THE EFFECTS OF HIGHWAYS ON TROUT AND SALMON RIVERS AND STREAMS IN THE WESTERN U.S.

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Abstract

The population declines of numerous anadromous and resident salmonids in the latter half of the 20th century is evidence of the degradation of western U.S. riverine systems. Past highway practices often provided little or no mitigation for the adverse impacts of highway construction. Streams respond to channel alterations by changing local slopes and velocities, rearranging bed materials, transporting more or less sediment and by changing channel pattern or configuration. The changes in channels brought on by highway location, and accompanying channel adjustments, typically result in simplified habitat for fish. Highways can separate stream channels from their floodplains, making floodplains dysfunctional and affecting instream habitat. Losses of riparian habitat due to highway location affect the future recruitment of large wood in forested areas and stream temperature. Improperly designed stream crossings can create fish passage barriers resulting in loss of habitat and habitat fragmentation. Highway construction, maintenance and use can degrade adjacent aquatic ecosystems with sediment and chemical and toxic pollution. Recommendations to restore the form and function of altered streams are provided.

Introduction

Rivers have been used by humans as travel and transportation routes for thousands of years. In North America, the indigenous peoples settled along river corridors. Trading routes through mountains followed the lower gradient river bottoms to high mountain passes. One of President Thomas Jefferson=s instructions for Lewis and Clark=s 1804-1806 expedition across North America was to A*explore the Missouri River, & such principal stream of it, as, by it=s course & communication with the waters of the Pacific Ocean, may offer the most direct & practicable water communication across this continent for the purposes of commerce*@ (Gilbert 1973). Lewis and Clark traveled west across the northern plains along the Missouri and Yellowstone Rivers. After crossing the continental divide they descended the Locksa and Clearwater Rivers in Idaho then followed the Columbia River to the Pacific Ocean. As settlers moved west, they too followed the rivers across the plains and mountains. Wagon trails eventually became roads; roads have become highways. Today, interstate highways often follow travel routes originally established by indigenous Americans. Within the northwestern states of Oregon, Washington, Idaho and Montana alone there is over 17,000 miles of primary state and US highways (Figure 1).

The population declines of numerous anadromous and resident salmonids in the latter half of the 20th century is evidence of the degradation of western U.S. riverine systems. In the past several years, numerous populations of salmon and steelhead trout (*Oncorhynchus mykiss*) have been listed under the Endangered Species Act (ESA) . Bull trout (*Salvelinus confluentus*) have been listed or proposed for listing throughout their range in the Pacific Northwest and listing actions have been proposed for rainbow trout (*Oncorhynchus mykiss*) and cutthroat trout (*O. clarki*) populations. Native coldwater fisheries issues are classic cumulative effects problems. Salmonid habitats have been degraded by many different human activities in addition to highways: timber harvest, mining, agriculture, livestock grazing, railroad construction, dam construction, recreational developments, pollution, and urban and rural development. There are many factors that require correction if native, coldwater fisheries are to be restored. In the U.S. Pacific Northwest, the factors affecting native salmonid fisheries have been summarized into what have become commonly known as the 4 AH=s@: harvest, hatcheries, hydropower, and habitat. Within the context of this conference we propose to add a 5th AH@: highways.

Highways are just one of many factors that have degraded North American coldwater fisheries habitat. And obviously, not all highways have caused adverse impacts to riverine habitat, but typically when highways have been built near streams, adverse impacts have occurred. These impacts are more likely to occur on small and medium streams and rivers which are easier to control with engineered methods. As a result, today there are many stream reaches, and sometimes nearly entire streams, which no longer function hydrologically like a natural stream. These streams may still provide habitat for salmonids, but at levels which support smaller, less robust populations. Much of the damage happened decades ago. Past practices often provided little or no mitigation for the adverse impacts of highway construction. However, adverse impacts continue to occur, as the authors will explore in the paper. To restore native coldwater fisheries, there needs to be mitigation for, or restoration of, these impacted stream reaches.

Highway effects on stream channels

Roads have been constructed in valley bottoms in mountainous regions in order to take advantage of the flatter valley topography and gentler valley gradient. Where valley bottoms become constricted, roads and streams are in competition for the limited available space (Figure 2). In order to reduce the amount and severity of curves in the road and to reduce the amount of cuts and fills it was standard practice to occupy, realign or encroach on stream channels and to cross and recross the channel. Relocated channels are generally shorter than the original stream resulting in a loss of channel sinuosity and an increase in local stream gradient. Extensive riprap revetments are built to protect the road right-of-way from erosion during high streamflow events. As a result of these highway construction practices many stream reaches have become straighter and more constricted, have greater velocities, and channel roughness has been reduced from natural conditions.

Road and railroad construction have had a significant impact on streams in the west. Road and railroad construction accounted for 66 percent of the channel alterations in 45 Idaho streams and for 51 percent (129 miles) of 13 Montana streams. Substantial reductions in salmonid populations have been reported in severely altered stream channels. For example, in the Idaho and Montana studies, the undisturbed reaches contained 7-8 times the weight of game fish as did the channeled reaches. (Irizarry 1969 and Whitney and Bailey 1959 *cited in* Wydoski and Helm 1980, Knudsen and Dilley 1987).

