DFG Exhibit 3

Flows Needed in the Delta to Restore Anadromous Salmonid Passage from the San Joaquin River at Vernalis to Chipps Island

California Department of Fish and Game
Central Region
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Fresno, CA 93710

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Necessary to Protect Public Trust Resources
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Stream Flows Needed in the Delta to Restore Anadromous Salmonid Passage from the San Joaquin River at Vernalis to Chipps Island

1 Summary

When determining Delta outflow needs, California Department of Fish and Game (CDFG) views the sources of those outflows to be very important. Using the CDFG San Joaquin River Salmon Model V.1.6, San Joaquin River (SJR) flows at Vernalis were analyzed to evaluate flow magnitude and duration scenarios to predict resulting SJR smolt outmigrant populations. Empirical information generated from SJR basin studies was used in the model and the identified results strongly indicate that improving SJR stream flow in the spring time period is necessary to accomplish the State and Federal salmon doubling goal by doubling the juvenile (smolt) abundance at Chipps Island.

2 Salmon Life History

In order to understand the importance that source flows have on influencing juvenile abundance at Chipps Island, it is important to understand the life history stages (Table 1) of Chinook salmon that are most prevalent within the Delta, their associated timeframes (Table 2), and factors that may effect them. Generally speaking, the stages that are most likely to occur within the Delta involve migration (both adult and juvenile) and rearing.

Table 1: Life History Summary

Life History Stage	Description
Adult Ocean	Period when young of year, yearling or sub-adult salmon emerge from freshwater systems to grow and mature to full adult size before returning to spawn. May last for 1 – 5 years but more typically lasts 3 – 4 years.
Adult Migration	Fully grown adults return to their natal stream (more often and more consistently under natural conditions or appropriate seasonal flows) from the ocean environment to spawn and complete their life.
Spawning	Adult females develop redds by excavating gravel before depositing eggs and burying them after males have fertilized them, effectively completing their lives. Most salmon spawn very near their arrival time but in the case of spring-run Chinook, they will typically hold in coldwater pools for an extended period of time before initiating spawning.
Incubation/Egg Development	Period when deposited, fertilized and buried eggs develop and grow until alevin and fry emerge and seek refuge as juveniles. Typically lasts 40-90 days from fertilization to emergence with water temperature driving egg development.
Rearing	Young salmon begin to move into areas where they can feed and grow while avoiding predation. They may move to different areas within the system before following a

Life History Stage	Description
	migration cue to move out of the system. This may last from several weeks to more than a year depending upon the race and environmental conditions.
Juvenile Outmigration	Period when juvenile salmon undergo physiological changes to prepare for the transition from fresh to saltwater (smoltification) as they begin to move out of the system into adulthood.

2.1 Adult Migration

Adult salmon begin upstream migration to return to their natal spawning areas typically three years after emerging as juveniles. This represents the final stage in their life history as adults typically die once spawning is complete. Successful adult migration depends on environmental conditions that que the response to return to natal streams. Optimal conditions help maintain egg viability and fecundity rates.

Typical fall-run Chinook salmon migrate from October through early January, and late fall-run migrate from October through April (Table 2). However, spring-run Chinook salmon migrate upstream from March through September (Yoshiyama et al. (1998), cited in Moyle 2002), and hold in deep pools until they are ready to spawn in late-summer/early-fall and are subject to warmer summer and early fall temperatures.

Adult steelhead in the Central Valley migrate upstream beginning in June, peaking in September, and continuing through February or March (Hallock et al. 1961, Bailey 1954, McEwan and Jackson 1996, cited in SJRRP FMWG 2009). Spawning occurs primarily from January through March, but may begin as early as December and may extend through April (Hallock et al. 1961, as cited in McEwan and Jackson 1996).

Table 2: Upstream Migration Periods

	Jan - Feb - Mar - Apr - May - Jun - Jul - Aug - Sep - Oct - Nov – Dec
Spring-run Chinook	---
Fall-run Chinook	--- -------------------------
Late Fall-run Chinook	-------------------------------- -------------------------
Steelhead	------------------------- ---

Water temperature is critical to successful migration. Although salmonid spawning migration may occur throughout the year for all three races of Chinook salmon and steelhead as the table above indicates, high water temperature is likely to delay migration and/or impose highly stressful conditions during summer and early fall migration, holding periods, and spawn. Stocks that are subject to longer migration distances to inland spawning grounds during the summer and early fall could be more vulnerable. Furthermore, increased water temperature is reported to create migrational blockages for several species of salmonids when water temperatures exceed 69.8°F (21°C) (Beschta et al. 1987, Major and Mighell 1967, cited in ODEQ 1995, cited in USEPA issue paper 1, 2001). The AFRP restoration plan (USFWS 2001) recommends that actions be implemented to minimize exposure and maintain suitable water temperatures for all life stages of Chinook salmon in the San Joaquin River. Targeted water temperatures are 56ºF between October 15 and February 15 and 65ºF between April 1 and May 31.

According to McCullough (1999) cited in US EPA issue paper 4 (2001), adult migration may be prevented when dissolved oxygen (DO), which bears a strong relationship to temperature, falls below acceptable levels. In Oregon’s Willamette River, a combination of an average daily minimum DO of 3.3 mg/L and an average daily maximum water temperature of 72.3°F (22.4°C) resulted in cessation of upstream migration of spring Chinook past Willamette Falls (Alabaster 1988, cited in US EPA issue paper 4 2001). Data from Hallock et al. (1970), collected in the San Joaquin River Delta, showed that the average minimum DO at which Chinook migrate while avoiding temperatures greater than 66°F (18.9°C) was about 4.2 mg/L. Even a temporary delay in migration may result in higher susceptibility to increased temperatures and reduced gamete viability, therefore reducing spawning success. The Stockton Deep Water Ship Channel (SDWSC) presents a dissolved oxygen barrier due to altered flow characteristics in the deepened ship channel favoring reduced oxygen. Hallock et al. (1970) showed that radio-tagged adult fall-run Chinook salmon delayed their migration at Stockton whenever DO concentrations were less than 5 mg/L and(or) water temperatures exceeded about 65°F (18.3°C), typically in October.

In addition, flows are critical in allowing salmonids to move past physical barriers during adult migration. Reduced flows present both biological and physiological limitations including but not limited to the movement across structures, movement within the water column, and entrainment.

Entrainment more frequently refers to passage challenges endured by juvenile fish. However, NMFS (2008) defines entrainment as the unintended diversion of fish into an unsafe passage route. Adults, following olfactory geochemical cues, may become entrained at State Water Project (SWP) and Central Valley Project (CVP) facilities as export and recirculation flows exceed flows coming from the San Joaquin River and its tributaries; in turn, limiting the ability for salmonids to respond to cues from their natal streams. When exports are high relative to San Joaquin River flows, it is likely that little if any San Joaquin River water reaches the San Francisco Bay where it may be needed to help guide adult salmon back to their natal stream. Practices such as increasing Delta export rates in the fall at the SWP and CVP facilities have been shown to increase adult straying. One occurrence of this was in 1996 when export rates were increased to near maximum rates (about 9,600 cfs) to “make-up” for reduced pumping rates during the spring period.

An analysis by Mesick (2001) of recovered adult salmon with coded-wire-tags (CWT) suggests straying occurs when the ratio of exports to flows is high. The analysis by Mesick indicates that during mid October from 1987 through 1989 when export rates exceeded 400 percent of Vernalis flows, straying rates ranged from 11 – 17 percent. In contrast, straying rates were estimated to be less than 3 percent when Delta export rates were less than 300 percent of San Joaquin River flows at Vernalis during mid-October. Migration rates of adult salmon are substantially higher when Vernalis flows exceed about 3,000 cfs and total exports are less than 100 percent of Vernalis flows. Additionally, various sloughs and canals feeding into the San Joaquin River and its tributaries can have greater agricultural drainage flows than mainstem flows creating a stronger attraction to false migration pathways.

2.2 Rearing

Upon emergence from spawning beds, juvenile salmonid fry begin foraging for food and seek cover in areas of reduced flow or are displaced downstream due to reduced swimming ability (Healy 1991). It has been suggested that peak downstream migration periods may be tied to the period of reduced swimming ability (Thomas et al. 1969). Once started downstream, juveniles may continue to the river estuary, or may stop migrating and rear in the mainstem for a period of time ranging from a few weeks to a year or more (Healy 1991). Kjelson et al. (1981) observed that peak catches of Chinook fry in the Sacramento-San Joaquin delta often followed flow increases and speculated that flow surges influence the numbers of fry that migrate from the upper river spawning grounds to the delta. Healey (2001) also observed that downstream juvenile movement correlates to river flow. Juvenile fall-run Chinook salmon out-migration monitoring in the SJR tributaries also indicates that fry movement is stimulated by elevated flows in the February and March time frame.

The large downstream movement of Chinook fry shortly after emergence is typical of most populations. Following emergence, salmonid fry smaller than 2 inches (50 mm) occupy low-velocity, shallow areas near stream margins, including backwater eddies and areas associated with submerged vegetation and bank cover such as large woody debris or large substrate, though larger juveniles may also rear on seasonally inundated floodplains. As fry grow, they move into deeper and faster water further from banks.

Fall-run Chinook salmon typically rear in freshwater for one to three months before outmigrating and typically disperse downstream from early January through mid-March, whereas smolts primarily migrate between late March and mid-June in the Central Valley (Brandes and McLain 2001) though some rear in the river through the summer and outmigrate the following fall. Late fall-run Chinook salmon juveniles typically rear in the stream through the summer before beginning their emigration in the fall or winter (Fisher 1994).

The length of time spent rearing in freshwater varies greatly among juvenile spring-run Chinook salmon. Spring-run Chinook salmon may disperse downstream as fry soon after emergence, early in their first summer, in the fall as flows increase, or as yearlings after over-wintering in freshwater (Healey 1991). In addition to rearing on inundated floodplains during winter, juvenile spring-run Chinook salmon may also remain in the river over summer, taking advantage of instream pools and runs in the mainstem channel.

