The purpose of this chapter is to assist the broadest possible readership in understanding the ongoing controversy regarding the stipulation of minimum flows in the lower Klamath River between April and September 2001 to protect threatened coho salmon. It is not intended to be an evaluation of the National Marine Fisheries Service’s (NMFS) Biological Opinion (BiOp) on Klamath Basin coho salmon. Instead, it aims to provide a synthesis of the most relevant hypotheses (or theories with a small “t” as defined in Chapter 4, “Science”), data, and conclusions from available reports and studies on coho salmon in the Klamath Basin. The topics covered are:

- Main tributaries of the lower Klamath River
- Coho salmon habitat requirements
- The status of coho salmon in the Pacific Northwest and in the Klamath Basin
- Effects of hatchery supplementation on wild coho salmon
- Human activities that affect salmonids and their habitat in the Klamath Basin
- Methods for establishing minimum flows
- Various flow recommendations for the lower Klamath River
- Water quality issues related to coho salmon
- The most salient aspects of the 2001 water allocation recommendations
- Potential effects of the 2001 decisions on coho salmon
- A suggested basinwide approach to planning

### Background

The Klamath River Basin, from its headwaters in south-central Oregon to its estuary by Requa, California, covers approximately 15,600 square miles (USDI 1985). For practical purposes, the Klamath Basin can be described as consisting of an upper and a lower section separated by a river reach with a series of six dams (two water diversion dams and four hydroelectric dams) (see map in Chapter 1, “Background”). In this chapter, we consider the Upper Klamath Basin to be the area upstream from Keno Dam, including the subbasins of the Williamson, Wood, Sprague, and Lost rivers; Upper Klamath Lake; Agency Lake; Tule Lake; Clear Lake; and Gerber Reservoir. We consider the Lower Klamath Basin to be the area downstream from Iron Gate Dam (IGD). It includes the tributary subbasins of the Shasta, Scott, Salmon, and Trinity rivers, in addition to the middle and lower sections of the Klamath River.
This report focuses primarily on the Lower Klamath Basin because, in this basin, the distribution of anadromous salmonids (those that spawn and rear in freshwater, but complete their growth and maturation at sea) is restricted to the lower section by hydroelectric dams.

The upper and lower parts of the basin have different geologies. The Upper Klamath Basin is characterized by a complex series of northwest/southeast-oriented valleys dominated by alluvial fans and lake clay sediments. These valleys are separated by ridges of volcanic origin, which are underlain by thick, very porous basalt flows. The great extension and thickness of these highly permeable basalt flow units give the Upper Basin a high water-storage capacity. Snowmelt recharges the groundwater reservoirs of the Upper Basin on an annual cycle. Before dam construction, these aquifers, in combination with Upper Klamath Lake, Lower Klamath Lake, and a vast network of wetlands in the Upper Basin, may have maintained relatively high and constant flows in the lower Klamath River during late summer and early fall (Boyle 1976; Hecht and Kamman 1996).

In contrast, the geologic setting of the Lower Basin is more diverse due to multiple fold systems and faults that have created a mosaic of deposits of various origins: volcanic (e.g., basalts), granitic (e.g., granite), intrusive (e.g., diorite, pyroxenite), metamorphic (e.g., marble), and sedimentary (e.g., shale, sandstone, limestone) (USDI 1985; KRBFTF 1991).

The following species of anadromous fish are found in the Klamath Basin: coho salmon (*Oncorhynchus kisutch*), chinook salmon (*O. tshawytscha*), steelhead trout (*O. mykiss*), coastal cutthroat trout (*O. clarkii*), green sturgeon (*Acipenser medirostris*), eulachon (*Thaleichthys pacificus*), and Pacific lamprey (*Lampetra tridentata*).

Historically, chinook salmon (both fall and spring types) and steelhead trout entered Klamath Lake. From Upper Klamath Lake, it is likely that they moved farther upstream into the uppermost tributaries of the Basin (USDI 1985; KRBFTF 1991). Coho salmon capture data from the 1920s at the Klamathon Racks indicate that this species probably reached the lower portion of the Upper Basin (Snyder 1931).

Many studies indicate that fisheries resources in the Klamath Basin have been negatively affected by the cumulative effects of more than a century of human activities. However, during the past decade, the effects of water diversion and hydroelectric projects on fish populations have been the primary focus of investigation and debate. Although the reduction in fish stocks has been caused by a variety of interactive factors, dams and water diversion projects have attracted attention for two reasons. First, they clearly block fish access to hundreds of miles of habitat. Second, according to several hydrological studies, they have changed the lower Klamath River’s annual hydrograph (the graphical representation of water discharge over time) (USGS 1995; Hecht and Kamman 1996; USFWS 1999; Hardy 1999).

Although all species of anadromous fish in the Klamath River are in serious decline, two salmonid species in particular—coho salmon and steelhead trout—have undergone status review by the NMFS under the Endangered Species Act (ESA). As a result, coho salmon have been listed as threatened.

A formal ESA Section 7 consultation process was initiated on January 22, 2001, between the Bureau of Reclamation (BOR) and the NMFS. As a result, the NMFS issued a BiOp that found “jeopardy and adverse modifications” of critical salmon habitat in the lower Klamath River by the BOR’s proposed operation of the Klamath Reclamation Project in response to the critically dry conditions anticipated in the summer of 2001. The BiOp provided what is known as a Reasonable and Prudent Alternative (RPA),
which established an interim spring-through-fall
Iron Gate Dam water release schedule aimed at
preventing further decline of the listed fish and
adverse modifications to its habitat.

**Main tributaries of the lower Klamath River**

In addition to the lower Klamath River
mainstem, salmonids are known to utilize
spawning and nursery habitats in its many
tributaries. The largest tributary systems, such as
the Shasta, Scott, Salmon, and Trinity subbasins,
may influence the lower Klamath River
mainstem’s water volume and quality and,
therefore, its salmonid carrying capacity
(KRBFTF 1991).

The confluence of the Shasta River with the
lower Klamath River is located approximately
14 miles downstream from IGD, at mile 176 of
the river’s mainstem. The Shasta River subbasin
covers an area of approximately 340 square
miles. It contains an estimated 50,000 acres of
agricultural land under active irrigation, which in
1988, as an example, used 150,500 acre-feet of
water (KRBFTF 1991; Siskiyou County Farm
Bureau 2001).

Like the upper part of the Klamath Basin, the
Shasta Valley receives very little rainfall
(between 11 and 17 inches per year), and
groundwater within this system is recharged via
melting snow, which is stored in porous volcanic
rocks. Stream flows and agricultural uses within
the Shasta River subbasin depend on inputs from
springs and subsurface flows.

In 1928, Dwinnell Dam was built on the
upper Shasta River to hold irrigation water for
the Montague Water Conservation District. This
dam eliminated anadromous salmonid habitat
above the dam and created Lake Shastina,
with a maximum water-storage capacity of
41,300 acre-feet (KRBFTF 1991).

Little water (up to 3 cfs) is released from this
reservoir into the Shasta River during the sum-
mer. The release was established to meet water
rights in the reach below, where diversion points
had been displaced by dam construction. This
water is immediately withdrawn from the river,
and it does not make much of a contribution to
flows in downstream reaches. The limited
summer flow of the upper Shasta River (below
the dam) is maintained by springs. The water
released by these springs has low dissolved
oxygen, which creates some localized water
quality problems during summer (Deas, personal
communication).

The Scott River enters the lower Klamath
River at mile 143, or 47 miles downstream of
IGD. The Scott River Resource Conservation
District (RCD) is 1,176,160 acres in size,
with 294,160 privately owned acres and
882,000 acres of public land (CARCD 2000). In
this region, flat, fertile valleys have been used
since the early 1900s for crop production,
grazing, and urban development.

Estimates of water use within the Scott
River Valley in 1988 show that 96,400 acre-feet
of water were delivered via 200 diversions along
240 miles of ditches and pipelines to
34,100 acres of crop and pasture lands. The
amount of irrigated land in the valley was
reported to have changed very little between
1958 and 1991 (Siskiyou County Farm
Bureau 2001).

Although large, permanent dams were never
built on the Scott River, summer nursery habitat
for salmonids has been affected by other human
activities. As early as 1974, fish habitat-related
problems were documented in many reaches of
this river, which were either totally dry or
running in an intermittent manner during July,
August, and part of September (CDFG 1974).

The Salmon River subbasin, which drains
into the lower Klamath River near mile 68, is the
only major subbasin within the Lower Klamath
Basin that is not affected by water diversion
projects. A large portion of this catchment area is
under National Wilderness designation and is
covered by forests. Therefore, fire, road con-
struction, and timber harvest have been the main
types of disturbances that have affected the system during the past century (USFWS 1994). In 1977, fires burned 56,000 acres of forest in this subbasin, and some 450 million board-feet of wood were reported salvaged during the following 5 years. Another 78,128 acres of forest burned in 1987 (KRBFTF 1991).

Numerous landslides and high sediment loads have negatively affected spawning gravel and invertebrate production in the Salmon River. USFWS (1994) assessments of habitat attributes, however, indicate that the relatively low quality of spawning habitat may have only minor negative implications for salmon production in this subbasin. The main limiting factor is the elevated summer water temperature, which is high enough to reduce the survival of juvenile salmonids (USFWS 1994).

The Trinity River subbasin is the largest and most complex of all Klamath River subbasins and joins the lower Klamath River at mile 43. Until the middle of the 20th century, the Trinity River was characterized by a dynamic and meandering channel that moved back and forth across its relatively broad floodplain over time (USFWS 1999). This subbasin sustained large runs of chinook salmon, coho salmon, and steelhead until the construction of the Trinity and Lewiston dams (a.k.a. Central Valley Project’s Trinity River Division or TRD) in the early 1960s.

The TRD Project not only prevented fish access to 109 miles of spawning and nursery habitat above Lewiston, California, but it diverted between 74 and 90 percent of the annual flow of the upper portion of the Trinity River into the Sacramento River Basin. This resulted in drastic changes in the flows of the Trinity River, which affected its channel morphology, its substrate composition, and the characteristics of both its floodplain and riparian areas. The original channel structure included an alternating sequence of gravel-rich riffles and deep pools that provided good salmonid habitat. In the absence of high flow events after dam construction and operation, the channel structure changed to a continuous and uniform “run” or glide type of habitat that became confined, over time, by riparian berms (KRBFTF 1991; USFWS 1999; USDI 2000).

