of extensive placer mining. I had not appreciated the magnitude of the forty-niner's effort. In most areas, the placer mining extends 500 to 1,000 feet away from the stream" (Holland 2000). The mining activities removed most of the topsoil found in the riparian zone and thus the understory plants associated with that soil.

Agriculture became the dominant land use in Placer County during the first part of the 1900's. During this period, 20,600 acres of the Rocklin quadrangle contained cultivated land, orchards or live stock (Holland 2000). To successfully farm orchards required productive topsoil, but the miners of the Mining Era had essentially flushed the riparian zone topsoil down Secret Ravine. Therefore, the orchards during the early part of the 1900's did not extend to the stream edge as in most agricultural areas and much of the vegetation that pioneered the mine tailings remains to the present.

Since the Mining Era, the main land use in Secret Ravine has been agriculture. During this period, the riparian area partially recovered from the Mining Era. However, the large-scale mining disturbance completely changed the overstory and understory found throughout the stream system. The grassland environments changed from native bunch grasses to non-native annual grasses, the shade tolerant shrubs were replaced with the sun-loving Himalayan Blackberry, poison oak and nettle, and the pioneer plant species, Fremont cottonwood, shared the overstory with the native oaks (Schartz 1996 and Holland 2000).

The question remains whether the altered riparian vegetation poses a modern day risk to chinook. The vegetation assemblages found historically in Secret Ravine can be divided into three basic phases: pre-Columbian, Mining Era, and present day (**Table 3.1**). The vegetation found during the pre-Columbian period represents the ideal riparian vegetation for chinook salmon, while the near de-vegetation experienced during the Mining Era could be considered the poorest kind of vegetation cover for chinook salmon.

	Current Vegetation	**Mining Era Vegetation**	**Pre-Columbian Vegetation**
Fish Cover Value	0% < X < 100%	~0	100%
Dominant Understory (Forbs*/Grasses)	Naturalized annual grasses and invasive forbs have replaced nearly all native grasses in California.	~0 cover Mining activity removed most riparian vegetation.	Native bunch grasses community largely creeping wild rye (*Leymus triticoides*).
Dominant Scrub	Early seral community and invasive species indicative of large–scale disturbance.	~0 cover Mining activity removed most riparian vegetation.	Community composed of native shade tolerant shrubs
Dominant Overstory	Oak woodland riparian habitat composed largely of Valley Oak (*Quercus lobata*) & Fremont cottonwood (*Populus fremontii*).	Only a few Valley Oaks (*Quercus lobata*) remain after mining activity.	Nearly closed canopy dominated by Valley Oak (*Quercus lobata*).

Table Plants: To understand the threat posed to chinook salmon from altered riparian vegetation, a description of the previous plant communities in Secret Ravine provides prospective on the risk to the salmon population. This table compiled information presented in *The Jepson Manual: Higher Plants of California* (Hickman, J., Ed., 1993) and Holland 2000. The Jepson Manual is a taxonomic key providing a comprehensive treatment of the flora of California and Holland developed tools to classify plant communities in California.
*A forb is a low-growing herb. The combination of forbs and grasses typically compose the ground cover in many ecosystems.

TABLE 3.1 VEGETATION ASSEMBLAGES ON SECRET RAVINE

The altered vegetation currently found on Secret Ravine includes two characteristics that may be impacting the salmon: composition of the plant community and a reduced areal extent of the riparian buffer zone along the banks of Secret Ravine.

Vegetation composition effects salmon in two direct ways: 1) by moderating water temperature through providing shade and 2) by creating bank complexity when vegetation falls into the creek that juvenile chinook use to evade aquatic predators (Li and Fields, Jr. 1999, Bishop 1997). To address cover and bank complexity the Li study of habitat suitability was used. In general, the Li study concluded that the riparian vegetation cover was fair with a median value of 38.33% by area and the overhead cover, the vegetation that moderates water temperature, was fair with a median value of 39.14% by area in 814 observations (Li and Fields, Jr. 1999). From these two index values the overall cover rating was evaluated to be approximately 40% by area, a fair value for foothill streams (Li and Fields, Jr. 1999). However, the Li study reported that the in-stream cover, the vegetation that provides fish with cover from predators was poor due to the amount of sand substrate that buried many of these structures. The issue of sand substrate will be addressed in other parts of this analysis. However it should be noted, that if in-stream cover could be augmented that cover would probably also be buried in sand due to the excess amount of sediment in Secret Ravine.

Also, vegetation composition effects salmon indirectly through hydrologically related processes such as interception of rain drops by vegetation and root stabilization of soil, thus preventing sedimentation and erosion (Bishop 1997, Li and Fields, Jr. 1999). These processes have been addressed in other stressor analyses for this risk assessment, however a change in dominant plant community can change the effectiveness of the plant community at mitigating sedimentation and erosion problems. The main change in Secret Ravine plant species composition has been due to invasive plants though these changes were not found to be a significant stressor to chinook salmon. Invasive plants in Secret Ravine have been examined in **Appendix G: Invasive Plants and Blackberry (Rubus *discolor*)**, with special attention given to Himalayan blackberry (*Rubus discolor*). To evaluate the extent of the riparian area, a GIS analysis approximated the riparian buffer of 100 ft -on each side of the stream- and compared it to an estimation of actual riparian cover projected from aerial photography of Secret Ravine.

3.4.6 Reduced Access

Barriers cause reduced access on Secret Ravine, which were historically designed for human use in flood control, irrigation and agriculture (e.g. culverts, pipelines and cattle fences, respectively), and also include "natural barriers", or beaver dams. Although members of the Bren group discovered one of the last large artificial obstructions this summer for removal (a chain-link fence at Loomis Park), there are still several unscreened or inadequately screened diversions in Secret Ravine (DCC 2001). Although beaver dams are now the primary concern in terms of reduced access on Secret Ravine, reduced access and/or beaver dams convey other types of stress: decreased sediment, altered flow, superimposition of redds and increased rates of predation. Evaluations of the severity of each of these criteria are made for both models, with particular emphasis on the most egregious secondary stressor: superimposition of redds.

Total fish passage barriers have the potential to block flows that attract migrating adults and send them to non-natal tributaries (Mesick as cited in DCC 2001). Although Secret Ravine has no total barriers, partial barriers, in combination with rainfall patterns and other sources of flow, influence run timing and geographical distribution, and have the potential to send adult chinook to less suitable habitat and/or superimpose their redds, and delay juvenile emigration. Although there are several shallow passages along Secret Ravine (most notably the shallow stretch below the East Roseville Parkway Bridge, **Appendix J-6: Reduced Access**), adult chinook require a minimum water depth of only 24 cm (10 inches) for passage (Reiser and Bjornn, as cited inVanicek 1993). Thus, in the absence of the data required to construct a complete hydrological profile, we determined passage criteria based on a rule of thumb used by fish passage experts. We used different criteria to determine passability for the MRRM and SDRM models.

We took "low" and "high" flow scenarios into account in both models. Adult migration takes place from July through December, with peak spawning occurring after November 1 (DCC 2001 and R. Titus, pers. comm. 2003). However, it is important to note that until the nine-foot high Hayer Dam is opened (further downstream on Dry Creek), which usually occurs around Labor Day, adult fish are completely prevented from passing (B. Washburn, pers. comm. 2003). Juvenile rearing and smolt emigration takes place from January through June. We needed to consider many factors in order to estimate the average rates of flow for different life stages to determine passage for an unusual system such as Secret Ravine. First, there must be sufficient runoff to increase flow in the Natomas East Main Drain Canal for adults to be able to enter the Dry Creek watershed (DCC 2001). Secondly, because the headwaters of Secret Ravine are at an elevation too low to collect snowpack, as complicated by the increase in impervious surfaces, "the hydrology of the stream is dependent on rain in addition to groundwater and ag[riculture] and urban returns" (DCC 2001). Finally, change in additions to flow from Placer County Water Agency and inefficient water delivery via this canal system can result in reduced flow during fall migration. Therefore, although the incision of the channel through hydraulic mining deposits has created a high-flow floodplain that still persists today (Swanson 2001), contributing to a very "flashy" system, if rainfall occurs relatively late during the fall season, the periods that barriers will be impassible will be increased. Flow is between .5 and 2-3 cubic feet per second during the fall, with the average rainfall being 25 inches per year, with the peak occurring from December to February. Thus it is quite reasonable to expect that adults - and possibly juveniles - would frequently be subjected to low flows on this system.

Since adult fall-run chinook often immigrate after peak storm events (Thomas 2001), flow for passage was evaluated under different scenarios (with lows representing smaller initial storm events, the tapering off of a rain event, or later than average seasonal storm events). Thus, for the initial ranking, we used two flow scenarios. "Low" flows were based on adult fish migration during very low rainfall taken from ECORP data (as they were surveying in late summer and early fall, prior to the first runs); "high" flows were taken from the second storm event of the year in the just-past-peak month of spawning (Ayres, Love and Knapp 2002). In both cases, we used values to correct for depths of pools downstream of dams within different regions of the creek. **Appendix J-6: Reduced Access** contains the complete table and analysis for how passage was estimated. Juvenile passage was evaluated in a less rigorous, but supportable manner, based on the expertise of regional biologists.

Allen and Hassler (1988) determined that "chinook salmon eggs are particularly vulnerable to shock injury," most of which they believed to be caused by superimposition of redds. We looked at substrate quality, the average area needed to build a redd, the abundance of known and/or historic spawning sites between difficult-to-pass barriers and the number of adults attempting to spawn in given reaches (**Appendix J-6: Reduced Access** and **Appendix M-1: Reduced Access**) in order to assess the probability of superimposition by females on Secret Ravine. Although research indicates that superimposition of redds is positively correlated with density dependence (i.e. the likelihood of superimposition increases with increased population) and negatively related to flow (Fukushima et al. 1998 and Williams 1997), a U.S. Fish and Wildlife Service biological report confirmed work by Vronskiy (1972) and Burner (1951) that the size of the redd is inversely related to density of chinook spawners (Allen and Hassler 1988). Although the size of average adult fall-run chinook on Secret Ravine is likely smaller than chinook found on some of the larger Central Valley tributaries (R.

Titus, pers. comm. 2003), the fact that the females construct larger redds (presumably as a fitness strategy to compensate for low returns) on already substrate-limited habitat to which some of these barriers confine them, must greatly increase the probability of superimposition on this creek.

This analysis includes beaver dams that Hal Freeman and Sarah Egan of ECORP observed during their fall 2002 habitat survey, and other barriers, which group members had located and sited in previous habitat suitability assessments. The risk regions for which there was vital data from which to glean fish passage potential (e.g. dam height, downstream pool depth), include fourteen data points in the lower half of Secret Ravine. The reach from Confluence to the China Garden Gauge contains a high density of beaver dams and some artificial barriers as well as a high density of known and/or historic spawning sites that could pose a problem to fish passage. Although a later habitat survey by B. Washburn and G. Weber confirmed that, qualitatively, there were no dams of concern in upper regions, there are large boulder and large woody debris near Penryn Road. These elements tend to be associated with ideal habitat suitability, "roughness elements provide obstructions to flow allowing energy to be released at the point of contact and causing pools to scour and undercut banks to form" (Swanson 2000), and were not assessed to pose a problem to fish passage. **Appendix J-6: Reduced Access** contains photographs of several of the most problematic barriers. **Appendix B: GIS Maps** contains the GIS map with barrier sites, spawning sites and count survey reaches.

3.4.7 Toxicity

Toxicity can be characterized by the measure of contaminants in a watershed. Studies have shown that toxic substances from wastewater discharges, storm water runoff, and land-based activities both historic and current have adversely affected salmonid species. The most likely man-made contaminants include organochlorines, such as polychlorinated biphenyls and dioxins, and aromatic hydrocarbons (B. Washburn, pers. comm. 2002).

Salmonid species such as chinook may bioaccumulate chemicals that they ingest through their diet. Bioaccumulation occurs when salmonids ingest more chemicals than they can metabolize. When this happens, there is a greater likelihood for detrimental effects such as chemical modification of

S. LIEBERMAN, J. LOVE AND E. AYRES TAKING WATER AND SEDIMENT SAMPLES FOR TOXICITY AT LOOMIS PARK

DNA and the alteration of immune functions.

Water and sediment samples were taken in each of the five risk regions in Secret Ravine. These samples were tested and analyzed at the UC Davis aquatic toxicology lab. The analysis was based upon the survivability of the *Hyalella azteca* and *Ceriodaphnia dubia* in the water and sediment samples that we took.

Toxicity testing followed the 10-day static renewal procedures described in Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates (U.S. EPA 2000). It should be noted that an analysis-specific contaminants test was not conducted. Rather, the analysis measured the integrated effects of all the contaminants in the five sub-watersheds. Toxicity includes metals, pesticides, hydrocarbons and excessive nutrients in this study. **Appendix B: GIS Maps** contains the map for toxicity sampling sites.

3.4.8 Metals

The aquatic toxicity of metals is a phenomenon involving interactions between the environment and the metal pollutants of concern. Predicting the toxic effect that metals have in natural waters requires evaluating the bioavailability of the metal pollutants. The accumulation of metals in an aquatic environment has direct consequences to humans and to the ecosystem. Interest in metals like zinc and copper, which are required for metabolic activity in organisms, lies in the narrow "window" between their health values and toxicity (Skidmore 1964 and Spear 1981). Others like cadmium and lead exhibit extreme toxicity even at trace levels (Merian 1991 and DWAF 1996). Because there is a history of intensive mining activity associated with the Secret Ravine watershed, persistent metals are a concern (**Appendix A: Mining in the Secret Ravine Watershed**).

Seven metals were tested and analyzed at the University of California at Davis, based upon five samples taken in each of the five sub-watersheds identified along Secret Ravine on December 4, 2002. **Appendix B: GIS Maps** contains watershed delineations). To test for the presence of silver (Ag), cadmium (Cd), copper (Cu), chromium (Cr), lead (Pb), nickel (Ni), and zinc (Zn), homogenized sediment (1200 ml) from each site was mixed with 200ml of amended control water and incubated in the original sample bucket at 23 ± 2°C. This ratio of sediment to control water (6:1) was considerably higher than the ratio used in the toxicity test (approximately 1:2). This elevated ratio was thought to better represent the concentrations of metals that might be biologically available to Hyalella azteca while residing in the upper few centimeters of the sediment. The control water was amended to match the average pH and hardness of all sample waters collected from Secret Ravine. After 48 hours, waters were decanted into pre-acidified bottles provided by the analytical laboratory, Caltest Analytical Laboratory in Napa, CA.

The metals analysis conducted at UC Davis registered values for total metals. Total metal counts were compared to the National Recommended Water Quality Criteria for Priority Toxic Pollutants. Final analyses of lead, copper, and zinc levels in Secret Ravine were done through a comparison with the Criterion Continuous Concentration (CCC). The CCC is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect. The CCC is just one of the six parts of an aquatic life criterion; the other five parts are the acute averaging period, continuous maximum concentration (CMC), chronic averaging period, acute frequency of allowed exceedance, and chronic frequency of allowed exceedance. Because the aquatic life criteria are based on national guidelines, they are intended to be protective of the vast majority of the aquatic communities in the United States.

All of the aquatic life criteria CCC metals we used for comparison were dissolved metal criteria that were calculated using a hardness of 100 mg/L $CaCO_3$.

Lead

Lead and its compounds can be found in all parts of the environment, for example, in plants and animals used for food, air, drinking water, rivers, lakes, oceans, dust, and soil. At low solubilities, metals may either precipitate out of solution or bind to solid particles in a process called adsorption.

Lead is defined by the United States Environmental Protection Agency as potentially hazardous to most forms of life, and is considered toxic and relatively accessible to aquatic organisms (U.S. EPA 1986). Low lead concentrations affect salmon by causing the formation of coagulated mucous over the gills and subsequently over the entire body and thus cause the death of fish due to suffocation (DWAF 1996b). Lead is bio-accumulated by benthic bacteria, freshwater plants, invertebrates and fish (DWAF 1996b).

Copper

Copper is one of several heavy metals that is essential to life despite being as inherently toxic as non-essential heavy metals exemplified by lead and mercury (Scheinberg 1991). Copper is toxic at very low concentrations in water and is usually introduced into aqueous environments through industrial, municipal and agricultural processes and is one of the most common pollutants (Nriagu 1979 and Sadiq 1992). In the case of Secret Ravine, copper is a concern due to heavy mining activity in the watershed. Likewise, copper is an essential trace metal required in small concentrations by organisms for metabolic functions, but it is potentially very toxic when the internal available concentration exceeds the capacity of physiological/biochemical detoxification processes (Rainbow 1992).

Zinc

Zinc is an essential element for all living organisms. In natural waters, zinc occurs both in dissolved form and in natural particulates. The refining chemicals chiefly associated with placer mining were zinc and cyanide (Haley 1923). Only the dissolved fraction is thought to be toxic to fish (Finlayson and Verrue 1980). Most of the zinc introduced into the aquatic environment is eventually deposited in sediments.

At elevated levels in the environment, however, zinc may pose a threat to chinook salmon. Significant deleterious effects were observed in the most sensitive fish species at a waterborne zinc concentration of 10 mg/L (US Fish and Wildlife 1998). When larvae and alevins of rainbow trout (*Oncorhynchus mykiss*) were exposed to 10 µg Zn/L, 54 percent of them died after a 28-day exposure (Spear 1981). Acute 96-h LC50 values for salmon were observed at >1,270 µg/L (Hamilton and Buhl 1990). Both deficient and excessive amounts may cause adverse effects in all aquatic species. Zinc is most harmful to aquatic life during the early life stages in soft water where it is more water-soluble (Eisler 1993).

Trace amounts of silver were detected in the headwaters of Secret Ravine, but were deemed innocuous to chinook health. Zinc and copper levels exceeded EPA CCC recommended levels in four of the five sub-watersheds. The results of these three metals correspond highly with the degree and location of historic mining sites (**Risk Characterization for Source, Appendix A: Mining in the Secret Ravine Watershed**).

3.4.9 Food Supply

Only members of the juvenile life stage consume food while in Secret Ravine. Adults feed only while they are in the ocean, not while they are spawning in freshwater. Juvenile chinook of Secret Ravine are opportunistic drift feeders, eating a variety of invertebrates, which they pick out of the water column. In the Sacramento River, juveniles eat mainly terrestrial and aquatic insects such as chironomid midges, baetid mayflies, hydropsychid caddisflies (Moyle 2002), true flies, and insects from the class Homoptera (Croot and Margolis 1991). Juveniles also eat other types of invertebrates like copepods, water fleas (Croot and Margolis 1991), and amphipods (I. Werner, pers. comm. 2003).

Juveniles feed mostly during the day, and tend to feed near the edge of the stream where the invertebrates are most abundant. Foraging can occur in runs, riffles, and at the tail end of pools (Moyle 2002).

To characterize risk to juvenile salmon in Secret Ravine, three criteria were used: 1) percentage of edible invertebrates, 2) juvenile feeding habits, and 3) amount of riffle habitat available to invertebrates.

To characterize the food supply in Secret Ravine, an understanding of recent benthic macroinvertebrate populations was needed. Two studies that spanned from 1999-2001 were utilized: the Benthic Macroinvertebrate Fauna of Secret Ravine Creek, Placer

County, California (Fields, Jr. 1999) and the Benthic Macroinvertebrate Counts performed by the DCC (DCC, unpub. 2000-2001). Both studies used California Stream Bioassessment Protocol. Thus, data from both studies were combined for this analysis. An understanding of juvenile feeding habits was obtained through researching several sources (Moyle 2002 and Fields, Jr., pers. comm. 2002). An understanding of riffle habitat was obtained through several studies done in the Secret Ravine area (Li and Fields, Jr. 1999 and DCC 2001).

3.4.10 Predation by Fish

The fish assemblages of California have changed greatly over the last century. The introduction of approximately 60 species of fish for various reasons, including sport fishing, mosquito control, ornamental landscape ponds, and some accidental introductions, has lead to broad changes in fish communities (Moyle 2002, McMahon et al. 1984, Dill and Cordone 1961). In the confluence of Secret Ravine with Miners Ravine, Dr. Rob Titus, of CDFG, noted the presence of 15 exotic fish species in his emigration monitoring from November 6, 1998 to June 2, 1999 and from January 9, 2000 through June 8, 2000 (Titus 2002, Titus 2001). Of the fifteen species of exotic fish identified in the creek system eight species could potentially be competing with juvenile salmon for food or predating on salmon eggs or juvenile salmon (**Appendix H: Introduced Fish Species List**). The most influential of these fish maybe the spotted bass (*Micropterus punctulatus*) due to the abundances of this fish observed in monitoring done by screw trap and electro-fishing in 1998, 1999, and 2000 (Titus 2003). The presence of these fish is significant in two ways: it suggests that these species are present when chinook salmon are in the Secret Ravine system and that predation and competition by exotic species could be affecting chinook salmon.

The monitoring done by Dr. Titus identified two differing fish communities in Secret Ravine. The lower reach from the confluence to Sierra College, a slow moving, low gradient reach, supports a fish community dominated by spotted bass (*Micropterus punctulatus*), Sacramento pikeminnow (*Ptychocheilus grandis*) and Sacramento sucker (*Catostomus occidentalis*). The upper reach of Secret Ravine from Sierra College to the headwaters of this creek system tend to be dominated by native fishes Sacramento pikeminnow, Sacramento sucker, steelhead (*Oncorhynchus mykiss*) and Pacific lamprey (*Lampetra tridentate*) (Titus 2003). Of the dominant fish in Secret Ravine, spotted bass tend to be the species of most concern for two reasons: 1) spotted bass dominate the lower reach where the majority of chinook spawning gravel exists and 2) their introduced status means that chinook salmon did not co-evolve with spotted bass predation.

Of the three bass species found in the Secret Ravine system, spotted bass tend to prefer faster water than largemouth bass and more turbid water than smallmouth bass (Moyle 2002, McMahon et al. 1984, Smith and Page 1969, Vogele 1975). The spotted bass tends to utilize habitats of moderately sized, clear, low gradient streams (Moyle 2002, McMahon et al. 1984, Vogele 1975) that could describe most of the lower reach of Secret Ravine (Li and Fields, Jr. 1999, Holland 2000). Moyle states that spotted bass do well in streams with a summer temperature between 24-31°C (Moyle 2002), and spawn in streams with temperatures between 14-15° in early April and late March (Moyle 2002, Aasen and Henry 1981). Temperature influences growth and thus the predation activity of spotted bass in creeks such as Secret Ravine. Moyle states that "Growth rates vary with habitat; fastest rates are typically achieved in fairly new warm water reservoirs, slowest rates in cool streams" (Moyle 2002 p406). Limitations on spotted bass growth have been observed at temperatures below 10 degrees C (McMahon et al. 1984); this occurs in January and February on Secret Ravine (Weber unpublished data) (**Figure 3.1**).

The preferred food of spotted bass includes aquatic invertebrates, fish, crayfish, and terrestrial insects (Moyle 2002, McHahon et al. 1984, Mullan and Applegate 1968, Howland 1931). Crayfish and, secondarily fish, tend to comprise the majority of the spotted bass diet in streams especially as the spotted bass grow in size (Moyle 2002, McMahon et al. 1984, Howland 1931, Scalet 1977, Smith and Page 1969). Therefore spotted bass may predate on juvenile salmon given that the water temperature is sufficient to allow hunting activity. Additionally, studies of the Columbia River have found salmonid prey in the stomach contents of smallmouth bass, a close relative of spotted bass (Vigg et al. 1991). They are so close in relation, in fact, that smallmouth bass and spotted bass have been known to hybridize, and the genetic purity of spotted bass is believed to be questionable in some locations in California (Dill and Cordone 1961).