Considering the historical extent of floodplain inundation in the San Joaquin system, and the expanse of Tule marsh along the San Joaquin River prior to land development, it is possible that juvenile Chinook salmon, and possibly steelhead, reared on inundated floodplains in the San Joaquin River and its tributaries in the lower reaches. These downstream reaches were inundated for a good portion of the year during normal and wetter years and benefited from increased ground water augmentation (which no longer exists) providing suitable water temperatures for juvenile rearing from January to at least June or July of most years. As snowmelt runoff declined, and ambient temperatures increased, water temperatures in slow-moving sloughs and off channel areas probably increased rapidly.

Juvenile salmonids rear on seasonally inundated floodplains when available. Sommer et al. (2001) found higher growth and survival rates of Chinook salmon juveniles reared on the Yolo Bypass compared with those in the mainstem Sacramento River. Moyle (2000) observed similar results on the Cosumnes River floodplain. Drifting invertebrates, the primary prey of juvenile salmonids, were more abundant on the inundated Yolo Bypass floodplain than in the adjacent Sacramento River (Sommer et al. 2001).

The benefit of flood events to an aquatic system is highly variable, transient, dynamic, and influenced by hydraulic loading of the river, as well as by the magnitude, duration, timing, and the geomorphic and biological conditions on the floodplain. These variables in the right combination exhibit temporary optimal conditions for salmonid rearing. These conditions may only exhibit themselves for a particular species at specific times of the year and under particular flood conditions or over particular types of terrain. A particular terrain that may be optimal during flooding in the upper reaches of the river may be found to be detrimental to salmonid wellbeing in lower reaches.

The benefits of floodplains on juvenile rearing habitat for salmon are significant. The high productivity of floodplains is largely attributed to a nutrient rich environment. These nutrients are derived both from the river and from the floodplain. A flooding river in response to a rain event caries increased suspended sediment and nutrients from associated runoff and increased turbulence and velocity. Suspended nutrients are deposited as the river loses velocity over the floodplain. The floodplain contributes nutrients to the system by releasing dried and mineralized nutrients from previously receded floodwaters (Bailey 1995). Inundated grasses, plants and other organic material including leaf litter and woody debris also contribute to the nutrient load. These organic substances have been shown to decompose quickly during flooding (Junk et al. 1989). The decomposition rate is largely governed by the existing water temperatures.

As a result of the increased nutrients and higher temperatures in the floodplain, a rich invertebrate productivity occurs that is a beneficial food source for young fish.

Invertebrate productivity can be so high on the floodplain, that it has been shown to provide an over abundance of prey for young fish. Increased growth rates of juvenile salmon have been observed on floodplains (Stillwater Sciences 2003). Attainment of adequate size is critical for the survival of juvenile salmon. Floodplain rearing habitat allows juveniles to grow faster and larger, which in turn helps with out migration, predator avoidance and ultimately higher survival rates (Stillwater Sciences 2003). The floodplain also creates an important refuge for fish and prey from higher flows found in the main river channel (Stillwater Sciences 2003). The velocity of the river slows as the surface area of flow increases.

In addition to providing habitat for juvenile salmon, the floodplains of the SJR also provide spawning and rearing habitat for other freshwater native species, including Sacramento pike minnow, hardhead, and hitch. On the Cosumnes River in Central California, Moyle (et al. 2007) found 32 species along the river system over a seven year period. Of these 32 species, 25 were found during the winter-spring flooding season within the floodplain and 18 of the species were found on a regular basis. Sacramento splittail was found to be an obligate floodplain spawner, and Sacramento blackfish, common carp and goldfish generally spawn on submerged vegetation, but do not seem to require flooded terrain.

There are several factors that may lower the value of floodplains for salmon such as water quality including temperature, and depth as well as timing, duration, and magnitude of inundation. Shallow floodplains may experience greater swings in temperature. The temperature swings can be beneficial when the temperatures are near optimal levels for salmonids and thus accelerate growth rates, or they can be prohibitive when temperatures reach lethal levels. Water temperatures reaching lethal levels within the floodplain may lower DO and increase stress levels, possibly increasing susceptibility to disease. Depth can also influence the susceptibility of juvenile Chinook to predators. Shallow floodplains may expose fish to more avian predators. Gawlik (2002) found that juvenile salmonids tend to be located in waters deeper than 30 cm. Inundation depths greater than 30 cm may reduce the risk of mortality by avian predation.

The most successful native fish in terms of abundance are those that utilize the floodplain for rearing, but leave before the river disconnects from the floodplain (Moyle et al. 2007). Receding flood waters may pose a risk of stranding; however, Moyle (et al. 2007) found that native fish on the Cosumnes River, in particular Chinook salmon, showed fewer instances of stranding by receding waters as compared to non-native species. Adult spawners left when inflow decreased; their juveniles persisted as long as flood pulses kept water levels up and temperatures low (Moyle et al. 2007).

McCullough (1999) notes that the higher thermal preferences of juvenile salmonids may attract this age group to warmer downstream waters; improving growth opportunities early in the season. Bioenergetic modeling suggests that increased prey availability on the Yolo Bypass floodplain was sufficient to offset increased metabolic demands from higher water temperatures (9ºF higher than mainstem). However, as seasonal water temperatures increase and the availability of preferred thermal conditions cease, this age group is least capable of reactive behavioral thermoregulation because of limited swimming capacity. Therefore, juvenile fish may be physically incapable of migrating to cooler upstream reaches to escape unfavorably high stream temperatures. Water temperatures within the floodplain tend to be more variable and more responsive to ambient temperatures than in the river channel because they are typically shallower and have slower velocities. Emergence occurs in late fall and winter months for spring and fall-run Chinook while ambient temperatures are low thus providing more usable floodplain habitat. Optimal floodplain habitat would decline as summer temperatures increase; leaving only the uppermost reaches of the rivers suitable for salmonids.

2.3 Outmigration

Outmigration success by juvenile salmonids may be influenced by rearing habitat as already discussed, but is also greatly influenced by water diversions and conditions related to flow.

Juveniles are essentially committed to outmigration when they begin to undergo smoltification in preparation for the oceanic environment. Smoltification is the physiological process that increases salinity tolerance and preference, endocrine activity, and gill Na+-K+ ATPase activity. It usually begins when the juveniles reach between three to four inches (76 to 102 millimeters) fork length (FL); however, some fish delay smoltification until they are about 12 months old (yearlings) when they reach four to nine inches (102 to 229 millimeters) FL (SJRRP 2009, Appendix A). Environmental factors, such as streamflow, water temperature, photoperiod, lunar phase, and pollution, can affect the onset of smoltification (Rich and Loudermilk 1991).

The timing of peak downstream migration varies substantially from year to year in most river systems. In addition to annual variation in the peak of the run, there is a large day-to-day difference in abundance of downstream migrants.

The rate of downstream migration of Chinook juveniles appears to be dependant on several factors including time, size, location of the juvenile in the stream and discharge. In 1975, a year of low and consistent flow, the rate of downstream migration was negatively correlated with discharge. However, in 1976, a year of higher and more variable flow, the rate of migration was positively correlated with discharge. The negative correlation in 1975 reflected a decrease in rearing habitat as floodplains were probably not inundated as discharge dropped. Conversely, the positive correlation in 1976 illustrated a direct effect of discharge on the migration rate at higher discharge.

Mortality at diversions has been well-documented both from entrainment into false passageways or mechanical losses. Unscreened diversions often result in direct mortality or stranding in canals and related irrigation facilities (CH2MHILL 2007). Direct entrainment losses at the SWP and CVP facilities have been identified as a cause of juvenile salmon mortality in the Delta (Brandis and Mclain 2001). Kjelson (1981) reported that records of salmon observed in salvage and respective spring export rates between 1959 - 1967 and 1968 - 1979 indicated that as exports increased more downstream migrating salmon are observed in the salvage. Healy (1991) states that in large rivers, juvenile Chinook migrate near the edges of the river rather then in the center where they can be swept away by high velocities. Without directly observing losses at pumping facilities, survival reduction diminishes with increased distance from the influence of pumps. Furthermore, smolt survival is reduced during the later outmigration phase due to reduced flows accompanied by higher water temperatures that are further exacerbated by continued export rates. Studies indicate that export reduction periods greater than 7-days may be necessary to allow for smolt emigration (Kjelson et al. 1989).

Data from 1957-1973 (Kjelson et al. 1981) and ongoing studies in the Sacramento-San Joaquin Delta (Kjelson et al. 1989) indicate that returning Chinook adults are influenced by flows 2.5 years earlier during juvenile rearing and emigration phases. Influences include reduced flows and high export rates with both factors altering flow regimes and influencing survival for outmigrating salmon. Updating the data from Kjelson et.al. 1981 to escapement year 2000, Marston and Mesick (2006) found that spring flow vs. adult returns 2.5 years later still has a strong correlation.

Kjelson et al. (1981) indicate that additional inflows of freshwater at the appropriate time during the winter and spring will increase the numbers of fry and juvenile salmon utilizing the estuary and the survival of juveniles in the estuary. Flow related concerns for salmon in the estuary stem from water development activities in the Central Valley that have altered the distribution of flow resulting in impacts on juvenile and adult salmon migrations, as well as the lack of comprehensive flow standards on the tributaries and main stem river reaches that are protective of salmon. Kjelson et al. (1981) further explain that water development projects have caused major changes in the flow patterns within the estuary and the amount of flow entering the ocean from upstream sources. The San Joaquin River system has been particularly altered as most of the upstream inflow to the basin has been captured and utilized in regions upstream of the Delta. Typical export rates substantially exceed San Joaquin River flow rates; hence it is numerically possible that most of the San Joaquin River is diverted before reaching the ocean. However, San Joaquin River flows split at the Head of Old River approximately at a 1:1 ratio so it is unknown if all water from the San Joaquin River is diverted out of the Delta or simply appears to do so. The conclusion is that the distribution and flow of water through the Delta waterways are heavily influenced by the design and operation of the state and federal water projects.