The changes in the Trinity River had a strong negative effect on the subpopulations of salmonids that relied upon it. Despite hatchery supplementation, fish abundance in the Trinity River has been reduced between 53 percent (steelhead) and 96 percent (coho salmon) after the construction and operation of the TRD Project began (USFWS 1999; USDI 2000).

After a lengthy review and decision-making process, the Department of the Interior in 2000 ordered the TRD Project to put into practice a “preferred alternative” that included the augmentation of variable annual in-stream flow releases from Lewiston Dam, a plan to introduce gravel to the stream, the construction and rehabilitation of 47 stream channels, and the implementation of adaptive management and watershed restoration programs (USDI 2000). It is estimated that transbasin water exports from the Trinity into the Sacramento River will be curtailed to an average of 52 percent of the water flowing into the river above Lewiston (Ahern 2000; USDI 2000).

In addition to the four subbasins described above, smaller scale water diversion projects for irrigation have been built in several minor direct tributaries of the lower Klamath River. The affected creeks are Grider Creek, Cottonwood Creek, Horse Creek, Bogus Creek, Little Bogus Creek, and Willow Creek (KRBFTF 1991).

**Coho salmon habitat requirements**

Habitat can be defined simply as the place where an organism lives and the range of environmental conditions (both physical and biological) it requires to live, grow, and reproduce (Odum 1971). The abundance and distribution pattern of animals is determined by the availability of resources and their spatial distribution (Milinski and Parker 1991). The uneven distribution of resources, in both space and time, creates
patches of better or poorer habitat among which individual organisms distribute themselves.

The scale of an organism’s habitat is not fixed; rather, it is determined by the home range of that organism. Thus, the habitat of a large or relatively mobile organism (e.g., a bird) is large and contains within its physical boundaries the smaller scale habitats of smaller, or less mobile, organisms. This kind of organization implies a hierarchy of habitats that are nested in space.

A river represents a particularly good system to illustrate this point. The entire watershed makes up an environment of smaller scale subsystems, such as stream sections, which in turn constitute the environment of habitat systems at even smaller scales, such as stream reaches. Each stream reach is made up of smaller components, such as pools and riffles, and these habitats contain patches or microhabitats of different types (Frissell et al. 1986).

All of these habitat components are connected by flowing water and receive the cumulative effects of upstream human activities and natural landscape processes. Such cumulative effects may reduce or eliminate fish habitat in large river channels, small stream reaches, marshes, and even estuaries (Henderson 1991; Turner and Meyer 1993; Williams 1993).

To understand how land-use activities such as agriculture, dam construction, mining, logging, or urban development might affect fish production, it is necessary to know the habitat requirements of the different species and to identify the general environmental changes brought about by human activities in each watershed. Because juveniles of different salmonid species have specific nursery habitat requirements and different lengths of freshwater residence, they are not equally susceptible to all development activities. In British Columbia, for example, human activities have harmed some sockeye salmon (O. nerka) stocks at two different stages of their life cycle. During the egg incubation phase, they are negatively affected by the silt deposition and gravel displacement that some land uses may cause. During the juvenile migration period, they are prevented from entering lake nursery habitat by newly built dams (Nehlsen et al. 1991).

Coho salmon are anadromous salmonids that typically exhibit a 3-year life cycle, almost equally divided between the freshwater and sea phases. Their relatively long period of residence in freshwater makes this species particularly vulnerable to habitat alterations (Hicks et al. 1991; Henderson 1991).

**Coho spawning and nursery habitat**

Small coastal streams and the tributaries of large rivers offer the type of spawning and nursery habitat that coho salmon prefer (Sandercock 1991). Shortly after emergence from the gravel, coho salmon fry establish feeding territories, which they defend from other salmonids. They tend to be more territorial in stream reaches with fast-flowing waters than in slow-flowing areas, where it is common to find them forming loose aggregates and cruising for food (Mundie 1969). Although, coho salmon fry are predominantly stream dwellers, they also have been observed in the littoral zone of lakes (near the shore) (Mason 1974).

Individuals that “take residence” normally occupy a small area of slow-moving water, from which they make short excursions to feed or to chase away intruders. Subordinate fish, which are not able to establish a territory, tend to be less aggressive than dominant individuals and have a reduced growth rate due to their lack of access to good feeding areas (Chapman 1962).

In general, the young of this species prefer zones with reduced water velocity. They favor pools over other types of habitat and use in-stream structures as protection from fast currents. In this manner, they may minimize their energy expenditures to maintain position while feeding on drifting prey (Mundie 1969; Everest and Chapman 1972; Fausch 1993). Coho are visual predators and seldom feed from the bottom. They prefer to capture invertebrates that drift in the water column or on the surface (Nielsen 1992).

In addition to providing prey items and shelter from water velocity, in-stream and
riparian cover provides other benefits. Low-hanging overhead cover such as undercut banks and root wads may decrease the amount of light reaching the water surface, thereby making fish less visible to potential predators and minimizing stream temperature extremes (Murphy and Hall 1981). In-stream cover also can provide refuge from predators and increase visual isolation among competitors. Visual isolation may reduce aggressive interactions among competitors and, therefore, could lead to an increase in the number of fish occupying a given area (Doloff 1986; Fausch 1993; Giannico 2000).

The amount of spawning habitat in a stream is regulated by flows. D.H. Fry (cited in Bjornn and Reiser 1991, page 89) explains:

“… as flow increases, more and more gravel is covered and becomes available for spawning. As flows continue to increase, velocities in some places become too high for spawning, thus canceling out the benefit of increases in usable spawning area near the edges of the stream. Eventually, as flows peak, the losses begin to outweigh the gains, and the actual spawning capacity of the stream starts to decrease. If spawning area is plotted against stream flow, the curve usually shows a rise to a relatively wide plateau followed by a gradual decline.”

Egg incubation is affected by the amount and velocity of the water circulating among the gravel particles and eggs. This, in turn, may increase or decrease with the depth and quantity of the surface water (Wickett 1954). An additional problem associated with increases in peak water flows is possible redd (nest) scouring and gravel displacement that can cause the mortality of eggs and alevins (recently hatched fish that have not yet absorbed their entire yolk sac) (Chamberlin et al. 1991).

Seeding rate (abundance of spawners) is the primary factor regulating the abundance of juvenile salmonids present in a stream. Because numbers of anadromous spawners are determined in part by their ocean survival, their numbers do not necessarily show a direct relationship with in-stream flows in their natal streams. That said, it is worth noting that Smoker (1955), in 21 western Washington basins, found a correlation between the commercial catch of coho salmon and annual runoff, summer flow, and lowest monthly flow 2 years earlier. Smoker’s data were for the 1935–1954 period, but in the last decades of the 20th century, hatchery production of coho salmon smolts increased to the point that such comparisons no longer are possible in most systems. (Smolts are juvenile salmonids that are undergoing the physiological changes needed to survive in saltwater.) However, Mathews and Olson (1980) analyzed data from Washington for the 1952–1977 period and found that summer in-stream flows still had an important positive influence on total coho salmon production in streams in the Puget Sound area.

Although coho salmon show a strong preference for small streams over mainstem river habitat, some fry may end up being displaced into mainstem and even estuarine habitat if fish densities are too high or stream habitat is somehow limited (Sandercock 1991). In the spring, shortly after emerging from the gravel, coho fry distribute themselves throughout their natal stream reach and establish feeding territories that are aggressively defended from intruders. As late-emerging fry try to establish their own feeding “posts,” they find that most of the nearby good nursery habitat already has been claimed by the early-emerging individuals. Because they can start feeding earlier, the early-emerging fry grow bigger and become successful at defending their territories. This forces other fry to move in search of vacant nursery habitat (Chapman 1962). Although some fry move upstream, the vast majority move downstream. Thus, many individuals end up in the river’s mainstem and even in the estuary, where they are less likely to survive (Sandercock 1991).

A 1997 USFWS report and the 2001 mainstem trap records (USFWS unpublished data) show that young-of-the-year coho salmon
emigrate from the Shasta and Scott rivers, where they probably were spawned, into the mainstem of the lower Klamath River between March and July. Considering that there are very low densities of coho salmon fry in all Klamath subbasins, it is unlikely that these fish were displaced downstream because of competitive interactions with other juveniles of their own species. Possible hypotheses to explain their summer movement are: (1) the declining quantity and quality of water in these tributaries (USFWS records indicate that the Shasta and Scott rivers were warmer than the mainstem Klamath during the summer of 2001), or (2) interspecific competition with steelhead (see Harvey and Nakamoto 1996).

**Coho temperature tolerance**

Juvenile coho salmon’s temperature tolerance and their use of cool-water areas in the Klamath River have received a lot of attention recently. Unfortunately, this is a complex issue that can be addressed adequately only with field studies and experimental manipulations in the Lower Klamath Basin.

A number of studies have shown a rather consistent pattern of temperature preference. Like other salmonids, coho salmon prefer cool, well-oxygenated waters. Brett (1952) observed that coho prefer a temperature range of 12 to 14°C (53.6 to 57.2°F), which is close to the optimum temperature for maximum growth efficiency reported by other authors (see Sandercock 1991). Although fish may survive at temperatures near the extremes of the tolerance range (1.7 to 28.8°C, 35.1 to 83.8°F) (Bjornn and Reiser 1991), growth is reduced at both low and high temperatures.

Regarding the maximum temperature that juvenile coho salmon can withstand, several studies have reported different results, depending on a variety of factors. For example, Eaton et al. (1995), using an extensive database of primarily large stream and river data, estimated that the maximum temperature that juvenile coho salmon tolerate is 23.4°C (74.1°F). Brett (1952) found that exposure to temperatures in excess of 25°C (77.8°F), or a quick rise in temperature from less than 20 to 25°C (68 to 77°F), resulted in high mortality rates. Becker and Genoway (1979) reported a lethal temperature limit of 28.8°C (83.8°F) when they gradually exposed fish to increasingly warmer waters. Bisson et al. (1988) found neither evidence of mortality nor lethargic behavior in juvenile coho salmon when stream temperatures exceeded 24.5°C (76.1°F) during extended periods, and even when they peaked at 29.5°C (85.1°F) for 3 consecutive days in two Mount St. Helens streams (Washington). Relatively similar high tolerance levels were reported by Konecki et al. (1995), who tested the critical maximum temperature for wild juvenile coho salmon from three streams in Washington. They found consistently high thermal tolerance levels that ranged from mean maximum temperatures of 28.21°C (82.8°F) for one population to 29.23°C (84.6°F) for another.