The impacts to stream channels can be extensive. Highway 22 in Oregon runs parallel to the North Santiam River for 22 miles upstream from Idanha, Oregon. The location for this highway was planned in the mid 1930=s. We estimated that the length of stream impacted by encroachment of the highway or by channel relocation is nearly 4.75 miles, or almost 22% of the stream length. The impacts are even greater in the upper 10 miles (RM 85-95), where the river is constrained by adjacent hillslopes; 32% of the existing channel is impacted by the highway (Figures 3 and 4).

Complex interrelationships exist between valley and channel slope, sediment supply, channel roughness, channel patterns and channel dimensions. This paper will attempt to summarize some of the processes which result when stream channels are altered, for a more in-depth discussion the reader should refer to Gordon et al. (1992) and Heede (1986, 1980). Stream channels are considered to be at equilibrium when there is a balance between sediment discharge and particle size and streamflow and slope. For example, if slope increases and streamflow remains the same, either the sediment load or the particle size must also increase. Streams are dynamic and naturally adjust to changed conditions in an attempt to regain equilibrium: natural or man-made changes imposed on a fluvial system will cause upstream and downstream channels adjustments in an attempt to compensate for the change. Channel adjustments take place in response to imposed increases in energy conditions (Simon 1994) which can be altered by changing factors such as channel width, gradient, and roughness. Streams adjust to these changes by changing local slopes and velocities, rearranging bed materials, transporting more or less sediment and changing channel pattern or configuration (Gordon et al. 1992, Heede 1986).

Under natural conditions, channel adjustments may occur at such low rates that they may seem imperceptible. But when natural stream conditions are altered by highways, rapid channel adjustments begin to occur and long time periods may be required before the stream attains a new equilibrium. When road fills and armoring confine the main channel and fill secondary channels, the stream will attempt to adjust by eroding its banks or degrading the main channel. Usually the channel bottom will scour and downcut to bedrock, and spawning gravels and cobble will be transported downstream, often filling in pools. If the channel is constrained by bedrock and is unable to widen or downcut, the stream will expend the additional energy in a downstream reach were it is able to entrain additional sediment. As a process, aggradation does not affect all stream reaches but decreases at a certain distance downstream of the local base level change. In contrast, degradation may continue to advance into the headwaters (Heede 1986). Today, impacted stream channels reflect the channel adjustments made, or still in process, in response to past highway construction practices.

Streams which have been modified by channelization, highway encroachment, and realignment generally have been made shorter, narrower and steeper and have higher flow velocities. The tendency to meander, even in straighter channels, is a response by the stream to dissipate energy by reducing stream slope. Channel slope is directly and positively related to flow velocity and stream power. When highways cut-off or truncate stream meanders and bends, streams become shorter and less sinuous, channel slope is increased, and flow velocities increase. Higher reach velocities also occur when constrained channels are constrained even further by highway encroachment. These straighter, more confined channels typically provide less productive fish habitat due to the high energy demands on the fish. Changed hydraulic conditions may also selectively alter or reduce fish fauna in favor of fish more efficient at living in high energy systems.

Changes in stream roughness characteristics can also affect stream velocity. Roughness refers to channel elements which act to retard flow and induce turbulence and therefor slow velocity. Factors affecting roughness include streamside vegetation, channel irregularity and alignment, bed and bank roughness, flow obstructions (i.e., large boulders and fallen and lodged trees), and meandering of the channel. Reductions in roughness elements as a result of placing roads near streams include: replacement of natural streambanks and riparian vegetation with riprapped banks, lose of large wood from within the stream channel and the lose of future large wood inputs when roads and reveted banks replace riparian vegetation, replacement of sinuous, irregular channels with straighter, relatively consistent channels and the loss of floodplain connectivity.

Spawning habitat for salmonids in stream reaches which have been subjected to higher velocities will likely be reduced or eliminated. Higher velocity increases the ability of the stream to transport larger sediment particles; spawning gravels are washed downstream leaving riffles with a cobble/boulder substrate. Depending on how extensive the channel modifications are, these gravels may move considerable distances downstream before they are deposited in lower gradient reaches. In addition, new gravels carried to the main channel by tributary streams maybe transported to downstream reaches where they are unavailable to fish.

Complex stream channels provide a diverse array of habitats for trout and salmon, including deep pools; cover provided by boulders, large wood, an undercut banks, riffle areas for food production; and areas of gravel for spawning. The diversity and abundance of fish within habitat units is directly related to their complexity. The changes in channels brought on by highway location, and accompanying channel adjustments, typically result in simplified habitat for fish. Channelized reaches are often long, uniform riffles with armored banks. There are limited pools, backwaters and low velocity refugia during high flows, and little, if any, large wood due to the high transport capacity of the channel. While efficient at transporting water and sediment the reaches offer little habitat for salmon or trout, particularly during bankfull and greater discharges. Unconstrained stream reaches have numerous side channel and backwater habitats which provide a greater diversity of fish habitats and provide lateral refugia during high flow events. Research in Oregon has shown that unconstrained reaches generally have greater numbers and diversity of fish than constrained reaches (Moore and Gregory 1989; Reeves 1988). Highway encroachment along unconstrained reaches may effectively turn these into constrained channels with a resultant loss in fish productivity (Figure 3).