From the life histories of spotted bass and chinook salmon, one can draw the conclusion that spotted bass could potentially predate on the juvenile chinook salmon from March through June. To investigate the extent of predation of spotted bass on chinook salmon, an estimation of the biomass of black bass (small mouth, large mouth and spotted bass) for Secret Ravine was evaluated on a projected population of juvenile chinook salmon (**Appendix H: Introduced Fish Species List**). To do this a range of biomass consumptions by spotted bass was calculated and then compared to a projected population of juvenile chinook salmon for 2002. The analysis showed that spotted bass have the potential to reduce the chinook salmon population from 7% to 14%, given that salmonids comprise 1% of the spotted bass diet. The lower figure probably represents the better estimate due to the small size (26 g) of the bass in Secret Ravine and the cooler temperatures of the water during these months.

4 Risk Analysis Methods (Modified Relative Risk Model)

4.1 General Method

The Modified Relative Risk Model systematically quantifies ecological risk posed by sources and stressors in Secret Ravine. The model integrates quantitative and qualitative data by converting them to ranks, calculating a risk score using an equation that incorporates habitat, exposure and effect. A risk score can be calculated for stressors, sources, habitats, and risk regions. These risk scores capture the risk associated with each element and allow for prioritization.

To begin, all relevant data for Secret Ravine was collected. On May 17, 2002 a stakeholder meeting was held in Roseville to identify the stressors that might be affecting chinook salmon in Secret Ravine. We created the conceptual model based on synthesis of information generated at this meeting regarding the relationships between stressors, sources and effects in the system, expressed as pathways in the model. We revised and and streamlined the conceptual model throughout the project in order to better reflect our understanding of these pathways. **Appendix E: The Conceptual Model** contains the most recent incarnation.

In the MRRM process, this data is then divided up to correspond with its representative sub-watershed. Consequently, the sub-watersheds, or "risk regions", combine all data that is relevant to that area (**Appendix B: GIS Maps**). For example, data taken near the confluence of Secret Ravine and Miners Ravine is pooled together to assess risk specifically in that area. This raw data is then converted to ranks.

Allowable ranks in the MRRM are 0, 2, 4 and 6. A rank of zero indicates no or little associated risk, and six indicates large risk or mortality. To fit this scale, breaks are determined, wherever possible, using dose-response and effect estimates from scientific literature. When this information is not available, a statistical method is used to assign natural breaks in the data (**Section 4.1.2**). Ranks are relative within each stressor, not across stressors. Therefore, equivalency is not addressed, as a rank of two for temperature does not imply the same level of risk as a rank of two for morphology.

Sources that lead to these stressors are quantified using Geographic Information Systems (GIS). These are then ranked using areal extent or frequency. Habitat, or stream length, is also ranked using GIS. Once again, ranks are relative within each source or habitat, not across them. Exposure filters are also used to assess the connections between the sources and stressors, and between stressors and habitat.

The ranks for stressor, source, and habitat are combined with exposure filters, culminating in a total risk score for each risk region. These components are explained in detail below.

4.1.1 Risk Regions

The study area boundary was developed based on the land area drained by the Secret Ravine system. For the source analysis involved in the MRRM, the Secret Ravine watershed was first divided into sub-watersheds, or "risk regions", based on watershed boundaries (**Appendix B: GIS Maps**). Dividing watersheds into subunits is a common practice in watershed analysis. Essentially, the divisions within a creek system are a function of topography; high points in the topography suggest the direction water will follow when a rain event occurs. Our sub-watersheds were adopted from a Placer

County study of flood risk (Montgomery 1992). These five risk regions are henceforth referred to as Risk Regions A, B, C, D or E. Risk Region A is the farthest sub-watershed downstream, where Secret Ravine confluences with Miners Ravine. Risk Region E is the farthest sub-watershed upstream, and encompasses the headwaters.

4.1.2 Source Ranks

To help in the identification of each source, three categories were established: urbanization, legacy, and rural residential. Each category contains multiple sources present in the Secret Ravine watershed. Each source was evaluated and assigned a rank value based on its relative impact within a risk region. Several methods assisted in establishing the extent and frequency of the various sources: aerial photography, GIS coverages describing zoning, land use, or historic landmarks, topographic maps, and personal observation. **Appendix F: Sources and Stressors** lists the twelve sources we identified for Secret Ravine and enumerates the stressors associated with each source.

Appendix I: Source Analysis and Characterization describes in detail how each source was analyzed and ranked. The traditional method of ranking all non-point sources is based on their areal extent (Hart Hayes 2002). We, however, divided by the stream length within each risk region to capture a "concentration". For example, take two sources with equal areas. The Risk Region with the smaller stream length will have the higher risk because the source is concentrated into a small length of water.

Non-point sources included landscape maintenance, impervious surfaces, construction and development, dirt and gravel roads and introduced fish. Channelization was characterized by the length of creek channelized divided by the length of stream within the respective risk regions. Since no digital maps existed, mining and orchards were characterized based on visual estimates of areal extent utilizing topographic maps and historic accounts in the literature.

Point sources (water treatment plants, irrigation canals and beaver dams) were ranked based on the number of occurrences within each risk region. In most cases, the risk region with the highest number of occurrences of that point source received the highest rank.

Once the areal extent of non-point sources or the frequency of point sources was determined, natural breaks were used to assign ranks (Landis 1997). Natural breaks finds groupings and patterns inherent in data using a statistical formula (Jenk's optimization). Jenk's optimization minimizes the sum of the variance within each of the classes. Our data was separated into four categories (0, 2, 4, 6) in accordance with the RRM.

A source is assigned one rank for each risk region. Consequently one source has five associated ranks. The source rank can be the same across all the risk regions, or vary for each risk region. Due to the nature of assigning ranks, source ranks are relative within one source, but not across different sources.

4.1.3 Habitat Ranks

"Habitat" was used as another parameter to capture the affected life stages of salmon (as opposed to conventional ecosystem-type habitats used in a regional risk assessment). Habitat in our study refers to the water column, the benthos, or both.

Potential habitat for our assessment endpoint includes only the main channel of Secret Ravine, as no data exists to indicate spawning or juvenile rearing within the tributaries (G. Bates, pers. comm. 2002 and R. Titus, pers. comm. 2002). Therefore, habitat size is defined to be the main channel stream length for a risk region. The habitat lengths were normalized using the shortest habitat length from Risk Region E. Using Jenk's optimization, these values were converted to ranks (**Table 4.1**).

	A	B	C	D	E
Habitat Length (ft)	13152	18872	5995	9009	2171
Normalized Habitat Value	6.1	8.7	2.8	4.2	1
Habitat Rank	6	6	4	4	2

TABLE 4.1 HABITAT RANKS

The longest habitat lengths (not necessarily the largest risk regions) received the highest rank of 6, and the shortest habitat length received the lowest rank of 2. The habitat length of Risk Region E was reduced to Rock Springs Road because that is the highest point salmon have been observed historically (B. Everhart via B. Washburn, pers. comm. 2003). Currently, there is no evidence of spawning or juvenile rearing above Loomis Park on the boundary between Risk Regions C and D (G. Bates, pers. comm. 2002 and R. Titus, pers. comm. 2002).

Habitat ranks were assigned to the water column or the benthos based on the life stages of salmon: early life stages (egg and alevin) occupy the benthos, while the juvenile and adult phases occupy the water column. The benthos for this analysis includes the top portion of sediment in the stream channel (Merriam-Webster 2002). Any stressor known to affect the early life stages were considered benthic habitat stressors. The water column or the open-water environment of the creek includes those environments distinct from the bed or shore that may be inhabited by freshwater organisms (EUNIS 1998). Any stressor known to affect the juvenile or adult phase were considered water column habitat stressors. Additionally, habitat ranks require that the fish be present when the relevant stressor affects a particular habitat and life stage. **Table 2.1** contains relevant time periods.

4.1.4 Effects Ranks

Effects caused by the stressor to the endpoint were given ranks of 0, 2, 4 or 6 based on dose-response curves (where data existed) or best professional judgment. A rank of zero reflects low (or no) effect and a rank of six is a highly negative effect, usually related to direct mortality. Site-specific data exists for sediments, barriers, introduced fish, temperature, invertebrate food supply, morphology, and contaminants.

4.1.5 Exposure Filters

Two exposure filters were utilized in calculating the risk score. The first exposure filter (Exposure 1) assesses whether or not the source emits the stressor. This is based on the conceptual model. A one is assigned if a direct pathway exists from the source to the stressor in the conceptual model, and a zero is assigned if no pathway exists. A value of 0.5 is assigned if there is an indirect pathway (occurring via another stressor) from the source to the stressor. **Appendix F: Sources and Stressors** differentiates between sources that are direct and indirect. We defined an indirect source as any source that generates a stressor via another stressor or relates to a source that was originally emitted many years prior to this analysis. The modeling of legacy sources, for the most part, contains an indirect exposure filter. The exception to this rule occurred with regard to the relationship between chemical stressors and mining and orchards. In this case, the literature suggested that persistent chemicals (DDT) and heavy metals (Cu), could stay biologically active, even though the emission is temporally remote. The two direct links between sources and stressors are the links between toxicity and orchards, and metals and mining. In these two cases, Exposure filters of 1 were assigned to indicate a direct link between a legacy source and a current stressor to the salmon.

The second exposure filter (Exposure 2) assesses whether or not the habitat will be exposed to the stressor. Some stressors, such as metals, affect only the water column and others are specific to the benthos. A one is assigned to both the water column and the benthos in circumstances where the stressor could be affecting both habitats.

4.1.6 Risk Scores

The main goal of this analysis is to determine the most significant stressors and the sources thereof. This is achieved by calculating risk scores. The general formula for this calculation is shown in **Equation 1.** The risk score for each stressor is calculated by multiplying together all the ranks and associated filters for that stressor and summing across risk regions. The risk score for source is calculated in a similar fashion.

$$\boxed{RS = (\text{Source Rank})^* (\text{Habitat Rank})^* (\text{Effects Rank})^* (\text{Exposure 1 filter}) * (\text{Exposure 2 filter})}$$

EQUATION 1 TOTAL RISK SCORE EQUATION FOR MODIFIED RELATIVE RISK MODEL

Risk scores are first calculated over each risk region. An example calculation is demonstrated below. In this calculation, the stressor is flow, the source is mining and the habitat is the water column. The resulting risk score is the relative impact that mining has on flow alterations in Risk Region A.

Stressor = Flow; Source = Mining; Habitat = Water Column

RS = (Mining Rank) * (Water Column Rank) * (Effects of Flow Rank) * (Exp1) * (Exp2)

RS = 2 * 4 * 6 * 0.5 * 1 = 24

FIGURE 4.1 EXAMPLE CALCULATION FOR RISK REGION A

Risk scores can then be summed for a specific stressor or source the entire risk region. These values represent the relative impacts that the specific stressor or source is affecting the risk region.

Finally, risk scores are generated to assess the cumulative impacts of a stressor or source. This is achieved by summing the relative risk scores for the stressor or source over all five risk regions. Another risk score is calculated to assess cumulative impacts to habitat (water column or benthos).

4.1.7 Assumptions (Modified Relative Risk Model)

The MRRM utilized assumptions that allowed the regional evaluation of risk. Each component of the model involved different assumptions with a few overarching posits that allowed these parts to be integrated into a working model.

Risk Regions

To begin, the division of the watershed into five independent risk regions required the delineation of watersheds based on topography and water movement in Secret Ravine. The model should include all areas that drain into the creek, however due to anthropogenic changes in the watershed not all these areas could be included. Specifically the canal system brings water from the neighboring Yuba/Bear watershed into the Secret Ravine system and the storm water system diverts some water from neighboring watersheds into the Secret Ravine watershed. The rerouting of water through Secret Ravine from the Yuba/Bear and movement of water through urban and rural storm water system was assumed to have a minimal effect; therefore, the risk regions did not incorporate these remote sources of Secret Ravine water. Also the risk regions should represent the actual change in drainage patterns caused by the construction of I-80, however in some cases the full extent of the tributaries that pass under the highway and the connectivity of these tributaries were not ground-truthed.

Therefore, another assumption of the model is that the extent of the risk regions includes all the area on the northwest side of I-80 that drain into Secret Ravine.

Sources

We evaluated the non-point and point sources of stressors to chinook salmon through the source analysis. In general, we assumed that the greater the extent of a possible non-point source, the higher frequency of a point source, or the smaller stream length associated with a risk region, the greater the potential stressor effect. Such source attributes as whether the source is a point or non-point source, whether the source has different types or intensity of emission than other sources or the sources ability to cause the stressor were not considered in the assigning of ranks.

The assumptions related to source come from the ranking of source within Secret Ravine and the equivalency of a certain rank for one source to that same rank for another source. The MRRM ranks each source relative to other risk regions within the watershed. For example, a 4 in Risk Region A for impervious surface may indicate that Risk Region A has a larger area of impervious surface than Risk Region B, with a rank of 2. However the confounding factor of stream length and point sources prevents a rank from being a simple comparison of land area. The area of source in each risk region is divided by the length of the stream in the risk region, so the same area of source in Risk Region A, with a stream length of 13,152 feet, may have a different rank than that same area of source in Risk Region E, with a stream length of 2,171 feet. Also, the ranking of point sources followed a completely different scheme. In the case of a point source, the number of point sources in a risk region determined the rank given.

The MRRM assumes that a rank assigned to one source is equivalent to that same rank assigned to a completely different source. Sources can be weighted equally even if they 1) differ in absolute area, 2) have different stressors emitted from them, 3) affect different stream (habitat) lengths, 4) affect different habitats (benthos or water column or both), or 5) differ in nature (point or non-point source). The consequence of this 'relative' assigning of ranks means that a certain rank can be difficult to evaluate in the context of the other sources (e.g. a rank of 4 for both channelization and impervious surfaces assumes that they pose the same risk, but that may not actually be the case).

Habitat

The stream habitat utilized by chinook salmon includes the water column and benthos of the main stem of Secret Ravine. The first assumption related to habitat is that the salmon remain in the main stem of Secret Ravine throughout their stay in the creek; use of tributaries as cover or for forage were not taken into account (G. Bates, pers. comm.2002, R. Titus, pers. comm.2002). A related assumption, that each life phase solely uses either the benthos or the water column, was necessary to divide the habitat into these two categories. An example where this assumption might be violated would be for toxicity in sediment. Adult fish, affected in the model only by water column stressors, might be exposed to benthos stressors when in the process of constructing a redd; thus adult salmon may be exposed to sediment toxicity.

Exposure

The exposure filters were based primarily on conceptual model research. The conceptual model represents the synthesis of stakeholder input during a meeting held in the spring of 2002 and the research done by the ERA team throughout the following year. Therefore, one assumption is that the experts on Secret Ravine knew enough about the creek to provide a clear picture of the on-going processes in the stream system. Another assumption is that the ERA team successfully incorporated the data of experts, stakeholders and literature to develop a conceptual model that reflects the actual processes in the creek.

Effects

The treatment for each individual stressor details the assumptions made in the evaluation of different ranks for different stressors. A few overarching assumptions that occur prevalently in the stressor effects again included the idea of equivalency. It is assumed that a stressor 'relative' rank evaluated individually for each stressor in each risk region can be comparable across stressors. A 2 for altered riparian vegetation, for example, has an equal weight as a 2 for sediment or reduced access. Another assumption is that using best professional judgment, if applied in a constant and informed manner, in the assignment of ranks can result in an accurate rank. Given the imperfect data for Secret Ravine, the use of best professional judgment allowed the inclusion of stressors that could not be quantified readily. Finally, the use of Jenk's optimization to assign rank category was assumed to be an impartial and mathematically defensible way to define categories for the five risk regions. For many stressors, the analysis only included five data points, which makes the concept of "natural breaks" rather tenuous. Nevertheless, the algorithm beneath the GIS tool allowed categories to be assigned in a consistent manner.

4.2 Uncertainty Analysis

Uncertainty analysis on Secret Ravine differs from previous relative risk model assessments. In the MRRM, we conducted a sensitivity analysis on the effects ranks to determine the resulting changes in risk scores (and thus the relative prioritizing of stressors). We then conducted an alternative ranking scheme for the habitat ranks. We based the original ranking of habitats on the absolute area of the source divided by the length of stream (habitat) in the respective risk region. The alternative habitat ranking scheme ranked habitat based purely on absolute area of sources. Changes in risk scores were then assessed.

For quantitative data, the risk predictions produced in the MRRM are point estimates based on ranks and associated filters. Uncertainty for quantitative data was determined by the following three criteria: 1) number of data points; 2) confidence of methods; and 3) natural variability of the system. Quantitative uncertainty was established for each applicable source and stressor. The analysis, results and discussion of uncertainty for the MRRM is in Section 7.

5 Risk Analysis and Characterization Methods (Modified Relative Risk Model)

The following section describes how risk was estimated to the salmon in terms of effects and exposure for stressors. Here, we determined the method for assigning ranks to stressors (i.e. risk analysis), and assigned stressors actual ranks values (i.e. risk characterization).

5.1 Stressors

5.1.1 Sediment

5.1.1.1 Assigning Exposure Filters

Exposure 1 (Stressor from Source filter)
Direct sources of sediment were assigned an Exposure 1 filter value of 1. These sources include impervious surfaces, OHVs, construction and development, dirt and gravel roads and channelization. All other sources (except introduced fish) are considered indirect sources of sediment and were thus assigned an Exposure 1 value of 0.5.

Exposure 2 (Habitat Exposed to Stressor filter)
Impacts from sediment affect both the water column (via turbidity) and the benthos (via fine sediment accumulations in the bedload). Therefore Exposure 2 filter values of 1 were assigned to both habitats.

5.1.1.2 Assigning Effects Ranks

In the benthos, survival to emergence based on grain size distribution (Tappel and Bjornn 1983) was estimated each risk region. Below are the criteria we used to assess ranking for sediment in the benthos.

Percent survival	Rank
Greater than 40%	0
30% to 40%	2
10% to 29%	4
Less than 10%	6

TABLE 5.1 CRITERIA FOR RANKING SEDIMENT IN THE BENTHOS

SIEVE SHAKER AT CALIFORNIA STATE UNIVERSITY AT SACRAMENTO

Turbidity data (DCC 2003) was used to assess impacts to the water column from sediment. We calculated severities of ill effect (SEV) values for all risk regions based on methods developed by Newcombe and Jensen 1996. Below are the criteria we used to rank turbidity.

SEV (severity of ill effects)	Rank
Zero to 3	0
4 to 8	2
9 to 10	4
11 to 14	6

TABLE 5.2 CRITERIA FOR RANKING TURBIDITY

Appendix J-1: Sediment contains grain size distributions and associated mortalities for sediment in the benthos, and turbidity data used to calculate SEV values for sediment in the water column (turbidity). Summary tables of final ranks for sediment in the water column (turbidity) and the benthos are also located in this appendix.

5.1.2 Flow

5.1.2.1 Assigning Exposure Filters

Exposure 1 (Stressor from Source filter)

Direct sources causing alterations to the flow regime were assigned a value of 1. These include impervious surfaces, channelization, construction and development, water treatment plants, dirt and gravel roads, irrigation canals and beaver dams. All other sources (except introduced fish) were deemed indirect sources and were thus assigned a value of 0.5 for the Exposure 1 filter.

Exposure 2 (Habitat Exposed to Stressor filter)
Impacts from alterations in flow occur in both the water column (via sub-optimal velocities or depths) and the benthos (via scour or percolation). Thus, the Exposure 2 value for both habitats was assigned a value of 1.

5.1.2.2 Assigning Effects Ranks

Critical substrate depths were calculated for all risk regions based on the sediment data collected (Ayres, Love, and Vodopals 2002). These were compared with optimal (or tolerance) depths based on Allen et al 1998. The optimal (or tolerance) depth for juvenile rearing and adult migration were used to assess impacts to the water column while depths for spawning were used to assess impacts to the benthos.

Below are the criteria for ranking flow in the benthos (**Table 5.3**) and water column (**Table 5.4**)

Optimal spawning depths (cm)	Rank
Greater than 30	0
20 to 30	2
10 to 20	4
Less than 10	6

TABLE 5.3 CRITERIA FOR RANKING FLOW IN THE BENTHOS

Tolerance flow depths (cm)	Rank
Greater than 122	0
25 to 122	2
24 to 76	4
Less than 24	6

TABLE 5.4 CRITERIA FOR RANKING FLOW IN THE WATER COLUMN

Appendix J-2: Flow contains summary tables of final ranks for flow in the water column and the benthos.

5.1.3 Morphology

5.1.3.1 Assigning Exposure Filters

Exposure 1 (Stressor from Source filter)
Direct sources to changes in stream morphology include channelization, OHVs, construction and development and irrigation canals; these were assigned Exposure 1

values of 1. Excluding introduced fish, all other sources were deemed indirect sources and were thus assigned Exposure 1 values of 0.5.

Exposure 2 (Habitat Exposed to Stressor filter)
Alterations to stream morphology affect both the water column and benthos habitat. Changes, in such stream characteristics as the frequency of pools, can cause impact to the water column, while changes to the channel width and slope may alter the benthos. A 1was therefore assigned to both habitats for the Exposure 2 filter.

5.3.1.2 Assigning Effects Ranks

Percent pools by length (PBL)	Rank
Greater than 40%	0
30% to 40%	2
20% to 30%	4
Less than 20%	6

TABLE 5.5 CRITERIA FOR RANKING MORPHOLOGY IN THE BENTHOS AND WATER COLUMN

Appendix J-3: Morphology contains summary tables of final ranks for morphology in the water column and the benthos.

Appendix L contains the data we used to determine ranks for some of the morphology elements.

5.1.4 Temperature

5.1.4.1 Assigning Exposure Filters

Exposure 1 (Stressor from Source filter)
Each life stage of chinook salmon was given an exposure of 1 because each stage is susceptible to the temperature regime of each risk region. This was determined through an analysis of the conceptual model.

Exposure 2 (Habitat Exposed to Stressor filter)
Each life stage receives a 1 for their exposure to temperature in the water column. For the benthos exposure to temperature, the egg/yolk-sac fry receive a 1.

5.1.4.2 Assigning Effects Ranks

Water temperature data on Secret Ravine is only complete for Risk Region B. Risk Region B includes twelve monthly temperatures for 2002. Incomplete data (March – June) is available for the locations known as Risk Region A and Risk Region E. Rankings and implications were extrapolated for Risk Regions C and D because data was not available. This is regarded as a conservative data extrapolation because these two sub-watersheds are anchored by available data both upstream and downstream. All subsequent analyses were based upon the complete data of Risk Region B and the incomplete data of risk regions A and E.

Ranks for the three life stages and their associated habitats were established from relevant literature concerning previous studies on chinook salmon. Final ranks were determined by applying the highest (riskiest) correlate rank to each habitat. The final ranks apply to all Risk Regions (A-E).

Early Life Stages: Temperature Criteria for the Benthos

Ranks for the egg/yolk-sac fry life stage in Secret Ravine were based upon the above temperature ranges and associated percent mortalities. For the months November – February, the following ranking system applies:

Temperature Range (°C)	Rank
< 14.5	0
14.5 – 15.6	2
15.6 – 18.0	4
> 18.0	6

TABLE 5.6 CRITERIA FOR RANKING TEMPERATURE FOR THE EARLY LIFE STAGES IN THE BENTHOS

Juvenile and Adult Phase: Ranking Criteria for the Water Column

A combination of the temperature limitations in the juvenile and adult life phases supplied the criteria for determining rank.

Juvenile Phase

For the months late January through May, the following ranking system applies to juveniles:

Temperature Range (°C)	Rank
< 15.6	0
15.6 – 16.6	2
16.6 – 18.0	4
> 18.0	6

TABLE 5.7 CRITERIA FOR RANKING TEMPERATURE FOR THE JUVENILE PHASE (WATER COLUMN)

Adult Phase

The conservative lower threshold of 20.0 °C was selected for correlate rank partitioning for adults.

Temperature Range (°C)	Rank
< 16.5	0
16.5 – 18.9	2
18.9 – 20.0	4
> 20.0	6

TABLE 5.8 CRITERIA FOR RANKING TEMPERATURE FOR THE ADULT LIFE STAGE (WATER COLUMN)

Appendix J-4: Temperature contains summary tables of final ranks for temperature in the water column and the benthos.