These results suggest that juvenile coho salmon are able to tolerate different critical maximum temperatures, depending on stream channel size, acclimation period, food abundance, competition, predation, body size, and condition. Longer acclimation periods, higher prey availability, and lower numbers of competitors seem to increase the upper temperature limit these fish can endure.

Behavioral responses, such as migration, utilization of cool-water refugia, feeding rate, and activity level are some of the mechanisms fish use to survive adverse temperatures. A recent study by Welsh et al. (2001) on the summer distribution of juvenile coho salmon among tributaries of the Mattole River, in northern California, found fish only in creeks with maximum weekly temperatures below 18.1°C (64.6°F). These results corroborate that fish distribution is affected by water temperatures and that coho salmon seek relatively cool-water areas as summer refugia. Such thermal refugia are found in spring-fed tributaries, in main river channels below the confluence of tributaries, and around groundwater seepage areas.

A 1996 snorkeling survey of the lower Klamath River mainstem located 32 cool-water areas between IGD and Seiad Creek (60.27 miles
below IGD). Twenty-eight of these were associated with tributary confluences, and four with springs (Belchik 1997). During the course of this study (July and August), the temperature of the Klamath River mainstem ranged from 21.3 to 26.2°C (70.3 to 79.2°F), whereas cool-water areas ranged from 10.2 to 22.8°C (50.4 to 73°F). Seven tributary confluences did not offer cool-water areas because the tributaries were either dry (two creeks) or were warmer than the river (including the Shasta River). Juvenile salmonids were observed in 19 of the 32 cold-water refugia; most of them were chinook salmon and steelhead. Coho salmon were observed in only two of these areas (Belchik 1997).

During the summer of 2001, the USFWS counted thousands of juvenile salmonids in the mainstem of the lower Klamath River. Sampling was restricted to the mainstem and specifically to tributary confluence areas. For most locations, it was repeated several times between June and September. Mainstem Klamath temperatures ranged from 16.7 to 26.2°C (62.1 to 79.2°F) during this period and generally were warmer than both the tributaries (which ranged from 12.8 to 24.5°C, 55 to 76.1°F) and the cool-water areas these tributaries created in the mainstem. Although the vast majority of fish observed during this survey were juvenile chinook salmon and steelhead, a few coho salmon were seen in some mainstem cool-water refugia (86 individuals) and in several of the creeks (395 individuals) near their confluence with the river.

During some July and August days, water temperature in a small number of tributaries (Beaver, Grider, and Pecwan creeks and the Salmon River) was either the same or higher than in the main river, and many young fish were observed in these warmer waters. Later, on the afternoon of September 13, 240 juvenile steelhead, 233 juvenile chinook salmon, and 15 juvenile coho salmon were observed near the confluence of Pecwan Creek in 24.6°C (76.3°F) waters, while the mainstem Klamath was at 20.5°C (68.9°F). Only the Shasta and the Scott were warmer than the mainstem Klamath during the 3 days of the survey. In fact, these tributaries on average were warmer than the mainstem Klamath throughout July and August. The average July–August daily temperature for the Shasta was 22.9°C, or 73.2°F; for the Scott, it was 22.8°C, or 73.0°F. Nevertheless, these tributaries’ area of thermal influence in the Klamath occasionally seemed to attract small numbers of juvenile salmonids.

These observations support the notion that juvenile salmonids are able to respond in a flexible manner to temperatures around the mid-20s°C (70s°F). As discussed earlier, their tolerance to high temperatures seems to be determined by factors such as food abundance, competition and predation pressures, time to acclimate, fish condition, etc. (see Bisson et al. 1988; Konecki et al. 1995; Harvey and Nakamoto 1996; and Welsh et al. 2001).

In autumn, as water temperatures decline and flows increase, juvenile coho salmon redistribute into deeper pools, smaller tributaries, or lateral channels. In these areas, abundant cover from fallen logs or root wads provides shelter from winter conditions (Bustard and Narver 1975; Cederholm and Scarlett 1982; McMahon and Hartman 1989; Nickelson et al. 1992). Winter habitat availability tends to be one of the most important factors affecting the survival of juvenile coho salmon in streams (Moyle 2002).

Coho requirements
for water quality and quantity

The quality and quantity of water determine whether fish can live in a particular aquatic habitat, what species of fish can use it, and how many individuals can occupy it. Water quality requirements for salmon have been well established by a large number of studies (see Bjornn and Reiser 1991; Groot and Margolis 1991). Salmonids can live only in water with chemical characteristics (e.g., oxygen concentration and pH) and physical characteristics (e.g., temperature) that are within their relatively narrow range of tolerance.
Quantity requirements, particularly for stream-dwelling fish, have been more difficult to determine. Some of the most common tests of flow/fish relationships consist of analyses of correlations between fish abundance and flow, as well as physical and chemical characteristics affected by the flow regime (Binns and Eiserman 1979). Measures of density (number of fish per unit of area) are one way to measure abundance.

Despite regional and watershed-specific differences, several studies have identified the same set of variables as very important in controlling salmonid abundance. These variables are water velocity, minimum water-column depth, in-stream cover, substrate composition, water temperature, dissolved oxygen, alkalinity, and turbidity (Gosse and Helm 1981; Shirvell and Dungey 1983). The fact that almost all of these variables are directly or indirectly influenced by in-stream flows explains why water flows can have such a strong controlling effect on fish numbers.

Water velocity and water-column depth affect upstream fish migration. Under increasingly fast water velocities, it becomes harder for fish to migrate upstream (although fish may be assisted in their upriver migration by turbulent flows and eddies). As the water column in a channel becomes deeper, fish seek to save energy by migrating closer to the river bottom through slower and relatively colder waters. For information on a series of techniques to estimate stream discharges that provide suitable depths and velocities for upstream passage of adult salmonids, see Thompson (1972).

The amount of suitable stream habitat to be occupied by salmonids is a function of in-stream flows, channel morphology, gradient, and in some cases in-stream or riparian cover availability. Suitable habitat for each salmonid life stage requires water of sufficient depth and quality to be flowing at appropriate velocities.

Diversions of water from streams and/or impoundments alter water discharge and reduce or eliminate flow variation over time, thus changing the stream’s carrying capacity for salmonids. The relationship between flow and carrying capacity varies with channel geometry and valley form. (For example, it differs between a channel dominated by riffle habitat within a narrow canyon and a channel with many pools in a broad valley.)

In general, the relationship must start at the origin (no flow, no fish), increase (not necessarily in a uniform manner) with flow increases up to a point, and then level off or even decline if flows become excessive. The existence of this relationship has been demonstrated empirically (see Kraft 1972; Stalnaker 1979; White et al. 1981) and is not in dispute. What remains to be defined is the nature of the relationship (or the shape of the curve representing the relationship) between flow levels and fish abundance. Because the relationship is not linear, and it varies with channel structure and the fish species under consideration, its theoretical formulation has been the goal of many models.

Status of coho salmon in the Pacific Northwest

Each salmonid species is made up of local populations, referred to as stocks, which are adapted to the specific environmental conditions of their watershed of origin (Ricker 1972). In the case of anadromous salmonid populations, the strong tendency to spawn in their natal streams (homing behavior) maintains a high level of reproductive isolation among populations and makes them highly susceptible to local extinctions.

This type of reproductive isolation allows for the development of watershed-specific adaptations (e.g., thermal tolerance, migration timing, etc.) at the population level and increases the genetic variability of the species as a whole (Thorpe et al. 1981). A high level of genetic variation among the populations of a species provides the basis for future evolution and an “insurance” of adaptation to environmental changes (White and Nekola 1992). Consequently, the genetic diversity within each species must be maintained by protecting local breeding populations and their habitats. To consider only
the overall abundance of salmonids at a regional level is not a reasonable long-term resource management approach (NRC 1996).

Many wild populations of anadromous salmonids (*Oncorhynchus* spp.) in western North America are at risk of becoming extinct, while others have declined between 50 to 85 percent from their average historical abundance (Nehlsen et al. 1991; Northcote and Burwash 1991; Slaney et al. 1996). A review by Weitkamp et al. (1995) of coho salmon status in California, Oregon, and Washington identified six population groups (Evolutionary Significant Units, or ESUs) and indicated that wild populations in all ESUs are significantly below historical levels. In southern Oregon, Nehlsen et al. (1991) considered all but one coho salmon population to be at “high risk of extinction.” In northern California, coho salmon populations, including hatchery fish, might be at 6 percent of their abundance during the 1940s. They have been eliminated in many streams, and in some watersheds, adults are observed only 1 year in 3 (CDFG 1994). In other words, two of the three spawner lines have been lost.

It is obvious that the anadromous salmonid populations of the Klamath Basin are not the only ones in the Pacific Northwest that face a bleak future. Such widespread declines cannot be attributed to one single land-development project, nor even to one natural factor.

Several hypotheses have been advanced to explain these declines (e.g., overfishing, freshwater habitat loss, interactions with hatchery fish, and ocean habitat changes). It is worth noting, however, that freshwater habitat loss has been associated with the decline of every one of the 214 salmonid stocks that Nehlsen et al. (1991) identified as either facing high to moderate risk of extinction or being of special concern. These researchers recognized several factors that had a negative effect on wild stocks, but concluded that freshwater habitat degradation and loss were among the leading causes of their decline.

Although some stocks may be affected primarily by a single factor, it is reasonable to conclude that a combination of the above-mentioned factors, with their relative importance varying from year to year and location to location, is behind the widespread decline in salmonid abundance.

Commercial fishing has been one factor contributing to the decline of salmon abundance throughout the Pacific Northwest. However, salmon mortality caused by the combined effects of other human development activities and natural factors usually exceeds the mortality caused by fishing. This chapter focuses on human activities that are particularly important in the case of Klamath Basin coho salmon. Because retention of naturally produced coho salmon has been prohibited in marine fisheries south of Cape Falcon, Oregon since 1994, the commercial fishery currently is not a significant barrier to recovery of the wild population.

