Rehabilitation, With the Goal of Fisheries Protection and Restoration.") The assessment would include a prioritized list of high erosion potential sites that could be treated cost effectively. Implementing erosion control and prevention will have several benefits: fish populations should rebound, loss of valuable forest soils will be averted, and prevention of road failures will maintain access for the watershed's land owners.

Assessing gravel supply and bed load transport in the Garcia River is essential to understanding the productivity of fisheries resources. If the ultimate goal of restoration in the Garcia is re-introduction of coho and Chinook salmon, then clean, stable spawning gravels must be available in the main river channel. The Garcia Watershed Enhancement Plan had a qualitative finding that there was an excess of fine sediment in gravel found in the lower river and in tributaries. Pacific Watersheds Associates has outlined a procedure (Attachment 2A) to discern the amount of sediment transported in various reaches of the river, the stability of gravels in spawning areas, and any change in the size of bedload materials between reaches or over time. This information will give a clear assessment of the quality of fisheries habitat in the main channel of the Garcia River. The location of study reaches will be partially determined by where concentrations of spawning fish are found, similar to studies conducted by Nawa et al. (1991).

Fisheries: The Garcia Watershed Enhancement Plan included habitat typing of the lower main stem of the Garcia River, the North Fork, and Pardelo Creek. This scientific method of fisheries habitat inventory was devised by Bisson et al. (1982) but has been refined by McCain et al. (1991) and tailored for use in California by Flossi and Reynolds (1991). Habitat typing and attendant fish population estimation for the remaining stream segments that harbor anadromous salmonids would give insight into what may be "limiting factors" in their spawning and rearing phases. This complete baseline of information would also provide an excellent reference to determine if fish habitat was improving over time. The cost estimate in the budget is based on an additional 70 miles of stream habitat.

Very little information is available about adult salmonid run trends on the Garcia River. Scientific studies show that restoration potential for salmonids is highest if native gene resources are still available (Helle 1981) so greater effort to determine current coho population status is an essential first step toward restoring them. Getting accurate counts of adult steelhead and noting any net scarring on carcasses could give the community concrete evidence as to whether steelhead from the Garcia River are experiencing problems on the high seas due to the longline driftnet fishery. Long term spawning trends would be another barometer for success of restoration efforts.

The spawner counts would be organized and volunteers would be trained by a professional fisheries biologist. Participation in activities such as this helps the community identify with the river's restoration and also keeps costs of collecting this essential data from becoming prohibitive. The counts would be directed and a written report submitted annually for five years. Fish population information could become part of the baseline data for the California Department of Fish and Game and be used to devise an optimal management strategy so that the river could approach a maximum sustainable yield. Annual spawner surveys would also help determine when there was a harvestable surplus of coho salmon and later Chinook salmon when their populations are restored.

Surveys will reveal where the highest concentrations of spawning occur (areas sometimes referred to as biological "hot spots.") A great deal of information can subsequently be gathered on a site specific basis. The sediment study (Attachment 2A) can determine whether scour and fill of the streambed is great enough to disturb fish nests or redds. Direct dive observation in the spring proximate to the nests can also help determine the rate of emergence and survival of young salmon and steelhead. Biological consulting to organize spawner counts and to determine "hot spots" and conduct follow up assessments are all included as one line item in the budget.

Aquatic Invertebrate Monitoring: While salmon and steelhead are definitely indicators of water quality, their complex life history often masks the relationship between habitat decline and fish population trends. Stream insects, conversely, have a narrow habitat range and short life cycle. The insects are also the dominant stream organisms in Pacific Coast streams both in diversity and abundance. Dr. David Lauck of Humboldt State University and his associate John Lee (vitae as Attachment 3) have designed the study below which will use aquatic insect biodiversity to assess stream habitats in the Garcia River Basin.

Habitat disturbances can be assessed using community structure or indicator species (Chandler 1970, Roback 1974, Hilsenhoff 1977). Since most of the Garcia River tributaries flow from areas with similar geology, stream flows and insect fauna may be very similar. If differences exist between basins, it may be indicative of changes in the stream related to land use impacts. Twenty-one sampling stations would be chosen throughout the Garcia River Basin. Samples would be taken from five areas on the main river (including stations previously sampled above and below the spill site) but also from the upper and lower reaches of eight significant tributaries within the basin.

Samples would be collected using a standard "kick net" method in riffles areas. Sampling would take place in fall, winter and spring to account for natural seasonal variations in abundance.

Insects would be preserved in 80% ethanol and identified in the laboratory to the lowest taxonomic level practical (Allen and Edmunds 1963, Brown 1972, Edmunds et al. 1976, Merritt and Cummins 1984, Usinger 1956, Wiggens 1977). The report on aquatic invertebrates would include diversity and biotic indices, functional feeding group analysis, measures of relative abundance, and a clear explanation of the significance of the findings relative to water quality or stream characteristics.