5.1.5 Altered Riparian Vegetation

5.1.5.1 Assigning Exposure Filters

Exposure 1 (Stressor from Source filter)
The preliminary analysis, necessary to construct the conceptual model, determined that the source of altered riparian vegetation directly came from OHV activities crushing vegetation and compacting soil in the riparian zone, construction and developing clearing land for new development, landscape maintenance that changed the composition and cover of vegetation in the watershed. Indirectly, all the sources that effect hydrologic processes and the movement of toxicants influence vegetation including impervious surfaces, dirt and gravel roads, channelization, irrigation, beaver dams, mining, orchards, and water treatment plants. Eleven sources influence altered riparian vegetation either through direct or indirect processes; the indirect sources were assigned 0.5 and the direct sources 1.

Exposure 2 (Habitat Exposed to Stressor filter)
The chinook salmon of Secret Ravine require a certain water temperature, a certain amount of in-stream cover, and a riparian zone sufficient to buffer harmful substances from entering the creek. The natural services provided by the vegetation in Secret Ravine affects the benthos and water column habitats of all three life stages of chinook salmon. Therefore, each life stage of chinook salmon was assigned an Exposure 2 of 1 for each sub-watershed.

5.1.5.2 Assigning Effects Ranks

The criteria utilized to assign ranks to altered riparian vegetation utilize a combination of the historic conditions of the riparian zone and analysis of the current cover and extent of the vegetation.

Ranks	Criteria
0	Pre-Columbian vegetation with nearly 100% cover and a riparian zone extent greater than 100 ft on each side of the stream for the length of the stream.
2	A less than 1000 feet length of riparian zone with a width of less than the ascribed buffer zone of 100 ft, on both sides of the stream.
4	A larger than 1000 feet length of riparian zone with a width of less than the ascribed buffer zone of 100 ft, on both sides of the stream.
6	Near de-vegetation of Mining Era with approximately no overhead cover and few areas where the riparian zone extends beyond the ascribed buffer.

TABLE 5.9 RANKING CRITERIA FOR ALTERED RIPARIAN VEGETATION

The risk to fish on Secret Ravine, due to altered riparian vegetation, should be highest during the Mining Era. The miners, by denuding the riparian zone, would have exposed the chinook salmon to high water temperature and reduced available cover, which chinook juveniles use to evade predators. Therefore the risk for this stressor in the mining period, a worst-case scenario, should be set at 6. Conversely, the habitat that chinook salmon coevolved with existed during the pre-Columbian period of California. The habitat projected for this period of Secret Ravine should be accessed a 0. The 0 in this case would be the best-case scenario for the chinook salmon and pose nearly zero risk to the fish.

Recall from the background section, that certain risk regions have a greater or lesser extent of stream with a riparian zone less than the prescribed buffer of 100 ft on both banks of the creek. **Appendix J-5: Altered Riparian Vegetation** provides a summary of the incidences of overly small riparian zone extent by risk region. This information provided the criteria used to rank the stressors for Secret Ravine as a 2 or a 4; Risk Region A received a 4 (3,935 feet of incidence) and Risk Region B-E were assigned 2's (ranging from 201-855 feet of incidence).

5.1.6 Reduced Access

5.1.6.1 Assigning Exposure Filters

Exposure 1 (Stressor from Source filter)
Pathways, as derived from the conceptual model, exist from source (beaver dams and artificial barriers, under Construction and Development) to the following stressors: sediment, flow, predation and reduced access. Thus, we assigned '1s' to all risk regions.

Exposure 2 (Habitat Exposed to Stressor filter)
Adult chinook are potentially exposed directly to reduced access in the water column, during their upstream migration from late October through late December. Juvenile chinook are also potentially directly exposed to reduced access in the water column, during their downstream emigration from January through May, so they also received Exposure Filter 2 scores of 1. Eggs are potentially exposed to reduced access (barriers) indirectly, through the increased potential of superimposition of redds during low flows

and for the increased potential of blowout during high flows, thought these secondary stressors can result in direct mortality. Thus, eggs received a 1 for the benthos. However, impacts to the benthos cannot be evaluated easily using this model (because of multiple complex interactions), thus only the water column as it pertains to reduced access is addressed in this analysis.

The habitat ranking is applied to reduced access in the same manner as for the other stressors. The greater the stream reach, the greater potential for beavers to build dams, and thus the greater potential reduced access. This is supported by the fact that Secret Ravine undergoes very negligible grade change throughout its entirety, averaging around two percent (Swanson 2001), which topography suggests that the preferred vegetation for beavers for building dams is abundant and constant throughout all regions. This consists of softwoods such as alders, willow and cottonwood, which correspond to the broad alluvial floodplain geology of the stream reach north of Sierra College (Risk Region B, approximately where the ECORP survey ends) (Holland and Morgan 1868).

5.1.6.2 Assigning Effects Ranks

For the MRRM, experts consulted (H. Freeman, pers. comm. 2002 and C. Lee, pers. comm. 2003), concurred that in order for a barrier to be rendered "passable" the depth of the pool or riffle immediately downstream of a barrier must be at least 150% the height of the dam immediately above it (a.k.a. "the 150% rule").

Criteria for Passage - Water Column	**Rank**
Fish can pass during low and high flow scenarios	0
Fish can pass during low-flow scenario, but not high flow scenario	4
Fish can neither pass during low nor high flow scenarios	6

TABLE 5.10 RANKING CRITERIA FOR REDUCED ACCESS

Given the relatively unpredictable flow conditions described for Secret Ravine in Section 3.4.6, a four is assigned when the barrier would prevent the fish from passing during an average low-flow year, to render a more conservative decision. A zero indicates that fish could pass during high and low flow scenarios; that in effect, the dam has virtually no effect on passage. A six indicates that fish could pass during neither low nor high flow regimes, but not that a barrier would be impassable in the absolute sense, as counts indicate that salmon continue to migrate well into Risk Region C, despite highly obstructive barriers in Risk Region B (**Appendix M-1: Reduced Access** contains the original count data). We assigned final effects scores were based on the highest risk score determined for a barrier per risk region, consistent with the way we treated risk scores for other stressors. This ranking also helps underscore the fact that excessively high dams, particularly if they are located closely together, can compound the risk posed to fish not only in terms of passage (energy costs), which together with delays, creates density dependence downstream, limiting the amount of habitat available to the fish for spawning, and thus increasing the likelihood of straying or superimposition (SRAMP 2001).

Appendix J-6: Reduced Access contains the mathematical models used to derive ranks and a summary table of final ranks, as well as photographs of some of the problematic barriers.

5.1.7 Toxicity

5.1.7.1 Assigning Exposure Filters

Exposure 1 (Stressor from Source filter)
Direct sources of toxicity include impervious surfaces, OHVs, landscape maintenance, orchards and water treatment plants. These sources were assigned a value of 1 for the Exposure 1 filter. No indirect sources were identified.

Exposure 2 (Habitat Exposed to Stressor filter)
Toxicity only affects the benthos, and consequently, the early life stages. Therefore, Exposure 2 equals 1 for the benthos and 0 for the water column.

5.1.7.2 Assigning Effects Ranks

The results showed that all of the water column tests were negative. In the sediment tests, however, *Hyalella azteca* recorded percent mortalities ranging from 21.4 to 60.0%. Since all of the water column tests came back negative, it can be concluded that there is no toxicity in the water and therefore, there is no risk posed to the juvenile and adult phases of chinook salmon. However, in the sediment a range of toxicity was found.

The results are as follows:

Site of sample taken	Risk Region	% Mean Mortality	Standard Error(%)
Confluence	A	53.5	17
Secret Court	B	21.4	18
Dias Lane	C	60	25
King Road	D	41.4	21
Rock Springs Rd.	E	22.5	17
Control	---	5.3	4

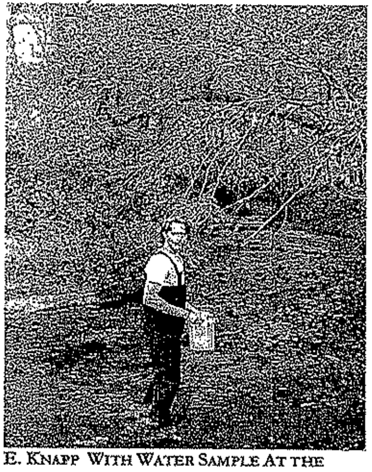
TABLE 5.11 MORTALITY RESULTS FOR TOXICITY

Below are the criteria for ranking toxicity in the benthos. Toxicity was subdivided into four ranges of percent mortality from which ranks were assigned.

Toxicity Range (% mortality)	Rank
< 5.3	0
5.3 – 22.4	2
22.5 – 40	4
> 40.0	6

TABLE 5.12 CRITERIA FOR RANKING TOXICITY IN THE BENTHOS

Appendix J-7: Toxicity contains a summary table for toxicity testing as well as a summary table of final ranks for toxicity in the benthos.



E. KNAPP WITH WATER SAMPLE AT THE CONFLUENCE.

5.1.8 Metals

5.1.8.1 Assigning Exposure Filters

Exposure 1 (Stressor from Source filter)
Impervious surfaces and mining directly contribute to toxicity. Therefore, they each received an Exposure filter of 1. The remaining sources received 0s.

Exposure 2 (Habitat Exposed to Stressor filter)
Metals only occur in the benthos in this analysis, thus they only affect the egg and yolk-sac fry. Therefore, the Exposure 2 filter was assigned a value of 1 for the benthos and a value of 0 for the water column.

5.1.8.2 Assigning Effects Ranks

The results obtained from the seven metals tests described above were as follows:

Risk Region	Ag	Cd	Cr	Cu	Pb	Ni	Zn
A	ND	ND	52	83	36	66	280
B	ND	ND	300	520	270	380	2300
C	ND	ND	140	230	83	210	430
D	ND	ND	110	140	56	100	210
E	9	ND	520	760	420	460	1000

*All values are based on Freshwater CMC (ug/L)

**All values within dotted lines represent concentrations exceeding the reported LC50 values

TABLE 5.13 TOTAL METALS COUNT

The results show that levels of copper, lead, and zinc exceeded the LC_{50} for *Hyalella azteca* in all Secret Ravine sediment samples. These metal concentrations represent near maximum levels that the test organisms may have been exposed to.

Of these seven metals, cadmium (Cd) was not detected in any risk region. Only 9 µg/L of silver (Ag) was detected in one risk region (E). The lack of cadmium and trace amount of silver renders these metals to be innocuous to chinook salmon in Secret Ravine. The metals chromium (Cr) and nickel (Ni) are not considered harmful to chinook in Secret Ravine because they did not represent concentrations exceeding the reported LC_{50} values.

Hardness values were concomitantly obtained from the five risk region samples using titrimetric methods (standard methods). The results for hardness are as follows:

Total Hardness (mg/L as $CaCO_3$)

Risk Region	At Day 0	At Day 9	Mean of Days 0 & 9
A	52	48	50
B	48	64	56
C	76	72	74
D	36	64	50
E	52	72	62
Mean	52.8	64	
Overall mean		58.4	

TABLE 5.14 TOTAL AND MEAN HARDNESS

The hardness mean of the five risk regions in Secret Ravine was 58.4 mg/L $CaCO_3$. Since toxicity decreases with increasing hardness, the toxicity of the metals in our risk regions may be higher than the results and subsequent ranks indicate. Hardness values are listed in this section to further elucidate the effect that metals may have upon Secret Ravine. Hardness values were not used for the assignment of ranks. As stated earlier, the assignment of effects ranks were based upon comparisons made between total metals and dissolved metals. Values in the risk regions, therefore, appear to be significantly higher than recommended levels. Dissolved metal comparisons were not conducted because dissolved metal testing was not performed on Secret Ravine.

Lead Criteria

We assigned a rank of 6 for all values that were greater than the EPA recommended CCC level of 2.5 ug/L for lead. Values under 2.5 ug/L received a 0.

EPA Rec. CCC (ug/L)	**Ranking**
> 2.5 ug/L	6
< 2.5 ug/L	0

FIGURE 5.1 CRITERIA FOR RANKING LEAD

Copper Criteria

We assigned a rank of 6 for all values that were greater than the EPA recommended CCC level of 9.0 ug/L for copper. Values under 9.0 ug/L received a 0.

EPA Rec. CCC (ug/L)	**Ranking**
> 9.0 ug/L	6
< 9.0 ug/L	0

FIGURE 5.2 CRITERIA FOR RANKING COPPER

Zinc Criteria

We assigned a rank of 6 for all values that were greater than the EPA recommended CCC level of 120 ug/L for zinc. Values under 120 ug/L received a 0.

EPA Rec. CCC (ug/L)	**Ranking**
> 120 ug/L	6
< 120 ug/L	0

FIGURE 5.3 CRITERIA FOR RANKING ZINC

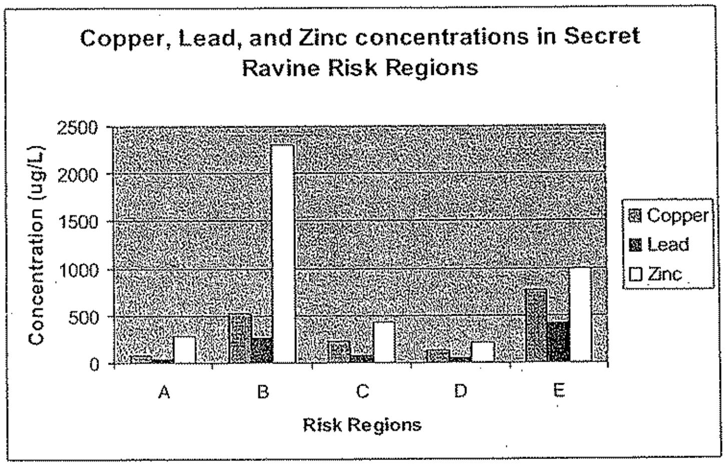


TABLE 5.15 COPPER, LEAD AND ZINC CONCENTRATIONS IN SECRET RAVINE RISK REGIONS

Appendix J-8: Metals contains a summary table of final ranks for metals in the benthos.

5.1.9 Food Supply

5.1.9.1 Assigning Exposure Filters

Exposure 1 (Stressor from Source filter)
Food Supply is affected directly and indirectly by eleven sources. OHVs, water treatment plants, impervious surfaces, and landscape maintenance affect invertebrate populations directly, hence they were assigned an Exposure 1 filter of 1. Channelization, construction and development, dirt and gravel roads, irrigation, and beaver dams affect food supply indirectly, hence they were assigned an Exposure 1 filter of 0.5. Mining and orchards are a special case. When they were present, they would have affected food supply directly. But considering the elapsed time, the Exposure 1 was assigned as 0.5, indicating the time period and the indirect effect they presently have.

Exposure 2 (Habitat Exposed to Stressor filter)
Invertebrates that are a chinook salmon food source are found both in the benthos and the water column, but are only eaten in the water column by juveniles. Consequently, the Exposure 2 value equals 1 for water column because the juvenile stage is affected. The Exposure 2 value equals 0 for benthos.

Inherently this is incorrect because the stress of food supply is realized equally in both the water column and the sediment. But the MRRM requires the capture of life stage in this exposure filter.

5.1.9.2 Assigning Effects Ranks

We assigned a rank for food supply using three criteria: 1) percentage of edible invertebrates, 2) juvenile feeding habits, and 3) amount of riffle habitat for invertebrates (**Table 5.16**).

Rank	Criteria
0	High percentage of edible invertebrates Opportunistic feeding habits Optimal amount of riffle habitat for invertebrates
2	High percentage of edible invertebrates Opportunistic feeding habits Suitable amount of riffle habitat for invertebrates
4	Low percentage of edible invertebrates Opportunistic feeding habits Suitable amount of riffle habitat for invertebrates
6	Low percentage of edible invertebrates Opportunistic feeding habits Little riffle habitat for invertebrates

TABLE 5.16 CRITERIA FOR RANKING FOOD SUPPLY

We calculated the percentage of edible invertebrates **Appendix J-9: Food Supply** using the aforementioned list (**Section 3.4.9**). In Risk Region A 62% of the invertebrates were edible, in Risk Region B 65%, and in Risk Region C 63%. No data was collected in the upper two risk regions, therefore the average percent of edible invertebrates (63%) was used.

When looking at the percentages in each risk region, it becomes apparent that they are very similar. Notably, Fields, Jr. also indicates that species richness did not vary across his sample sites (Fields, Jr. 1999). With the guidance of our CalEPA clients, we determined that these percentages were acceptable levels for food source, and posed no or little risk to juvenile salmon. Due to the similarities across the creek, the same rank should be assigned across all risk regions.

Along with these seemingly high percentages, a look at the feeding habits of juveniles played a role in determining the rank of food supply. Juvenile chinook are "by nature opportunistic, and the riparian zone is pretty healthy, providing them with plenty of food of terrestrial origin" and with "their proclivity for eating small benthic forms and staying along the margins, they would find sufficient food of that type as well" (Fields, Jr., pers. comm. 2002). This indicates that risk due to the amount of food is minimal.

Appendix J-9: Food Supply contains a summary table of final ranks for food supply in the water column and the mathematical models used to derive those ranks.

5.1.10 Predation

5.1.10.1 Assigning Exposure Filters

Exposure 1 (Stressor from Source filter)
The only source of fish predation is introduced fish. It was therefore assigned a value of one for the Exposure 1 filter.

Exposure 2 (Habitat Exposed to Stressor filter)
Both the benthos and water column received a value of one for the Exposure 2 filter since predation occurs on both the early life (eggs and yolk-sac fry) and juvenile life stages.

5.1.10.2 Assigning Effects Ranks

To assign ranks to this stressor, the effect of spotted bass predation on chinook salmon juveniles in the water column was considered. The ranking system used to assign a weight to introduced fish for the MRRM resulted from a series of criteria (**Table 5.17**). First criteria considered whether spotted bass would predate on chinook salmon. To predate on chinook the two fish must occur in the same habitat and the temperature of the water must be above the threshold value of 10° C and salmonids must be part of the spotted bass diet. For any rank to be assigned these three criteria must be satisfied; this occurs in March through June of most years.

Ranks	Criteria
0	No predation on juvenile chinook
2	A low degree of predation, less than 5% decrease in biomass
4	Medium degree of predation, less than 25% decrease in biomass
6	High degree of predation greater than 25% decrease in biomass

TABLE 5.17 CRITERIA FOR RANKING PREDATION

6 Results (Modified Relative Risk Model)

6.1 Evaluating the Entire Watershed

6.1.1 Cumulative Stressor Risk Scores

Summing risk scores across all risk regions per stressor yields cumulative risk scores for each stressor (**Figure 6.1**). Flow scored the highest relative risk when considering both habitats (3924 cumulative risk score). Flow also had the highest cumulative risk score overall (2400 cumulative risk score in the water column).

Sediment and morphology were the next highest scoring stressors (2616 and 3816 cumulative risk score, respectively). Reduced access was the lowest-scoring stressor (96 cumulative risk score).

The reduced access and food supply stressors had cumulative risk scores only in the water column. This is due to the assumption that these two stressors affect only the life stages in the water column. This assumption is accounted for in the Exposure 2 filter.

The toxicity and metals stressors had cumulative risk scores only in the benthos based on the assumption that they only affect life stages in the benthos (also accounted for in the Exposure 2 filter).

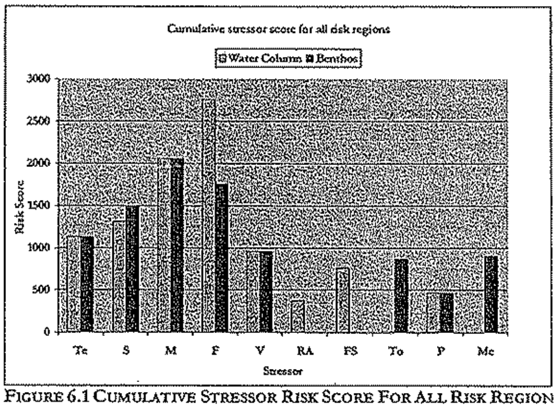


FIGURE 6.1 CUMULATIVE STRESSOR RISK SCORE FOR ALL RISK REGIONS

See **Appendix F: Sources and Stressors** for the list of stressors.

6.1.2 Cumulative Source Risk Scores

Summing across all risk regions per source yields cumulative risk scores for each source (**Figure 6.1**). The impervious surfaces source scored the highest (3104 cumulative risk score). Beaver dams, channelization and mining were the next highest scoring sources (2364, 2100 and 2072 cumulative risk scores, respectively).

Dirt and gravel roads, landscape maintenance, OHVs and irrigation canals all had cumulative source risk scores close to 1800.

Water treatment plants were the lowest scoring source (372 cumulative risk score).

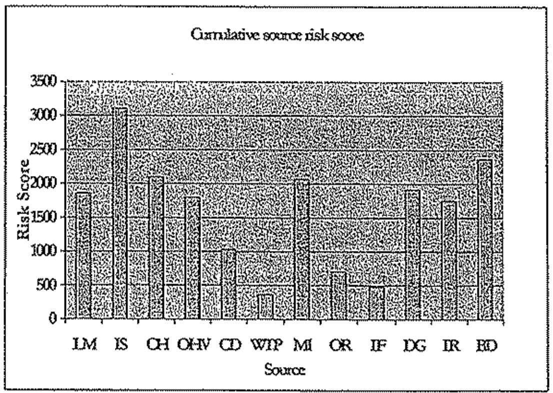


FIGURE 6.2 CUMULATIVE SOURCE RISK SCORE FOR ALL RISK REGIONS

See **Appendix F: Sources and Stressors** for the list of sources.

6.1.3 Cumulative Habitat Risk Scores

Overall, the water column scored a higher total risk than the benthos (**Figure 6.3**). The difference, however, does not seem significant.

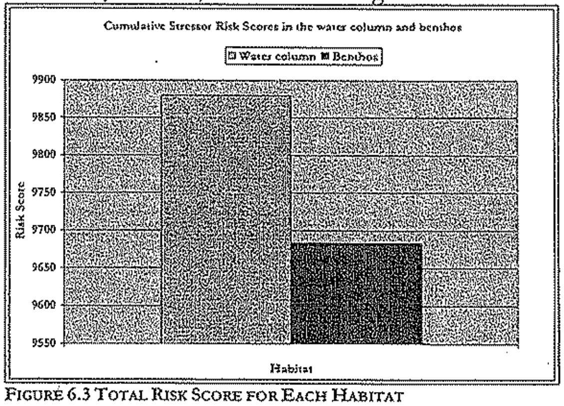


FIGURE 6.3 TOTAL RISK SCORE FOR EACH HABITAT

6.1.4 Comparing Risk Regions

Summing up all stressor scores for each risk region yields the total stressor risk score per region (**Figure 6.4**). These values can be used to compare risk from stressors among all risk regions. Risk Region A scored the highest (7308 total risk score) and Risk Region D the lowest (1840 total risk score).

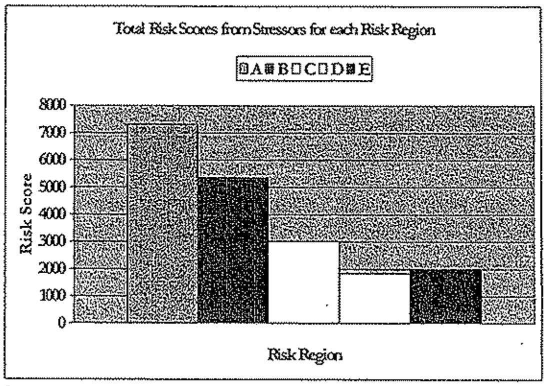


FIGURE 6.4 TOTAL RISK SCORES FROM STRESSORS FOR EACH RISK REGION

6.2 Evaluating the Individual Risk Regions

Total risk scores for stressors (or sources) per risk region can be obtained by summing across all stressors (or sources) in that risk region. These risk scores indicate the stressors (or sources) that pose the highest risk within the region being analyzed.

6.2.1 Risk Region A

6.2.1.1 Stressors in Risk Region A

The morphology and flow stressors had the highest risk scores in Risk Region A (**Figure 6.5**). Altered riparian vegetation was the next highest scoring stressor. Toxicity was the lowest scoring stressor.