The increased capacity to transport sediment may also cause downstream bank erosion resulting in channel widening, a loss of riparian vegetation and increase of sediment into the stream. Often, in an attempt to control downstream bank erosion to protect the road right-of-way or other property, the eroding banks are armored with riprap. This new armoring in turn can alter channel hydraulics and result in additional bed and downstream bank erosion; a process which maybe repeated over again.

The impacts of highway location on streams and fish habitat can extend beyond the stream of immediate impact. As a channel degrades upstream it will encounter tributary streams. The main channel, owing to its greater capacity to transport sediment, will incise faster than the tributary forming waterfalls at the location of the junction. The tributary adjustment will advance upstream in an attempt to adjust its base level to that of the main channel. This adjustment process may continue upstream until even the smallest headwater channels have adjusted also (Heede, 1986). Waterfalls at tributary junctions may be potential barriers to fish migration.

If base level changes take place there may also be consequences for the adjacent riparian vegetation. When channel incision occurs, the local water table will also lower and riparian vegetation may be left stranded, no longer able to reach water, and be replaced by upland species. If the base level rises, the adjacent riparian vegetation could be buried by excessive sediment brought from the upstream channel reaches.

Highway effects on floodplains

Stream channels can be separated from all or portions of their floodplain if the highway occupies or bars access to the floodplain (Figure 5). During flood events, flows in unconstrained channels will inundate the floodplains where much of the flows energy is dissipated by the riparian vegetation. Floodplains provide temporary storage areas for floodwater, reducing the amount of water which must be conveyed in the channel during the event. Without access to floodplains, floodwaters must be contained within the stream channel or within a constricted floodplain, generating higher in-channel velocities and intensifying stream power. In keeping with the equilibrium equation the stream will respond by increasing its sediment load by eroding its bed and banks. Fish habitat can be impacted by increased sedimentation; loss of riparian vegetation; higher velocities in incised channel reaches; loss of low velocity refugia such as side channel and backwater habitats; and channel widening and pool filling in downstream deposition areas.

Highway effects on riparian vegetation

Riparian vegetation is a critical component to the proper functioning of aquatic ecosystems. Critical functions of riparian vegetation which can be impacted by highways include shade, cycling of nutrients, contribution of large wood, and refugia for fish during floods. Streamside shading is one of the most important elements in temperate climates for maintaining cold water temperature for salmon and trout. Streamside vegetation takes up nutrients from the stream and banks and returns it in the form of litter fall which provides food and habitat for aquatic insects. Terrestrial insects dropping from the overhanging vegetation are an important source of food for salmonids. Riparian vegetation and habitat permanently lost when highways occupy or encroach on stream channels. These loses maybe extensive both longitudinally along the channel and horizontally away from the channel depending on the valley constraint and highway location. The roadway may occupy the historic riparian zone and road fills protected with boulder revetments may extend into the channel. Removal of riparian vegetation can allow sun light to reach the stream channel causing heat transfer to the water; sometimes the revetments can act as a reflector and direct sun light at the channel. Temperature can rise rapidly in short distances under direct sunlight: a 6E C increase was observed in 1,000 m within a stream flowing about 1.4 m^3/s in central Idaho (Bjornn and Reiser 1991). Elevated water temperature can contribute to increases in primary productivity, most noticeable is increased algal growth. As water temperature increases above 15 EC steelhead are increasingly subjected to thermal stress and susceptibility to diseases. In addition, warmer water may allow other fish species to compete with native salmon and trout for habitat. Reeves et al. (1987) found that juvenile steelhead production decreased 54 percent when temperature increased to 19-22 EC and shiners were present. Changes in water temperatures can affect fish migration, spawn timing, and egg incubation. Bull trout, because of their preference for very cold waters, are especially vulnerable to increases in water temperatures (Figure 5).

Most large wood enters channels from adjacent riparian areas through windfall, landslides and when trees on streambanks are undercut during high flows. The importance of large wood for protecting and stabilizing streambanks, trapping and storing sediment and inorganic matter, and providing cover for fish habitat in forested streams is well documented (Bisson et al. 1987). Riparian source areas maybe permanently lost when highways occupy near stream areas, or when roads disconnect the stream from adjacent hillslopes. Large wood is susceptible to decay, abrasion by bedload, and to transport downstream so local and upstream sources of new wood are necessary to maintain adequate amounts of wood in the channel.

Highway effects on fish passage

During the past two or three decades there has been an increased awareness of the problems that poorly designed stream crossings can have on fish migrations. This awareness has focused primarily on anadromous species, however, even anadromous species have been and continue to be impacted. A recent survey of county and state managed roads in Oregon found approximately 4,000 culverts which partially or completely block fish passage (Al Mirati, personal communication). The Oregon Department of Transportation has replaced or modified 54 fish passage problems and has restored or enhanced access to over 139 miles of habitat (ODOT 1999a).