In general, higher flows resulted in greater numbers of adults returning to spawn. Kjelson et al. (1981) also implicates the potential adverse effects of the pumps in the reduced survival of fish emigrating through the Delta, indicating that as export rates are increased, more downstream migrating salmon are drawn to the fish screens. Kjelson et al. (1981) estimates that the number of fish observed at the fish screens is probably only 5 percent of the total downstream migration in the system, but that a "much larger fraction probably is drawn out of their normal migration path" by the effects of the pumps on water flow in the Delta's channels. Kjelson et al. (1981) states that the "alteration in flow distribution caused by drafting increased volumes of water across the Delta to the pumps apparently increases the mortality of salmon that do not ever reach the fish screens." In support of this statement, Kjelson et al.(1981) points out those mark-recapture studies in which fish that migrate downstream in waterways that are far removed from the effects of the pumps had higher relative survival rates than those released in waterways under the influence of the pumps.

Kjelson et al. (1982), found that Chinook salmon smolt survival decreased as flow rates decreased and water temperatures increased, particularly in the later portions of the outmigration period. Furthermore, they restated their belief that the influence of the state and federal exports negatively impacted the survival of emigrating smolts through the Delta.

In a study assessing the influence of San Joaquin River inflows, state and federal exports and migration routes, Kjelson et al. (1989) released experimental fish (coded wire tagged hatchery Chinook salmon) during the spring of 1989 at Dos Reis on the San Joaquin River below the head of Old River, and in the Old River channel downstream of the head under conditions with low San Joaquin River flow (≈ 2,000 cfs) and high/low export conditions (10,000 cfs and 1,800 cfs). The results of the study were unexpected as the rate of survival was not greater for the low export conditions compared to the higher export conditions. Upon further examination of the data, Kjelson et al. found that survival was comparatively lower for all upstream release groups that year compared to other studies conducted in previous years. In addition, Kjelson et al. surmised that the short period of reduced exports (7 days) was not long enough to allow fish to exit the system and move beyond the influence of the exports when higher pumping resumed. Based on the times to recovery at Chipps Island, it was concluded that a sizeable proportion of the released fish were still in the Delta when the higher export levels resumed. This conclusion is further reinforced by the salvage of fish released at Jersey Point, indicating that fish were drawn upstream into the interior of the Delta and towards the pumps. The study, although having several significant flaws, did conclude that survival was higher in the main stem San Joaquin River compared to Old River and that survival in the Delta interior was lower compared to the western Delta (i.e., Jersey Point releases). The authors cautioned about drawing conclusions about export rates and survival from the data due to its obvious flaws.

A paper by Kjelson and Brandes (1989) reports on the results of ongoing mark-recapture studies conducted in the Sacramento-San Joaquin Delta and the effects of river flows, percent diversion of Sacramento River water through the Delta Cross Channel, and river temperatures. The findings of this paper also conclude that elevated flows, as measured at Rio Vista on the Sacramento River, increase survival of Chinook salmon smolts from the Sacramento River basin through the Delta as measured by both ocean recoveries of adults and recaptures of tagged smolts at Chipps Island in the mid-water trawls. Similarly, adult escapement in the San Joaquin River basin also increases with spring time flows at Vernalis 2.5 years earlier. Increasing water temperature was also shown to decrease smolt survival through the Delta during the critical April through June outmigration period of fall-run Chinook salmon.

In a more recent report, Mesick et al. (2007) assessed the limiting factors affecting populations of fall-run Chinook salmon and steelhead in the Tuolumne River. The paper describes potential limiting factors which may affect the abundance of fall-run Chinook salmon and both resident and anadromous (steelhead) forms of rainbow trout in the Tuolumne River. This information was then synthesized into conceptual models to help guide management decisions in regards to these two salmonid species. In general, Mesick et al. found that river flows were the limiting factor with the greatest influence on the salmonid populations in the Tuolumne River. As found in previous studies, there is a strong relationship between adult escapement and spring river flows during the juvenile/smolt outmigration stage. Flows measured over the period between March 1 and June 15 explains over 90 percent of the variation in the escapement data. However, Mesick et al. identified two critical flow periods for salmon smolts on the Tuolumne River: winter flows which affect fry survival to smolt stage, and spring flows which affect the survival of smolts migrating from the river through the delta. Based on results from ongoing Vernalis Adaptive Management Plan (VAMP) studies, Mesick et al. also noted that increased flows at Vernalis also increased survival of smolts emigrating through the Delta. Water temperature in the river was also identified as a potential limiting actor for salmonid survival within the emigration time period. Flows have a substantial role in maintaining suitable water temperatures within the river system, with higher flows prolonging and extending the cool water migratory corridor downstream than low flow conditions. Mesick et al. found that for Tuolumne River fall-run Chinook salmon escapement data, that exports had little effect on adult production compared to winter and spring flows.

3 Flows Needed to Protect Salmon Passage Through the Delta

The purpose of this section is to identify the objectives and methods used to develop flows through the Delta needed to adequately protect fall-run Chinook salmon in the SJR basin, and to help understand the relationship that SJR basin flow has with smolt abundance. Because steelhead, and to a lesser degree spring-run, are rare in the SJR basin, it is assumed that improved stream flow conditions for fall-run Chinook salmon will benefit to some degree steelhead rainbow trout. Since smolt production is critical to both species, spring time flow levels are primarily emphasized (e.g. for enhanced smolt outmigration survival). However, the in-river mechanisms for producing fall-run Chinook salmon and steelhead smolts, aside from elevated spring flows, are not the same.

Fall-run smolt production is dependent upon floodplain encroachment in the late-winter and spring time periods; whereas, steelhead need high quality (cool water temperature) over summer rearing habitat (Mesick et.al. 2007). So, while the primary management action for salmon and steelhead is to provide sufficient spring flow levels (CDFG et.al. 2008), the secondary management action for salmon is elevated winter pulse flows for fry rearing and for steelhead it is sufficient flows to provide over-summer rearing habitat. Several technical documents were consulted in preparing the San Joaquin River east-side tributary stream flow recommendations such as stream flow study reports, limiting factor analyses, restoration management plans, various monitoring reports, smolt vs. flow level study reports, and CDFG's SJR salmon model (CDFG 2005, 2008b, and 2009). Table 3 shows the biological mechanisms being targeted for each species.

Table 3: Monthly Flow Schedule

Month	Fall-run Chinook
October	AA, UM
November	SP, UM
December	SP, UM
January	FR, UM
February	FR
March	FR
April	SM
May	SM
June	SM
July	SM
August	JR
September	JR
AA - Adult Attraction UM - Upstream Migration HO - Holding SP - Spawning	FR - Fry Rearing JR - Juvenile Rearing SM - Smolt Outmigration

Since restoration for both salmon and steelhead in the SJR primarily hinges on obtaining sufficient magnitude, duration and frequency of spring time flows, flow schedule development begins here. Spring flows in the SJR (at Vernalis) are a combination of flow from the east-side tributaries (Merced, Tuolumne, and Stanislaus Rivers), mainstem SJR flow, and west-side agricultural and storm water run-off. Historically, Vernalis flows of 10,000 cfs or less are primarily comprised of tributary flow. When Vernalis flows are greater than 10,000 cfs, flood control releases from Friant Dam can substantially contribute to flows at Vernalis (CDFG 2005). Fall-run juvenile monitoring has been conducted in the tributaries and in the SJR near Mossdale. The CDFG's Mossdale trawl survey is the longest running calibrated juvenile monitoring effort in the SJR and has been operated annually since 1988. Mossdale Trawl methodology is documented in Johnson (2005) and represents an index of primarily fall-run juvenile out-migration but, captures of both steelhead and spring-run (based on size charts) have occurred as well. Smolt abundance at Mossdale, by year, is presented in Figure 1. Smolt abundance has ranged from a low of 268,000 in 1990 to 4.3 million in 1989 with an overall average of 1,049,074 per year. Previous empirical data correlations between average spring flow (3/15 to 6/15) and Mossdale smolt production index abundance have shown a fairly strong correlation (Hubbard 2008).

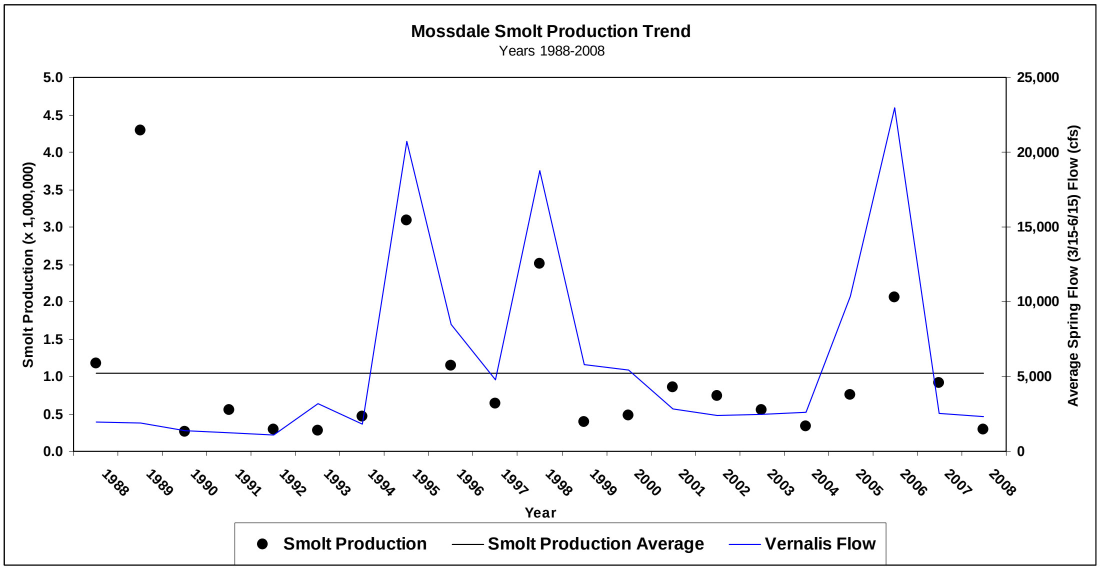


Figure 1: Mossdale Production Trend Years 1988 to 2008.