**Status of coho salmon in the Klamath Basin**

According to the 2001 BiOp (NMFS 2001), the Southern Oregon/Northern California Coast coho salmon Evolutionary Significant Unit (SONCC ESU) “was listed as threatened under the ESA on May 6, 1997. This ESU includes coho salmon populations between Cape Blanco, Oregon, and Punta Gorda, California.” The listing of these stocks was the response of the NMFS to abrupt declines in their abundance, in particular during the past decade. The designation of “critical habitat” within this ESU (waterways, stream bottoms, and riparian zones below impassible natural barriers) followed in May 1999.

Historically, the Klamath River Basin was well known for its large runs of chinook salmon. Its coho salmon populations were relatively large, but never as abundant as in some of the larger basins north of Cape Blanco, such as the Columbia River or the Fraser River (Weitkamp et al. 1995). Over time, however, coho salmon stocks have been greatly reduced and now consist largely of hatchery fish. Only small runs of wild coho salmon remain in the Basin (CDFG 1994).
Out of a total of 396 streams within this ESU that once had coho salmon runs, Brown et al. (1994) found survey information for 115 (30 percent) of them. Seventy-three (64 percent) of these streams still supported coho salmon, while 42 (36 percent) did not. The streams identified as lacking coho salmon were all tributaries of the Klamath or Eel rivers (Brown et al. 1994; Weitkamp 1995).

Estimates from 1994 showed an average spawning coho salmon population in the Klamath Basin of 7,080 wild fish and 17,156 hatchery fish. Combined with Rogue River data, spawning adult coho salmon were estimated to be 10,000 wild fish and 20,000 hatchery fish (PFMC 1999).

Coho salmon enter the Klamath River from the Pacific Ocean between mid-September and late December. Spawning typically takes place in tributaries between early November and mid-February (USDI 1985). Some limited spawning also occurs in the mainstem, where USFWS biologists have recorded coho spawning in the Klamath River between Iron Gate Dam and the confluence of the Shasta River (Shaw 2001).

Because fish sampling in the Klamath River traditionally has focused on fall chinook salmon, and coho salmon runs peak later in the season, data on wild coho spawners have not been collected consistently. Fish-counting weirs are removed from the river after the fall chinook salmon migration is over and before flows reach very high levels. The migration of adult coho salmon typically coincides with periods of high water discharge, which make the use of counting weirs impractical and often dangerous. Unfortunately, trapping efforts for juveniles in the Basin also have focused on chinook salmon smolts and have provided relatively poor estimates of coho salmon smolt output.

Notwithstanding these technical difficulties, the California Department of Fish and Game has estimated that total coho salmon runs are less than 6 percent of what they were in the 1940s (CDFG 1994). This is within the range estimated by Nehlsen et al. (1991).

Fish-counting weir data from the Shasta River and carcass counts from the Scott River show similar declines in the abundance of coho salmon spawners during the past 30 years. Shasta River fish counts, during years when trapping started and ended at equivalent times, show an average of 217 spawners in the 1970s and only 7 in the 1990s. Between 1991 and 2000, coho salmon counts ranged from 0 to 24 fish, with 1 or 0 fish counted during 4 of these years (CDFG, unpublished data).

Counting weirs in the Scott River indicated a similar trend, with an annual average count of 25 coho salmon (range = 5 to 37) between 1982 and 1986, and an average of 4 fish (range = 0 to 24) between 1991 and 1999. Again, within the past decade, a single year accounted for most of the fish observed, whereas no coho salmon were counted during 4 of those years (CDFG unpublished data). These data emphasize the importance that 1 year’s spawning success can have on the survival of these coho salmon stocks.

Smolt data also suggest that Klamath Basin coho salmon stocks are in trouble. Juvenile traps, operated on the river’s mainstem, were used to estimate smolt production. Based on counts from these traps between 1991 and 2000, the annual average number of wild coho salmon smolts was estimated at only 548 individuals (range = 137 to 1,268 individuals) (USFWS 2000). For the same period, an average output of 2,975 wild coho salmon smolts (range = 565 to 5,084 individuals) was estimated for Willow Creek within the Trinity River subbasin (USFWS, unpublished data).

The incomplete trapping record provides limited information on trends, but remains a useful indicator of the extremely small size of coho salmon populations in the Klamath Basin. Furthermore, the presence of coho salmon fry in these smolt traps helps to shed some light on how the young fish are distributed within the system during their period of freshwater residence.
Effects of hatchery supplementation on wild coho salmon

A comprehensive review of the effects of hatchery operations warrants an entire chapter. Unfortunately, such an evaluation is beyond the scope of this report. Instead, we will present a brief summary of the main hatchery-related issues as they relate to Klamath Basin coho salmon.

The idea to use hatcheries to offset habitat destruction and overfishing is not new. In the Klamath Basin, a series of attempts began as early as 1889 with small facilities that were operated for only a few years. To compensate for the habitat lost to Copco Dam, Fall Creek Hatchery was built in 1920. This facility, which was operated by the California Department of Fish and Game, released an annual average of 3,400,000 chinook and 600,000 steelhead fingerlings between 1920 and 1948 (KRBFTF 1991).

The two large-scale hatcheries that currently operate in the Klamath River Basin are the Iron Gate and Trinity River hatcheries. The fish produced in these hatcheries are derived from a combination of Klamath Basin and Columbia Basin coho. The hatcheries were built in the 1960s to mitigate for habitat lost to Iron Gate Dam on the mainstem of the Klamath River and to the Lewiston and Trinity dams on the upper Trinity River (KRBFTF 1991). Currently, coho salmon stocking goals have been reduced to 75,000 yearlings for Iron Gate Hatchery and 500,000 yearlings for Trinity River Hatchery (Rushton 2001).

The intended goal of most hatcheries was to mitigate or reduce the negative effects of human activities on salmonid stocks. In retrospect, it has become clear that they have created a number of unintended biological problems. These problems derive from the hatcheries’ goal of increasing run sizes and the poor integration of genetic, evolutionary, and ecological principles into hatchery planning and operation. The problems associated with past and most current hatchery practices listed by the National Research Council (NRC) (1996) include:

- Demographic risks (e.g., overfishing in mixed-population fisheries, which tends to drive the smaller wild stock to extinction)
- Genetic and evolutionary risks (e.g., loss of genetic diversity, inbreeding, domestication)
- Differences in behavior (e.g., size-related competitive displacement of smaller wild fish, inadequate response to predators by hatchery fish)
- Physiological state (e.g., higher susceptibility to disease and lower proportion of individuals that smolt among hatchery fish)
- Ecological effects (e.g., reduction of number of carcasses in streams, overload carrying capacity of rivers)

In the case of Klamath River wild coho salmon, competition with the more abundant hatchery fish for limited resources (e.g., food, space, and spawning beds) is likely to result in reduced survival for both hatchery and wild fish (Stempel 1988; Steward and Bjornn 1990). Despite their lower ability to survive, hatchery salmon greatly outnumber their wild counterparts and impose unnatural pressure on their populations and on the resources they require (NRC 1996). As the interim report by the NRC (2002) states, hatchery production of coho salmon has strong negative effects on the wild populations of the species in the Basin, and it does not represent the solution to the current wild coho salmon crisis.

Human activities and fish habitat

Fish habitat degradation and loss are side effects of various types of human activities. Changes to the aquatic parts of a watershed begin when humans alter its terrestrial components. Mining and logging have historically preceded a number of other land-use activities in coastal watersheds of the Pacific Northwest. These operations indirectly affected stream
channel shape and water movement by modifying the soil and its vegetation cover. In the past, they also directly altered stream channels and their substrates through practices such as moving heavy machinery, skidding logs across channels, and building (and subsequently blasting) “splash dams” to float and transport logs downstream.

The expansion of agriculture into some river valleys and the encroachment of grazing into some riparian zones have altered the connectivity of stream channels with their floodplains. In some cases, government assistance was provided for straightening and moving stream channels. In California and Oregon, hydroelectric projects are common. Dams created impassible barriers to fish migration, and the regulation of flows altered the structure of channels and the hydrology of rivers. More recently, urban sprawl has begun to cover ever-larger portions of coastal watersheds (Gregory and Bisson 1997).

**Land use activities in the Klamath Basin**

The Klamath Basin has a long history of human activities that have altered its hydrology and, as a result, the availability and quality of fish habitat in the system. Commercial harvesting of timber in the Lower Klamath Basin started in the late 1800s, concurrent with the development of a commercial fishery in the river estuary and surrounding coastal waters (KRBFTF 1991). Mining, primarily for gold, was a very common activity, particularly in the middle reaches of the Klamath River. The cultivation of crops and the raising of cattle began in the 1850s. The hydrology of most of the Klamath Basin was altered drastically by the development of many water diversion projects. Although mining was the first activity that diverted water from the river, irrigation diversions for agriculture have been, and still are, common practice, not only in the Upper Basin, but also in some lower tributaries to the Klamath River such as the Shasta, Scott, and Trinity rivers.

**Mining**

In the 1800s, gold mining was carried out primarily by means of suction dredging and placer mining—two methods that disrupt stream substrates and negatively affect fish spawning beds, food production, and nursery habitats (Bjornn et al. 1977; Hassler et al. 1986). Other types of mining, such as tunnel mining for gold, copper, and chromite, have been intermittent in different parts of the Basin during the past 100 years. In-stream gravel mining has been a more sporadic activity (KRBFTF 1991).

**Forestry**

Forestry represents a very important industry in the Klamath Basin. High timber demand began with gold-mining activities, and this demand made possible the establishment of many lumber mills in the central part of the Klamath Basin (Wells 1881). Timber harvest increased with the arrival of the railroad to Yreka, California in 1887, and it experienced extraordinary growth after World War II. As a result, log rafting, road construction, skid-trail construction, earth removal, and other related practices increased to the point of presenting a threat to fish life in the Klamath River.

“Corrective actions” were ordered by the California legislature in 1957 (KRBFTF 1991). Although an increasing number of regulations have been implemented since that time to minimize the negative effects of timber harvest practices on fish habitat, many questions regarding their effectiveness remain unanswered.

**Agriculture**

While forestry has been the predominant type of land use in the Lower Basin, crop production and ranching have flourished in the fertile valleys and hillside grasslands of the Upper Klamath Basin, as well as in the floodplains of tributaries such as the Shasta and Scott rivers. Land clearing to provide cropland and ranchland modified the vegetation of entire valleys, with native trees and perennial grasses being replaced by crops, junipers, brushes, and forbs (USSCS 1983; KRBFTF 1991).