Stream crossing passage barriers affect spawning and rearing of both anadromous and resident salmonids. Complete barriers prevent access to all life history stages while partial barriers may prevent passage at particular flows, to particular sizes of fish (juveniles vs. adults, small adults vs. larger adults, etc), or to some species. Improperly designed culverts can stop adult spawning migrations because outfall barriers, excessive water velocity, lack of jump or resting pools, insufficient flow, or a combination of these factors. When adults are unable to access upstream spawning areas there maybe increased egg mortality due to competition for available downstream spawning habitat, increased adult mortality by predators as adults congregate below a barrier, and increased density dependent mortality among juveniles forced to use limited rearing habitat. Because dispersal of juvenile fish occurs both upstream and downstream, substantial rearing habitat can be lost because of impassable culverts on smaller streams. The effect of a passage barrier on anadromous fish is typically a decrease in production due to lost spawning and rearing habitat. In resident fish populations a similar loss in production may follow, particularly with fluvial and adfluvial populations. With habitat loss, these populations may decline in size, or be restricted to marginal habitats and become more vulnerable to stochastic events.

Highway barriers can also affect dynamics of resident salmonid populations by isolating that portion of the population above the barrier from fish of the same species below the barrier. A population is defined as a group of animals that has a high probability of mating among its members relative to mating with members of other populations of the same species. For example, a population would be a group of fish which spawns and rearing in a specific tributary and has little interaction with fish of the same species in another tributary. A metapopulation is a collection of populations, usually associated with large watersheds, lakes, or river basins, that interact through the exchange of individuals. Poorly designed highway stream crossings that block streams can increase the likelihood that metapopulations may become fragmented into isolated populations, or that local populations maybe divided into smaller, isolated populations. Isolated populations have a greater risk of extinction due to stochastic processes and through loss of genetic diversity.

Stochastic processes are those that events which happen by chance, such as drought or flood. Small or isolated populations face higher risks from stochastic events than do large, connected populations. Rieman and McIntyre (1993) found that extinction risks for local, isolated bull trout populations increased sharply as population sizes drop below about 1,000-2,000 individuals.

A loss in genetic diversity may lead to extinction if genes crucial to survival are lost, however isolated populations will likely face a greater risk from stochastic events than from genetic loss or inbreeding. However, important life history traits can be lost to outmigration of individuals who cannot return back upstream. For example, a cutthroat trout population in a given tributary may consist of both resident and fluvial individuals. With the creation of a barrier, those individuals exhibiting fluvial behavior will move downstream past the barrier and will not be able to return. The remaining population will consist of only resident individuals and maybe more susceptible environmental change.

Highway effects on sediment

Highway construction and maintenance activities are potential sources of sediment to streams. Potential sources of sediment during construction include surface erosion from fill slopes and exposed soils in work areas, storage areas and temporary access roads; mass wasting of fill slopes; blasting; and construction sites near streams for bridges, culverts, and bank revetments. Dust emissions from equipment traffic over temporary access roads at construction site may have substantial shot-term impacts to water quality. Highway construction contractors are required to apply erosion control measures during construction, however the risk of sediment reaching streams is high because construction activities can last for several years and often require construction of stream crossings.

Failures of older highways can impact nearby streams. Causes for these failures include saturation of fill material, road locations on unstable soils, erosion of the road right-of-way by flooding, debris plugged stream crossings, and indirectly when upslope debris torrents come in contact with, and destroy, stream crossings. These failures are frequently corrected quickly to ensure public safety, to maintain public access and to reduce additional resource damage from occurring. However, this often means construction activities must take place on wet soils when soil erosion risks are high. These failures can be particularly impacting to fall-spawning salmon and trout, some of which are listed under the ESA, because the failures generally happen in mid-winter after the fish have spawned and the eggs are still in the gravel. Emergency repairs are often exempt from the usual environmental requirements, even if the construction takes place months or years after the event.

A significant, chronic source of sediment to streams is winter sanding to provide vehicle traction on snow and ice covered roads. Sand and cinders are often the most cost-effective tool for providing vehicle safety but can cause significant impacts to streams adjacent to highways. In its fiscal year 1997, the Oregon Department of Transportation applied 297,194 cubic meters of sanding materials to highways in Oregon (ODOT 1999b). Sanding materials can enter streams indirectly when the snowmelt water transports it off the road surface into drainage systems discharging into streams, and directly when snowplows push or blow sand packed snow to nearby streambanks or streams. Sanding materials can often be found in deep layers on streambanks, filling pools, and coating riffle and shoreline areas.

The impacts of sediment from land management activities on salmonid habitat and biology has been intensively studied for many years (Hicks et al. 1991; Everest et al. 1987). Fine sediment deposited in spawning gravels can reduce interstitial water flow, leading to reduced intergravel dissolved oxygen concentrations, and can physically trap emerging fry in the gravel. Fine sediment can reduce both winter and summer habitat carrying capacity. Small salmonids (<15-20 cm) have been observed moving into interstitial spaces in stream substrates in autumn as water temperatures drop. This behavior may be a defense against high winter flows in coastal streams and ice in inland streams (Bjornn and Reiser 1991). Excessive fine sediments fill interstitial spaces, reducing winter refugia, as well as pool habitats used in summer. In addition to directly affecting salmonid survival, fine sediments can reduce habitat for aquatic invertebrates which can affect the availability of food for fish.