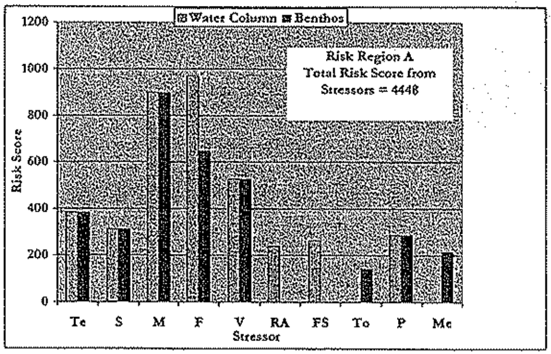


FIGURE 6.5 TOTAL RISK FROM STRESSORS IN RISK REGION A

6.2.1.2 Sources in Risk Region A

Summing risk scores across sources for Risk Region A (**Figure 6.6**) indicates that beaver dams are the source posing the most risk to that region (1404 total risk score). OHVs is the next highest scoring source (1332 total risk score) followed closely by channelization (1260 total risk score). Water treatment plants, orchards and dirt and gravel roads had total risk scores of zero in this risk region.

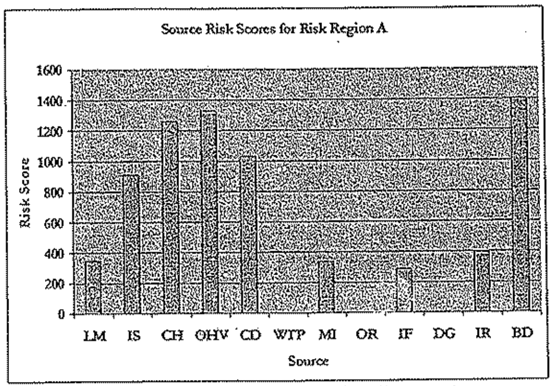


FIGURE 6.6 TOTAL RISK FROM SOURCES IN RISK REGION A

6.2.2 Risk Region B

6.2.2.1 Stressors in Risk Region B

Flow scored the highest stressor risk score (792 in the water column and 528 in the benthos) in Risk Region B (**Figure 6.7**). Sediment and morphology were the next highest scoring stressors.

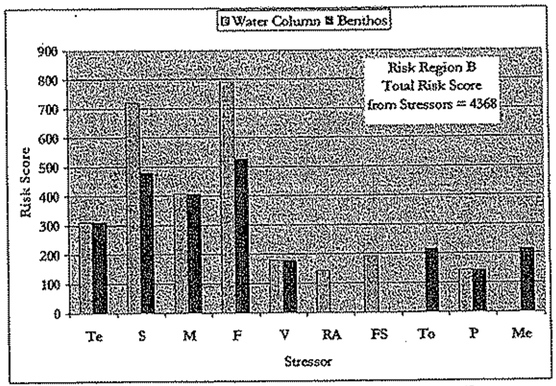


FIGURE 6.7 TOTAL RISK FROM STRESSORS IN RISK REGION B

6.2.2.2 Sources in Risk Region B

The dirt gravel roads source scored the highest (1116 total risk score) in Risk Region B (**Figure 6.8**). Beaver dams and channelization were the next highest scoring sources (960 and 840 total risk score, respectively). Construction and development, orchards and water treatment plants scored zero in this risk region.

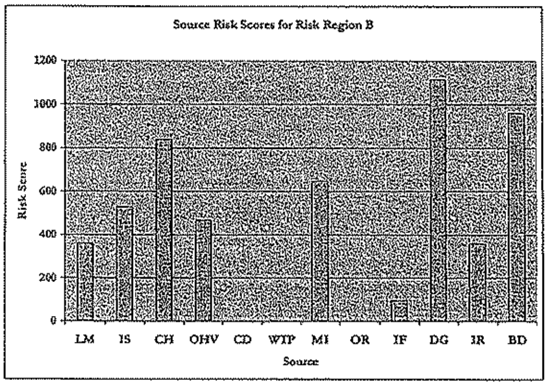


FIGURE 6.8 TOTAL RISK FROM SOURCES IN RISK REGION B

6.2.3 Risk Region C

6.2.3.1 Stressors in Risk Region C

Flow was the highest scoring stressor (384 total risk score in both the benthos and water column) for Risk Region C (**Figure 6.9**). Morphology was the next highest scoring stressor (288 total risk score in both the benthos and water column) and sediment in the benthos also had a high score (360 total risk score). Reduced access scored a zero in this risk region.

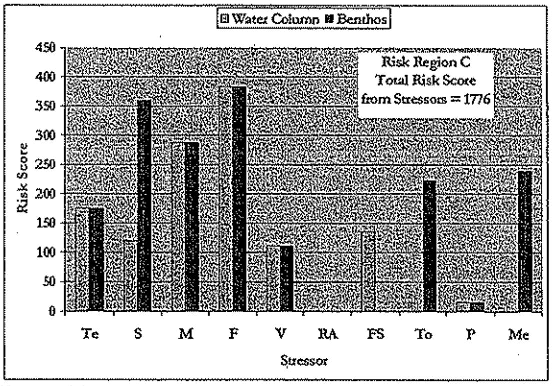


FIGURE 6.9 TOTAL RISK FROM STRESSORS IN RISK REGION C

6.2.3.2 Sources in Risk Region C

Impervious surfaces scored the highest total source risk score (1056 total risk score) in Risk Region C (**Figure 6.10**). Landscape maintenance was the next highest scoring source (720 total risk score) followed by mining (464 total risk score). Channelization, OHVs, construction and development, water treatment plants and beaver dams all scored zero for source total risk score in this risk region.

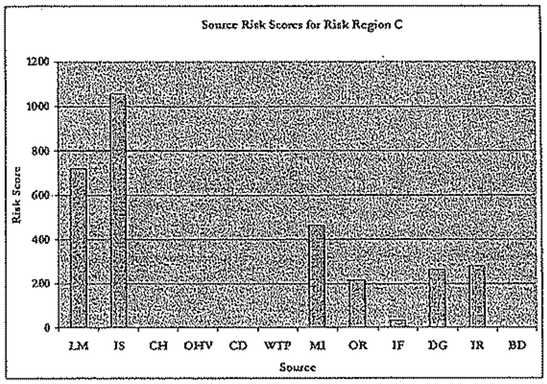


FIGURE 6.10 TOTAL RISK FROM SOURCES IN RISK REGION C

6.2.4 Risk Region D

6.2.4.1 Stressors in Risk Region D

Morphology was the highest scoring stressor (240 total risk score in both the water column and benthos) in Risk Region D (**Figure 6.11**). Flow in the water column also had a high score (288 total risk score). Reduced access scored a zero in this risk region.

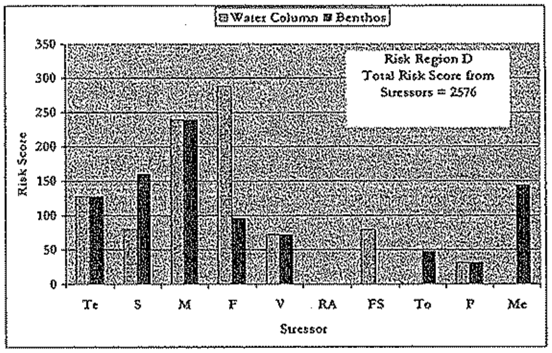


FIGURE 6.11 TOTAL RISK FROM STRESSORS IN RISK REGION D

6.2.4.2 Sources in Risk Region D

Irrigation canals scored the highest source risk score (480 total risk score) in Risk Region D (**Figure 6.12**). Mining was the next highest scoring stressor (416 total risk score). Channelization, OHVs, construction and development, water treatment plants and beaver dams scored zero for total risk in this risk region.

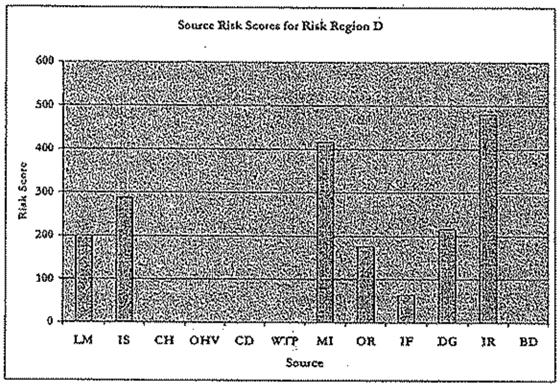


FIGURE 6.12 TOTAL RISK FROM SOURCES IN RISK REGION D

6.2.5 Risk Region E

6.2.5.1 Stressors in Risk Region E

Morphology scored the highest (228 total risk score in both the water column and the benthos) in Risk Region E (**Figure 6.13**). Flow in the water column and toxicity also scored high (324 and 240 total risk scores, respectively). Reduced access and predation scored zeroes in this risk region.

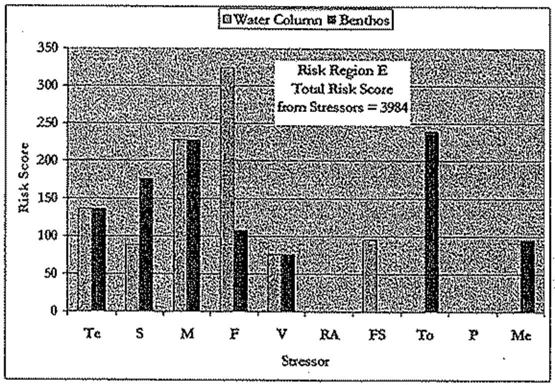


FIGURE 6.13 TOTAL RISK FROM STRESSORS IN RISK REGION E

6.2.5.2 Sources in Risk Region E

Water treatment plants scored the highest risk score (372 total risk score) in Risk Region E (**Figure 6.14**). Dirt and gravel roads, impervious surfaces and orchards were the next highest scoring sources (approximately 320 total risk score for each). Channelization, OHVs, construction and development, introduced fish and beaver dams all scored zero in this risk region.

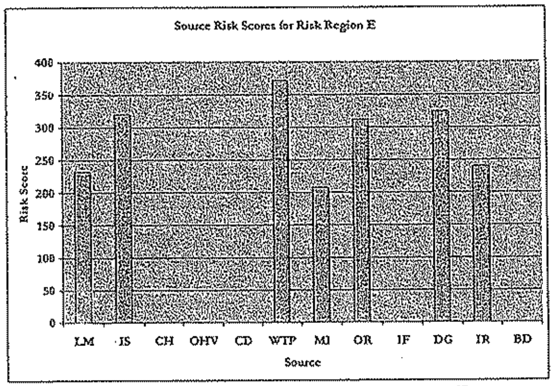


FIGURE 6.14 TOTAL RISK FROM SOURCES IN RISK REGION E

7 Uncertainty (Modified Relative Risk Model)

Uncertainty analysis for qualitative data was based on Best Professional Judgment (BPJ) and was determined by the following three criteria: 1) difficulty of evaluation; 2) confidence of evaluator; 3) number of observations (**Table 7.1** and **Table 7.2**). Qualitative uncertainty was established for each applicable source and stressor. It should be noted that best professional judgment was used for some quantitative data as well. Monte Carlo techniques were then applied for our uncertainty analyses to assess the parameters of our uncertainty in the risk predictions (**Section 7.4**).

	Data Points	**Natural Variability**	**Confidence Level**
High Uncertainty	Low # of data points	High natural variability in system	Low confidence in methods
Medium Uncertainty	Intermediate # of data points	Intermediate variability in system	Some confidence in methods
Low Uncertainty	High # of data points	Low natural variability in system	High confidence in methods

TABLE 7.1 UNCERTAINTY CRITERIA FOR QUANTITATIVE DATA

	Evaluation	Confidence Level	Observations
High Uncertainty	Very difficult evaluation	Low confidence in observer	Low # of observations
Medium Uncertainty	Moderately difficult evaluation	Some confidence in observer	Intermediate # of observations
Low Uncertainty	Relatively easy evaluation	High confidence in observer	High # of observations

TABLE 7.2 UNCERTAINTY CRITERIA FOR QUALITATIVE DATA

7.1 Uncertainty for Effects Ranks

The uncertainty associated with the effects ranks pertains to the quantity and quality of data, as mentioned above. We utilized these uncertainties to conduct a sensitivity analysis to assess whether or not changing the ranks associated with the stressor would result in a change in risk scores and how this would affect the overall prioritizing of stressors. This sensitivity analysis (Monte Carlo analysis) is summarized in **Section** 7.4. The assigned uncertainties for each stressor are described below.

Sediment

Low uncertainty was applied to the benthos for all risk regions. Many quantitative data points were accumulated for sediment in addition to significant anecdotal and observation data (Swanson 2000, Li and Fields, Jr. 1999). Medium uncertainty was applied to the water column for all risk regions. Although turbidity data does exist, it is not sufficiently detailed for accurate assessment.

Flow

High uncertainty was applied to both the benthos and the water column for all risk regions. Utility of flow data is low the scientific literature does not report robust relationships that link flow and mortality. Available data on flow is from Stacy Li percolation studies. This data exists for only three sites and records just one year of record.

Morphology

Medium uncertainty was applied to both the benthos and the water column for all risk regions. Although detailed, region specific data does exist, it is only for the two lower risk regions. Other data, Barbara Washburn survey and Stacy Li records, is limited for the rest of the risk regions.

Temperature

Medium uncertainty was applied to both the benthos and the water column for all risk regions. Sequential data was available for 12 months in risk region B. Other data points were available for risk regions A and E. Quantitative is limited by data points and was not representative of all risk regions. Extrapolation was utilized.

Altered Riparian Vegetation

High uncertainty was applied to the benthos and water column for all risk regions. All data concerning altered riparian vegetation is anecdotal and/or observational. There was no abundance data for invasive plant species and no detailed plant list exists for Secret Ravine.

Reduced Access

High uncertainty was applied to the benthos and water column for all risk regions. All available data points are located in risk regions A and B. Although the effects of beaver dams are straightforward (measured in terms of fish passage), there are numerous secondary effects that are more difficult to measure. High natural variability is associated with assessing fish passage given reduced access.

Toxicity

Medium uncertainty was applied for the benthos and the water column for all risk regions. *Hyalella* toxicity testing was performed on sediment from the Secret Ravine watersheds in December 2002 at the Aquatic Toxicology Laboratory at the University of California, Davis. Although the region specific data exists for all risk regions, samples were not taken directly after the first flush when most toxic chemicals are present. *Ceriodaphnia* toxicity testing was performed on the water column at all five risk regions and was subject to medium uncertainty for the same reason as the *Hyalella* sediment testing.

Food Supply

Uncertainty in the stressor rank was determined by the availability of data and the use of best professional judgment. There was a high confidence associated with the quality of the benthic macroinvertebrate data collected. It was collected by reliable sources (DCC), using reliable and published methods(California Stream Bioassessment Protocol), and there was a sufficient number of sampling points over a span of three years. Reliable information from a related study, Li and Fields, Jr. 1999, provided a sound basis for best professional judgment. As a result, uncertainty for this stressor was low across all risk regions for both the water column and the benthos.

Predation

High uncertainty was applied to the benthos and water column for all risk regions. Most data concerning fish predation was anecdotal and/or observational. The available population data included only one year for chinook salmon and one year for spotted bass. In addition, no data exists for both bass and salmon in the same year. Therefore much of the analysis was based on projection and best professional judgment.

7.2 Uncertainty for Sources

A sensitivity analysis similar to that conducted for the effects ranks was not conducted on the source ranks due to the fact that the source ranks were based on data that contained a relatively lower degree of uncertainty. Specifically, gross estimates of area (for non-point sources) and frequency (for point sources) could be more easily transferred into ranks than estimates of percent mortalities or habitat losses. In general, however, we concluded that risk scores associated with the legacy sources (mining and orchards) are fairly tenuous since they have not been active or abundant for a long period of time.

7.3 Uncertainty for Habitat Ranks

The alternative habitat-ranking scheme involved ranking habitat based on area of the risk region rather than stream length. The ranks underneath both schemes were as follows:

Original ranking scheme (Stream length)						
Risk Region		A	B	C	D	E
Stream Length (feet)		13152	18872	5995	9009	2171
Habitat	WC	6	6	4	4	2
	BE	6	6	4	4	2
Alternative ranking scheme (Area)						
Risk Region		A	B	C	D	E
Risk Region Area (Acres)		2899	3472	2724	1587	3765
Habitat	WC	4	6	4	2	6
	BE	4	6	4	2	6

TABLE 7.3 ALTERNATIVE RANKING FOR HABITAT

Changes in risk scores for both stressor and sources were insignificant under the alternative habitat-ranking scheme (**Figure 7.2** and **Figure 7.4**). Risk scores simply increased consistently for all stressors.

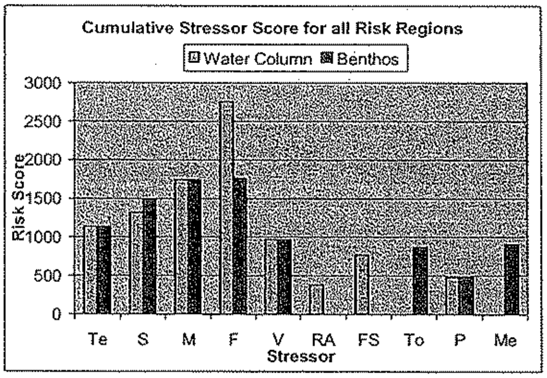


FIGURE 7.1 CUMULATIVE STRESSOR RISK SCORES (ORIGINAL)

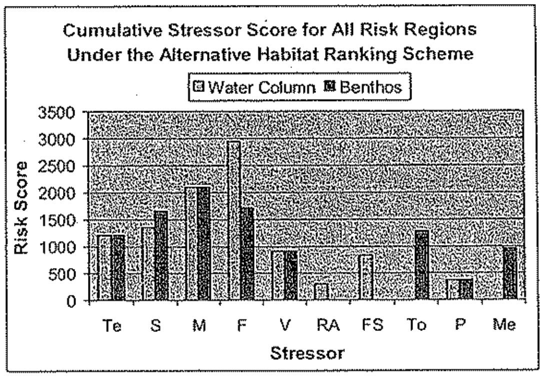


FIGURE 7.2 CUMULATIVE STRESSOR RISK SCORES (ALTERNATIVE)

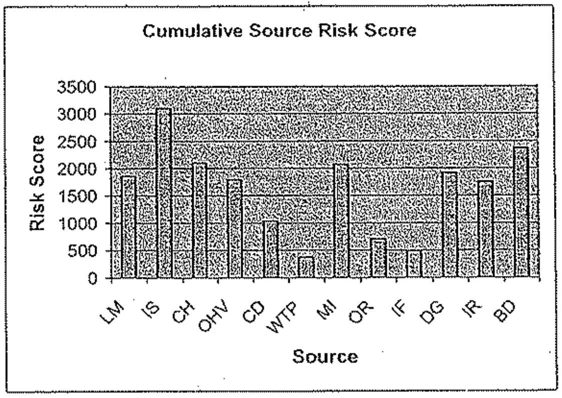


FIGURE 7.3 CUMULATIVE SOURCE RISK SCORES (ORIGINAL)

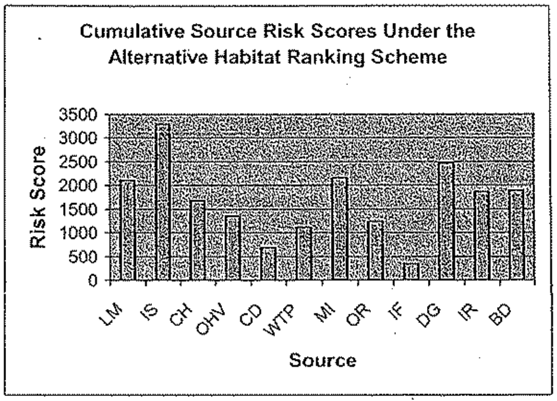


FIGURE 7.4 CUMULATIVE SOURCE RISK SCORES (ALTERNATIVE)

A similar alternative ranking scheme was applied to all non-point sources. No significant differences in stressor risk scores occurred.

7.4 Monte Carlo Analysis

Monte Carlo techniques were applied for our uncertainty analyses to assess the parameters of our uncertainty in the risk predictions. To determine output variables, Monte Carlo uncertainty analysis combines assigned probability distributions of input variables (Burmaster and Anderson 1994). In the case of the sub-watershed risk assessment, the input variables are the ranks and associated filters with high and medium uncertainty and the output variables are the corollary risk estimates.

Designations of low, medium, or high uncertainty were applied to each source, habitat rank, exposure, and effects filter based on available data and best professional judgment. We assigned discrete probability distributions to ranks and filters with medium and high uncertainty according to the criteria in the following tables.

Uncertainty Analysis Monte Carlo input distributions for ranks with medium and high uncertainty:

Assigned Rank Value	*Uncertainty*	*Assigned Probability (%) for Ranks*			
		0	2	4	6
0	High	60	20	20	0
0	Medium	80	10	10	0
2	High	0	60	20	20
2	Medium	0	80	10	10
4	High	0	20	60	20
4	Medium	0	10	80	10
6	High	0	20	20	60
6	Medium	0	10	10	80

TABLE 7.4 MONTE CARLO DISTRIBUTIONS FOR UNCERTAINTIES

The Monte Carlo analysis produced a variety of distributions for our stressor data. Four stressors showed means that matched the predicted risk scores exactly for either the water column or the benthos. These risk components reflected low uncertainty and high confidence for our MRRM predictions. These stressors were: sediment (BE), food supply (BE), toxicity (WC), and metals (WC).

Sediment in the benthos recorded low uncertainty due to a large number of data points, the recent collection of the data, and the peer-reviewed sampling methods that were conducted.

Food supply in the benthos showed low uncertainty due to the absence of juvenile chinook in this habitat. There is high confidence that juveniles are not affected by the food supply in the benthos.

Toxicity and metals showed low uncertainty in both the water column and the benthos. Tests at the Aquatic Toxicology Lab at UC Davis were all negative for toxicity in the water column. For the benthos, the data collection was thorough and analyses were conducted professionally.

Metals revealed narrow distributions in the water column and benthos because the metals, which adsorb to sediment particles, tested positive in the benthos and were absent in the water column.

Eight stressors had means that did not match the predicted risk score for the water column, benthos, or both. Of these eight stressors, four exhibited wide distributions with differences over 1200. The wide distributions suggested high uncertainty and low confidence. Temperature had a wide distribution in the benthos because the data was for the water column only. Temperature data was extrapolated for the benthos.

Sediment showed a wide distribution in the water column because assumptions had to be made about the duration of turbidity measured in Secret Ravine. The data stemmed from event-based sampling and did not span adequate time for robust analysis.

Flow and vegetation exhibited wide distributions for similar reasons. Neither stressor had adequate data in Secret Ravine. Without data, these stressors were highly uncertain as reflected in the Monte Carlo uncertainty analysis.