As farmland became more valuable, flood-control measures became increasingly common. As a result, riparian vegetation was removed from entire river reaches, stream channels were straightened, and dikes were built along stream
banks. Flooding was not the only problem, however. By the mid-1900s, pressure to conserve soil and water resources prompted farmers and ranchers in various valleys to organize soil conservation districts (KRBFTF 1991).

**Water diversions**

The U.S. Bureau of Reclamation began construction of the Klamath Reclamation Project, near Klamath Falls, Oregon, in 1905. Marshes, Lower Klamath Lake, and most of Tule Lake were drained, and a complex network of levees, dikes, pumping stations, and channels was developed to divert water from Upper Klamath Lake and the Klamath and Lost rivers to irrigate about 220,000 acres of agricultural land and wildlife refuges. The main water diversion facilities that were built on the Klamath River immediately downstream from Upper Klamath Lake include the A-Canal (1905–1907), the Link River Dam (1921), and Keno Dam (1967). (See Chapter 2, “Klamath Reclamation Project,” for a detailed description of the water diversion system in the Upper Klamath Basin.) The network of irrigation channels was designed to reroute water from the lake and river through farmland and national wildlife refuges and return unused water back to the upper river above IGD.

The combined effects of Project water requirements and the dams that were built on the Klamath River for electricity production reduce summer flows, increase nutrient load, and alter water temperature in the river. These changes seem to affect the quantity and quality of fish habitat downstream from IGD during summer and early fall, especially during dry years (KRBFTF 1991; USGS 1995; Deas and Orlob 1999).

**Hydroelectric projects**

During the late 1800s, small, water-impounding dams supplied the water needed for mining and farming operations. However, these small projects did not represent a permanent barrier to fish migration because they often were washed out during floods. It was not until 1892 that the first large dam was built; it was part of a hydroelectric power plant project on the Shasta River. After that time, the California Oregon Power Company (COPCO) identified numerous potential dam sites on the Klamath River. Because the proposed projects were not always feasible based on hydroelectric power production alone, the company tried to develop irrigation supply benefits as well whenever possible (Boyle 1976; KRBFTF 1991).

The KRBFTF (1991) report shows that COPCO’s Klamath River flow records started in May 1910, before the construction of any of the dams. These flows were measured on a daily basis at Ward’s Bridge and ranged from 1,450 cfs to 4,500 cfs. Boyle (1976) and the USGS (1995) have attributed the relative uniformity in the river’s flow to the moderating influence of the large, shallow Upper and Lower Klamath lakes.

Over time, these records revealed a change in the river flow regime from a relatively uniform flow to one with higher flows in early spring and lower flows in the summer. This hydrological change, which was primarily caused by construction of four hydroelectric dams (KRBFTF 1991), apparently became accentuated by the concurrent development of the Bureau of Reclamation’s irrigation projects (Boyle 1976).

The first large hydroelectric dam on the mainstem of the Klamath River was Copco 1, which was completed in 1917 in the Ward’s Canyon area, northeast of the town of Yreka, California. Copco 1 created a reservoir with a holding capacity of 58,800 acre-feet of water. This hydroelectric project created the first impassible barrier to the migration of anadromous salmonids to the Upper Klamath Basin (Snyder 1931). In 1925, Copco 2 was completed immediately downstream from Copco 1 (Boyle 1976).

Because no minimum flows were required for the operation of these dams, their water releases fluctuated from 200 cfs to 3,200 cfs in response to peak power demands and regulatory capacity. Such changes in flow often made the water level in the river rise or drop several feet within a 20-minute period (Jones and Stokes
1976; KRBFTF 1991). These extreme and frequent changes in flow had very negative effects on fish habitat and fish production in the Lower Klamath Basin (Snyder 1931; Jones and Stokes 1976).

In 1947, the proposed “solution” to this problem was the construction of a reregulating dam below Copco 2 that would eliminate the daily peaks of water discharge. It took 13 years for construction of this dam to begin. Water users in the Upper Basin were concerned about the allocation of water and opposed COPCO’s plans for more dams.

It was not until the Federal Power Commission (FPC) approved COPCO’s Big Bend hydropower project, and commanded the extension of its contract with the Bureau of Reclamation, that Upper Basin water rights were dealt with in a manner that allowed construction of a flow-regulating dam (KRBFTF 1991). In 1958, the FPC granted approval for the construction of Big Bend Dam and power plant (now known as J.C. Boyle) upstream of Copco 1 on the Oregon side of the state line. By then, COPCO had reached an agreement with the California Department of Fish and Game regarding flow-release regimes and thus had obtained the state water rights and the license from the FPC to build the recommended flow-stabilizing dam downstream from Copco 2 (Jones and Stokes 1976).

The construction of the flow-regulating Iron Gate Dam began in 1960 and was completed by 1962. IGD is located 7 miles below Copco 2, and its reservoir has a capacity of 46,850 acre-feet of water. It now marks the limit to upstream fish migration in the Klamath River.

Methods for establishing recommended minimum flows

The complex dynamics of river systems, combined with salmonids’ diverse repertoire of adaptive behaviors, limit the predictive capability of any model. Methods for establishing minimum flow requirements are no exception. Nevertheless, such methodologies constitute broadly applicable and useful tools to establish the minimum flows needed in a stream channel to ensure that a specified proportion of habitat remains available to fish during low-flow periods. Because predetermined in-stream flows are not compatible with the emerging emphasis on ecosystem-based management, these methodologies are more effective at protecting aquatic resources if used within the context of watershed-scale management programs.

In-stream flow quantification methodologies are classified into two general categories: standard-setting and incremental methodologies. Standard-setting methodologies are techniques used to determine the minimum flow needed to protect certain habitat types of interest for the benefit of fish and other aquatic life. The application of these methods usually results in a minimum flow value for a specified stream reach, below which water may not be withdrawn. The minimum or “threshold” flow almost always is less than the historical level and, therefore, reduces the amount of available habitat. Nevertheless, these methods are used in many states.

Standard-setting methods can be further divided into nonfield types (e.g., the Tennant Method) and field types (e.g., R2CROSS) (Espegren 1998). The Tennant Method is a nonfield technique used for setting “target” percentages of mean annual discharge that are expected to “protect” specified amounts of aquatic habitat (Tennant 1976). This method was developed for fish-bearing stream sections and has become popular because it is quick, cheap, easy, objective, and can be readily applied to both recorded flows and estimated mean annual discharges. The Tennant Method has been commonly used in the U.S. since 1976 and is second in popularity only to the In-stream Flow Incremental Methodology (IFIM).

Many regulatory agencies still consider the Tennant method a useful, albeit coarse, tool that can be used to set in-stream flow targets over a large number of streams in a short period of time and at a relatively low cost. However, because it is a nonfield method, many managers and
scientists believe it should not be used as the sole basis for developing in-stream flow recommendations (Castleberry et al. 1996). In fact, Tennant (1976) indicated that field verification of this method is necessary to establish appropriate “target” flow levels.

Incremental methodologies, such as IFIM, combine hydraulic data with biological information on selected aquatic organisms to assess habitat alteration relative to incremental changes in flow. They help evaluate potential effects of alternative development scenarios on aquatic species (Stalnaker 1993). These methods were developed from habitat-versus-flow functions that take into consideration specific needs of target species at various life stages (e.g., migration, spawning, and rearing).

Incremental methodologies simulate the quantity and quality of potential habitat resulting from proposed water development, illustrated for a series of alternative flow regimes (Trihey and Stalnaker 1985). These methodologies are field-based techniques often used to evaluate the impacts of hydroelectric projects and to develop conditions for water licenses and permits on very controversial stream segments with high potential for water development. Their downside, from the perspective of the stream ecosystem, is that they do not define flow targets in terms of the natural variability of the hydrograph. In other words, they pay little attention to the importance of flow changes in maintaining the river ecosystem structure and function. They also focus only on the most “valued” species and the most vulnerable life stages of those species, thus requiring a subjective value judgment. This is a particularly important issue if we are to begin thinking of stream-flow management as part of a larger program of ecosystem management.

**Lower Klamath River in-stream flows**

All of the Klamath River Basin hydrological studies that we could obtain (USGS 1995; Hecht and Kamman 1996; Hardy 1999) conclude that human activities have altered flows in the lower Klamath River. However, the nature of these changes and their precise magnitude is somewhat ambiguous; thus, their effects on salmonid habitat availability and fish abundance remain contentious, to say the least. In this section, we limit ourselves to summarizing those studies and their main conclusions. Review of their data and critical analysis of their conclusions are beyond the scope of this chapter. Additional discussion of in-stream flows is found in Chapter 2 (“Klamath Reclamation Project”).

Some individuals have raised concerns about the conclusions of those studies and have proposed alternative hypotheses regarding the effects of human activities on river flows. Although we consider that those hypotheses should be examined, we do not discuss them in this section because we were not able to find any hydrological studies that addressed them. The only study of Klamath River hydrology of which we are aware that is not included in our synthesis is INSE 2002 (Institute for Natural Systems Engineering, Utah State University). Its release coincided with the completion of this chapter.

It is important to note that looking at historical flows does not imply that we can go back in time and match historical conditions. Rather, these analyses are intended to help us understand patterns of change and to provide guidance toward selecting appropriate flow regimes for the future.

A 1995 USGS study characterized the baseline flow regime for the Klamath River Basin. Baseline flows in this case meant historical flow conditions that provide a basis for comparison of past flow conditions to contemporary and possible future alternative water management scenarios. This study did not identify any significant changes in annual water discharge at Keno Dam (a water diversion dam on the Klamath River, upstream from the hydroelectric dams) between 1914 and 1960 that could be attributed to human intervention in the flow regime.

However, the analysis of monthly flows showed a discernible seasonal change in water discharge both below IGD and in the Scott River
after 1960. Lower Klamath River flows below IGD have become higher in February and lower between June and September than in previous decades. Evaluations of seasonal trends in flow for the Scott River near Fort Jones also show a reduction in flow between July and August after 1960. Such changes in flow were attributed by the USGS (1995) to changes in crop patterns and irrigation techniques, as well as water availability and demand due to changes in weather patterns.

The analysis of daily flow fluctuations in the lower Klamath River presented in the USGS study confirmed that the operation of IGD created a steady flow and eliminated abrupt changes in water discharge of up to 2,000 cfs. The biggest single change in the USGS gauge records was reduced flow during dry years. This led the authors of the study to conclude that human water use during years of drought drastically reduces the already limited flows of the lower Klamath River.