Note: This figure depicts the Mossdale smolt production trend for years 1988 to 2008 (black dots). The average smolt production for this time period is 1,049,074 (black line). Average spring flow for each year (blue line) indicates smolt production almost always follows the flow level trend (e.g. more flow = more smolts). The 1989 data point is considered

3.1 South Delta Smolt Survival

For about 20 years, experiments have been conducted to determine the relationship between SJR origin smolt survival and both flow (Vernalis) and South Delta exports (combined state and federal). In 2008, the US Fish and Wildlife Service (Newman 2008) authored a report detailing results of many coded wire tag juvenile salmon survival studies. The analysis looked at results of studies conducted with the Head of Old River Barrier both in and out, SJR at Mossdale flows ranging from 1,400 cfs (1990) to 29,350 (2006) cfs, and exports ranging from 805 cfs (1998) to 10,295 cfs (1989). The results of this analysis (covering 22 years and 35 individual study replicates) are (Newman 2008):

(a) The expected probability of surviving to Jersey Point was consistently larger for fish staying in the San Joaquin River (passing Dos Reis) than fish entering Old River, but the magnitude of the difference varied slightly between models ;

(b) Thus if the HORB effectively keeps fish from entering Old River, survival of out-migrants should increase;

(c) There was a positive association between flow at Dos Reis and subsequent survival from Dos Reis and Jersey Point, and if data from 2003 and later were eliminated from analysis the strength of the association increased and a positive association between flow in Old River and survival in Old River appeared;

(d) Associations between water export levels and survival probabilities were weak to negligible. Given complexity and number of potential models for the

VAMP data, however, a more thorough model selection procedure using Reversible Jump MCMC is recommended.

In summary, these findings are consistent with CDFG's findings (CDFG 2005) that increased flow going into the South Delta increases salmon smolt survival and that exports have little influence upon salmon smolt survival. It appears that the HORB-in produces a higher survival rate than the HORB-out condition and is likely due to flow being concentrated into the main river channel rather than being split between two channels (e.g. old and main river). It is interesting to note that using data prior to 2003, there was a positive relationship between old river flow and smolt survival in the old river.

Further indication that the State and Federal exports, though capable of entraining juvenile salmon, are not a substantial source of mortality for out-migrating SJR juvenile salmon is found in the estimated loss of hatchery smolts released at Mossdale as part of the South Delta (i.e.,VAMP etc.) smolt survival studies. Figure 2 shows that the median loss of coded wire tagged hatchery origin salmon smolts is less than 1 percent.

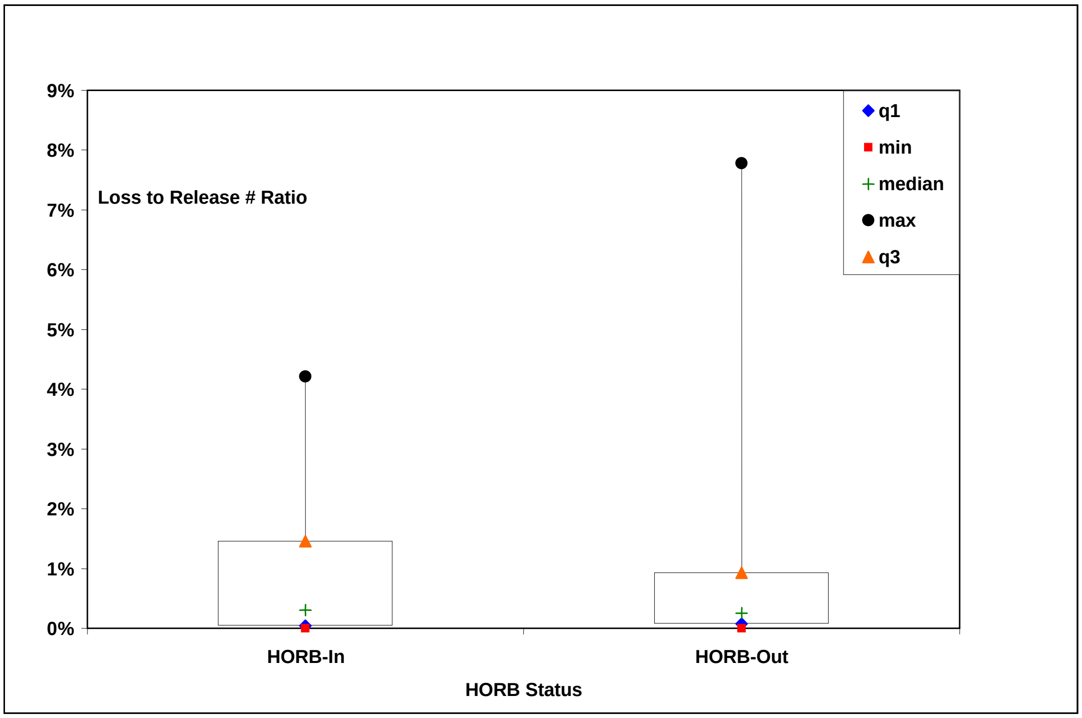


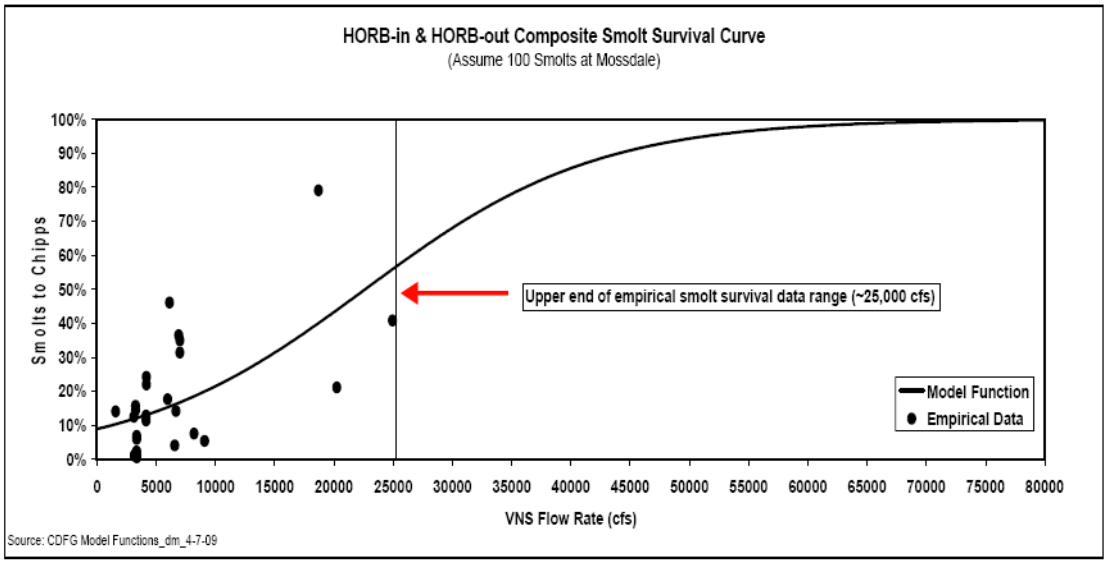
Figure 2: Box Plot for Combined Export Losses for Mossdale CWT Releases

Note: This figure (box plot) shows the loss to the South Delta State and Federal Project pumps from juvenile (smolt) salmon releases at Mossdale that occurred for South Delta juvenile salmon smolt survival vs. both flow and export evaluations for the last 20 years. The trend is that the less than 1 percent loss (entrainment) occurs by the pumps. HORB refers to the Head of Old River barrier. The box plot shows the maximum, 25 percent quartile, median (50 percent quartile), 75 percent quartile, and minimum loss occurring for all Mossdale releases for each group (HORB-in and HORB-out).

As an alternative to the export mortality hypothesis, the main river has its own potential mortality sink which is the Stockton Deep Water Ship Channel. The National Marine Fisheries Service recently built a computer model that predicts the level of juvenile salmon mortality as a function of ship traffic and ship size (described by propeller size). Model results indicate that ship traffic has the capacity to cause mortality (Jeff Stuart- unpublished data and model). Other sources of juvenile mortality include predation and water quality. In any event, increased flow into the South Delta increases survival by reducing the effects of these various mortality factors.

In 2009, Dr. Alan Hubbard (UC Berkeley) reassessed the South Delta juvenile salmon study data (Newman 2008). Upon re-analysis of the South Delta salmon smolt survival vs. flow level survival relationships, Dr. Alan Hubbard recommended use of a composite smolt survival relationship (CDFG 2009). To understand why Dr. Hubbard arrived at this recommendation it is important to understand some of the nuances in the smolt survival data set. It is clear from the existing data sets that there is no substantive overlap in the HORB-in and HORB-out data sets (range or replicates) therefore, it is not known if the difference in the slope between the two data sets is due to an actual difference in smolt survival as a function of the HORB being in or out, or due to variance within the data sets.

The difference in the slopes of the HORB-in and HORB-out regression lines is not statistically significant inferring that they are not different. Therefore, a composite smolt vs. flow survival relationship was chosen. It is important to note that when using a composite smolt survival (HORB-in and HORB-out) vs. flow rate relationship, the resulting relationship between smolt survival and flow rate is not statistically significant. However, it should also be noted that the trend between smolt survival and flow level indicates that higher flow equates to higher survival. The trend that higher flow equated to higher survival is consistent with other smolt survival vs. flow studies that have been conducted in the SJR tributaries. A diagram of the composite of the South Delta smolt survival vs. flow relationship is provided below in Figure 3.