Direct Water Quality Monitoring: Friends of the Garcia River has already begun efforts to monitor stream temperatures, flows and rainfall at two sites along the lower Garcia River. The device used to record this information is the Campbell Four Channel Data Logger which needs professional installation and seasonal recalibration for measurement of summer low flows and winter peak flows. Current sites where the recorders are being installed are at the Highway 1 bridge and at the Connor Hole where a USGS stream gauge was operated from 1963-1983. Ten additional Campbell Data Loggers will allow monitoring at each reach of the main river where fisheries and sediment budget investigations will take place and in seven major tributaries. Long term flow and temperature data will give a clear picture of which sub-basins are in recovery.

Gravel Extraction Study: Pool depths in the lower Garcia River are much shallower than in previous times (Monschke in press) indicating that there is a surplus of material that has eroded from upland areas and been transported downstream. These coarse gravels can be mined for use in road building and other construction but negative side effects on the stream and its riparian condition often occur. Riparian conditions in the lower Garcia River are in their most advanced stage of recovery since at least 1937 and probably since before the turn of the century. One year old and two year old steelhead juveniles are in high abundance in the deepest pools in the lower river, yet average maximum depth is only five feet. It is quite possible that there might be some method by which gravel could be extracted in such a way as to increase channel depth and accelerate the river's restoration.

The lower Garcia River needs a long term (5 year) study on whether any method of gravel extraction could be devised that would allow continued improvement of fisheries habitat. This question could be explored by the Humboldt State University Institute for River Ecosystems. The mission of the Institute is to further understanding, preservation, and management of river ecosystems. Dr. Bill Trush (vitae as Attachment 4), Director of the Institute, currently has a grant proposal under consideration by the California Division of Mines and Geology to study similar questions on the Mad, Eel, and Smith Rivers. The Institute would use graduate students under Dr. Trush and

Dr. Terry Roelofs to scientifically monitor various means of extracting gravel on the Garcia River and determine whether any of those methods increased the quality of fisheries habitat.

Estuarine Study: Estuaries can play an important role as rearing habitat for chinook salmon and steelhead juveniles (Reimers and Downeyl982, Smith 1988). Changes in the shape of the Garcia River estuary over time were noted by Monschke (in press) but more information is needed to guide restoration efforts. Additional information would be gathered both by fisheries biologists and geologists. The Garcia River estuary should be studied to determine what habitat types (Cowardin et al. 1979) are currently found and their use by different species of fish. Geologists could discern if the trend in widening of the estuary is the result of an increase in sediment load or the result of seismic activity along the nearby San Andreas Fault. Substrate conditions could be analyzed to determine if the "bay" subsystem within the estuary can be stabilized with eel grass as suggested in the Garcia Plan. Re-examination of historical maps and aerial photos by trained geologists might yield a better understanding of what the estuary was like before disturbance and provide clearer goals for restoration.

Riparian Restoration: The restoration of coho salmon runs and the re-introduction of chinook salmon to the Garcia River will require lower stream temperatures. Re-establishment of riparian vegetation in all Garcia River sub-basins would help achieve this goal. Stable stream banks will also create a more confined stream course helping scour deeper pools which will also increase the carrying capacity for steelhead. Efforts on the North Fork Garcia and for Pardelo Creek are outlined in the Garcia Plan (Monschke in press) but action should be initiated as soon as possible to replant riparian areas on all tributaries. The request below is meant to allow a quick start for riparian restoration efforts beyond those currently in the planning stage.

Volunteers from the community could help neighboring land owners in stream side reforestation. Of the funds requested, $10,000 could be used for identification of sites needing replanting and coordination with land owners and volunteers. The remainder of the budget could be used for tree stock. Dollars allocated for tree stock could also be used as a match for California Department of Forestry funds available for forest improvement (CFIP). Labor to plant trees might also come from the California Conservation Corp.

Education: Restoration of rivers and watersheds is necessary because of a lack of stewardship. By teaching young people about fisheries resources and restoration, they will be better stewards in the future. Directly involving students in restoration efforts can provide additional labor but, more importantly, it can give students a "hands on" learning experience outside the classroom. Studying water quality or restoration can involve students in relevant learning activities and make them aware of career options in the biological and physical sciences. Activities related to the Garcia River to guide teachers and students would be put into lesson format by a professional curriculum developer with funds allocated.

Students at Point Arena could assist in water quality monitoring as part of their curriculum in general science or chemistry classes. With use of two Hach DR 2000 spectrophotometers, students could determine dissolved oxygen, pH, chlorine, nitrate, heavy metals, turbidity, and dozens of other parameters in local water bodies and water supplies. This information would not only benefit the restoration program to help protect the water quality of the Garcia but could help safe guard drinking water from wells and other surface waters. The school could enter information into the EPA data base, and may be able to acquire more funds for equipment through EPA grant sources. Students might also learn about the Campbell Data Loggers installed on the river and help with their operation.