Highway effects on stream pollution

The use and maintenance of highways can lead to the introduction of various chemicals, many of which are toxic to aquatic organisms, into streams and rivers. Highway runoff and hazardous materials spills are the most common pathways for chemicals to enter streams. Contaminants are deposited on roadway surfaces and rights-of-ways from lubrication system losses (drips of oil, grease, hydraulic fluids, antifreeze, etc), tire and brake wear, atmospheric fallout, fuel combustion processes, herbicides, deicing agents, paving oils, lead-based paint from bridges and transportation load losses. Approximately 90 percent of the steel bridges in the U. S. are protected with lead-based paints which can contaminate aquatic habitats as the paint weathers and during maintenance operations such as painting and paint removal. During the 10 year period from the mid-1980's to mid-1990's about 10 million tons of rock salt were applied to roads each year and this amount has been increasing in the past few years with colder winters. While there is no quantified data to estimate how much road salt enters streams and lakes, in 1992 salt was cited as a cause of 11 percent of impaired stream miles nationally. Montana reported that salt was impacting wetlands (U.S. EPA, 1996).

Highway run off can be highly polluted and negatively affect water quality and aquatic organisms. The impacts of highway runoff are highly site specific and vary with the frequency, intensity and duration of precipitation and with the amount of vehicular use. Research in the 1970's found that highway runoff had significant effects only from highways with traffic volumes greater than 30,000 vehicles per day (major highways and urban arterials). Still, pollutant concentrations levels in storm water runoff from highways exceed concentrations found in runoff from residential and commercial areas and highways may contribute up to 50 percent of the suspended solids, 16 percent of the hydrocarbons, and 75 percent of the metals in some streams (U.S. EPA, 1996). During the past twenty years many western states have experienced rapid population growth and increasing traffic volume on many highways has expanded the number of highway miles with the potential to affect water quality.

Between 1990 and 1994 there was an average 10,000 hazardous materials spills annually, with an annual average of 646,000 gallons of hazardous materials spilled, on highways in the U.S. (U.S. EPA, 1996). Flammable and/or combustible liquids made up 75 percent and corrosive materials made up 11 percent of the materials spilled. The remaining 14 percent included radioactive materials and poisons. Many of these chemicals are toxic to fish and other aquatic organisms. The impact of a hazardous materials spill is highly site-specific. It depends on the type and quantity of material spilled, amount recovered in cleanup, chemical properties (such as toxicity, combustibility), and the impact area characteristics (such as climatic conditions, topography, and sensitivity of local species and habitats). Many of these spills did not affect aquatic habitats but those that do may cause severe impacts, particularly in streams where flowing water can transport the hazardous materials away from the local site.

Addressing highway effects to fisheries in environmental documents

When new highway development or capacity additions are planned it is important that the environmental analysis documents and biological assessments for listed species address the direct and indirect affects to fisheries and fisheries habitat. The impacts of actions such as channel relocation and encroachment extend beyond the local disturbance site and may last for decades. The analyses should address:

1. Identify past highway impacts and potential corrective measures
2. Status of the fisheries populations in the watershed, including the presence of listed species
3. Local and off-site impacts to fish habitats and channel stability
4. Impacts to riparian habitats and floodplains
5. Habitat fragmentation
6. Potential impacts to the aquatic ecosystem from the future use and maintenance of the highway.

Restoration and avoidance of impacts

First, new roads should be designed to avoid impacts to riparian habitats and stream channels. Second, past impacts need to be identified and corrected. We propose the following restoration and mitigation measures to restore the form and function of river systems and their capacity to provide habitat for coldwater fisheries:

1. Reestablishment of historic channel reaches lengths and sinuosities
2. Reestablishment of the form and function of floodplains

3. Restore riparian habitat including large tree components
4. Mitigate permanent river/stream highway impacts by acquisition or conservation easements to protect upstream or downstream functioning riparian stream portions
5. Identify and correct fish passage barriers with bridges or other suitable structures that provide for habitat connectivity for all aquatic organisms
6. Use construction and maintenance techniques that minimize sedimentation and toxins into streams
7. Move highways out of riparian areas and floodplains when other measures are ineffective.

The Mt. Hood National Forest in Oregon has attempted to restore two abandoned meanders on the Clackamas River. It is estimated that as much as 40 percent of the original channel within a 2 mile section was lost due to highway construction. The project restored flow to nearly 2500 feet of historic channel which now provides slow velocity, off-channel habitat for coho salmon (*Oncorhynchus kisutch*) and ESA listed chinook salmon (*O. tshawytscha*) and steelhead trout (Bob Bergamini, Mt. Hood National Forest, personal communication).

Conclusion

The construction, maintenance and use of the highway transportation system in the western U.S. is often overlooked as a factor contributing to the decline of these populations. Most of the impacts of highways has occurred over a period of several decades and the rate of major new construction has flattened. The total land area occupied by existing roads is relatively small: nationwide, roads and highways occupy less than 0.5 percent of the U.S. land area. Viewed in relation to many of the other factors affect fish habitat this maybe considered to be small. The problem with viewing roads and highways in this context is that highways can have localized disturbances which can significantly impact miles of stream habitat both above and below the local site. These impacts, for all practicable purposes, can often be considered to be permanent due to the values that society places on the transportation system and because of the immense cost of building and maintaining this infrastructure.