Source: CDFG Model Functions_dm_4-7-09

Figure 3: Composite (HORB-in & out) Delta Smolt Survival Relationship

Note: The composite smolt survival relationship resulting from use of both HORB-in and HORB-out data sets has a minimum survival rate of 10 percent (at flow rates less than 1,580 cfs) and a maximum rate of 56 percent (at flow rates more than 24,950 cfs). The survival rates are combined differential recovery rates using recovery of coded-wire-tagged juvenile salmon at various locations (data from Newman 2008).

3.2 Mossdale Smolt Abundance Linkage to Jersey Point Smolt Production

The picture becomes clearer after more than 20 years of study, that more spring flow from the SJR tributaries results in more juvenile salmon leaving the tributaries, more salmon successfully migrating to the South Delta, and more juvenile salmon surviving through the Delta. To gain a better appreciation for the relationship between Mossdale salmon smolt abundance and Jersey Point abundance, the two were compared by year and Vernalis flow level (Figure 4). As Vernalis flow increases, the estimated smolt abundance also increases. This is intuitive given that the composite South Delta smolt survival relationship described (higher flow = higher survival) above was applied to daily Mossdale smolt out-migration.

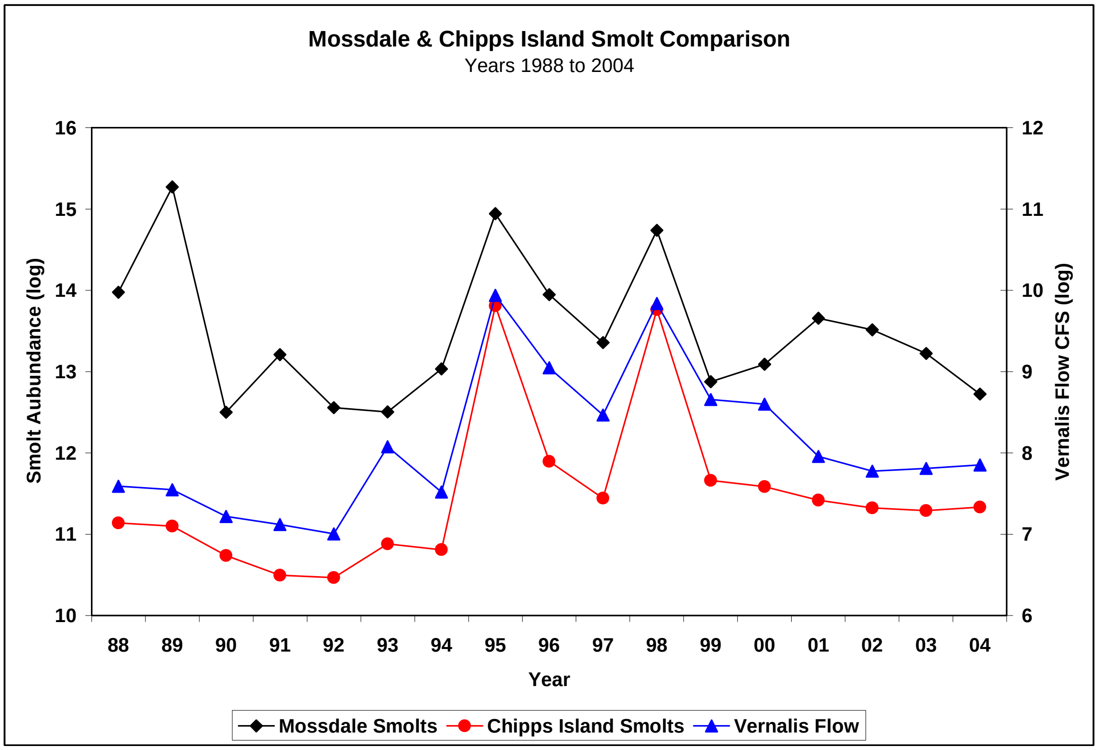


Figure 4: Mossdale to Chipps Island Smolt Abundance by Vernalis Flow Level

Note: This figure shows the relationship of smolt abundance (log transformed) at Mossdale to estimated smolt abundance at Chipps Island by average spring (3/15 to 6/15)Vernalis flow level (log transformed). To estimate the number of smolts at Chipps Island the smolt survival vs. flow level relationship developed by Dr. Hubbard was applied on a daily basis to the Mossdale smolt abundance and out-migration pattern. Smolt abundance at Chipps Island (or stated differently smolt survival through the Delta on an annual basis) can change by an order of magnitude pending Vernalis flow rate.

3.3 Jersey Point Juvenile Salmon Abundance Linkage to Adult Salmon Abundance

The importance of smolt abundance out of the east-side SJR tributaries, through Mossdale, to Jersey Point, and returning subsequently as adult is revealed in Figure 5, where recoveries of coded wire tagged juvenile salmon released at Jersey Point is compared to amount of juveniles released. Over the several years, as part of the South Delta juvenile salmon survival studies, juvenile fall-run Chinook salmon (from Merced River Hatchery (MRH) and Feather River Hatchery (FRH) origin) have been released at Jersey Point in varying quantities. Though these releases were primarily designed to assist in determining smolt survival throughout the South Delta (by being the downstream control release group) they also served a secondary purpose which is to determine how the release number affects adult return (or recovery) abundance. Whether viewed from a combined MRH and FRH perspective or singularly (MRH only or FRH only) the relationship between smolt abundance at Jersey Point (Figure 5) and adult returns is substantial and statistically significant (p = .001). These results demonstrate that if substantial smolt abundance to Jersey Point can be achieved then a corresponding increase in adult abundance will occur.

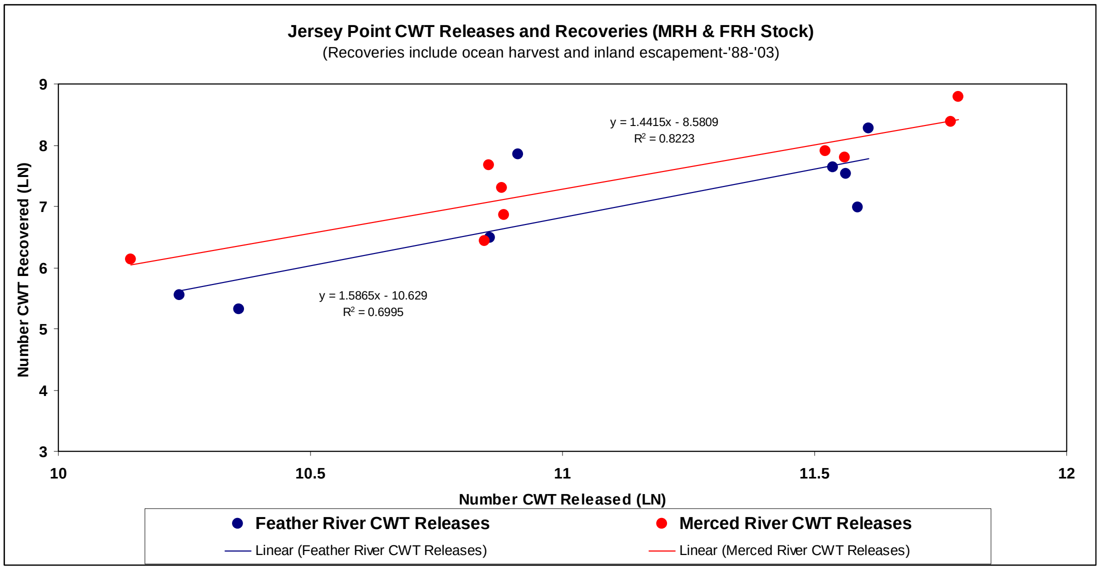


Figure 5: Recovery Abundance of Juvenile Salmon Released at Jersey Point

Note: This figure shows the relationship (log normal transformation) of adult recoveries as function of amount of juvenile salmon released at Jersey Point. Adult returns increase and the number of juveniles increase. The overall adult return rate is approximately 3 percent of the number of juveniles released. There appears to be a stock affect based upon the differences in adult recoveries between Merced River Stock (red dots) and Feather River Stock (blue dots). This stock effect is consistent with Newman (2008). The overall data set (MRH and FRH combined) regression correlation (r-square) is 0.72 (p = .001).

The primary mechanism needed to substantially produce more smolts at Jersey Point is to substantially increase the spring Vernalis flow level (magnitude, duration, and frequency) which will i) produce more smolts leaving the SJR tributaries, and ii) produce more smolts surviving to, and through, the South Delta. The production model is based on (and supported by) the empirical data as follows:

Higher Spring Trib Flow = More Smolts out of Tribs =
More Flow & Smolts to Delta =
More Smolts to Chipps Island =
More Adults Escaping from Ocean =
Progress towards Numeric Doubling Goal Attainment

CDFG used empirical data collected to date built this model (CDFG 2005, 2009, and CDFG et al. 2008b).

The primary goal then is to maximize spring flow in the tributaries to maximize juvenile production, which leads to maximizing future year adult returns. It is noted that poor ocean conditions, while random, rare, and unpredictable (at present) appear to be able to cause stochastic (random) high mortality of juvenile salmon entering the ocean (reference to 2005 event), the overwhelming evidence is that more spring flow results in higher smolt abundance and, higher smolt abundance equates to higher adult production. For reference, using the Tuolumne River as an example, spring flows >2,000 resulted in substantially elevated adult production in 80 percent (four out five) of years. This means that the probability of achieving substantial adult production from elevated spring flows is 0.8 (i.e., very likely). Based upon i) the relationship of spring flow and Mossdale smolt production, ii) both Mossdale smolt production and Vernalis spring flow level to Jersey Point smolt production, and iii) Jersey Point smolt production and adult production, the goal of doubling Chipps Island smolt production was developed.