In 1996, Hecht and Kamman (Balance Hydrologics, Inc.) were commissioned by the Yurok Tribe to quantitatively estimate the historical flow patterns in the Klamath River. Although agricultural diversions were in place in 1905 above Upper Klamath Lake (on the Williamson and Sprague rivers), water diversions were at a minimum until the construction of the Lost River Diversion Dam in 1912 (Hecht and Kamman 1996). Thus, USGS gauge data from 1905 through 1912 at Keno were used to estimate “natural flows” in the river.

The years 1905 through 1912 were identified to be above average for precipitation and runoff in much of the Upper Klamath Basin. To counter this, stream flow and rainfall data were normalized to a period of average rainfall using annual precipitation indices. Hecht and Kamman (1996) divided the average flow/annual precipitation during the 1905–1912 period by the average flow/annual precipitation value over a long-term period (1905–1994). They reported that:

“… indices derived from precipitation records suggested that conditions during the 1905–1912 period were wetter in northern California at Yreka (index 1.21) than in southern Oregon at Klamath Falls (index 1.04); i.e., the higher the index above 1.0, the wetter the 1905–1912 period relative to the long-term average. If this trend of decreasing relative wetness to the north and east is extrapolated up into the upper Klamath basin, we could surmise that much of the upper basin experienced normal conditions (index of 1.0) during the 1905–1912 period. The index derived from the Bureau of Reclamation’s inflow record was 1.34 for this period, suggesting much wetter conditions than either of the rainfall records would suggest. However, this index is probably inflated for the following reason: inflow to Upper Klamath Lake has continuously decreased during the 20th century due to upstream diversions and withdrawals from the Sprague and Williamson River systems. This artificially reduces the long-term inflow average which, as the denominator in the index calculation, leads to an inflated index” (Hecht and Kamman 1996, page 14).

To estimate pre-Project flows at IGD, Hecht and Kamman (1996) added historical flow accretions between Keno and IGD to the Keno flow record. These accretions were estimated in a separate study by CH2M Hill using USGS flow records, because no gauge data existed for IGD until 1960. After adding the estimated accretions to the pre-Project flows at Keno, Hecht and Kamman (1996) concluded that the average annual flow in the lower Klamath River at IGD was about 1.8 million acre-feet per year prior to the completion of the Klamath Reclamation Project.

A second phase of Hecht’s and Kamman’s study (1996) involved analysis of changes in flow at a gauging station over time. Stations with long flow records were selected, and similar pre- and post-Project water year-types were identified. They chose and matched water year-types that had similar short-term and long-term
conditions, such as 1916/1985 and 1918/1987. For example, both 1916 and 1985 experienced above-normal runoff and precipitation and were preceded by 4 years of high water availability. Thus, the 1916/1985 year pair represents historical vs. current flow conditions for relatively wet periods. The 1918/1987 pair corresponds to flow conditions during relatively dry periods.

Based on their analyses, Hecht and Kamman (1996) concluded that flows in the lower Klamath River have been reduced from historical levels by water diversion projects in the Upper Klamath Basin and the Shasta, Scott, and Trinity subbasins. They also indicated that the Project changed the seasonal distribution of flows, usually increasing water discharge very slightly during fall and early winter and markedly reducing spring and summer flows. This shift in flow regimes between pre-Project times and the mean monthly 1961–1996 flows is shown in Figure 1 (based on Hecht’s and Kamman’s data). A graph of annual average pre-Project flows (hydrograph) indicates that higher flows were available in the river channel before all diversions and dams were built.

According to Hecht and Kamman (1996), the Upper Klamath Basin in July–August of 1911–1913 (pre-Project wet period) contributed between 30 and 35 percent of the river flow at its mouth. During July–August of 1983–1985 (a comparably wet post-Project period), this flow contribution was reduced to 10 to 15 percent of the flow at the river’s mouth. Their study estimated that, during droughts, the post-Project flow contributions of the Upper Basin to the flow recorded at the mouth of the river become even lower, approximately 5 percent.

Although the reports by the USGS (1995), Hecht and Kamman (1996), and the Institute for Natural Systems Engineering of Utah State University (INSE, in Hardy 1999) differ in their objectives, analytical techniques, and underlying assumptions, they all describe a common scenario of flow changes in the river that are related to human activities in the Upper Basin and in the main subbasins of the Lower Basin. Both the
USGS (1995) study and Hecht’s and Kamman’s (1996) report arrive independently at the conclusion that water management practices have increased late-winter and early-spring flows in the lower Klamath River, while reducing summer flows compared to estimated pre-Project flows.

Hecht’s and Kamman’s (1996) “pre-Project” flow estimate at IGD was used by Trihey and Associates (1996) to develop minimum in-stream flow recommendations. Trihey and Associates applied the Tennant Method based on 60 percent of the mean annual discharge estimated by Hecht and Kamman. The recommended minimum in-stream flows are included in Table 1, along with those originally established by the Federal Energy Regulatory Commission (FERC), those requested by the Yurok Tribe in response to the draft 2001 BiOp by the NMFS, and those recommended by INSE.

In 1999, a study was initiated by INSE to quantify the minimum monthly flows for the Klamath River below IGD needed to maintain and restore the aquatic resources of the river, with special emphasis on salmonids. These researchers elaborated interim minimum in-stream flow recommendations using a battery of hydrology-based methods. Such recommendations were intended to be of temporary application (Phase I) until field-based methods, incorporating site-specific information, tributary flows, and water quality, could be used to validate and refine the minimum recommended flows (i.e., Phase II of the INSE report, which was recently made public and was not reviewed in this chapter).

The minimum in-stream flow recommendations described by INSE (Hardy 1999) were calculated on the premise that suitable salmonid habitat is directly related to flow regimes. They focused on four basic flow components: fish habitat flows, channel maintenance flows, riparian flows, and valley maintenance flows.

For purposes of determining interim minimum in-stream flows for the Klamath River, INSE (Hardy 1999) used five different minimum

Table 1. Estimated pre-Project mean monthly flows, mean monthly flows between 1961 and 1996, and various recommended minimum monthly flows at Iron Gate Dam.

<table>
<thead>
<tr>
<th></th>
<th>Mean monthly flows 1905–1912 (pre-Project)</th>
<th>Mean monthly flows 1961–1996</th>
<th>FERC (Tennant method)</th>
<th>Yurok Tribe (mean, various methods)</th>
</tr>
</thead>
<tbody>
<tr>
<td>October</td>
<td>1,536</td>
<td>1,664</td>
<td>1,300</td>
<td>1,300</td>
</tr>
<tr>
<td>November</td>
<td>1,809</td>
<td>2,142</td>
<td>1,300</td>
<td>1,500</td>
</tr>
<tr>
<td>December</td>
<td>2,358</td>
<td>2,744</td>
<td>1,300</td>
<td>1,500</td>
</tr>
<tr>
<td>January</td>
<td>2,827</td>
<td>2,825</td>
<td>1,300</td>
<td>1,500</td>
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<tr>
<td>February</td>
<td>3,331</td>
<td>3,047</td>
<td>1,300</td>
<td>1,500</td>
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<td>March</td>
<td>3,604</td>
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<td>3,627</td>
<td>2,046</td>
<td>1,000</td>
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<td>June</td>
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<td>July</td>
<td>2,147</td>
<td>758</td>
<td>710</td>
<td>1,000</td>
</tr>
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<td>August</td>
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<td>September</td>
<td>1,370</td>
<td>1,303</td>
<td>1,300</td>
<td>1,300</td>
</tr>
</tbody>
</table>


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in-stream flow-setting methods (Hoppe, New England Flow Recommendations Policy, Northern Great Plains Resource Program, Tennant, and Washington Baseflow). They then took the average monthly flow across the five estimated values to calculate the “best estimate.”

This study has been criticized by a consulting firm (see Miller 2001) in a review for the BOR. Miller argued that INSE made independent corroboration of its analyses and conclusions difficult by not providing supporting data, using “outdated” methods when “newer,” more biologically based, methods were available, and modifying the methods without clear justification. It is our understanding that Phase II of the INSE report addresses these issues.

Water quality issues

Although water quality often is mentioned as a “problem” in the Klamath Basin, very little attention is given to it in reports. There are several water quality issues related to coho salmon. For example, the metabolic activity of algae in the lower Klamath River mainstem causes a marked daily cycle in pH, with maximum readings of 9. Also, during the summer, water temperature can exceed 25°C (77°F) (Deas, personal communication). The combined effects of high temperatures, high nutrient concentrations, changes in pH, and low dissolved oxygen levels during the summer can create extremely stressful conditions for coho salmon and other salmonids in the lower Klamath River. High nutrient concentrations (especially nitrogen and phosphorus) typically promote the growth of algae and aquatic plants, which contribute to increased water temperatures, reduce water velocities, and lower the levels of dissolved oxygen at night.

Temperatures in the mainstem of the lower Klamath River regularly exceed 20°C (68°F) between mid-July and late September. This was particularly evident during the drought of 1994 (Kier and Associates 1997). In June 2000, temperatures reached critical levels in the Klamath River and resulted in an estimated kill of more than 1,000 salmonids per mile for about 10 miles (CDFG 2000).

Although in-stream flows between July 1 and September 1, 2001, were higher than during previous dry years, maximum daily temperatures below IGD ranged from 19.6 to 22.5°C (67.3 to 72.5°F), and minimum daily temperatures from 18.6 to 20.6°C (65.5 to 69.1°F) for the 90 days of record (USGS 2001).

Because increased flows provide a lower stream surface-to-volume ratio, they were recommended by INSE (Hardy 1999) as a way to buffer day–night fluctuations in stream temperatures and dissolved oxygen levels. This assumption is supported by the reservoir and river models developed by Deas and Orlob (1999), which indicate that increased flows in late spring, summer, and early fall moderate the daily temperature range, provide modest thermal benefits in downstream reaches, and reduce transit time in the IGD–Seiad Valley river reach.