If research is conducted on the fisheries, sediment processes, and aquatic invertebrates of the Garcia River, students could be acquainted with these studies by having the principal researchers come into physical and biological science classes at Point Arena High School. Money is allocated in this budget to cover costs of field trips so that students could also participate with experts in the field. In order to study aquatic invertebrates in the classroom, six binocular dissecting scopes are included in the budget. Some students may take special interest in these subjects and pursue careers in these fields. If the Humboldt State University Institute for River Ecosystems initiates studies on the Garcia River, they would welcome high school student "interns" to help their graduate students. Developing local talent to serve as resource professionals will help the community in the future.

Moat Creek: Small Coastal Stream Monitoring

Moat Creek suffered almost complete loss of its aquatic community for over two miles of its length as a result of the drilling mud spills in the drainage. The stream channel itself may have suffered damage as a result of clean up activities. Long term monitoring to assess the recovery of this stream is in order. Because there is no baseline information on channel conditions, fisheries, or the macroinvertebrates of the stream prior to the spill, a similar small coastal stream should be used for comparison and evaluation of recovery. Research on small coastal streams in this region is almost completely lacking. These streams may harbor gene resources for species such as coho salmon (Sommarstrom l984) that may prove invaluable in restoration efforts.

Sediment Studies: The stream channel of Moat Creek may have been damaged by clean up activities. Dredging of drilling muds and washing with hoses may have impacted the armor layer of the stream. Freeze cores and scour chains will be used to determine recovery from these impacts and lingering problems from drilling muds over a three year period. Several sites will be selected both on Moat Creek and the small coastal stream used for comparison. Limited numbers of cross sections will be used to determine bedload movement in conjunction with flow data collected from Campbell Data Loggers.

Fisheries Investigations: Downstream migrant traps would be set up on both Moat Creek and the control stream during spring to determine the number and species of salmon and steelhead juveniles produced. This activity would take place for three years and would provide insight into the use of these streams by anadromous fish and how it relates to stream flow conditions. Electrofishing would bve used to check index reaches of each stream to monitor use by different species as well as to check for abundance and diversity of amphibians. Fish and amphibians will also provide another indication of how well Moat Creek is recovering from spill impacts.

Aquatic Invertebrate Studies: As indicated above, insects are one of the best indicators of stream health. Study design, analysis, and reports would follow those described above for the Garcia River. Three reaches would be selected on both Moat Creek and the control stream and sampled in fall, winter and spring. These small coastal streams would also be sampled after two years, allowing assessment of whether Moat Creek has fully recovered. (Cost estimates presented at the 9/2/92 meeting in Point Arena did not account for follow up sampling needed.)

Direct Water Quality Monitoring: One Campbell Four Channel Data Logger would be installed in each of the small coastal streams under study. The purpose, installation, and maintenance needs for these devices would be similar to those for the Garcia River. Additional money is allocated here because data collection at the small coastal streams may not have the same level of volunteer involvement that Garcia River stations do. Flow data for small coastal streams is almost totally lacking and yet it is a key factor in the productivity of these systems. Use of these streams by anadromous fish is totally dependent on timing and magnitude of flows.

Education: Small streams make ideal "living laboratories" for elementary school students. Younger students could become acquainted with stream insects on a more general level than would be explored by high school students. Six binocular dissecting scopes are included in the budget to help in classroom studies of insects. Basic water quality monitoring could also be introduced to sixth through eight grade students using a Hach DR-700 which is in the budget. Money for field trips, lesson development, and in class assistance is also provided for in the budget.

Budget

Action	Cost
<u>**Garcia River Restoration**</u>	
Sediment Studies	
Erosion Prevention Assessment	$160,000
Sediment Transport / Gravel Quality	$190,000
Fisheries	
Habitat Typing	$140,000*
Spawner Counts / "Hot Spot" Search	$50,000
Aquatic Invertebrate Studies	$30,000
Direct Water Quality Monitoring	$30,000
Gravel Extraction Study	$200,000
Riparian Restoration	$50,000
Education	$30,000
Estuarine Studies	$100,000
<u>**Moat Creek: Small Coastal Stream Monitoring**</u>	
Sediment Studies	$60,000
Fisheries	$75,000
Aquatic Invertebrate Studies	$25,000**
Direct Water Quality Monitoring	$10,000
Education	$15,000
Total Funding Request	**$1,165,000**

* Current bids on habitat typing contracts have range from $1750-$2300 per mile. The $2000 per mile used is an intermediate value.

** Cost estimates submitted on 9/2/92 did not include follow up assessment two years after initial sample.

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