Stressor	WC & BE	Risk Score	Mean	Upper C.I.	Lower C.I.	*Difference*
Temperature	WC	2000	2239	2688	1792	896
	BE	2288	2239	2928	1648	1280
Sediment	WC	1840	1638	2288	912	1376
	BE	1712	1712	1712	1712	0
Morphology	WC	1968	2378	2736	1632	1104
	BE	2736	2390	2736	1760	976
Flow	WC	2464	2379	3216	1536	1680
	BE	2400	2473	3216	1680	1536
Vegetation	WC	2240	2029	2752	1296	1456
	BE	2352	2024	2864	1312	1552
Reduced Access	WC	64	67	96	32	64
	BE	32	69	96	32	64
Food Supply	WC	1360	1191	1648	912	736
	BE	0	0	0	0	0
Toxicity	WC	0	0	0	0	0
	BE	1344	1344	1344	1344	0
Introduced Fish	WC	272	327	448	192	256
	BE	304	315	480	192	288
Metals	WC	0	0	0	0	0
	BE	1872	1872	1872	1872	0

TABLE 7.5 MONTE CARLO ANALYSIS RESULTS

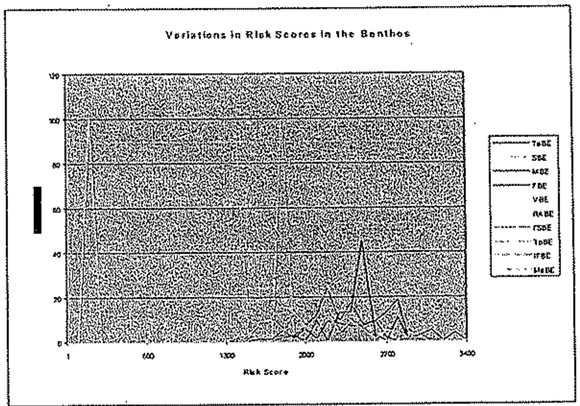


FIGURE 7.5 MONTE CARLO RESULTS FOR STRESSORS IN THE BENTHOS

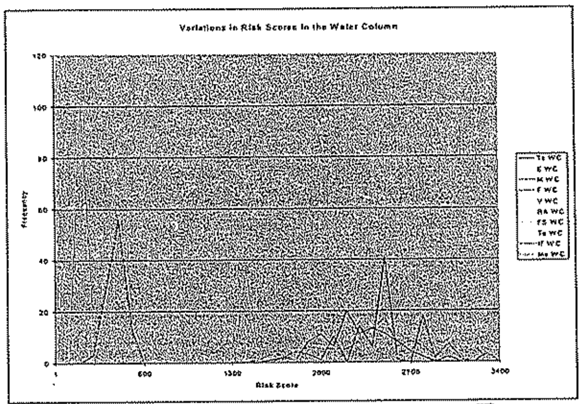


FIGURE 7.6 MONTE CARLO RESULTS FOR STRESSORS IN THE WATER COLUMN

8 Risk Analysis Methods (Stressor-Driven Risk Model)

8.1 General Methods and Modifications (SDRM)

As with the MRRM model, the main objective of the Stressor Driven Risk Model is to determine the most significant stressor and source in the Secret Ravine watershed. To attain this goal the stressor model quantifies stress in terms of effect on fish populations. The stressors produce a certain effect on the chinook salmon population. To better discern the effect of the stressor, this effect has been translated into percent mortality or percent reduction in habitat for each life stage. For the sake of flow, the 'Risk Region' delineations referred to in the MRRM are retained in the SDRM analysis

8.1.1 Evaluating Stressors

Where e = early life stage, j = juvenile and a = adult.

Percent Effect $_{\text{(per life stage per stressor)}}$ **= % mortality or % habitat reduction**
(Based on dose-response curves, reference values or habitat loss estimates)

Total Percent Effect $_{\text{(per stressor)}}$ $= 1 - [(1 - PE_e) \times (1 - PE_j) \times (1 - PE_a)]$
(TPE and PE are expressed here as a number between 0 and 1.)

PE is the effect of a stressor on a particular life stage, while TPE is the integrated effect across all life stages.

*PE: Percent Effect; TPE: Total Percent Effect

EQUATION 2 TOTAL PERCENT EFFECT EQUATION (SDRM)

Once the percent effect of an individual stressor has been determined, the percent effect for each life stage was multiplied together. In essence, the product simulates the percent survival of chinook salmon through the three life stages in Secret Ravine. The percent mortality result is subtracted from one and multiplied through the three life stages. This value is subtracted again from one, rendering a total percent survival. Mortality in this model refers to mortality that is stressor-induced, above and beyond the natural mortality of the salmon.

To illustrate, consider sediment in Example A (**Figure 8.1**). The percent mortality due to sediment during the early egg and alevin phase was determined to be 67% and the percent mortality estimated for the juvenile phase is 20%. A literature search uncovered no evidence that sediment causes mortality in adult salmon, therefore the effect is considered to be 0% for this phase. The percent mortality result is subsequently subtracted from one and multiplied through the three life stages. This renders a total percent survival.

Example A:

Ranking stressors:

PE_e (sediment) = % mortality of eggs = 67%
PE_j (sediment) = % mortality of juveniles = 14%
PE_a (sediment) = % mortality of adults = 0%

TPE (sediment) = 1 – [(1 – 0.67) x (1 – 0.14) x (1 – 0.00)] = 0.72
(risk score is not a rank rather a percent effect)

*PE: Percent Effect; TPE: Total Percent Effect

FIGURE 8.1 EXAMPLE A USING TOTAL PERCENT EFFECT EQUATION (SDRM)

8.1.2 Total Percent Effect Example

8.1.3 Evaluating Sources

We used the analysis described in the MRRM to identify the links between sources and stressors in the Secret Ravine watershed. However, we relaxed the assumption of the MRRM that all sources have the same intensity of effect. For the SDRM, for example, we did not assume that 1 acre of impervious surface is equal to 1 acre of historic orchard cultivation or 1 acre of dirt and gravel roads when evaluating effects on chinook salmon. Instead, each source was assigned a contribution category depending on whether that contribution per unit area (for non-point sources) or instance (for point sources) was low, medium, or high.

We limited our source analysis to sources associated with the three stressors with the most significant stressor effect. Having determined the contribution of a certain source in relation to a stressor, we next determined how much effect may be associated with each source. For each non-point source a combination of the contribution category, aerial extent, and best professional judgment was used to approximate effect for a stressor. For the point sources, the effect on a stressor was based on the degree of contribution, frequency, and best professional judgment.

8.1.4 Assumptions

In the absence of complete data sets, a few assumptions were required to construct a comprehensive ecosystem model. Two assumptions utilized in this model directly influenced the approximation of the effect that stressors had on life stages. The effect per life stage extrapolates percent effect based on data from the site; where direct data is unavailable, we use estimates available in the scientific literature. Another assumption that allowed the use of habitat loss to approximate effects is that some linear relationship exists between mortality of salmon and the loss of habitat salmon use to support integral life functions such as spawning, early growth and survival. This effectively assumes that density dependent mortality scales linearly with habitat availability, which may not be true for all processes. Finally, as in the MRMM, we assume that the full extent of the sources and stressors that effect chinook salmon in Secret Ravine have been included in the model. In particular, we do not consider the effects to the Secret Ravine salmon population when juvenile fish travel to the Pacific ocean and return via the same route to Secret Ravine. The only adult stressors considered are those that would prevent the fish from reaching or finding spawning habitat once the fish have entered the Secret Ravine watershed.

9 Risk Analysis and Risk Characterization for Stressors (SDRM)

9.1 Stressors

9.1.1 Sediment

In the SDRM, we calculated an average percent mortality to the early life stage (in the benthos) for the entire watershed using the sediment data mentioned above (**Appendix J-1: Sediment**). Grain size distributions were used to calculate percent mortalities (Tappel and Bjornn 1983) for ten sampling sites. These mortalities were then averaged to assess impacts to the entire watershed. We calculated the average percent mortality for the entire watershed to be 67% for the early life stages (eggs and yolk-sac fry).

We estimated average turbidity values for the entire watershed using the DCC turbidity data (DCC 2002, **Appendix J-1: Sediment**) to assess impacts from sediments suspended to the juvenile and adult life stages. The same assumptions as mentioned in Section 3.4.1 were made regarding duration of exposure and conversion from NTU to milligrams of suspended sediment (**Section 3.4.1**). We then calculated percent mortalities from this data set using methods developed by Allen et al 1996. The juvenile life stage was the only life stage estimated to have SEV values, as described in Section 3.4.1. These values were high enough to cause mortality. Average mortality values for the juvenile life stage were roughly 20%.

Next we calculated total percent effects (TPE) for sediment based on these two data sets with the assumption that turbidity is affecting the juvenile and adult life stages and the sediment in the benthos is affecting the early life stages. Thus, we calculated the TPE for sediment to be 74%.

9.1.2 Flow

As mentioned earlier, the lack of flow data limits the analysis of the flow stressor. In the SDRM, we calculated TPEs based on observational data specific to flow levels (Li and

Fields, Jr. 1999). This data set included observational estimates of flow depths and velocities specific to all three life stages. The percentages of depths below a minimum threshold and velocities above a maximum threshold were assumed to be equivalent to percent mortalities to the life stage being assessed. We calculated a PE of 27% for the juvenile life stage and a PE of 6% for the adult life stage yielding a TPE for flow of 31%.

9.1.3 Morphology

We used data from the entire watershed (Li and Fields, Jr. 1999) to assess alterations to stream morphology in the SDRM. The criterion used states that a stream (or stream reach) is rated high quality if it contains more than 30% pools by length (KRIS 2003). We assumed that a similar percentage of riffles and runs should exist in Secret Ravine (each being roughly one third). For the analysis, pools were regarded as juvenile habitat and riffles as early life stage habitat. Due to the limited residence time of spawning adults, and to avoid the possibility of double counting, no criteria was set for the adult life stage.

A deviation from this criterion (33% pools or riffles) indicated a loss of potential habitat and was thus the estimate of the PE. The data indicated an average percent riffles (early life stage habitat) by length of 20% and 17% for pools (juvenile habitat). Thus, the resulting TPEs were 13% for the early life stages and 16% for the juvenile life stage.

9.1.4 Temperature

In the SDRM, temperature is characterized by the number of times that Secret Ravine temperatures exceeded maximum weekly optimal temperatures. As stated in **Section 3.4.4**, maximum weekly optimal temperatures were slightly exceeded for the juvenile life stage (May) and the adult life stage (September & October). Although these temperatures exceeded maximum weekly optimal temperatures, they did not exceed the threshold for incipient mortality (Armour 1991). Since no percent mortalities were determined via dose-response curves, no life stages were affected for the SDRM.

9.1.5 Altered Riparian Vegetation

Overall, the condition of Secret Ravine in the broader context of foothill streams may be evaluated as fair. The basis of this evaluation comes from the habitat suitability study done in 1999 on Secret Ravine by Li (Li et al. 1999) (**Section 3.4.5**). The creek has a fair degree of riparian cover, a fair degree of riparian zone extent, and only a few areas where the riparian zone narrows to less than a 100-foot buffer. Within the watershed itself, however, gradations in riparian zone extent, areas with a riparian zone less than the ascribed riparian buffer of 100-ft, may indicate gradations in vegetation quality between risk regions. Therefore the percent effect on salmon habitat of altered riparian vegetation was considered the percent of the creek that were degraded due to a narrow riparian zone or approximately 10%.

Total Length of Incidence/Total Length of Stream	(5,595 ft)/(58,499 ft)=10%

EQUATION 3 CRITERIA FOR ANALYZING ALTERED RIPARIAN VEGETATION (SDRM)

9.1.6 Reduced Access

In the SDRM, Reduced Access is still embodied in the ability of a fish to pass a particular barrier, but actual counts are used to obtain more accurate estimates of the number of fish that successfully pass (**Appendix M-1: Reduced Access**). It is possible to grossly compare the average number of fish passing from risk region to risk region since barriers can be the only stressor impeding adult immigration in a single run, other than substrate quality.

Secret Ravine is not only unusually small for fall-run, but relatively distant from the Sacramento main stem for its size. Because the adult females usually move just upstream from a nest in order to build another nest within her redds, burying her eggs with excavated upstream material (Allen and Hassler 1988), it is reasonable to expect that earlier arrivals select the most downstream areas for spawning. This would make available downstream habitat increasingly limited as the fall-run season progresses. Since the count years span a range of different precipitation scenarios (1997-1998 was an El-Nino year, 1999 and 2000 were dry years), the averages of the counts also inherently contain different possibilities for flow. We mapped the survey reaches on Secret Ravine from the DCC count data (**Appendix M-1: Reduced Access**) and matched them against known barriers and spawning sites (**Appendix B: GIS Maps**). It is also reasonable to expect that the count trends reflect the reality of the creek from one fall season to another because beaver dams generally stay in the same location for several years at a time. "After a careful examination of some hundreds of these structures, and of the lodges and burrows attached to many of them, I am altogether satisfied that the larger dams were not the joint product of the labor of large numbers of beavers working together, and brought thus to immediate completion; but, on the contrary, that they arose from small beginnings, and were built upon year after year until they finally reached that size which exhausted the capabilities of the location" (Morgan 1868, p. 83).

Although there are numerous primary and secondary effects of reduced access as caused by barriers on small streams, we analyzed only those stressors associated with the potential to cause mortality to the different life stages. Superimposition of redds, predation on juveniles, exertion costs and the potential for dam blowout, were assessed in terms of percent mortalities through a combination of quantitative criteria from the literature and expertise from regional biologists.

PE(egg) was evaluated in terms of potential mortality due to superimposition and potential mortality due to blowout, as given by the formulae below.

PE(egg)= NP | (% no pass adults)*P(super)*No. females*Mort(super)

EQUATION 4 EQUATION FOR PERCENT EFFECT TO EGG AS CAUSED BY SUPERIMPOSITION

where:
P = pass via "150% rule" (supra **Section 5.1.6.2**)
NP = no pass via counts**NP |** connotes "given not having passed"
P(super) = probability of superimpostion of redds (whole watershed)
No. females = number of attempting spawning adults
Mort(super) = mortality to eggs due to superimposition

PE(egg) =NP | (% pass)*P(blow)*P(high flow)*No. females*Mort(blow)

Equation 5 Equation for Percent Effect to Egg as Caused by Blowout

where:
NP = no pass via counts
P(blow) = probability of blowout of beaver dams (based on no. of dams per reach)
P(high flow) = probability of high flows over one average life cycle (whole watershed)
No. females = number of attempting spawning adults
Mort(blow) = mortality to eggs due to blowout

Figure 9.1 Equations for Percent Effect to Egg From Reduced Access (SDRM)

The number of adults that did not pass per survey reach based on the 1997-2002 counts (**Appendix M-1: Reduced Access**), was multiplied by the probability of superimposition. The probability of superimposition was then multiplied by the number of females expected in the adult population (0.5), and then multiplied again by 0.33, an established estimate of the number of eggs anticipated to be lost due to superimposition of redds (McNeil 1964 and Fukushima 1998).

While there has been no direct observation of redds superimposition on Secret Ravine, the literature consensus is that it is highly likely when density dependence plays a role. While Secret Ravine does not experience density dependence per se, (the size of the creek alone could easily accommodate more than the hundred-plus average spawners), lack of quality substrate creates conditions of density dependence. Indeed, communication from Eric Gerstung via Dr. Rob Titus revealed that he "didn't think Secret Ravine would support 600 Chinook spawners anymore because of continued habitat degradation, especially in the form of decomposed granite" (R. Titus, pers. comm. 2003). And lack of available spawning habitat is one of the precursors to superimposition (Bartholow 1996). It must also be noted that the average area of the stream widths in stretches downstream of each of the barriers in this analysis is $16m^2$. This is considerably smaller than the 25 square meters average that a Central Valley fall-run chinook female uses to build her redds.

Thus, as mentioned above, substrate quality, the average area needed to build a redd, the abundance of known and/or historic spawning sites between difficult-to-pass barriers and the number of adults attempting to spawn in given reaches were used to assess the probability of superimposition by females on Secret Ravine (**Section 3.4.6**). The stretch from the Confluence to Brace Road (Loomis Park Basin) has both high density of known and/or historic spawning sites, three difficult-to-pass barriers under low flows, and poor substrate (**Appendix J-1: Sediment**). Brace Road to King Road was assessed in this appendix to have 0% survival of eggs attributed to excessively fine sediment. Thus, only the stretch from King Road to Rock Springs Road can be considered free from the conditions necessary to generate superimposition, even though negligibly few fish attempt to spawn there (**Appendix M-1: Reduced Access**). The region from Rock Springs Road to the headwaters has not been utilized at all since the 1970s for spawning (B. Washburn, pers. comm. 2002), and the reach from King Road to Rock Springs Road was assessed no potential for superimposition. Thus, the likelihood for superimposition on Secret Ravine for the entire watershed was assessed as 75% for the whole watershed.

In the McNeil study, he determined that "mortality was caused for the most part by superimposition of redds". He determined that the estimated equivalent number of females able to spawn safely (i.e. without superimposing their redds), was consistently less than the number of females spawning, when the density of females was higher than 24 per 100 meters squared. While the fish are not nearly as dense in Secret Ravine by a factor of 1,000 (an equivalent density might be reached at 24 fish per 100,000 square meters or 25 acres), chinook salmon are on average larger and longer than the pink salmon McNeil observed, and would be expected to build comparably bigger redds by a factor of 10, which the chinook females also spend more time defending (Allen and Hassler 1986). These factors, together with others mentioned above in **Section 3.4.6**, including particularly poor substrate where the highest density of fish choose to spawn, enable us to estimate mortality associated with superimposition to be 33% (as determined by McNeil, 1964 for pink salmon) for both risk regions.

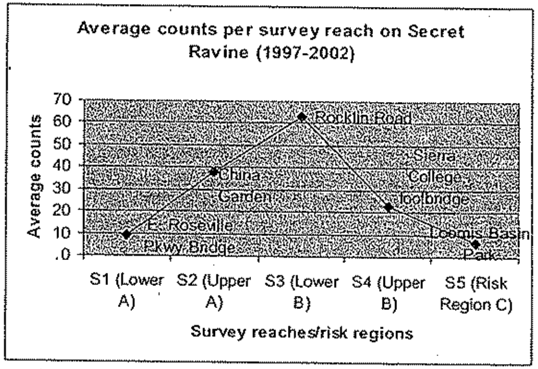


FIGURE 9.2 AVERAGE COUNTS PER SURVEY REACH ON SECRET RAVINE (1997-2002)

PE(egg) was also evaluated in terms of likelihood of blowout by beaver dams. Again, the number of adults not being able to pass was used and multiplied by beaver dams per region likely to be susceptible to high flows based on their size (threshold of three feet). This was multiplied by the number of females and the number of eggs expected to be killed during a blowout event (100%). Adult salmon live on average from 3-6 years and Chris Lee, who led a survey of habitat suitability for nearby Miners Ravine, with a similar extent of beaver dams, reported that beaver dams would probably be subject to blowout at 1or 2-year-storm events (Lee, pers. comm. 2003). Thus, 33% of the time, over the life-cycle of the fall-run we would expect the kind of high flows that cause blow out on Secret Ravine.

PE(juv) = NP | (% no pass juveniles)*P(pred)*P(low flow)*Mort(pred)

where:
NP = no pass via counts **NP |** connotes "given not having passed"
P(pred) = probability of predation by bass, given delay
P(low flow) = probability of low flows over one average life cycle
Mort(pred) = mortality to eggs due to predation

FIGURE 9.3 EQUATION FOR PERCENT EFFECT TO JUVENILES FROM REDUCED ACCESS (SDRM)

The risk to juveniles PE(juvenile) was evaluated in terms of the risk posed by predation during low flows, where bass are known to congregate in downstream pools below small dams as juvenile salmon spill over the dams (DCC 2001). Both Chris Lee of DWR and Rob Titus of CDFG estimated that juveniles would have no problems emigrating at high flows and that juveniles might become entrained behind some barriers at low flow, but that the presence of barriers of this magnitude would not exacerbate the numbers of juveniles that already emigrate relatively far into the spring season (Lee, pers. comm. 2003 and Titus, pers. comm 2003).

PE(adult) = P | (% pass adults)*M(energy)

where:
P = average percent adults, given that they pass **P |** connotes "having passed"
Mort(energy) = mortality to adults due to energy costs associated with barrier navigation

EQUATION 6 EQUATION FOR PERCENT EFFECT TO ADULTS AS CAUSED BY ENERGY COSTS (SDRM)

PE(adult) reflects energy costs associated with adult upstream migration in navigating particularly difficult to pass barriers, once passed. Although energy costs are associated with adult upstream migration against particularly hard to pass barriers, the total percent effect for adults PE(adult) was assessed to be zero in terms of direct pre-spawning mortality (i.e. they should have been able to reproduce).

9.1.7 Toxicity

In the SDRM, toxicity is still characterized by the measure of contaminants in a watershed as stated in **Section 3.4.7**. Toxicity tests were performed on samples from five sites in Secret Ravine. For the SDRM, mean mortality was calculated by averaging all the percent mortalities incurred to *Hyallela azteca*. This single numerical value represents the average mortality of the egg/yolk-sac fry stage in Secret Ravine. This value was calculated with the following equation:

$$\boxed{\frac{\text{Mean \% mortality} * \text{Length of Reach}}{\text{Total Length of Stream}}}$$

EQUATION 7 EQUATION FOR PERCENT EFFECT FOR TOXICITY (SDRM)

The percent mortality value was multiplied by the length of the reach where the sample was taken. This value was subsequently divided by the total length of the stream. This rendered a composite percent mortality number for the entire stream.

9.1.8 Metals

Metals were not analyzed separately for the SDRM. Since the toxicity tests conducted at UC Davis included the effects of metals in Secret Ravine, the percent mortalities for metals thus fell under the umbrella of toxicity in the SDRM.

9.1.9 Food Supply

To characterize percent mortality to juvenile salmon in Secret Ravine, three criteria were used: 1) percentage of edible invertebrates, 2) juvenile feeding habits, and 3) amount of riffle habitat available to invertebrates. These criteria are the same as those used for the MRRM (**Section 5.1.9**).

As mentioned in Section 5.1.9, there is little to no risk associated with the food supply in Secret Ravine. The percentage of edible invertebrates in the riffles of Secret Ravine is seemingly high (**Appendix J-9: Food Supply**). Juveniles are opportunistic feeders and capable of finding many sources of food (Fields, Jr., pers. comm. 2002). The amount and quality of riffles may be poor (Li and Fields, Jr. 1999), but there is still no indication that juveniles are limited by the amount of food in Secret Ravine. Therefore, percent mortality equals 0% for juveniles.

There are no associated percent mortalities for adults and the early life stages because they are not affected by food supply.

9.1.10 Predation

One can draw the conclusion that spotted bass could potentially predate on the juvenile chinook salmon from March through June. To investigate the predation of chinook salmon by spotted bass, an estimation of the biomass of black bass for Secret Ravine was evaluated on a projected population of juvenile chinook salmon (**Appendix J-10: Predation**). To do this a range of biomass consumptions by spotted bass was calculated and then compared to a projected population of juvenile chinook salmon for 2002. The analysis showed that spotted bass could reduce the chinook salmon population from 7% to 14%, given that salmonids comprise 1% of the spotted bass diet. The lower figure probably represents the better estimate due to the small size (26 g) of the bass in Secret Ravine and the cooler temperatures of the water during these months.

10 Results (SDRM)

10.1 Evaluating the Entire Watershed

10.1.1 Total Percent Effect for Stressors

Evaluating the influence of different sources and stressors over the entire watershed required the integration of data from Secret Ravine and information from the literature on chinook salmon. To represent these processes, a single value approximating the percent reduction in population for each stressor on a certain salmon life stage was determined. To bring these single values together in the context of the chinook salmon, the percent reductions per life stage were subtracted from one and then multiplied together. This value was subtracted again from one, rendering a total percent survival. (**Equation** 2). These percent reduction values allow the model to bring together disparate stressor effects on chinook salmon. The results of our analysis are summarized in **Table 10.1**. The construction of each of the entries in **Table 10.1** is discussed below our results. The results indicate that the cumulative impact of the nine identified stressors varies from life stage to life stage and varied between different stressors; the egg phase experienced the largest percent effect on population 92% and stressors related to sediment cause the largest total percent effect of 74%. The model approximates that the overall effect of stressors in Secret Ravine is 97%.

		Percent Effect			
		Egg	Juvenile	Adult	Total
Stressor	Sediment	67%	20%	0%	74%
	Flow	0%	27%	6%	31%
	Morphology	13%	16%	0%	27%
	Temperature	0%	0%	0%	0%
	Altered Riparian Vegetation	10%	10%	0%	19%
	Reduced Access	44%	0%	0%	44%
	Toxicity	43%	0%	na	43%
	Food Supply	na	0%	na	0%
	Predation	0%	11%	0%	11%
	Percent Effect Per Life Stage	92%	60%	6%	97%

TABLE 10.1 TOTAL PERCENT EFFECTS PER LIFE STAGE PER STRESSOR

The three stressors with the largest magnitude TPE are sediment, reduced access, and toxicity with respective effects of 74%, 44% and 43%. The stressor with the next highest magnitude of effect is flow with 31%. Lower-ranking stressors were assessed lower percent effects due to either lack of effects that translated into direct mortality, or else could not be quantified in a manner equivalent to the other stressors. Thus, only the top three highest-scoring stressors will be addressed in this section, and in **Section 12.2**.