The 2001 Biological Opinion and its implications for coho salmon

The first formal Section 7 consultation regarding effects of Project operations on coho salmon was held in 1999. For operating year 1999, the BOR proposed operating the Project in a way that would meet the FERC minimum flows at IGD (Table 2). The FERC minimum flows were established as a condition for dam licensing, but they are subject to water availability and senior water rights; thus, they have not always been met. Considering that 1999 was an above-average hydrologic year, and adequate water was available for irrigation, in-stream flows, and maintenance of Upper Klamath Lake elevation, the NMFS recommended higher flows. The BOR then proposed IGD releases similar to those recommended by INSE (Hardy 1999, see Table 1). Based on those flows, the NMFS found that Project operations would not cause jeopardy to coho salmon.

The 1999 Biological Opinion expired in March 2000, but the BOR did not request formal Section 7 consultations with the NMFS in 2000.
As a result, in May 2000, various conservation and fishing interests filed a lawsuit challenging the BOR’s 2000 Project operations plan (Pacific Coast Federation of Fishermen’s Assoc. v. U.S. Bureau of Reclamation). They argued that the BOR violated the ESA by releasing water for irrigation and water flows in the Klamath River prior to consultation with the NMFS regarding the Project’s effects on threatened coho salmon. (See Chapter 18, “Policy,” for additional discussion.)

On January 22, 2001, the BOR requested initiation of formal ESA Section 7 consultations with regard to the ongoing operation of the Klamath Project. The request letter included a Biological Assessment of the effects of Project operations on coho salmon in the SONCC ESU. The BOR proposed critically dry year minimum flows at IGD as low as 398 cfs (Table 2).

In April 2001, Judge Sandra Brown Armstrong ruled in the Pacific Coast Federation of Fishermen’s case and enjoined the BOR from sending irrigation deliveries to the Project at any time when IGD flows drop below the minimum flows recommended by INSE (Hardy 1999), until the Bureau completed a plan to guide operations during 2001 and consultation on that plan was completed.

As part of the 2001 consultation, the NMFS reviewed the status of SONCC coho salmon, the environmental conditions in the area, the potential effects of the proposed ongoing operation of the Project, and its cumulative effects. The NMFS concluded that the BOR’s proposed operation of the Project in 2001 was “likely to jeopardize the continued existence of SONCC coho salmon” and adversely alter critical coho salmon habitat.

Subsequently and as part of the BiOp, the NMFS presented its Reasonable and Prudent Alternative (RPA) to the operations proposed by the BOR (Table 2). The RPA was based on the premises that: (1) the operation of the Project substantially affects flows, fish habitat, and water quality in the lower Klamath River, and (2) the Project is not the only human activity that has a negative effect on salmonid habitat and anadromous salmonid populations in the Klamath Basin.

| Table 2. Minimum monthly flows (April–September) at Iron Gate Dam (FERC, the BOR Operations Plan, and the NMFS draft and final Biological Opinion), and actual flows, 2001. |
|---------------------------------|------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                | FERC minimum     | BOR proposed    | BOR proposed    | NMFS Draft      | NMFS Final      | Actual flows    |
|                                |                  | dry year        | critically     | 2001 Biological | 2001 Biological | 2001           |
|                                |                  | minimum         | dry year       | Opinion         | Opinion         |                 |
|                                |                  | (cfs)           | minimum         |                 |                 |                 |
| April 1–15                     | 1,300            | 728             | 569             | 1,700           | 1,700           | 1,528           |
| April 16–30                    | 1,300            | 754             | 574             | 2,100           | 1,700           | 1,667           |
| May 1–15                       | 1,000            | 761             | 525             | 2,100           | 1,700           | 1,749           |
| May 16–31                      | 1,000            | 924             | 501             | 2,100           | 1,700           | 1,704           |
| June 1–15                      | 710              | 712             | 476             | 1,800           | 2,100           | 2,099           |
| June 16–30                     | 710              | 612             | 536             | 1,400           | 1,700           | 1,695           |
| July 1–15                      | 710              | 547             | 429             | 1,000           | 1,000           | 1,008           |
| July 16–31                     | 710              | 542             | 427             | 1,000           | 1,000           | 1,016           |
| August                         | 1,000            | 647             | 398             | 1,000           | 1,000           | 1,026           |
| September                      | 1,300            | 749             | 538             | 1,300           | 1,000           | 1,025           |

A similar table is contained in Chapter 1 (“Background”), with flows measured in acre-feet.

According to the NMFS (2001), the proposed RPA aimed to prevent further decline of the listed species that the NMFS concluded was likely to be jeopardized by the ongoing operation of the Project. The agency indicated that it was in the process of collecting additional information and analyzing the relationship between IGD releases and fish habitat availability with the intent to develop a comprehensive BiOp addressing all water year-types by June 7, 2001. In the meantime, the April 6, 2001 BiOp was a subset of the more comprehensive report being developed and was intended to specify minimum in-stream flows only for the April–September period of 2001.

**Recommended IGD releases**

During summer months in dry years, water releases at IGD contribute significantly to in-stream flows in the Klamath River. Because of the hydrology of the system, the climate of the region, and the number of tributaries present, the influence of IGD water releases is greatest near the dam and diminishes as one moves downstream, according to a flow study conducted by the U.S. Geological Survey (1995).

Therefore, the IGD-to-Shasta-River reach is the one that relies the most upon IGD water. Based on USGS gauge data, the NMFS (2001) estimates that, on average, between July and October, from 1962 to 1991, water releases at IGD contributed approximately 60 to 85 percent of the river flows measured at Seiad Valley and 50 to 65 percent of the river flows measured at Orleans. These data also indicate that the importance of IGD water releases increases during dry years, when 90 percent of the summer flow at Seiad Valley is directly attributable to IGD water releases (NMFS 2001).

Considering both the contributions of IGD releases to the lower Klamath River flow and the preliminary field data provided by INSE (from its Phase II flow study, then in preparation), the NMFS presented an RPA in response to the BOR’s 2001 water-release plan for a critically dry year. The RPA stated that under IGD releases of 1,700 cfs for April and May, coho salmon fry would have access to approximately 50 percent of the maximum available habitat, and chinook salmon fry would have access to close to 65 percent of their nursery habitat.

Aiming to maintain between 40 and 65 percent of the mainstem channel’s salmonid habitat during various months, the RPA established April–September minimum water releases at IGD. Such releases (both from the draft and final versions of the BiOp) are summarized in Table 2, along with FERC’s minimum flows and the flows proposed by the BOR for dry and critically dry years (e.g., 2001). The table also includes the actual flows that were measured at IGD between April and September, 2001.

Although the RPA flows recommended in the final version of the BiOp (NMFS 2001) stand out as relatively high when compared to those recommended by either FERC or the BOR, they are much lower than the minimum in-stream flows recommended for the restoration and maintenance of aquatic resources by the INSE Phase I study, the basis for the 1999 flows (Hardy 1999, see Table 1). In fact, the RPA flows (NMFS 2001) are closer to the minimum in-stream flows recommended by Trihey and Associates (1996) and the Yurok Tribe (2001).

Notice, however, that the shape of the graphics (hydrographs) generated by these various flow regimes is somewhat different (Figure 2). The main difference between the in-stream flows recommended by FERC for a critically dry year, such as 2001, and the ones requested by the BiOp (NMFS 2001), Trihey and Associates (1996), or the Yurok Tribe (2001) occurs during spring and early summer.

Those who recommend higher flows during this time of the year argue that coho smolts (which have been rearing in the system for 12 to 14 months and are ready to enter coastal waters) migrate to the ocean in the spring and are likely to benefit from relatively higher flows. The assumption behind the request for higher flows is that the higher the flow, the shorter the duration of the trip to the estuary and, therefore, the higher the survival rate of coho smolts. Although there is no guarantee that the “additional” release
of water will work as intended and make a difference in the number of fish that survive their seabound migration, the assumption finds support in some studies on smolt migration and survival (see Sandercock 1991).

The BiOp’s RPA clearly states the importance of balancing the need for higher flows in the spring with the need for regulating flows in a manner that could ensure that, after one of the driest winters in recent decades, the limited available water supply would last until fall. This balancing act may explain why the water release at IGD (1,700 cfs) requested in the RPA for the spring period, although higher than the one approved by FERC, is lower than the water releases asked for by Trihey and Associates (2,500 cfs) or the Yurok Tribe (2,100 cfs).

The in-stream flows requested for the first 2 weeks of June by the RPA show a peak (2,100 cfs) in water discharge to assist the last coho salmon smolts leaving the system. Beginning in July, and continuing through September, the flows requested in the RPA remain constant at 1,000 cfs. Such flows are slightly more than those established by FERC for July during critically dry years, but they match the August flow levels established by FERC and recommended by Trihey and Associates (1996) and the Yurok Tribe (2001) (Table 1).

Contrary to what might be expected, the September flows requested in the RPA only match those suggested by Trihey and Associates (1996) and are lower than those established by FERC or asked for by the Yurok Tribe (2001). The slight increase in September’s water discharge has been proposed to assist upstream migrating fall chinook salmon. This type of action is supported by a study on fall chinook passage in the lower Klamath River by Vogel and Marine (1994), but only for late September and October. Based on the arguments presented in the RPA, the recommended in-stream flows for September seem to be another balancing act between what is needed for the maintenance of

![Figure 2. Minimum monthly flows at Iron Gate Dam under various proposals. Source: Data from Hardy, Thomas B. 1999. Evaluation of Interim Instream Flow Needs in the Klamath River, Phase I, Final Report (prepared for the Department of the Interior by the Institute for Natural Systems Engineering (INSE), Utah Water Research Laboratory, Utah State University, Logan) and from National Marine Fisheries Service (NMFS). 2001. Biological Opinion. Ongoing Klamath Project Operations (Southwest Region, April 6).](image-url)
fish habitat in the short term and what can be released from IGD without risking insufficient water availability later on.

The NRC (2002) interim report draws attention to the potential usefulness for management purposes of models that relate indicators of coho salmon year class strength (abundance of spawners from one particular year) to specific flow conditions during their emergence and migration as smolts. Unfortunately, as that same report acknowledges, “the small size and scattered nature of the present native coho population [make] collection of such data difficult.”

Given the limited information available on Klamath Basin wild coho salmon, it is not surprising that it has been impossible to determine whether relatively strong year classes have emerged from wet years in the recent past. However, better data are available for Klamath Basin fall chinook salmon. Notwithstanding the confounding effect of hatchery production on any attempt to establish a correlation between flow and spawner abundance, the chinook data do show a relationship between river flows during emergence and smolt migration and spawner abundance of that year class 3 and 4 years later (USFWS, unpublished data on spawner escapement and age composition).