3.4 San Joaquin River Modeling Objectives

In 2005, CDFG built a simple linear regression empirical data driven fall-run Chinook salmon production simulation model, Version 1.0 (CDFG 2005). The CDFG model, based upon empirical data trends, contained three parameter predictions i) simulated Mossdale smolt production as a function of previous year fall spawners and current average spring (3/15-6/15) Vernalis flow level (cfs), ii) smolt survival through the South Delta as a function of daily average Vernalis flow level (cfs), and iii) adult escapement as a function of Chipps Island smolt abundance. The model was independently peer reviewed, which resulted in model refinements producing SJR Salmon Model V.1.5 (CDFG 2008). The primary differences between V.1.0 and V.1.5 included i) changing the estimation parameters from linear to non-linear relationships and ii) changing the adult salmon production metric from annual salmon escapement (single year multi-age based inland ocean escapements) to single brood year production salmon escapement cohorts (number of salmon escaping the ocean linked to a specific brood production year).

In 2009, SJR Salmon Model V.1.6 was released with the primary model refinements consisting of i) use of a composite South Delta smolt vs. survival relationship (rather than two separate relationships consisting of HORB-in and HORB-out) and ii) bounded parameter predictions (model estimates limited to the range of the empirical data sets used in the model). Model V.1.6. retains the parameters that allow the number of smolts produced at Chipps Island and number of adults escaping, as function of spring daily Vernalis flow (cfs), to be estimated. The goal for modeling was to:

1. Double juvenile production at Chipps Island; and
2. Identify spring Vernalis flow magnitude, and duration, as a function of water year type (per San Joaquin River hydrologic classification) needed to accomplish Chipps Island juvenile doubling.

Before conducting model scenarios it was important to develop the model representation of historical juvenile salmon production at Mossdale and at Chipps Island. Figure 6 compares Model V.1.6. historical juvenile salmon production at Mossdale with the historical empirically based estimate. The actual historical average (for years 1988 to 2008) is 887,066 whereas, the model generated average historical estimate is 893,379. The year 1989 is excluded in the data set used to derive this average because this year is considered to be an outlier or anomaly. With year 1989 included the actual average is 1,049,074 and the model average is 880,138. Using a geometric mean rather than an arithmetic mean, which reduces the effects of extraordinarily high values upon the mean, for all years the actual mean is 729,035 and the modeled mean is 722,726.

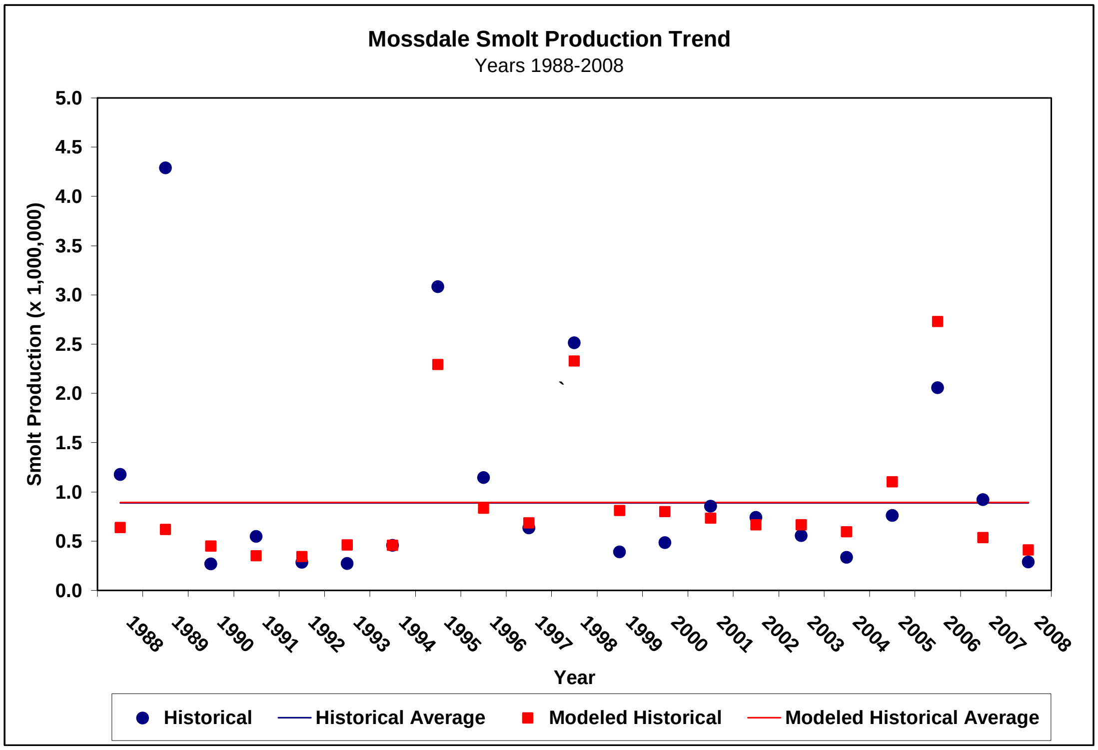


Figure 6: Modeled Mossdale Salmon Production for Years 1988-2008

Note: This figure shows the Mossdale smolt production trend, by year, for both actual historic and modeled historic time period. The historical 1988 to 2008 Mossdale production average (blue line) is 887,086 whereas, the model generated average historical estimate is 893,379 (red line). The average lines are so close to one another in value that they are superimposed. Year 1989 is removed from both actual and modeled historical averages as it is considered an outlier. If 1989 is included the historical average is 1,049,074 and the modeled historical average is 880,138.

3.5 Model scenarios

Various model scenarios were developed and segregated by water year type (per the SJR water year type classification designation)[1]. Water year types include Critically Dry, Dry, Below Normal, Above Normal, and Wet. Years 1967 to 2004 were categorized by water year type and baseline salmon production estimates categorized for each year. Year 2004 was chosen as the end year because adult salmon from brood production year 2005 are still contributing to escapement (five year old salmon expected in 2009 fall escapement).

Applying the South Delta smolt survival vs. flow relationship to the daily model generated Mossdale smolt production estimates, the average Chipps Island smolt production estimate for the 1967 through 2004 time period is 78,210. High flow years ('67, '69, '78, '82, '83, '86, '95, and '98) were not included in the average as, flows in these years are typically unusually high (greater than 15,000 cfs daily average) and were not changed during the course of modeling (with one exception: 1986 where the last half of the spring time period, when flows dropped below 15,000 cfs, flows were increased). Therefore, the Chipps Island smolt doubling goal is 156,420. Model

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[1] **http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST**

scenarios were developed to evaluate a variety of flow magnitudes and durations with the aim at identifying a combination of flow levels, that varied by water year type, which would achieve the Chipps Island juvenile doubling goal objective. Model scenarios are provided in Table 4.

Table 4 SJR Salmon Model Scenarios

Water Year Type	Magnitude														Duration				
	3200	4450	5700	7000	8000	8500	9000	10000	11000	12000	12500	15000	20000	25000	31	40	50	60	70
Critical Dry	X														X	X	X	X	
		X													X	X	X	X	
			X												X	X	X	X	
				X											X				
								X							X				
Dry															X				
		X													X	X	X	X	
			X												X	X	X	X	
				X											X	X	X	X	
						X									X				
Below Normal															X				
					X										X	X	X	X	
						X									X				
							X								X	X	X	X	
								X							X	X	X	X	
Above Normal															X				
								X							X	X	X	X	
									X						X	X	X	X	
										X					X	X	X	X	
Wet										X					X				
											X					X	X	X	
												X			X	X	X	X	
													X		X	X	X	X	

Notes: In addition to the above scenarios, each water year type included both a base historical model run (using historical flow levels) and a "VAMP-like" model run (where historical model flows were transformed into a 31-day pulse flow during the April 15 to May 15 time period

3.6 Modeling Results

3.6.1 Critically Dry Water Years

Critically dry years included in the modeling scenarios included nine years ('76, '77, '87, '88, '89, '90, '91, '92, and '94). Base (historical) Chipps Island average flow was 52,274 cfs. Modifying the historical spring flows into a VAMP-like pattern (31-day pulse flow during the Apr. 15 to May 15 time period) increased the Chipps Island average slightly to 53,292 (2 percent). Modifying flow magnitude, using VAMP-like flow pattern, flows were increased to 3200, 4450, 5700, and 7000. Chipps Island smolt production increased by 10-15 percent with each increase in flow providing a smolt production increase from 58,045 at 3200 cfs (11 percent increase from the base) to 73,480 at 7,000 cfs (59 percent increase from the base). Modifying flow duration, using an extended VAMP-like flow pattern, from a 31-day pulse to 40, 50 and 60 days resulted in a predicted Chipps Island smolt production increase ranging from 59,592 at 40 days-3200 cfs (14 percent increase above the base) to 105,776 at 60 days-7000 cfs (102 percent increase above the base). Results for all critically dry years are provided in Table 5. A flow rate of 7,000 cfs for 31 days was chosen because this flow magnitude/duration combination i) provides a substantial boost (59 percent) in Chipps Island predicted smolt abundance increase, ii) allows for smolt survival vs. flow level study test continuity[2] should VAMP studies continue in the future, and iii) the overall water cost is relatively minimal (as compared to other scenarios).

For reference, an example of changing a critically dry year flow pattern from a non-VAMP-like flow pattern to a VAMP-like flow pattern, with predicted Chipps Island smolt production, is provided in Figure 7. The recommended critically dry year flow schedule, with predicted Chipps Island smolt production estimate, is compared to the VAMP-like modified historical flow pattern (for year 1994) (Figure 7).