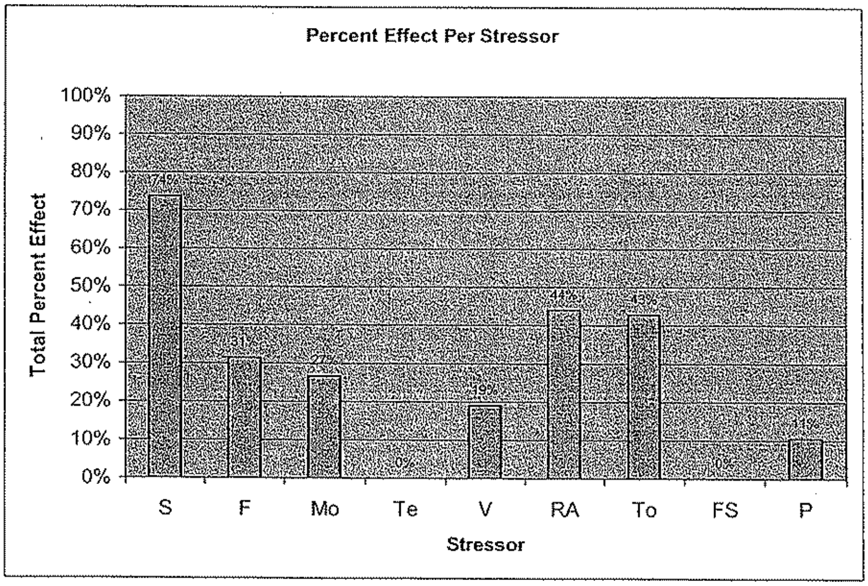


FIGURE 10.1 PERCENT EFFECT PER STRESSOR

Sediment

We used grain size distributions from ten sampling sites in Secret Ravine (**Appendix J-1: Sediment**) to calculate percent mortalities based on methods developed by Tappel and Bjornn 1983. Percent mortalities ranged from 100% to 26% with an average mortality of 67%. Thus, the mortality to the early life stages was estimated to be 67% (**Table 10.1**).

Turbidity data (DCC 2003, **Appendix J-1: Sediment**) was available over a three-year period (2000 to 2002). DCC water quality data indicated highly turbid flows during spring runoffs (approximately 1000 NTU during isolated events from February to May). This period corresponds to the peak period of residence for juveniles. Analysis based on Allen et al. 1996 estimated percent mortalities to juveniles on the order of 20% (Mortalities to the early life stages and adults were determined to be insignificant, although behavioral modifications could be occurring) (**Table 10.1**).

Reduced Access

Percent effect to egg caused by reduced access

PE(egg) = NP | (% no pass adults)*P(super)*% females*Mort(super)
NP | connotes "given not having passed"

superimposition - average high and low flow years						
	P(adults)	NP(adults)	P(super) whole watershed	Females	Egg mortality	**RS(egg)**
Confluence to China Garden Gauge	0.72	0.28	0.75	0.50	0.33	0.03
China Garden Gauge to Brace Road	0.11	0.89	0.75	0.50	0.33	0.11
						0.15

PE(egg) = NP | (% no pass adults)*P(blow)*P(high flow)*% females*Mort(blow)

blowout - high flows							
	P(adults)	NP(adults)	P(blow)	P(highflow) whole watershed	Females	Egg mortality	RS(egg)
Confluence to China Garden Road	0.72	0.28	0.50	0.30	0.50	1.00	0.07
China Garden Road to Brace Road	0.11	0.89	0.50	0.30	0.50	1.00	0.22
							0.29

total risk assessed to egg: **.44**

Percent effect to juvenile caused by reduced access

PE(juv)= P | (%pass juveniles)*P(predation)*(Predation rate)
total risk assessed to juvenile: **0**

Percent effect to adult caused by reduced access

PE(adult)= P | (% pass adult)*P(mortality due to energy costs)*Height of dam navigated
total risk assessed to adult: **0**

Total percent effect due to Reduced Access: 44%

FIGURE 10.2 EFFECTS ANALYSIS FOR REDUCED ACCESS

The region from Rocklin Road to the Loomis Park basin had an average of 89% adults not passing through to the next region (**Appendix M-1: Reduced Access**). The presence of many impassable barriers (three even in high flow), together with the small width of the stream and redds biology alluded to above and the poor substrate quality (**Appendix J-1: Sediment**), made the likelihood of estimated superimposition in this region extremely high and contributed to the high overall risk assessed to this secondary stressor. Likewise, half of the beaver dams in this stretch had heights above three feet, thus having the potential to contribute highly to blowout during high flows. Nevertheless, the high density of beaver dams, together with the high density of known and historic spawning sites from the Confluence region (most downstream region), also adds 10% mortality as caused by reduced access.

As with the MRRM, reduced access data was only available for the lower reaches of Secret Ravine. However, less than 4% of fish surveyed passed on average (1997-2002) north of Loomis Park. And these areas also have relatively adverse substrate quality (4s, **Appendix J-1: Sediment**). Therefore, barriers upstream of King Road, other than incident woody debris and large boulders, should have negligible impact on mortality to the fish population for all life stages.

Toxicity

Tests revealed that toxicity is present in the benthos at every sample site in Secret Ravine. These sites were strategically placed throughout Secret Ravine, so we can extrapolate that the entire creek is affected by toxicity in the benthos. Percent mortality was 38.9% for toxicity (**Equation 7**). Toxicity tests were negative for the water column. Due to this, the only life stage vulnerable to the effect of toxicity is the egg/yolk-sac fry stage. Percent mortalities for toxicity pertain only to this life stage.

10.1.2 Total Percent Effects and Sources

		Stressor									
		S	**F**	**M**	**Te**	**V**	**RA**	**To**	**Me**	**FS**	**P**
Source	**LM**	L	L	L	L	H	0	H	0	H	0
	IS	H	H	M	H	L	0	H	H	H	0
	CH	M	M	H	H	M	0	0	0	L	0
	OHV	H	L	H	M	H	0	L	0	H	0
	CD	M	M	L	M	H	H	0	M	L	0
	WTP	L	M	L	H	L	0	H	0	M	0
	MI	M	L	H	L	M	0	0	H	M	0
	OR	L	L	L	L	M	0	M	0	M	0
	IF	0	0	0	L	0	0	0	0	0	H
	DG	M	L	M	M	L	0	0	0	L	0
	IR	M	M	M	H	H	0	0	0	L	0
	BD	L	L	M	H	L	H	0	0	L	L

TABLE 10.2 RELATIVE CONTRIBUTION OF SOURCES TO STRESSORS

The source analysis for the SDRM centered on the three stressors with the highest percent effect values: sediment, reduced access and toxicity. The sources of these stressors were evaluated using both quantitative and qualitative measures. **Table 10.1.2** reports the connections between sources and stressors depicted on the conceptual model. For each of these connections the contribution per source to a particular stressor was described in three ways: H indicates a high contribution to the stressor seen in Secret Ravine, M designates a medium contribution to the stressor, L denotes a low contribution to the stressor effect, and 0 means no connection exists on the conceptual model between the source and the stressor. The contribution factor can be visualized by considering 1 acre of one category non-point source and comparing it to 1 acre of another category. For example for sediment the contribution from an acre of landscape maintenance and an acre of impervious surface would be qualitatively compared to evaluate which source would be expected to contribute more to the percent effect value. Also point sources were considered through a similar process. Each frequency of a point source was considered against other frequencies of point sources in the watershed. Once these two categories were determined, a qualitative analysis of how a high contribution point source is equivalent to a high contribution non-point source was conducted. Once this contribution factor has been determined, the extent or frequency of the source in the watershed as a whole was considered. Then the sources were space discussed in the context of what the contribution factor and the extent of the sources were in the watershed.

Sediment:
The sediment stressor had a high source contribution from impervious surfaces and OHVs. The medium contributing sources were channelization, construction and development, mining, dirt and gravel roads, and irrigation. The low contribution stressors were landscape maintenance, water treatment plants, orchards, and beaver dams.

Reduced Access:
This stressor had two high-contribution sources: construction/development and beaver dams.

Toxicity:
The high contribution sources for toxicity include landscape maintenance, impervious surface, water treatment plants, and orchards. The low contribution source was OHVs.

10.1.3 Percent Effect and Life Stage

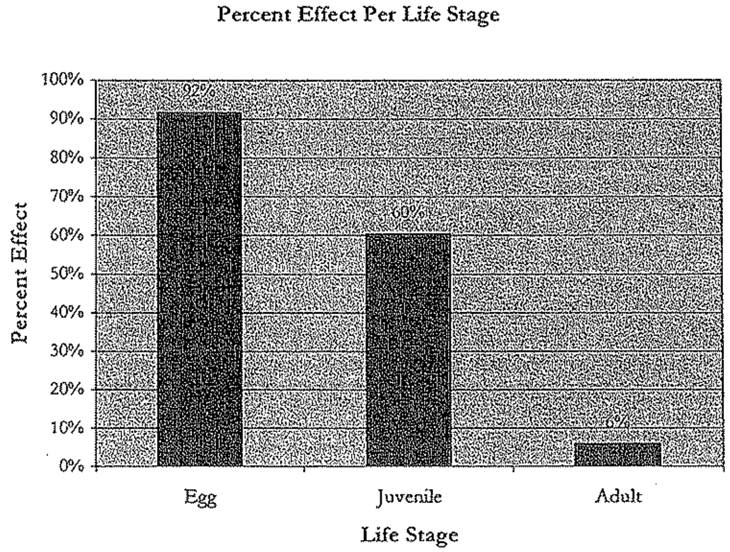


FIGURE 10.3 PERCENT EFFECT PER LIFE STAGE

The life stage with the highest percent effect was the egg phase with a percent effect of 92%. After the initial reduction in population of 92% the juvenile phase experienced a reduction of 60%, and from that surviving population, the adult phase salmon population had a simulated reduction of 6%. Integrating these effects over the three life stages, multiplying these percent reduction values together after subtracting from one for each effect, and then subtracting the resulting percent reduction from 1 again, gives a total percent reduction of approximately 97%.

11 Uncertainty (SDRM)

Uncertainty was analyzed in the SDRM for the three stressors that had the highest associated percent effect. Sediment, toxicity, and reduced access had their uncertainty calculated, each according to the respective effect of the stressor.

Sediment
We collected data from a total of ten sampling sites in order to calculate the average mortality of eggs (67%) throughout Secret Ravine due to sediments in the streambed (benthos). The standard deviation of this data was 30.7%. This yielded a standard error

of 9.8 percentage points. Thus, we are 95% confident that the mortality values for sediment (for the eggs) ranges from 47.6% to 86.7%. This large range of values implies that the data are fairly uncertain since these sampling sites were chosen based on the assumption that they were frequently used and/or historic spawning sites.

Reduced Access

Only one component (secondary effect expressed in terms of percent mortality) was quantitatively examined for reduced access in the SDRM, namely, estimated egg mortality associated with superimposition of redds. However, there is high uncertainty associated with this value, because while estimates were based on overall percent of redds superimposed (33%) for chinook salmon (Fukushima et al. 1997), while the 33% figure for mortality to the eggs themsevles was based on a study of pink salmon, which are smaller and construct much smaller redds. We have fairly high confidence in the percent mortality attributed to reduced access in terms of predation, based on the size of the fish, known flow, and the fact that predation rates were adjudged to be low in this system to begin with (**Section 3.4.10**). Although we have low confidence in the actual percent mortalities associated with the four secondary stressors, we have high confidence in their probability of occurring, as well as the life stages they effect - as well as the extent to which they affect the life stages proportionally. Therefore, there is fairly high uncertainty associated with Reduced Access as characterized by the SDRM.

Toxicity

Uncertainty was calculated in terms of percent mortality with the following formula:

$$SE = \text{sq. rt. } (\Sigma_i S_i^1)$$

i = risk region
S_i = standard error reported for region i
W_i = length of reach i / length of stream
$S_i^1 = W_i^2 * S_i^2$

Equation 8 Calculating Uncertainty for Toxicity

An uncertainty value represented by the standard error was calculated using the associated reach lengths and percent mortality for each risk region in Secret Ravine. The input used for this calculation was:

Risk Region	% Standard Error (S_i)	Reach Length (ft)	W_i	S_i^1
A	17	13152	.2673	20.63
B	18	18872	.3835	47.65
C	25	5995	.1218	9.27
D	21	9009	.1831	14.78
E	17	2171	.0441	0.56

Table 11.1 Criteria for Assessing Uncertainty Associated with Toxicity

The SDRM percent mortality output for toxicity was 38.39% across the watershed. In terms of standard error, the uncertainty is 9.638%. The SDRM model thus has high uncertainty associated with toxicity.

There is high uncertainty associated with the analyses of sediment and toxicity for the SDRM - which could be assessed quantitatively - due to the high use of data extrapolation from other fish on other systems. There is also fairly high uncertainty associated with reduced access because data was for the most part extrapolated and criteria were evaluated in a completely qualitative manner. All three suffer from lack of a complete data set.

12 Discussion and Recommendations

12.1 Discussion of MRRM

12.1.1 Risk Regions

One goal of the MRRM is to determine the total risk associated with each risk region. This Total Risk Score encompasses every source and stressor present in the risk region, along with habitat and exposure. As seen in **Figure 6.4**, Risk Region A has the highest Total Risk Score, followed by B, then C, E, and D (Error! Reference source not found.).

Risk Region	Total Risk Score
A	7308
B	5376
C	3032
D	1840
E	2008

TABLE 12.1 TOTAL RISK SCORE PER RISK REGION

Several factors contributed to making Risk Region A the highest in Total Risk Score. Firstly, nine of the twelve sources were represented (**Figure 6.6**). Beaver dams scored the highest risk in this region, followed by OHVs, then channelization. Not only were these sources the highest scores in Risk Region A, they were also the highest scores of any source for a risk region in the entire watershed (**Table 12.2**). Consequently, they contributed a very large amount of risk to Risk Region A.

Construction and development ranked fourth, with a score similar to the highest source scores from Risk Region B and C (**Table 12.2**). These sources are not surprising given the large amount of urbanization occurring in this section of the creek, and correctly reflect this area.

Secondly, all the stressors were represented in Risk Region A (**Figure 6.5**). Flow in the water column scored the highest risk in this region, followed by morphology in both the water column and the benthos. Not only were these stressors the highest scores in Risk Region A, they were also the highest scores of any stressor in the entire watershed (Error! Reference source not found.).

Top 10 Source Scores in Secret Ravine

Source	Risk Score	Risk Region
Beaver Dams	1404	A
Off Highway Vehicles	1332	A
Channelization	1260	A
Dirt and Gravel Roads	1116	B
Impervious Surfaces	1056	C
Construction & Development	1032	A
Beaver Dams	960	B
Impervious Surfaces	912	A
Channelization	840	B
Landscape Maintenance	720	C

TABLE 12.2 TOP 10 SOURCE SCORES IN SECRET RAVINE

Thirdly, the Risk Region A habitat was ranked as six, meaning it had the longest stream length. This is important when you consider two risk regions with the same exact scores for stressor, source and exposure. If these components are the same in two risk regions, the risk region with the higher habitat rank will get the higher Total Risk Score. This may not accurately reflect what is occurring in the two regions. A longer stream length does not necessarily mean a higher risk.

Yet it is not surprising that Risk Region A scored the highest. It is at the bottom of the creek, which means it captures all risk that enters the creek from above. Also, it is characterized the best because data was available for most stressors. Consequently, the Total Risk Score of this region is as accurate as possible with the MRRM.

Risk Region B had the second highest Total Risk Score (Error! Reference source not found.).

Nine of the twelve sources were represented. Dirt and gravel roads scored the highest risk, followed by beaver dams, and then channelization. All of the stressors were also represented. Flow in the water column contributed the highest risk, followed by sediment in the water column. Flow in the benthos followed, and had the same risk score as altered vegetation from Risk Region A (the fifth score in Risk Region A). Similar to Risk Region A, Risk Region B has a large amount of risk associated with it given its placement in the creek. Risk Region B also had a large amount of data associated with it, making this Total Risk Score as accurate as possible with the MRRM.

Top 10 Stressor Scores in Secret Ravine

Stressor	Risk Score	Risk Region
Flow WC	972	A
Morphology WC	900	A
Morphology BE	900	A
Flow WC	792	B
Sediment WC	720	B
Flow BE	648	A
Flow BE	528	B
Altered Vegetation WC	528	A
Altered Vegetation BE	528	A
Sediment BE	480	B

TABLE 12.3 TOP 10 STRESSOR SCORES IN SECRET RAVINE

Risk Region C had the third highest Total Risk Score (Error! Reference source not found.). Nine of the twelve sources were represented. Impervious surfaces scored the highest risk, which was 1.5 times larger than the second highest scoring source, landscape maintenance. Mining scored third. Nine of the ten stressors were represented. Flow in the water column and the benthos contributed the most risk, followed by morphology in the water column and the benthos, then sediment in the benthos.

Interestingly, even though the top three sources contribute largely to metals (effect rank=6) and toxicity risk (effect rank=4), these stressors scored 4th and 6th in risk score respectively. This possibly indicates a flaw in the MRRM design, because toxicity and metals data suggest a higher risk associated with these stressors.

Risk Region E had the fourth highest Total Risk Score (Error! Reference source not found.). Seven of the twelve sources were represented. Water treatment plants scored the highest risk. Dirt and gravel roads, impervious surfaces, and orchards followed, each very close to the other. Eight of the ten stressors were represented. Flow in the water column contributed the most risk, followed by morphology in the water column and the benthos, then by toxicity in the benthos. Although water treatment plants scored the highest risk, this result is questionable. It is possible for the water treatment plants to contribute toxicity and flow to Secret Ravine, but the magnitude of these inputs was small in the past, and cannot be captured accurately by the MRRM. Data for this region is the scarcest. Results in this region are based on many assumptions and extrapolations, therefore risk characterization is not as precise as the other risk regions.

Risk Region D has the lowest associated risk; four times less than Risk Region A (Error! Reference source not found.). In this risk region seven of the twelve sources were represented. Irrigation scored the highest risk, followed by mining and impervious surfaces. Nine of the eleven stressors were represented. Once again flow in the water column and morphology contributed the highest risk, but at approximately three and four times less than they did in Risk Region A. Again, results in this region are based on many assumptions and extrapolations, therefore risk characterization is not as precise as the other risk regions.

12.1.2 Stressors

Looking at both habitats (water column and the benthos), flow was the overall highest-ranking stressor from the MRRM (4524 cumulative risk score). Morphology followed with a cumulative risk score of 4128 and sediment thereafter with a score of 2808.

Sediment

Sediment was the third-highest scoring stressor overall (2808 cumulative risk score for both habitats). Effects on the benthos were higher (1488 cumulative risk score) than those in the water column (1320 cumulative risk score). Thus, impacts to the early life stages are greater than those to juveniles and adults.

Impacts in the water column were assessed via turbidity. The results indicated approximately 20% mortality to juveniles during spring flow events. Mortality from turbidity rarely occurs (Allen et al. 1996), so our estimate of mortality is a worst-case scenario that contained many assumptions about duration of exposure and actual suspended sediment concentrations. Effects such as behavioral or physiological changes, however, can be common even under lower turbidity values. Thus, the impact to juveniles via turbidity is a risk that needs to be assessed in more detail through a more rigorous sampling routine (variable duration sampling and a turbidity to suspended sediment rating curve).

Impacts of sediment in the benthos were assessed via grain size distribution analysis (E. Ayres, J. Love, and K. Vodopals 2002) and mortality estimation (Tappel and Bjornn 1983). Average mortality throughout the three risk regions sampled was approximately 70%. This value is roughly equivalent to numerous research values of average mortality rates in chinook redds (Kondolf 2000).

This is not to say, however, that overall mortalities to the early life stage due to sediment are not significant. The areas that we sampled in Secret Ravine represented a majority of the most heavily-utilized spawning habitat (Bates, pers. comm., 2002). Geographically, this area runs from the lowest point in the watershed (the confluence) up to roughly Rocklin Road, which represents approximately one-fifth of the total watershed by area. Thus, mortalities associated with the remaining habitat in Secret Ravine are unknown and are likely to be high since the area we sampled was prime spawning habitat.

Risk Region B scored the highest risk scores for sediment (720 in the water column and 480 in the benthos). The high water column risk score is due to high turbidity values on March 23, 2002 (roughly 5000 NTU). This was an event-based sample and was conducted at the request of a homeowner (DCC 2002).

Direct sources of increased sediment include impervious surfaces, channelization, OHVs, construction and development and dirt and gravel roads. All of these sources (except dirt and gravel roads) are present in Risk Region A (**Section 6.2.1.2**). Of those mentioned, OHVs had the highest risk score in Risk Region A. Efforts to curb OHV usage of the watershed in Risk Region A (near Sutter Hospital) have not been successful (Bates, pers. comm., 2002). Numerous areas were observed within this risk region where severe bank erosion and streambed disturbance were the result of OHV usage.

Sensitivity calculations for sediment indicated a high degree of uncertainty for risk scores in the water column and low uncertainty for risk scores in the benthos. The lower confidence limit for sediment was a risk score of 912 in the water column. Thus, turbidity could theoretically be ranked below temperature, altered riparian vegetation, toxicity, and metals. Uncertainties associated with sediment in the benthos were relatively less than other stressors (due to more robust data) and resulted in no variations in risk scores.

Flow

The impacts from flow were higher in the water column (2760 cumulative risk score in the water column versus 1764 in the benthos). This can be attributed to the original ranking of flow. In the water column, flow received a ranking (**Section 5.1.2.2**) of six for all risk regions based on the determination that scour is most likely occurring at flow depths below the tolerance depths associated with adult migration and juvenile rearing. As stated earlier, scour is the movement of the sediment in the streambed caused by peak flows. Thus, these results indicate that the risk of scour is greater during periods of adult migration (September to December) and juvenile rearing (February to May). Actual impacts to all life stages, however, cannot be determined without actual flow data.

Risks from flow in the benthos can be interpreted as the risk of scour affecting the early life stages (eggs and yolk-sac fry). The risk in the benthos, due to flow, was determined to be less than that in the water column. Risk in the benthos, however, is probably underestimated due to the duration of the early life stages occupying the benthos and the small size of the eggs and yolk-sac fry.

Overall, impacts from flow via scour are very high due to the dominance of fine grain sediments in Secret Ravine. Actual changes to the flow regime could not be assessed due to the lack of robust flow data. Based on numerous observations (Swanson 2000, Washburn and Webber 2003), however, it is apparent that many sections within Secret Ravine are undergoing substantial bank erosion and entrenchment of the channel, which is most likely due to alterations of the flow regime via higher peak flows and flashier floods.

Risk Region A had the highest risk score for flow (1620 total risk score for the benthos and water column combined) compared with the other risk regions. In general, discharge (total volume of flow per unit time) increases downstream (Ritter et al. 2002). Thus, the high risk score for flow in Risk Region A (the risk region furthest downstream) is in agreement with general flow processes.

Sources that contribute to changes in flow include impervious surfaces, channelization, construction and development, water treatment plants, dirt and gravel roads, irrigation canals and beaver dams (**Appendix E: The Conceptual Model**). The three highest-ranking sources in Risk Region A were beaver dams, OHVs and channelization, all of which are direct sources of flow alterations (**Section 6.1.2 Cumulative Source Risk Scores**). In general, however, impervious surfaces are the largest contributor to flow based on absolute area and have been implicated as the one of the main sources of stress to Secret Ravine via increasing pressure from urbanization (Swanson 2000, Li and Fields, Jr. 1999).