Although the BiOp’s water release schedule was designed to protect coho salmon, other nonlisted species may have benefited more than coho. Steelhead, chinook salmon, and Pacific lamprey are likely to have gained the most from higher flows in the mainstem of the Klamath River.

The reduced water-release plan proposed by the BOR’s BA (Table 2 and Figure 2) could have been detrimental to coho salmon and to other anadromous fish species in the mainstem Klamath. According to the NRC (2002) interim report, stranding of fish and increased fish vulnerability to predation would have been two of the consequences of the progressive summer reduction of river flows proposed by the BA. Neither flow increases beyond those of the past decade nor the reduced IGD releases proposed by the BOR (the plan responsible for triggering the “jeopardy” BiOp from the NMFS) were justifiable based on available scientific evidence, according to the NRC.

In the absence of an integrated basin management plan, and facing the uncertain effects of the BOR’s proposed water release schedule on listed coho salmon, it is not surprising that the NMFS, which is responsible for the management of fisheries resources, opted for a risk-averse approach, rather than waiting to have complete certainty, because such certainty will never exist about natural resources (see Chapter 4, “Science”). In fact, such a precautionary approach is dictated by Congressional mandate, and it is difficult to imagine a regulatory agency ignoring such a directive. (See Chapter 5, “Suckers,” for a discussion of the U.S. Fish and Wildlife Service’s approach to biological uncertainty in the case of suckers.)

Potential effects of the 2001 BiOp on water temperature

The lower Klamath River has been listed as water quality impaired by both Oregon and California under Section 303(d) of the Federal Clean Water Act. Excessively high water temperatures, elevated nutrient concentrations, and the associated low dissolved oxygen levels have been identified as important limiting factors for salmonids. The recently released NRC (2002) interim report considers that “water temperature is a major concern for the welfare of the Klamath Basin coho salmon. Summer temperatures appear to be especially critical…. High temperatures are the result of reduced flow in the main stem and in tributaries as a result of diversions, warming of water in lakes prior to its flow to the main stem, and loss of shading. Climate variability, although probably responsible for some interannual thermal variation, is unlikely to be an important factor by comparison with changes in flow and loss of riparian vegetation.”

Data collected by M. Deas on Klamath mainstem summer temperatures show that water at IGD and Seiad Valley exceeded 20°C (68°F) for 24 hours a day between early July and August 2000; by early August, the mean daily
water temperature exceeded 22°C (71.6°F) at IGD and 25°C (77°F) at Seiad Valley. However, some intermediate locations closer to IGD experienced daily minimum temperatures below 20°C (68°F), even as low as about 18°C (64.4°F) (Deas, personal communication).

Despite such elevated temperatures, juvenile coho salmon and other salmonids are present in the river (USFWS, unpublished data). As discussed earlier (see “Spawning and nursery habitat”), various studies indicate that juvenile coho salmon, although considerably stressed, are able to survive water temperatures in the mid-20s°C (70s°F), depending on a variety of other factors (food, competition, predation, acclimation process, body size, etc.). In a system such as the Klamath River, salmonids (and juvenile coho salmon in particular) are expected to rely on the mainstem cool-water areas derived from spring-fed tributaries (NRC 2002). This strategy of seeking cool-water refugia may explain the distribution of juvenile coho salmon that the USFWS survey crews observed during the summer of 2001 (USFWS, unpublished data).

The water-release schedule requested in the BiOp’s RPA was intended to alleviate the effects of low in-stream flows on salmonid habitat by increasing the volume of water present in the channel. According to flow models (Deas and Orlob 1999), it was expected that the minimum in-stream flows requested in the RPA would moderate the daily fluctuations in water temperature, provide modest cooling in downstream reaches, and reduce the water-transit time between IGD and the Seiad Valley. However, the effectiveness of this practice is uncertain and deserves close examination.

The NRC (2002) interim report cast doubts that any significant degree of cooling could be accomplished in this way. In fact, the report suggests that higher flows may work to the disadvantage of coho salmon if the source water is warmer than the river below. However, this is only a hypothesis, and one that deserves rigorous testing. During the summer of 2001, no cooler groundwater was detected seeping into the river between IGD and the Salmon River confluence. Despite warm water and extremely reduced tributary flows in this river segment, juvenile coho salmon were observed, and no fish kills occurred (USFWS, unpublished data).

Looking ahead—a basinwide approach

As in many other places, natural resources in the Klamath Basin have been managed in a fragmented manner—as if the flow of water did not connect one part of the Basin with another. Effects of upstream land-use activities on water quantity, quality, and aquatic habitats downstream often have been ignored, and most studies and monitoring programs in the Klamath Basin have reflected an isolationist view and a narrow subbasin focus.

Within this context, the situation existing in the Klamath Basin in 2001 developed over a long period of time. Many of the early symptoms (collapse of fisheries, fish kills, algal blooms, overallocation of water in many subbasins, etc.) were observed more than a decade ago. Unfortunately, these early warning signals did not lead to the development and implementation of an integrated basin management plan.

The events of 2001 affected all basin stakeholders in a negative manner. Although some faced greater losses or more difficult circumstances than others, nobody emerged unscarred. However, as often is the case when trouble strikes, the events of 2001 offered a clear indication of the need to move away from the current development path, which clearly is not sustainable. An integrated basinwide management plan that balances the needs of all stakeholders is necessary to end the systematic and gradual erosion of natural resources in the Klamath Basin and provide for the needs of all users of the Basin’s water.

The need to renew the licenses of Klamath River dams before they expire in 2006 may represent an opportunity for all of the Basin’s stakeholders to heed the warnings of 2001 and move toward development and implementation
of a basinwide management plan. The relicensing of these dams is likely to differ markedly from the process that gave the green light to their construction and operation several decades ago. Current environmental standards and a broader spectrum of interested parties likely will slow down the process and involve upper management from the regulatory agencies. Increased stakeholder engagement should help identify issues and problems more effectively and lead to better coordination of land management decisions as well as fish and wildlife management recommendations. It would be desirable for this process to be open and collaborative.

A basinwide management plan can be developed and implemented only with a great deal of local support and cooperation. Furthermore, collaboration among different government agencies and interest groups is needed for the evaluation of appropriate management practices for this basin.

Of the several phases in the elaboration of such a plan, the first, and most fundamental, is the development of a “watershed health card/map” that integrates hydrologic and geologic information, the classification and location of environmentally sensitive areas, and the status of biological resources in the system. Much of this information already is available, but it is scattered among various agencies. Some of it may be of questionable quality for some stakeholder groups. In these cases, the information should be independently evaluated and, if necessary, collected or produced again.

The second phase involves developing a management plan that takes into account social needs and desires. This step involves deciding what is important and then choosing management options to meet the desired objectives. For example, it might be determined that integrity of the Klamath River and conservation of salmonid resources are important. If so, planners would need to choose options for protecting, rehabilitating, or further modifying the system’s hydrology and the river’s channel characteristics. It would be necessary to consider a minimum guaranteed summer flow as well as an adequate winter flow regime that enhances the connection between the river and its valley and increases the availability of fish habitat. Management decisions regarding biological components of the basin also would be needed (e.g., restoration of riparian vegetation, reduction of nutrient concentrations to control the abundance of algae, etc.).

Several alternatives for improving fish habitat could be considered as part of this process. Examples include:

- Flow restoration in tributaries
- Flow augmentation in the mainstem through higher dam bypass flows (Although habitat in tributaries is important to the long-term maintenance of wild coho salmon, mainstem habitat cannot be written off without negatively affecting the Klamath Basin populations.)
- Alteration of ramping rates (change in rate of water release)
- Purchase and retirement of water rights
- Creation of mitigation funds to purchase water rights
- Riparian and in-stream habitat restoration
- Wetland restoration
- Water quality improvement
- Spawning gravel enhancement
- Large wood placement
- Dam removal or retirement

These examples illustrate the breadth of options available to planners. By taking a basinwide approach and choosing a variety of restoration activities, all stakeholders could become part of the solution, and no one group would bear all of the burden.

Based on the flow and biological options selected, land-use management decisions could then be made. These decisions would control human-induced damage to the physical and biological parts of the system.
The last, but not least important, part of any plan is the financial compensation scheme and the nondevelopment alternative. Compensation usually is necessary when the costs of implementing a basin management plan are particularly burdensome for some stakeholders.

The implementation of an integrated basin management plan will not be possible without improvements in the functioning of the institutions involved (see Chapter 18, “Policy,” and Chapter 20, “Synthesis”). Examples of needed changes include a redefinition of the terms of cooperation among government agencies, the design of effective regulatory instruments (taxes, trusts, water markets, mitigation funds, etc.), and an improved public consultation system. These factors represent important “political” obstacles that must be overcome for any management plan to achieve the desired effects. Technical problems, although very important in many circumstances, tend to be less of an obstacle.

Continued improvement in our understanding of ecological systems is another key component to basinwide management planning. Several issues require rigorous study before the effects of future water management decisions on fisheries resources of the Klamath Basin are adequately understood. Examples include:

- The structure and dynamics of fish populations (Although initial efforts should focus on listed species, it is important to consider other species in the system when taking an ecosystem management approach and in order to avoid future listings.)
- Fish habitat distribution and utilization
- Fish migration patterns (both juveniles and adults)
- Water temperature regimes and their effects on fish
- Effects of increased water releases from reservoirs on downstream fish habitat
- Effects of early water spills on the seasonal release temperatures at Iron Gate Reservoir

In conclusion, development of an effective integrated basin management plan will require the cooperation of all of the Basin’s stakeholders (including government agencies), as well as continued analysis of the many components of the system and how they relate to each other. Success will be more likely if the following principles are kept in mind:

- Management decisions should be made within the context of the entire Basin.
- The integrity of the entire Basin should be protected by conserving and enhancing the processes that connect its many components (e.g., headwaters, hill slopes, mountain streams, riparian forests, lakes, valleys, wetlands, groundwater reservoirs, tributaries, mainstem channel, floodplains, estuary, etc.).
- Long-term monitoring and research should be conducted to evaluate the effectiveness of management practices and to determine whether environmental changes are naturally caused or human induced.
- Contingency plans should be developed in case monitoring reveals that the implemented management actions interfere with processes that maintain the connectivity of the system.
- Management plans should be flexible enough to respond to new scientific knowledge and the development of new techniques.

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