It is important that highway agencies recognize the problems that highways create for fisheries and become involved with the solution. It has largely been the listing of fish under the ESA that have focused highways issues. This is too late; we need to become more proactive - more concerned before the problems exist and more open to correcting existing problems. The fisheries expertise relating to highway impacts and solutions coldwater fisheries is in its infancy. It is similar to developing a National Interstate Highway System without engineers. One of the most important steps that highway departments can do now is to hire fisheries biologists, provide training, and empower engineers and biologists to design better highways.

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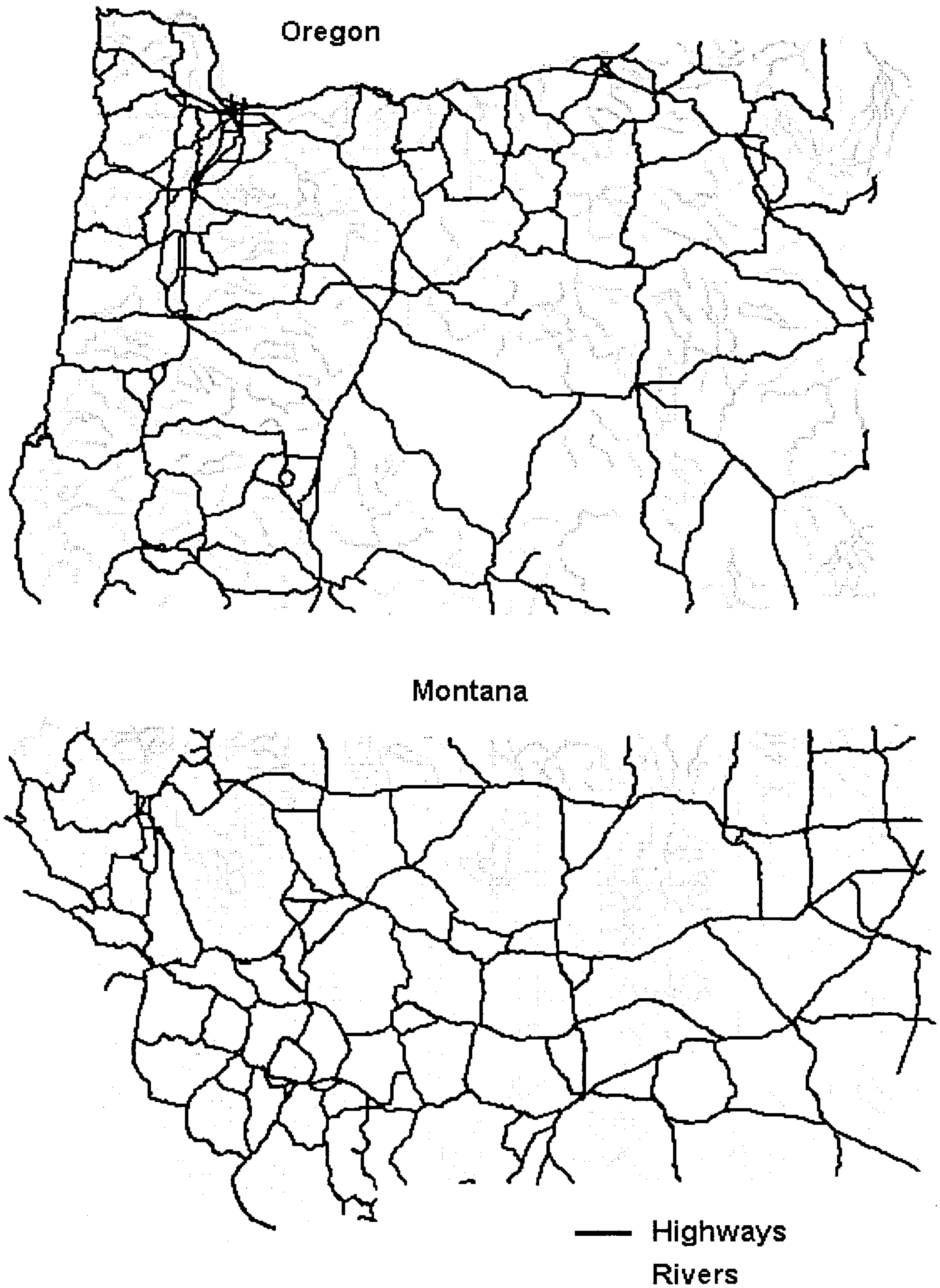

Figure 1. Location of major rivers and highways in Oregon and Montana, USA.