Sensitivity analysis calculations (**Section 7.4 Monte Carlo Analysis**) indicated that risk scores for flow could range from a minimum of 1536 to a maximum of 3216. This wide distribution indicates a high degree of uncertainty associated with the flow risk scores, which is expected due to the lack of detailed flow data. A risk score at the lower end in comparison with the minimum confidence limits of other stressors would result in flow being placed below temperature and metals. Thus, it could be the case that temperature and metals are more of a risk than flow.

Morphology

Morphology was the next highest-ranking stressor (4128 cumulative risk score). It was assumed that impacts from alterations to morphology would affect all life stages, thus cumulative risk scores were equal in both habitats (1944 cumulative risk score).

Criteria for ranking morphology were based on percent pools by length (PBL) and percent canopy cover (**Section 5.3.1.2 Assigning Effects Ranks**). In general, both the percentage of pools and percent canopy cover were below the threshold values. Average PBL was approximately three to ten percent below the ideal value of 30%. As stated earlier, this ideal canopy cover percentage is most likely an overestimate of ideal conditions for the Secret Ravine as it is based on forested, coastal watersheds in Northern California.

Risk Region A also had the highest risk scores for morphology (936 for both the water column and the benthos). Direct sources of alterations to morphology include landscape maintenance, channelization, OHVs, construction and development, and beaver dams. In Risk Region A, the beaver dams had the highest source risk score followed by OHVs and channelization.

Sensitivity analysis calculations for morphology also showed a wide distribution in risk scores, thus indicating a large amount of uncertainty in the final risk scores (**Section 7.4**). The lower confidence limit was at 1632 and the upper at 2736. At the lower limit, morphology would be ranked lower than temperature and metals.

12.1.3 Sources

The cumulative risk scores for each source reflect a couple of trends related to the organization of the model and the source analysis itself. The cumulative risk scores for the sources varied from 3,104 for impervious surface (IS) to 372 for water treatment plants (WTP) (**Table 12.4**). The trends in the data include the effect of the number of stressors caused by the sources in Secret Ravine, the nature of the interaction, either direct or indirect, and the location of that interaction that the source caused stress.

	[illegible]					
Source	A	B	C	D	E	
IS	912	528	1,056	288	320	3,104
BD	1,404	960	0	0	0	2,364
CH	1,260	840	0	0	0	2,100
MI	336	648	464	416	208	2,072
DG	0	1,116	264	216	324	1,920
LM	348	360	720	200	232	1,860
OHV	1,332	468	0	0	0	1,800
IR	396	360	280	480	240	1,756
CD	1,032	0	0	0	0	1,032
OR	0	0	216	176	312	704
IF	288	96	32	64	0	480
WTP	0	0	0	0	372	372
Totals	7,308	5,376	3,032	1,840	2,008	19,564

TABLE 12.4 RISK SCORES AND TOTALS FOR SOURCES IN EACH RISK REGION

The sources that cause eight stressors, impervious surface (IS) and beaver dams (BD), received the two highest risk score. The propagation of equations related to source, in this case, may increase the likelihood that a source will be given a higher risk score. A new equation is generated in the MRRM whenever the source and stressor is present in the same risk region and the habitat pathway, through the water column and the benthos, exists to the endpoint (**Equation 1, Figure 12.1**). For example, impervious surfaces, with a total of 65 individual equations, had a cumulative risk score of 3,104 (**Equation 9**). The average non-zero equation in the MRRM model had a risk score of 46 risk points, so sources that had higher numbers of source-stressor interactions in many different risk regions generally had higher risk scores (**Table 12.4**). Ecologically, this reflects the complexity of the chinook salmon ecosystem. Often sources have many different and spatially diffuse effects that could be a risk for the salmon. However, the propagation of equations can lead to a process where a source with more conceptual connections may be evaluated as a higher risk regardless of the actual rank of the source.

EQUATION 1: BASIC RISK SCORE EQUATION: THE TOTAL RSSOURCE COMES FROM THE ADDITIVE SUM OF EQUATIONS GENERATED FOR STRESSOR-SOURCE ASSOCIATION AND PER RISK REGION WHERE THESE INTERACTIONS OCCUR.

RSsource = (Source Rank)* (Habitat Rank)* (Effects Rank)* (Exposure 1 filter) * (Exposure 2 filter)

FIGURE 12.1 TOTAL RISK SCORE EQUATION FOR MODIFIED RELATIVE RISK MODEL

		Risk Score Totals (from highest to lowest risk score)	Stressors Caused by Sources	Indirect Sources (all .5 equations)	Risk Regions	Number of Equations
Source	IS	3,104	8	30	A, B, C, D, E	65
	BD	2,364	8	18	A, B,	28
	CH	2,100	6	40	A, B,	22
	MI	2,072	7	10	A, B, C, D, E	60
	DG	1,920	6	55	B, C, D, E	44
	LM	1,860	7	28	A, B, C, D, E	60
	OHV	1,800	7	8	A, B,	24
	IR	1,756	6	35	A, B, C, D, E	55
	CD	1,032	7	3	A,	12
	OR	704	7	33	C, D, E,	36
	IF	480	1	0	A, B, C, D,	8
	WTP	372	7	8	E	12

TABLE 12.5 INFLUENCES ON THE OUTCOME OF RISK SCORES

$$\boxed{\begin{aligned} NumberofEquations &= ((8*2)-3)*5 \\ NumberofEquations &= 65 \end{aligned}}$$

EQUATION 9 NUMBER OF IMPERVIOUS SURFACE EQUATIONS IN THE CUMULATIVE RISK SCORE

Number of Stressor/ Source Interactions = 8	Se, F, M, Te, V, RA, To, Me, FS, P
Number of Habitats = 2	water column and benthos
Minus number of Exp2 equaling zero = 3	where stressor does not effect endpoint
Number of Risk Regions with source = 5	all five Risk Regions A, B, C, D, E

Also, the counter positive can be true. If a source has only a few equations associated with its risk, then the total risk score may be low. Several examples of this were Introduced Fish (IF) and Water Treatment Plants (WTP) that respectively have 12 and 8 equations associated with their risk scores; these two sources have the lowest risk scores of the 10 sources in the analysis.

The exposure filter 2 described the presence of the endpoint in a habitat where a source could generate a stressor. Exposure 2 could have one of three values 0, 1, or .5: 0 denotes no interaction the 1 expressed a connection between a stressor and source, and the .5 represented an indirect effect. The source analysis included a total 426 different equations; of these equations 268 or 63% were determined to be indirect. An indirect source was defined as any source that generated a stressor via another stressor or related to a source that was originally emitted many years prior to this analysis. The modeling of legacy sources, for the most part, contained an indirect exposure filter. In the case of mining (MI) as a source, the indirect exposures moderated the effect of the number of equations (60 equations) associated with the source. The 12 indirect filters associated with mining reduced the cumulative risk score by approximately 1,600 risk points and moved mining from the source with the second largest risk score to the source with the fourth largest risk (**Table 12.6**).

Analysis without Indirect Sources	
	Risk Score Totals
LM	4,040
MI	3,688
BD	3,360
LM	3,032
DG	2,680
CH	2,592
IR	2,360
OHV	2,232
OR	1,288
CD	1,152
WTP	552
IF	480
	27,456

TABLE 12.6 ANALYSIS WITHOUT INDIRECT SOURCES

The other category of indirect sources contributed to stressors through a series of intermediate processes; an example of this type of source was landscape maintenance (LM). The production of this source occurs today when water is used to maintain a garden or lawn. In this case, the landscape maintenance source can induce changes in sediment, flow, and morphology, though secondary processes remote from the actual practice of watering a lawn.

The designation of landscape maintenance as an indirect source decreases the risk score by 1,200 risk points and drops the relative position of landscape maintenance from the source with the fourth largest risk score to the sixth largest risk score (Error! Reference source not found. and Error! Reference source not found.). The indirect source designation allows some differentiation of legacy and sources acting through a series of processes. However the arbitrary halving of source risk source may not reflect the actual natural attenuation of legacy sources and the actual influence of sources working though a series of intermediate processes.

The location of the interactions between source and stressor also played a part in the risk score associated with the source. The habitat rank in each risk region hold sway over the total risk score seen in the model. The habitat rank for each region came from the relative assessment of the length of the stream in each region.

Analysis with Indirect Sources	
	Risk Score Totals
IS	3,104
BD	2,364
CH	2,100
MI	2,072
DG	1,920
LM	1,860
OHV	1,800
IR	1,756
CD	1,032
OR	704
IF	480
WTP	372
	19,564

TABLE 12.7 ANALYSIS WITH INDIRECT SOURCES

For this reason the lower regions, Risk Regions A and B both received a habitat ranking of 6 due to the fact that these risk regions encompass the largest portion of Secret Ravine. However for each equation associated with a source a habitat rank value is part of the multiplicative (**Equation 1**). Therefore a rank of risk for Risk Region A or B, with a habitat rank of 6, generates 3 times the risk associated with Risk Regions E, with the same habitat rank.

	Stressors Caused by Source	Indirect Filters (all 5 filters)	Total Risk Score	Total Risk with No Indirect Effect
Construction & Development CD)	7	4	1,032	1,152
Water Treatment Plants (WTP)	7	8	372	552

TABLE 12.8 COMPARISON OF CONSTRUCTION & DEVELOPMENT AND WATER TREATMENT PLANT

An example of how location effect creates larger risk scores can be seen when comparing construction and development (CD) and water treatment plants (WTP) **Table 12.8**). For both these sources, the source only effects one risk region and the number of equations that generates the risk score is 12 (**Table 12.5**). The difference between these two sources come from the number of indirect filters (four indirect filters for construction and development and eight indirect filters for water treatment plants), the risk regions ranked (A and E) and ranking of the sources effect (construction and development effect Risk Region A with a lower rank of 4 than water treatment plants with a source rank of 6). To investigate the effect of only the location of the source ranking, one can pull the risk scores from the Table Analysis without Indirect Effects (Error! Reference source not found.); this table reports the risk scores that would be expected if the no indirect filter existed. In this case, CD received a risk score of 1,152 and the risk evaluated for WTP was 552. So even though water treatment plants received a higher rank of 6 the risk associated with water treatment plants was less than half the risk associated with construction and development with a rank of 4. This suggests that a strong location effect exists. Sources such as beaver dams (RS=2,364) and channelization (RS=2,100), the second and third ranked source may exhibit this effect. Both of these sources have six source-stressor relationships in the model, suggesting that they should fall lower on the risk score list. However, beaver dams and channelization both have high ranks for both Risk Region A and B, which compensates for the lower number of source-stressor association and any indirect filters associated with the sources. This location effect could be interpreted so that the habitat value of a larger portion of stream should be assigned a higher rank due to the larger capacity of the stream to support salmon.

In this case, the argument is made that a higher potential for risk exists for larger habitat. However, if the same amount of source moves into a smaller section of stream it would be expected to increase the risk to the fish in the stream due to the increase in source intensity.

Some fine grain differences do present themselves in the source results. In general, sources that are present in all five risk regions have a higher risk score and those sources with more than one rank of 6 or 4 tend to have higher risk scores. But the assignment of ranks tends to be less influential than the trends mentioned previously. Indeed the only source with two ranks of 6, dirt and gravel roads falls fifth on the list of total risk score. In consequence, these three general trends, larger number of equation equals a larger risk score, indirect versus direct exposure filters, and downstream effects in Risk Region A and B, influence the source analysis.

To collaborate the observation of these trends in the source data a regression analysis compared the three factors, larger number of equation equals a larger risk score, indirect versus direct exposure filters, and location effects in Risk Region A and B, influence the source analysis, with the total risk score. The regression analysis found that all three trends significant and returned an R-squared value of .767 (adjusted R squared of .604). These results suggest that the three trends may be a significant influence on the total source risk score and that much of the source risk score variability can be explained by the structure of the model.

Regression Variable	Description	P-Value
Total Number of Equations in the Risk Score	(# of source-stressor interactions equations)	0.002
'Location Effect	(# of equations with 4 or 6 in Risk Region A or B)	0.022
Indirect sources	(# of equations including an indirect source)	0.051

TABLE 12.9 REGRESSION ANALYSIS RESULTS FOR SOURCE

12.1.4 Habitat

The highest risk score was generated for the water column habitat at 9,880 risk points, while the benthos habitat scored 9,684 points. The similar magnitudes of these two values suggest that risk on Secret Ravine is disseminated approximately equally between the two habitats. The slightly larger value of the water column habitat may mean that this habitat could be slightly more at risk. However the difference of only 196 risk points may reflect no appreciable difference in risk between the two habitats. Implicate in this risk score, the risk to the egg phase habitat (benthos) and the juvenile/adult phase habitat (water column) appear to be approximately equal in magnitude. The assessment of the benthos and water column as having approximately equal risk seems counterintuitive due to the several distinctions in the way stressors effect different chinook salmon life stages. Possible overriding factors such as the source analysis, the ranking of habitat, and the interaction of stressors and sources may have overwhelmed the mathematical distinctions made to reflect different stressor effects per salmon habitat or there could simply be the same risk to egg phase habitat and juvenile/adult habitat.

Habitat	Total Risk Score
Water Column	9,880
Benthos	9,684

TABLE 12.10 TOTAL RISK SCORE FOR HABITAT

	Risk Region	A	B	C	D	E
Habitat	Water Column	6	6	4	4	2
	Benthos	6	6	4	4	2

TABLE 12.11 HABITAT RANKS FOR WATER COLUMN AND BENTHOS PER RISK REGION

12.2 Discussion of Stressor-Driven Risk Model (SDRM)

12.2.1 Top Three Stressors (SDRM)

Sediment

Overall, the highest mortalities estimated were due to sediment. 67% mortality was estimated for the early life stages and 20% for the juvenile life stage. Twelve sites total were sampled with ten of those being frequently-used spawning areas (Bates, pers. comm., 2002). Percent mortalities ranged from a minimum of 30% to a maximum of 100%. Numerous laboratory and field experiments indicate, however, an average survival rate of approximately 30% (mortality, therefore, equals 70%) in a typical chinook redd (Kondolf 2000). Thus, the average mortality in the redds sampled in Secret Ravine is approximately the same as the average mortality in other studied redds. As mentioned earlier, however (**Section 12.1.2**), overall mortality throughout the watershed is probably much higher due to the dominance of fine grain sand

As stated in the MRRM results, risks from turbidity were highest during spring flows but more robust sampling routines need to be developed to obtain more accurate estimates of mortality or behavioral modifications.

Numerous observations have been made (Swanson 2000, Li and Fields, Jr. 1999, Montgomery 1992) implicating fine sediments as the main cause of stress to the Secret Ravine watershed. Our data indicates that the most heavily utilized spawning areas have mortalities roughly similar to other researched redds. Other sites that we sampled had much higher mortalities (usually 90% and above). Thus, given that the poorer sites represent the majority of the potential spawning sites, it is evident that there is a deficiency in the overall abundance of prime spawning and rearing habitats.

Reduced Access

Reduced access was the second highest ranked stressor in the SDRM, with almost 50% mortality across life stages attributed to it. Although reduced access is directly an issue for adults in terms of upstream migration, eggs are subject to the consequences if adults are prevented from swimming as far upstream as it takes them to find suitable spawning habitat. Although each of the secondary effects explored in this analysis are hypothetical, there is strong evidence that each occurs. Blowout is seen yearly, and it contributed the highest impact relative to the other secondary stressors (29%). Superimposition of redds (15%), although not directly observed - or even investigated - on our system, is practically inevitable given how coveted downstream spawning sites are and how limited good substrate is in these areas and given literature that supports this. We have confidence in the suitability of the other two secondary stressors and their lack of apparent adverse effects to the creek.

Toxicity
Toxicity ranked as the third most highly ranked stressor in the SDRM. Total percent effect of toxicity was 43% in Secret Ravine. Although toxicity can theoretically harm all life stages of Chinook, it appears to only be adversely affecting the egg/yolk-sac fry life stage. Tests conducted at the Aquatic Toxicology Lab at UC Davis were negative for toxicity in the water column. Therefore, there is no risk to the adult and juvenile life stages. In the benthos, however, all of the five sampling points tested positive for toxicity. The mean percent effect across all the sampling points was 38.39%. This percent effect is derived from total mortality caused to *Hyallela azteca* in the toxicity tests. The toxicity tests conducted on Secret Ravine were measures of total toxicity and thus included the effects of metals in the SDRM model. Although a separate metals analysis was performed, it was not included in the SDRM model. The most likely anthropogenic contaminants include organochlorines, such as polychlorinated biphenyls and dioxins, and aromatic hydrocarbons. Toxicity ranked as the third highest percent effect in the SDRM model and is a likely threat to the egg/yolk-sac fry. But the extent of the effect of contaminants in Secret Ravine is unclear as evidenced by the high uncertainty value that is shown in **Section 11**.

12.2.2 Sources of Stressors (SDRM)

Sediment
We estimate that impervious surfaces and OHVs are the two sources contributing the highest potential concentration of sediment (**Table 10.2**). Impervious surfaces overwhelmingly exceed OHVs in terms of absolute area and should thus be considered the largest source of sediment to the watershed. The mechanism for delivery of sediment, however, is unclear and needs further research. Observations by Swanson (2000) as to the main sources of sediment include widely disturbed sources of channel erosion, historical disturbance and unfavorable channel morphology. Thus, the combination of an overabundance of introduced fine sediments (from placer mining and other historical uses) and poor channel hydraulics has created a system that is unable to rid itself of the excess fine sediments. Sections with deeply entrenched channels (rectangular with high banks) are unable to deposit fine sediments overbank. Furthermore, increased alterations of the flow regime due to increasing impervious surfaces further exacerbates problems associated with bank erosion and entrenchment.

The other significant sources most likely contributing to the sedimentation (medium concentration estimates in Table 10.2) problem include irrigation canals, dirt and gravel roads, channelization, construction and development and mining. Legacy impacts from mining are not well researched. It is still unclear whether areas of concentrated delivery of unconsolidated granite exist or if the issue is simply too widespread throughout the watershed.

Relationships between the remaining significant sources and individual sediment concentrations are not well understood. A detailed source analysis of these relationships should be the focus of any further studies into this issue.

Reduced Access

The two sources associated with reduced access - beaver dams and artificial barriers (via construction and development) - were assessed high direct effect to these stressors. The criteria used to determine total percent effects for the SDRM, in contrast to the MRRM, clearly demonstrate that factors other than whether fish can pass or not, must be taken into consideration when evaluating the impact of barriers. But whereas artificial barriers have the potential to confer mostly negative secondary impacts - with perhaps the exception of the formation of deep holding pools for adults - (C.D. Vanicek 1993), it must be remembered that beaver dams have the potential to confer other positive benefits. These include expediting materials transport downstream, maintaining water levels during low flows, increasing retention of organic matter and improving nutrient recycling, in addition to also creating first class pools (R. Naiman 1986). Indeed, R. Naiman emphasizes the role of beavers in second and third order streams as a keystone species for the system's "biogeochemical economy," benefiting plants, invertebrates and the fish themselves (R. Naiman 1986).

The high percent effects associated with the stream reach from the gauge at China Garden Road to Brace Road largely reflect the nature of the barriers (height, downstream pool depth, artificial versus natural), relative to the number of adults that attempt to spawn in this region, rather than simply the number of barriers in the region. With the exception of the triplicate fence at Sierra College Road, which obviously confers no benefits to migrating spawners, the benefits of beaver dams in terms of improved salmon habitat must be weighed against the adverse consequences of obstructed fish passage on a subshed-by-subshed basis. Secret Ravine is not particularly long to require a great frequency of deep holding pools. Furthermore, the most obstructive beaver dams over the past few years have been found in the downstream regions where substrate quality is still decent and where fish have been known to spawn most frequently historically - leading to the potentially high values for superimposition and blowout we received. Finally, it is important to remember that the prohibitively high Hayer Dam (further downstream on Dry Creek), also completely prevents adult fish from passing, thus lessening the overall magnitude of fish that should return to Secret Ravine to spawn by an unspecified amount (B. Washburn, pers. comm. 2003). Because the PCWA canal system helps maintain flows during summer, managers should err on the side of breaching the most obstructive dams, timed with upstream salmon migration, once beaver activity has been carefully monitored.

Toxicity

Toxicity recorded a high percent mortality due to the large number of direct sources that may be contributing toxic substances into Secret Ravine. These sources are a combination of both legacy and current sources. Most of the sources causing the high percent mortalities for toxicity reflect the consequences of urbanization due to the increasing number of housing developments and infrastructure in western Placer County. Although toxicity can kill chinook directly, it is more likely that toxicity in Secret Ravine is causing indirect harm by impairing reproduction, reducing the survivability of eggs/yolk-sac fry, restricting migration, and/or causing behavioral changes that limit survival.

In the SDRM source analysis, landscape maintenance, waste treatment plants, and impervious surfaces all received 'high' values for their respective contributions to the total toxicity. Orchards received a 'medium' value and OHVs registered a 'low' input. Of these sources, only the waste treatment plants are a point source; all the others are non-point.

Two waste treatment plants exist near the headwaters of Secret Ravine in Risk Region E. One plant, near the town of Newcastle, exists on the north side of Risk Region E and the other, part of the Castle City Trailer park, is on the south side. Since both plants use aeration basins combined with solid storage basins, there is no direct connection to Secret Ravine. In large rain events in the past, the Newcastle facility has chlorinated the effluent coming into its sewage ponds and been forced to release it into Secret Ravine to prevent flooding. Such events may increase toxicity in Secret Ravine in the form of increased nutrients. Some infrastructure improvements have occurred. However, with the increase in residential development, the water treatment plant will need to keep pace with the expanding population. Infrastructure designed to minimize the effects of heavy rain events must be implemented at these two waste treatment plants and Secret Ravine must be safeguarded from effluent spills and releases.

Impervious surfaces affect Secret Ravine by decreasing the time between when precipitation falls to when water enters the fluvial system, often associated with the alteration of peak flows. This tends to accrue fine materials (hydrocarbons and metals) on the surface. Heavy rain events flush these fine materials and contaminants into the stream in concentrated pulses. In areas where impervious surfaces are extensive, bio-filtration devices should be installed to minimize the effects of peak flow runoff.

Orchards contribute a legacy effect on Secret Ravine. During most of the twentieth century, orchards dominated the watershed and many agricultural products during this period involved the use of persistent pesticides such as DDT. Since orchards represent a legacy source, there are few best management practices suitable to offset these malignant effects. The effect of pejorative practices associated with historical orchards around

Secret Ravine continues to diminish as residual pesticides are broken down and filtered out.

Off-highway vehicles include all motorcycles, cars, trucks or all-terrain vehicles that utilize the floodplain of Secret Ravine for recreation. Oftentimes, these vehicles drive in the creek itself and contribute hydrocarbons and metals directly into the waters. OHV use needs to be restricted in and around Secret Ravine to inhibit further contamination and maintain the riparian vegetation within the buffer zone.

12.2.3 Affected Life Stages and Implications for Secret Ravine (SDRM)

Percent mortalities for sediment, reduced access and toxicity were averaged over the entire watershed and each rendered percent mortalities to the egg/yolk-sac fry stage, with 67%, 44% and 38%, respectively. Reduced access and toxicity only resulted in effects to the early life stages, although effects to the other two life stages were investigated, while sediment also yielded percent mortality to the juvenile life stage through turbidity (20%).

Despite high levels of uncertainty for all three stressors, these results are significant because the standards used to measure the effects for these particular stressors were related to direct potential mortality (as opposed to metabolic or behavioral effects or other chronic effects measured by some of the other stressors). Approximately 15,000 juveniles leave the system every year (after being corrected for observation error in the Predation stressor analysis (**Appendix J-10**). Assigning each female (half of the 160 figure) the average number of eggs fall-run females can be expected to lay in the Sacramento tributaries (5,000) having built the minimum number of redds (one), the number of juvenile offspring projected from these counts (400,000) would already drop the survival rate from egg to outmigrating smolt to 4%. This closely approximates our total percent effect value estimated from the SDRM (with perhaps 1% attributed to indirect or chronic mortality, such as temperature and flow effects, as moderated by factors such as riparian vegetation).