Table 5 Critically Dry Year Modeling Results

<table>
<tr><th colspan="16">Critical Dry Years-SJRSalmon Model Run Summary</th></tr>
<tr><th colspan="16">Includes Water Years: 1975-6;1976-7; 1986-7 thru 1992-3; and 1993-4 (9 Years)</th></tr>
<tr><th rowspan="2">Category</th><th rowspan="2">Base</th><th rowspan="2">VAMP-Like</th><th colspan="4">Increase Magnitude (cfs)</th><th colspan="3">Duration (3200 cfs)</th><th colspan="3">Duration (4450 cfs)</th><th colspan="3">Duration (5700 cfs)</th></tr>
<tr><th>3200</th><th>4450</th><th>5700</th><th>7000</th><th>45 Day</th><th>60 Day</th><th>75 Day</th><th>45 Day</th><th>60 Day</th><th>75 Day</th><th>45 Day</th><th>60 Day</th><th>75 Day</th></tr>
<tr><td>Juvenile Salmon to Mossdale</td><td>492,233</td><td>492,233</td><td>503,756</td><td>521,008</td><td>538,852</td><td>558,057</td><td>510,398</td><td>518,881</td><td>527,517</td><td>533,064</td><td>547,842</td><td>563,043</td><td>556,736</td><td>578,420</td><td>614,513</td></tr>
<tr><td>Add'l Mossdale Juveniles</td><td>n/a</td><td>n/a</td><td>11,523</td><td>28,775</td><td>46,618</td><td>65,824</td><td>18,165</td><td>26,648</td><td>35,284</td><td>40,830</td><td>55,609</td><td>70,810</td><td>64,503</td><td>86,187</td><td>122,280</td></tr>
<tr><td>Juvenile Salmon to Chipps</td><td>52,274</td><td>53,292</td><td>58,045</td><td>65,283</td><td>73,480</td><td>83,136</td><td>59,592</td><td>61,320</td><td>62,709</td><td>68,461</td><td>71,850</td><td>74,597</td><td>78,638</td><td>84,102</td><td>90,603</td></tr>
<tr><td>Add'l Chipps Juveniles</td><td>n/a</td><td>1,018</td><td>5,771</td><td>13,008</td><td>21,206</td><td>30,861</td><td>7,317</td><td>9,046</td><td>10,435</td><td>16,186</td><td>19,576</td><td>22,323</td><td>26,363</td><td>31,828</td><td>38,329</td></tr>
<tr><td>Percent Increase</td><td>n/a</td><td>2%</td><td>11%</td><td>25%</td><td>41%</td><td>59%</td><td>14%</td><td>17%</td><td>20%</td><td>31%</td><td>37%</td><td>43%</td><td>50%</td><td>61%</td><td>73%</td></tr>
<tr><td>Adult Salmon Escaping (Brood Year)</td><td>8,748</td><td>8,851</td><td>9,396</td><td>10,158</td><td>10,984</td><td>11,914</td><td>9,565</td><td>9,750</td><td>9,897</td><td>10,485</td><td>10,828</td><td>11,101</td><td>11,489</td><td>12,010</td><td>12,630</td></tr>
<tr><td>Add'l Adult Salmon</td><td>n/a</td><td>103</td><td>648</td><td>1,410</td><td>2,236</td><td>3,166</td><td>817</td><td>1,002</td><td>1,150</td><td>1,738</td><td>2,080</td><td>2,353</td><td>2,742</td><td>3,263</td><td>3,882</td></tr>
<tr><td>Percent Increase</td><td>n/a</td><td>1%</td><td>7%</td><td>16%</td><td>26%</td><td>36%</td><td>9%</td><td>11%</td><td>13%</td><td>20%</td><td>24%</td><td>27%</td><td>31%</td><td>37%</td><td>44%</td></tr>
</table>

Notes:

All data in table represent averages for the water year type expressed in the table title.

Composite Delta survival relationship used (includes HORB-in and HORB-out smolt survival data).

Mossdale juvenile salmon smolt estimates considered conservative (more flow from tribs improves smolt production in tribs, increases survival out of tribs and to Mossdale which produces more smolts to Mossdale and greater smolt survival through Delta.

Elevated flow scenarios have a pre & post pulse flow ramp

Category Title Definitions:

Base = Historical flows and model estimated salmon production

VAMP-Like = Historical flows re-shaped to a VAMP-Like 31 day pulse flow period (typically 4/15-5/15)

Juvenile Salmon to Mossdale = Model estimated number of juvenile salmon arriving at Mossdale as a function of prior year adult spawners and total current year spring flow at Vernalis.

Add'l Mossdale Juveniles = Change in estimated number of juvenile salmon arriving at Mossdale Juvenile Salmon to Chipps = Estimated number of juvenile salmon surviving to Chipps Island

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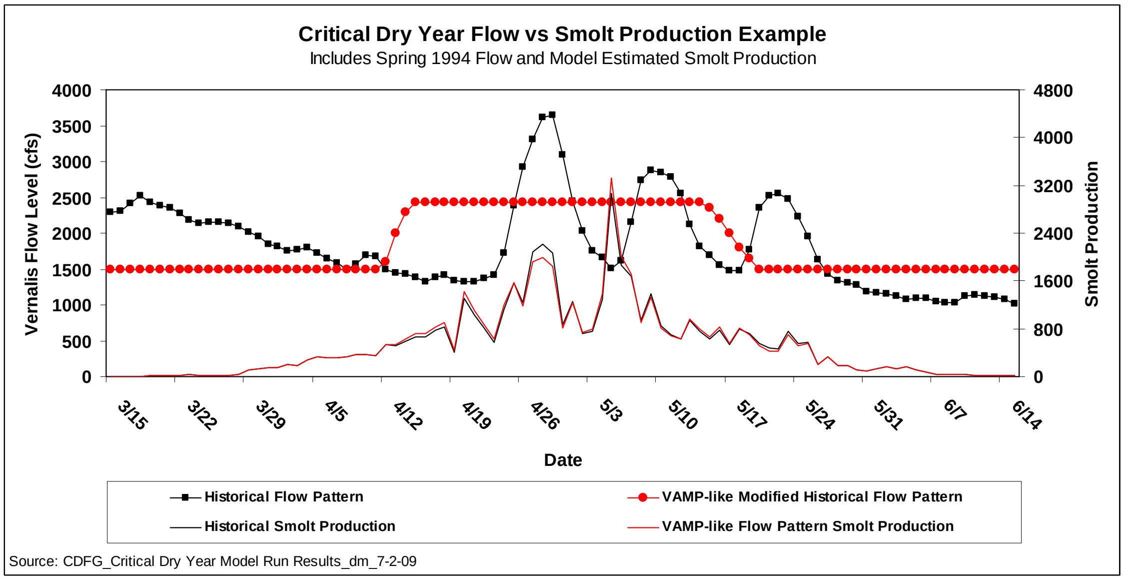
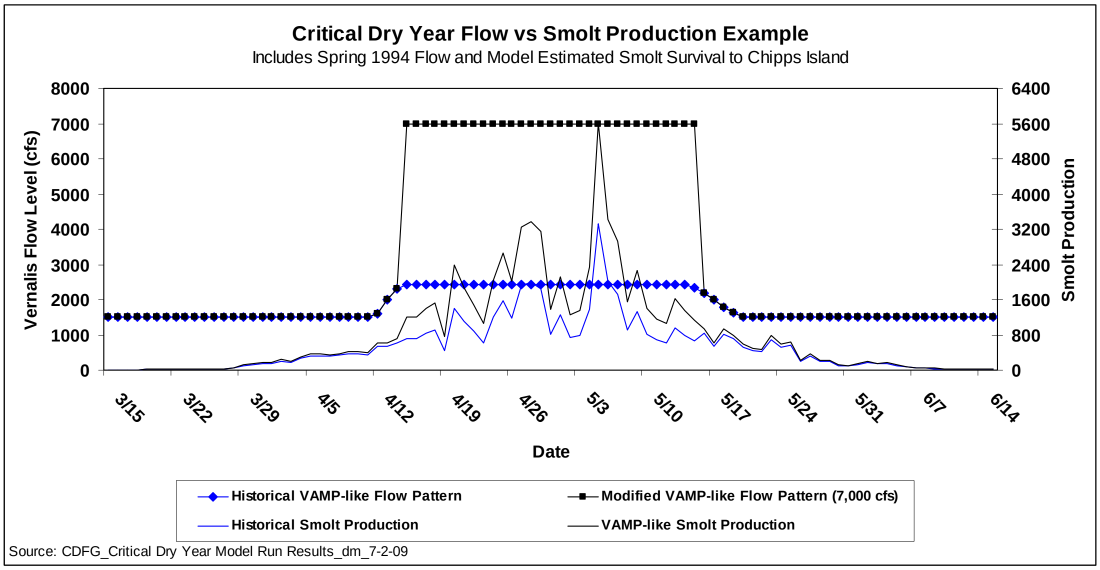
[2] **Current Vernalis Adaptive Management Program (VAMP) biological study calls for Vernalis spring flow ranges of 3200, 4450, 5700, and 7000 cfs to be tested. The VAMP study is scheduled to discontinue in 2011, but may already be discontinued since funding to provide the water called for was only guaranteed through 2009.**



Source: CDFG_Critical Dry Year Model Run Results_dm_7-2-09

Figure 7 Critically Dry Year Example-Changing Historical Flow to VAMP-like Flow

Notes: This graph compares smolt production using historical spring flow pattern to that using the same spring flow volume occurring historically but re-shaped to a VAMP-like flow pattern. Reshaping the historical hydrograph into a VAMP-like shape does improve smolt survival (production) to Chipps Island, albeit slightly.



Source: CDFG_Critical Dry Year Model Run Results_dm_7-2-09

Figure 8 Critically Dry Year Example-Changing VAMP-like Flow to 7,000 Max (31 Days)

Notes: This graph compares smolt production using historical spring flow volume re-shaped to a VAMP-like flow pattern to the scenario where spring flow is raised to 7,000 cfs for 31 days. Increasing the VAMP period flow from about 2,500 cfs (31 day average) to 7,000 cfs is estimated to improve smolt survival (production) to Chipps Island by about 60 percent and adult escaping salmon production by about 36 percent as compared to the historical base flow condition.