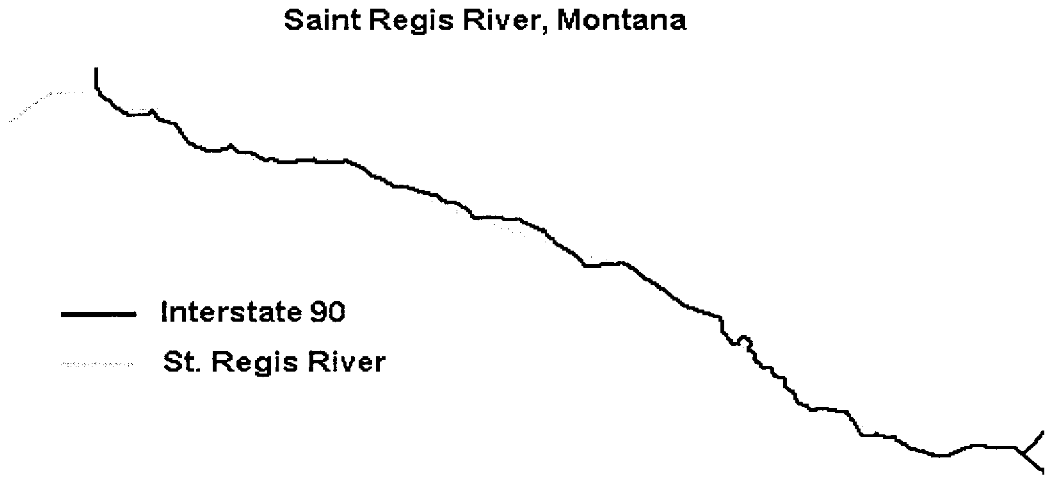

Figure 2. Example of highway, Interstate 90, encroachment on the St. Regis River, Montana. The St. Regis River is approximately 40 miles long.

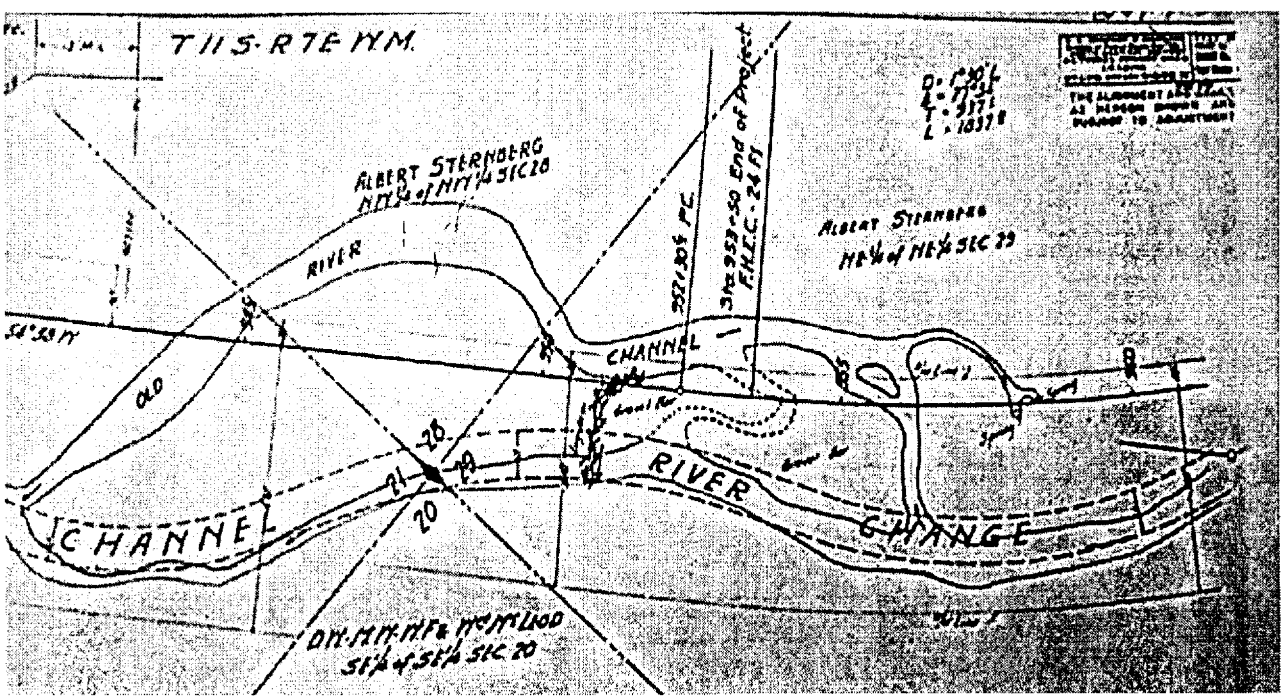

Figure 3. Loss of channel complexity due to highway construction. The present river channel, bottom, is no longer connected to the old river channel. The present channel is straighter, more confined and no longer has a floodplain. Highway right-of-way is the heavy, solid line across the center. Highway 22, North Santiam River, Oregon.