There are about 100 juveniles for every spawning adult, and the number of adults spawning on average in Secret Ravine has been relatively constant (hovering at 100) for the last decade. Because one adult is needed to return to Secret Ravine in completing the 3-5 year life cycle in order to maintain this population, we can estimate that approximately 3% of mortality to the salmon can be attributed to the ocean phase (.03 mortality from Secret Ravine x .03 mortality from the ocean = total mortality for the Secret Ravine population throughout their life-cycle). Overall, one can glean from these data that fall-run chinook experience on average a 0.001-0.0002 percent survival rate from egg to adult.

Taken together, these results imply two important trends. Firstly, that we can roughly estimate that the stressors on Secret Ravine contribute to approximately half of the mortality associated with the salmon engaged in the Secret Ravine life cycle. Depending on the role that density dependence plays in the ocean, this means that management targeted to our 37-square-mile watershed could, indeed, positively impact the future of the salmon population migrating through Secret Ravine. Of course, because we have already determined that because of pervasive substrate problems, density dependence also plays a role on Secret Ravine, for as many added salmon as we hope to see spawn in the future on Secret Ravine, improvements to substrate quality will have to be made in step. These results also show that because the egg life stage is implicated in half the mortality associated with Secret Ravine - which represents what we think is about half of the total mortality contributing to the population counts for the Secret Ravine fish - egg mortality represents almost half (46%) of the total mortality associated with this population. (The juvenile life stage was estimated to contribute 10%: 20% from SDRM x 50% of life cycle mortality). This information indicates that not only could the egg stage play a proportionally high role in perpetuating the fall-run life cycle, but that extra attention should be given to the mitigation of sources associated with the stressors causing mortality to the egg stage.

12.3 Comparing the Models

Modified Relative Risk Model

There were many positive and appropriate aspects of the Modified Relative Risk Model that helped in our analysis of Secret Ravine. The MRRM is a peer-reviewed method that gave us a systematic way to quantify ecological risk posed by sources and stressors in Secret Ravine. Risk can still be quantified with an incomplete data set, which was the case in Secret Ravine. For example, with altered vegetation we lacked plant lists and abundances, but we were still able to examine its effects on the salmon in Secret Ravine. We were also able to use literature references to fill in data gaps, and to make better decisions on how rank should be assigned. This made applying ranks more robust than the RRM method, which relied solely on GIS. Most importantly, the MRRM prioritized risk regions, sources and stressors using calculated risk scores.

But there are also flawed aspects of the MRRM. Converting data to ranks poses the biggest problem. Scientific importance is lost, and precision is thrown by the wayside. Determining actual ranks can also be arbitrary. Although ranks were based mostly on references from biology literature, sometimes this was not the case and Jenk's optimization was used. This weakens the analysis by ignoring important biological factors. Additionally, criteria for assigning ranks can be rather nebulous. The difference between a rank of two or a rank of four can be unclear, and therefore arbitrary. For example, what makes a toxicity level a two, versus a four? This distinction may have relied too heavily on best professional judgment. Moreover, the relativity of the MRRM lies within a source or a stressor, but cannot be applied across sources or stressors. For example, a rank of two for temperature does not imply the same level of risk as a rank of two for morphology. The separation of the watershed into risk regions also weakened the analysis. This required that data was present in every risk region, but this was not always the case. More often than not, data was missing in the top two risk regions, requiring extrapolation. A risk score in those regions is less accurate than a risk score in the lower regions because of the lack of data. Similarly, the delineation of these risk regions is somewhat arbitrary. Sub-watershed boundaries are based on the landscape, but regrouping sub-watersheds results in different risk regions. Different risk regions can mean different results, and there is no "correct" way to group them. Source estimation using areal extent also posses a problem. Big source does not equal big stress in most cases. Likewise, point sources have a small areal extent, but can emit a large stress. We rectified this problem with point sources by using frequency, but whether this is the best way to analyze point sources is not clear. Baseline risk is ignored in the MRRM. There is no accounting for natural risk that can occur in a system without stressors. Lastly, the MRRM is a poor communication tool. A rank or a Total Risk Score has less meaning than an actual effect, i.e. percent mortality. It is difficult to communicate a stressors effect on the salmon population merely by producing an arbitrary number that can only be understood in relation to other arbitrary numbers.

Stressor-Driven Risk Model

The development of the Stressor-Driven Risk Model rectifies some of the shortcomings of the MRRM, but still falls short of accurately analyzing the effect of sources and stressors to chinook salmon. The SDRM dealt structurally with stressors and habitat through the evaluation of percent reduction in population for the whole ecosystem. In the SDRM, the whole ecosystem could be analyzed as a unit; this placed importance on the system as a whole opposed to spatial units such as risk regions. Given the scale of Secret Ravine, 37 square miles, dividing the watershed into smaller units may be imposing arbitrary divisions on an area with more similarities than differences. Additionally, the analysis of risk on an ecosystem-wide scale allowed for greater statistical power, where dividing data into five risk regions often required the projection of data into regions of the watershed that were not characterized in the original data collection. Also, the SDRM allowed for the analysis of the salmon population via life stage, not through the often arbitrary division of water column and benthos habitat. For example, the food supply stressor affected the juvenile chinook salmon. Juvenile salmon primarily utilize the water column as habitat, however the food supply of the juveniles often originates in the benthos of a stream. So juvenile salmon depend on both water column and benthos and risk to either habitat should be important to overall risk to chinook salmon. Furthermore, the SDRM used the concept of percent reduction of population to characterize effect. The percent reduction in population eliminates the ambiguity in assigning ranks and decreases the amplifying of imprecision caused by multiplying rank by rank.

The shortcomings of the SDRM include three major hurdles: the source characterization was problematic, reduction in population does not address carrying capacity, and no baseline mortality evaluation was possible. The limited source characterization for the SDRM utilized a semi-quantitative approach for describing the average emission of a stressor by a source and discussed in a qualitative manner the sources for the three stressors with the most influence in the ecosystem. This approach allowed for the discussion of source in the SDRM analysis, but the source analysis could have been improved if a mathematical relationship between source and the stressor effect could have been generated. This type of model could be developed but the limitation of resources prevented the SDRM from including a more comprehensive treatment of source. However, compared with the source analysis in the MRRM, the SDRM addressed this data gap in a more straightforward manner. Another drawback of the model comes from the relationship between carrying capacity and percent reduction in population. The carrying capacity of an ecosystem defines the number of individual organisms an ecosystem can support. We do not know the carrying capacity of Secret Ravine, so a percent reduction in population may be greater than the carrying capacity of the creek. However no density dependence seems to be in evidence in Secret Ravine, therefore neglecting carrying capacity may not be a drawback of the model. Another drawback that limits the utility of the model is baseline mortality. In all ecosystems, even during the pre-Columbian time period, some baseline mortality occurred. The separation of anthropogenic and baseline mortality cannot be accurately approximated. However by concentrating on effects of stressors and not the actual survival rate some of this ambiguity between baseline and anthropogenic mortality was avoided.

Which Model is More Appropriate For Our Creek?
We determined that the Stressor-Driven Risk Model is a more appropriate model for evaluating risk to Secret Ravine chinook salmon. Its ability to assess risk in an ecosystem, coupled with its scientific relevance, makes it a better tool to analyze and communicate risk.

12.3.1 Reduced Access, Toxicity and the MRRM

Neither reduced access nor toxicity, high-scoring stressors in the SDRM, ranked highly in the MRRM. In the following section, we attempt to explain why this may be the case.

Reduced Access
With the MRRM model, there was little way of accounting for the secondary effects of some of the stressors, although they were identified in the Conceptual Model or in breaking down relationships among the stressor itself. Effects to only one life stage could be assessed at a time using the 'habitat' criterion in the ranking scheme. Since percent mortalities could be evaluated based on the effects of several stressors (secondary, in this case), values for these could be multiplied together to derive more refined results.

Reduced access was determined to be the lowest ranking stressor in terms of cumulative risk summed over the entire watershed in the MRRM. It was the third-lowest ranking stressor in Risk Region A and the lowest ranking stressor in Risk Region B. However, it was the second most highly ranked stressor in the SDRM, with almost 50% mortality across life stages attributed to it. This discrepancy is largely explained by the fact that reduced access only had two sources associated with it in the MRRM (beaver dams and construction and development), even though these two sources were given medium rankings based on the moderate areal extents they were associated with. Although beaver dams were assessed the highest source risk in Risk Region A (relative to the other risk regions), and received the highest source ranking for this region relative to the other sources, number of sources associated with stressors determined whether the stressor would exert an impact on the fish. However, it is interesting to note that the 150% passage rule employed in the MRRM yielded approximate the same results in terms of relative effects as the actual counts.

Nevertheless, while attempts were made to make beaver dams - a point source - equivalent to the impact that non-point sources would exert, areal extent is not a reliable way to infer beaver dams impacts. Barriers are by nature, best considered in terms of their cumulative impact to the fish: their navigation costs adults energy and their complete impassability during low flows limits already limited spawning grounds. Subjecting a source of this nature to comparison per risk region is especially erroneous using this type of analysis. In the grossest sense, barriers need to be evaluated in terms of the amount of delay they impart to the adult and juvenile life stages, which makes salmon susceptible to a host of other more extreme stressors (G. Marsh, pers. comm. 2003). Arbitrary breaking up of the watershed (and the barriers, themselves) for the purposes of barriers analysis does not allow the full picture to be revealed in terms of when and where fish are allowed to spawn given so many obstacles along the way.

The effects rankings were so low in the MRRM because only one life stage could be addressed at a time. But perhaps more importantly, the effects criteria used are simply wrong in terms of their characterization of barriers on salmon health. Passage does not necessarily imply that the adult will successfully spawn or even attempt to reproduce; and non-passage does not imply that an adult will not attempt to spawn. Indeed, Chris Lee of the DWR reported that, "salmon will do whatever it takes to try and spawn. ...they will definitely turn tail and go back downstream to find suitable substrate if a barrier is blocking upstream migration" (C. Lee, pers. comm. 2003). Thus, the potential effects associated with not passing/passing scenarios were analyzed using the SDRM.

Reduced access is the only stressor that deals directly with the potential consequences of delay, and delay (in adult spawning with early rains, in juvenile exit prior to temperature increases), has particularly egregious consequences for fall-run chinook. This is especially true given their large size and high rates of metabolic activity, in a stream of this nature (so far from the estuary). Thus, it is reasonable to conclude that reduced access would rank as one of the highest-ranking sources, rather than one of the lowest. Thus, although the MRRM is helpful in terms of comparing risk among regions in terms of reduced access, the SDRM is capable of the same and provides much more scientifically believable results for the entire watershed.

Toxicity

There were three reasons that toxicity did not appear in the MRRM. The most important reason is that toxicity had far fewer sources associated with it than did sediment, flow, and morphology. Toxicity had seven contributing sources whereas sediment, flow, and morphology had 11 contributing sources.

The second reason toxicity did not appear in the MRRM is that toxicity registered a "0" for the water column exposure filter. This occurred because the toxicity tests were negative for the water column. This worked to cut the effect of toxicity in half for the MRRM.

The third reason toxicity did not appear in the MRRM is because of the nature of one of its sources. Waste treatment plants registered as point sources. Due to this, waste treatment plants only affected the one risk region that they were located in. In the MRRM, waste treatments were found only in Risk Region E. This risk region received a "6" while all the others received ranks of "0," respectively.

12.3.2 Flow, Morphology and the SDRM

The MRRM indicated that flow and morphology were two of the three highest-ranking stressors. These stressors, however, did not rank in the top three for the SDRM. Some reasons for this as follows.

The lack of robust flow data for Secret Ravine required alternative methods for estimating risks associated with that stressor. In the MRRM, the risk of scour was the basis for estimating impacts of flow. Thus, in the MRRM, the flow stressor is not a true estimate of the risk from flow. It is more of a reflection of the condition of excess sand within the substrate. In the SDRM, actual observational estimates of flow depth and velocities (Li and Fields, Jr. 1999) were used to estimate risk. We did not use these data in the MRRM because they were not risk region specific. Therefore, the main reason that the flow stressor did not rank so high in the SDRM is because it does not consider scour.

In the MRRM, criteria for ranking morphology were based on the percentage of pools. We determined that most risk regions were deficient in the frequency of pools and therefore received high rankings. We determined, using the same data set in the SDRM that the loss of pool and riffle habitat resulted in a loss of roughly 27% of the habitat. According to the SDRM, this is not a high-ranking stressor, relatively. Thus, the MRRM, due to ambiguities in the criteria for ranking, may be overestimating the risk associated with this stressor.

Overall, it is apparent that fine grain sediments are a major stress on the Secret Ravine system. These sediments can lead to disruptions in both flow and morphology due to the complex nature of fluvial systems. Moreover, alterations to the flow regime and morphology can lead to changes in sediment fluxes. It is impossible to determine what the root cause of the problem is with this model. The SDRM, however, is better suited to estimate risk due to the data constraints and structural improvements to the model.

12.3.3 MRRM, SDRM and the Conceptual Model

Although we have noted glaring differences between the models in terms of how their structures emphasize certain key components and relationships of each, the conceptual model ultimately drives both. While the SDRM defines well the stressor-to-endpoint relationship without taking redundant pathways into account, the MRRM focuses strictly on magnitude - of source, habitat length, and effects to quantify stressor risk score magnitude. The MRRM helps express the complex number of ecosystem interactions that could occur to render certain effects; the SDRM helps elucidate the need to "work backwards" from the assessment endpoint to the stressor in order to determine the source that should be highly targeted for management. The difference was how the conceptual model was used (source to endpoint vs. endpoint to source). The latter (endpoint to source) seems more biologically believable; the former perhaps more easily implementable from a management perspective. However, both suffer from lack of being able to substantiate the source-to-stressor relationship source analysis.

12.4 Management Recommendations

Management recommendations for Secret Ravine were generated in light of the strengths of the MRRM and SDRM, respectively, based on the sources associated with the top-ranking stressors. While we concluded that both models are better suited to assess preliminary risk to fall-run chinook in this type of ecosystem, and as a data-needs assessment, management recommendations are also possible for different aspects of the study. It is important to keep in mind that by "management" we are referring to the potential to manage the sources of stress according to their biological, physical and chemical impacts to the fish but that any full-blown management plan for fall-run chinook salmon be accompanied by a cost-benefit analysis.

12.4.1 MRRM Management Recommendations

The MRRM analysis implicated the most harmful stressors in Secret Ravine to be flow, morphology and sediment. We determined that all three of these stressors, due to their complex ecological interactions, had eleven out of the twelve possible sources associated with them. Only direct sources, with the potential to contribute large amounts of the stressor, will be discussed here. Management recommendations for sediments will be discussed in the next section (**Section SDRM** Management Recommendations) since it was also one of the three highest-scoring stressors in that model.

The flow stressor had seven direct sources associated with it. Of these seven, impervious surfaces was determined to be the source most likely causing most of the stress (**Figure 6.2**). This source was also the highest-scoring source overall within Secret Ravine. Numerous management recommendations exist for this source and many are discussed in association with the sediment stressor. Direct mitigations for impervious surface alterations to flow include the standard practices of detention basins and floodplain protection. These practices need to be supplemented with accurate flow data, especially given the complex issues associated with the excess sand supply and habitat requirements for chinook.

This data would also be useful in helping to shed light on the flow inputs from the PCWA canal system. Direct sources of the morphology stressor include four sources. As stated earlier, OHV impacts on morphology are obvious in the downstream sections of Secret Ravine and should be immediately dealt with by gating off known access areas combined with a stakeholder-based public awareness program.

Planned structural alterations for flood control (including channelization) need to be researched in depth to determine impacts to morphology by taking into account the complex sediment loading issues. Little effort has been made to understand these issues (Bates, Pers. Comm., 2003). Introductions of large woody debris and roughness elements (boulders) to improve salmon habitat have already been recommended (Swanson 2001).

Numerous studies (Li and Fields, Jr. 1999, Swanson 2000, DCC 2001) have alluded to the legacy impacts associated with mining in Secret Ravine. No detailed information exists, however, concerning pre-mining conditions or predictions for sediment transport. Such information would be of great utility in determining whether the excess sediment supply issue could be dealt with expeditiously or if it is a long-term issue that cannot be solved via standard management practices.

12.4.2 SDRM Management Recommendations

The SDRM analysis revealed that sediment, toxicity, and reduced access are the three most harmful stressors in regards to chinook percent effect. Because we have more confidence in the scientific methods used to infer the relationship between the stressors and our biological endpoint, fall-run chinook population viability, we can also have confidence in the targeting of their associated sources for management actions, relative to the MRRM. Because our method for determining the relative contribution of sources was the weakest link in our SDRM analysis, however, and because there are many source the potentially contribute to the effects given by sediment and toxicity, the overlap in sources among the top stressors should be investigated in order to focus management efforts. In addition, those sources should be targeted that were associated with the highest magnitudes.

Sediment had eleven total contributing sources. Of these sources, two registered high contributions, five registered medium contributions, and four registered low contributions. Impervious surfaces and off-highway vehicles were the leading sources causing increased sediments in Secret Ravine. Impervious surfaces often alter the peak flows in Secret Ravine by decreasing the time between when precipitation falls to when water enters the fluvial system. In heavy rain events, impervious surfaces alter the flow regime by increasing peak flows. This increase accelerates erosion that can cause an increase in sediment loading in the stream. Both non-structural and structural best management practices should be implemented to prevent sediment loading.

Non-structural recommendations would include the concentration of development and the maintenance of open space. Zoning regulations requiring the inclusion of greenways and open spaces in new developments would further accomplish this. Existing impervious surfaces ought to be separated or disconnected with vegetated areas. Permeable pavements ought to be installed as an alternative to concrete and asphalt.

Structural best management practices that should be considered for Secret Ravine would be the installation of dry and extended detention basins. Such detention basins would control peak storm water discharges and provide temporary storage of storm water runoff with gradual release to minimize flooding. Dry and extended detention basins would offer a corollary benefit to reducing the impervious surface contribution to toxicity by promoting the settling of suspended solids and associated pollutants. Some pollutant removal would also occur through infiltration and vegetative uptake.

Off-highway vehicles are the other major contributor to sediment loading in Secret Ravine. Off-highway vehicles include all motorcycles, cars, trucks or all-terrain vehicles that utilize the floodplain of Secret Ravine for recreation. It is highly recommended that OHV use be restricted in and around Secret Ravine to inhibit further erosion and maintain the riparian vegetation within the buffer zone.

Toxicity poses another leading threat to chinook in Secret Ravine in terms of percent effect. Of the five contributing sources to toxicity, impervious surfaces, landscape maintenance and waste treatment plants are the highest potential contributors.
As stated in Section 9.1.1, impervious surfaces affect Secret Ravine by decreasing the time between when precipitation falls to when water enters the fluvial system, often associated with the alteration of peak flows. This tends to accrue fine materials (hydrocarbons and metals) on the surface. Heavy rain events flush these fine materials and contaminants into the stream in concentrated pulses. In areas where impervious surfaces are extensive, bio-filtration devices should be installed to minimize the effects of peak flow runoff. Hydrologists recommend implementing seeded or sodded grassed "infiltrating conveyances" as part of a design for storm-water management systems. These open, vegetated portions of the storm water system slow the rate of overland storm water flow. This allows sediment and other particulates to deposit themselves onto the vegetation thus slowing movement toward Secret Ravine. Such interaction with the biological (primarily microbial) component of the grass system would serve to decompose or chemically convert various pollutants, thus removing their component from the storm water. Trenches, dry wells, leaching catch basins and infiltration islands are other recommendations that could be installed to provide a holding area for runoff to allow infiltration into the soil profile and added pollutant removal. Such structural devices would also benefit Secret Ravine by promoting ground water recharge, and reducing the temperature of storm water runoff. In all other areas, buffer zones need to

be created and maintained around Secret Ravine. In these buffer zones, riparian vegetation should be protected to assist in contaminant filtration.

Toxicity from landscape maintenance may be in the form of fertilizers, herbicides, metals, and nutrients that are reaching Secret Ravine. Due to encroaching urbanization, there are many lawns and gardens in new housing developments, as well as golf courses and businesses with sod lawns and terraces. To protect chinook, individual homeowners must phase out their use of pesticides and herbicides in their homes, gardens, lawns, and workplaces. To encourage this, Placer County needs to develop a comprehensive pesticide use reporting system with publicly accessible data. To reduce levels of toxicity, Placer County ought to provide consumers with information about alternatives to pesticides and herbicides through educational opportunities, brochures, and media advertising. Restrictions involving the use of pesticides near Secret Ravine are also advisable. Lastly, comprehensive water monitoring ought to be made more vigorous for a fuller understanding of Secret Ravine's status in regards to toxicity.

In regards to waste treatment plants, infrastructure designed to minimize the effects of heavy rain events must be implemented at the two waste treatment plants at Newcastle and Castle City Trailer Park thus safeguarding Secret Ravine from accidental effluent spills and emergency releases.

Reduced access in Secret Ravine registered as the second most deleterious stressor to Secret Ravine. Again, this is not surprising, given that this is the only stressor to directly address the issue of timing delay in terms of migration, an important factor for anadromous fish on any system. Construction and development - in the form of artificial barriers - needs to be addressed mainly in terms of the direct impacts of reduced access. With the exception of the old concrete aprons at the Confluence and near China Garden Road, for their ability to create deep holding pools, only the fence at Sierra College Road remains an almost complete obstruction on Secret Ravine, and should be breached as soon as possible. And while the benefits of beaver dams, in terms of the requirements of this particular creek, seem to be outweighed by the costs of reduced access itself, the monitoring and breaching of particularly problematic beaver dams needs to be undertaken in a very cautious manner. There is an unusually high number of beavers in the Dry Creek watershed, particularly on nearby Miners, which has over 80 beaver dams.

According to Chris Lee, because of the rapid urbanization in the Dry Creek watershed area, the number of beavers found is probably higher than in less disturbed watersheds throughout Placer County and the Sierran foothills, because there are lower concentrations of beavers's natural predators in the region. So while certain dams should be breached during upstream adult migration periods, the area must be brought back into equilibrium in terms of limiting the take of natural predators to repopulate the area to some extent. Because the rise of development in this area makes this prospect unrealistic, mitigation of overly large beaver dams should occur. DWR also plans to remove the prohibitively high Hayer Dam downstream on Dry Creek, which should slightly increase the magnitude of adult fish returning to spawn in Secret Ravine (B. Washburn, pers. comm. 2003). Afterwards, as little breaching as possible should take place, as beavers should be integrated into resource management plans. The canal system must be considered in the planning process for Secret Ravine, because, depending on changes to the system, flows may be too high for beavers to want to build dams on this creek. Thus, management recommendations that target the sources of other stressors related to improved riparian health, including those addressing flow and sediment, should also help naturally control beaver populations and maintain flows high enough so that dams do not pose as much of a threat in terms of reduced access.

12.5 Conclusion

The chinook salmon is renowned for its preeminence in California for its economic and ecological value. To maintain the remaining population of chinook salmon, we recommend that the results of the Stressor-Driven Risk Model be appropriated for Secret Ravine. The SDRM utilizes scientific relativity to assess risk making it a more appropriate model to both analyze and communicate the risk posed to chinook salmon.

The SDRM functions to analyze risk by evaluating "...the likelihood that adverse ecological effects may occur, or are occurring, as a result of exposure to one or more stressors" (U.S. EPA 1998). The SDRM functions as a sound ecological risk assessment by incorporating available data and information to help understand and predict the links between sources, stressors, and their resulting ecological effects. These findings can then be used to prioritize environmental decisions (U.S. EPA 1998). With the SDRM, we have used the era process as defined by the U.S. EPA. In so doing, we have assessed the physical, chemical, and biological stressors on the fall-run chinook salmon in Secret Ravine. We have concluded that the MRRM and SDRM are good tools for preliminary risk assessment. However, the source component of the models is still greatly limited by insufficient data. With further research and data gathering, we believe this limitation can be overcome. It is our hope that this endeavor has prioritized sources and stressors in such a way that local and state organizations can protect the future viability of chinook salmon.

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