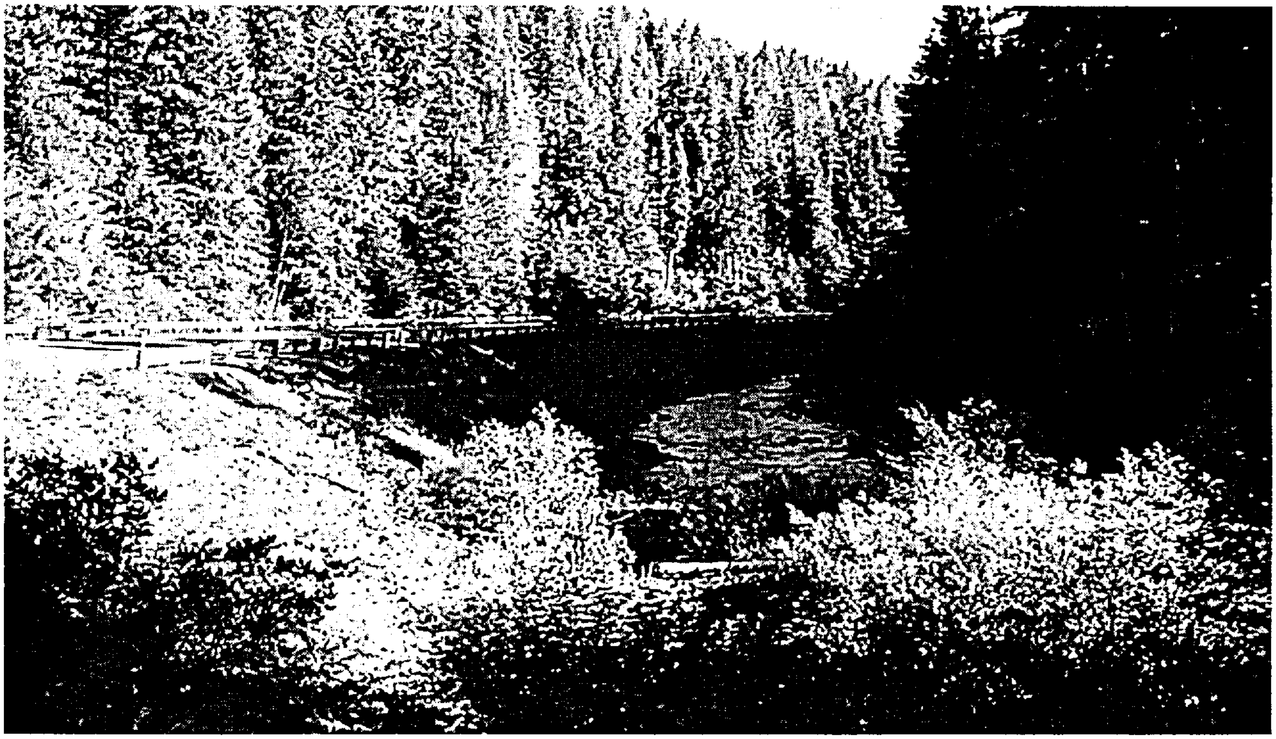

Figure 4. Relocated channel of the North Santiam River along Highway 22, Oregon. Channel has been confined against the hillslope (right). Old cut-off river bends are still existing to the east (left) of the highway.

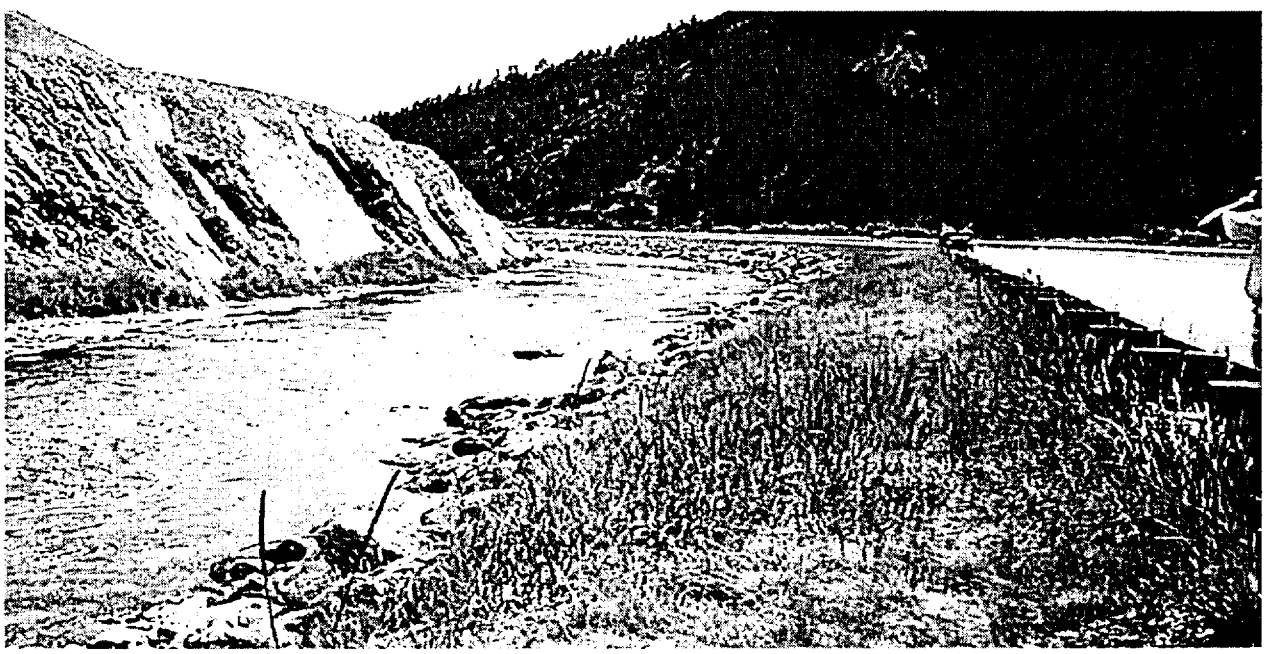

Figure 5. Interstate 90 and relocated channel of the Clark Fork River near Drummond, Montana. Note the lack of riparian vegetation and channel roughness elements. The river is no longer connected to its floodplain. High cutslope to the left of the channel reflects sunlight into the channel.