3.6.2 Dry Water Years

Dry years included in the modeled scenarios include seven years ('68, '72, '81, '85, 01, '02, and '04). Base (historical) Chipps Island average was 74,319. Modifying the historical spring flows into a VAMP-like pattern (31-day pulse flow during the Apr. 15 to May 15 time period) increased the Chipps Island average slightly to 75,604 (2 percent). Modifying flow magnitude, using a VAMP-like flow pattern, flows were increased to 4450, 5700, 7000, and 8500 cfs. Chipps Island smolt production increased by 15-20 percent with each increase in flow allowing a smolt production increase from 58,045 to 86,302 at 3200 cfs (16 percent increase from the base) to 126,487 at 8500 cfs (70 percent increase from the base). Modifying flow duration, using an extended VAMP-like flow pattern, from a 31-day pulse to 40, 50 and 60 days resulted in a predicted Chipps Island smolt production increase ranging from 89,603 at 40 days-4450 cfs (21 percent increase above the base) to 137,177 at 60 days-8500 cfs (85 percent increase above the base). Results for all dry years are provided in Table 6. A flow rate of 7,000 cfs for 40 days was chosen because this flow level-duration combination i) provides a substantial boost (60 percent increase) in Chipps Island predicted smolt abundance, ii) allows for smolt survival vs. flow level study test continuity[3] should VAMP studies continue in the future, and iii) the overall water cost is relatively minimal (as compared to other scenarios).

For reference, an example of changing a dry year flow pattern from a non-VAMP-like flow pattern to a VAMP-like flow pattern, with predicted Chipps Island smolt production, is provided in Figure 9. The recommended dry year flow schedule, with predicted Chipps Island smolt production estimate, is compared to the VAMP-like modified historical flow pattern (for year 1985) (Figure10).

Table 6 Model Scenario Results-Dry Years

Dry Years-SJR Salmon Model Run Summary															
Includes Water Years: 1967-8; 1971-2; 1980-1; 1984-5; 2000-1; 2001-2; and 2003-4 (7 Years)															
		VAMP-	Increase Magnitude (cfs)				Duration (4450 cfs)			Duration (5700 cfs)			Duration (7000 cfs)		
Category	Base	Like	4450	5700	7000	8500	40 Day	50 Day	60 Day	40 Day	50 Day	60 Day	40 Day	50 Day	60 Day
Juvenile Salmon to Mossdale	657,908	657,908	683,500	706,893	732,087	762,276	695,699	712,432	730,024	726,556	752,158	779,149	760,141	795,867	833,793
Add'l Mossdale Juveniles	n/a	n/a	25,592	48,985	74,180	104,368	37,791	54,525	72,117	68,648	94,251	121,242	102,233	137,959	175,885
Juvenile Salmon to Chipps	74,319	75,604	86,302	97,074	109,764	126,487	89,603	93,537	96,761	102,883	109,462	114,913	118,744	128,745	137,177
Add'l Chipps Juveniles	n/a	1,285	11,983	22,754	35,445	52,168	15,284	19,218	22,442	28,564	35,142	40,593	44,424	54,426	62,858
Percent Increase	0	2%	16%	31%	48%	70%	21%	26%	30%	38%	47%	55%	60%	73%	85%
Adult Salmon Escaping (Brood Year)	11,088	11,220	12,254	13,236	14,342	15,728	12,561	12,921	13,211	13,750	14,319	14,780	15,097	15,912	16,581
Add'l Adult Salmon	n/a	131	1,166	2,148	3,254	4,640	1,473	1,833	2,123	2,662	3,230	3,691	4,008	4,824	5,493
Add'l Adult Salmon	0	1%	11%	19%	29%	42%	13%	17%	19%	24%	29%	33%	36%	44%	50%

Notes: See Table 5 notes for category definitions

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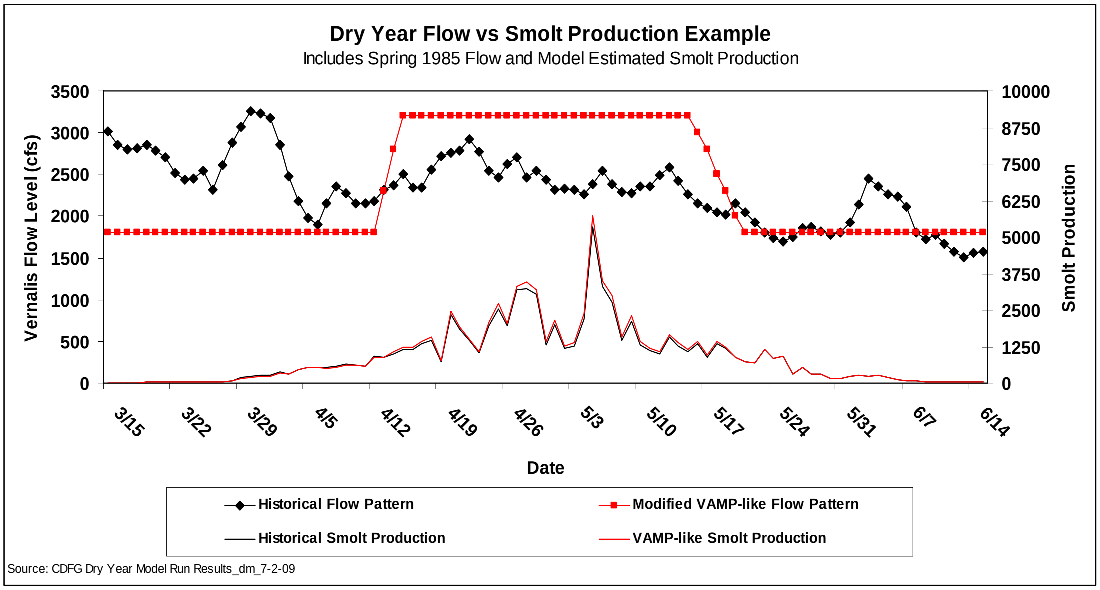
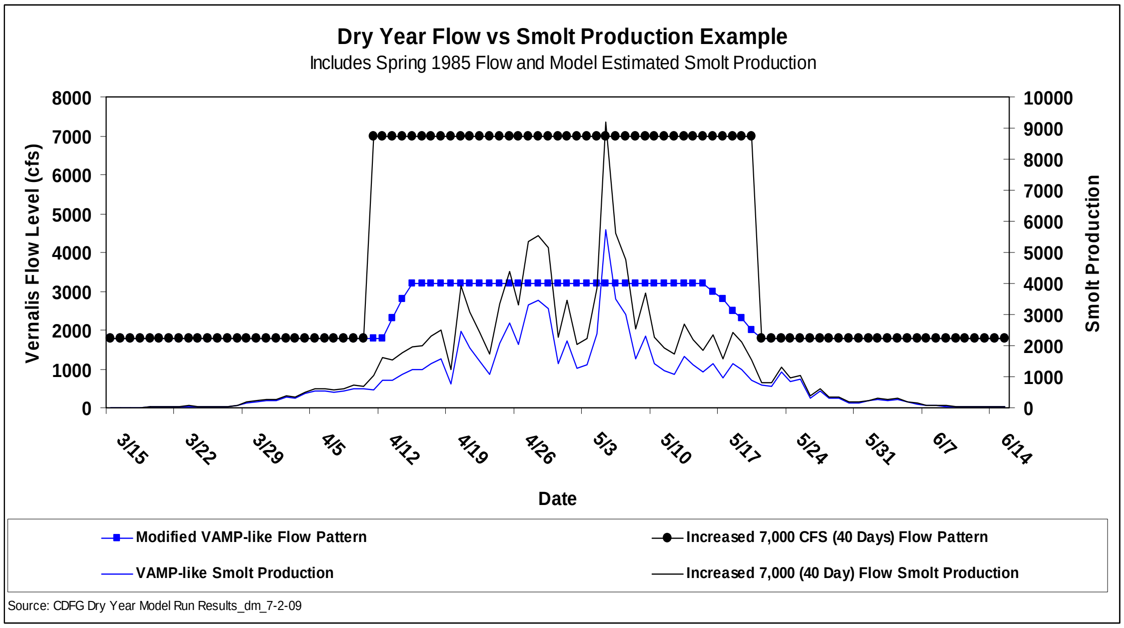
[3] **Current Vernalis Adaptive Management Program (VAMP) biological study calls for Vernalis spring flow ranges of 3200, 4450, 5700, and 7000 cfs to be tested. The VAMP study is scheduled to discontinue in 2011 but, it could already have discontinued because funding to provide the water called for was only guaranteed through 2009.**



Source: CDFG Dry Year Model Run Results_dm_7-2-09

Figure 9 Dry Year Example-Changing Historical Flow to VAMP-like Flow

This graph compares smolt production using historical the spring flow pattern to that using the same spring flow volume occurring historically but re-shaped to a VAMP-like flow pattern. Dry years 2000-01, 2001-2, and 2003-4 since flows in those years were already VAMP-like. Reshaping the historical hydrograph into a VAMP-like shape does improve smolt survival (production) to Chipps Island, albeit slightly.



Source: CDFG Dry Year Model Run Results_dm_7-2-09

Figure 10 Dry Year Example-Changing VAMP-like Flow to 7,000 Max (40 Days)

Notes: This graph compares smolt production using historical spring flow volume re-shaped to a VAMP-like flow pattern to the scenario where spring flow is raised to 7,000 cfs for 40 days. Increasing the VAMP period flow from about 2,000 cfs (31 day average) to 7,000 cfs (40 day average) is estimated to improve smolt survival (production) to Chipps Island by about 60 percent and adult escaping salmon production by about 36 percent as compared to the historical base flow condition.

3.6.3 Below Normal Water Years

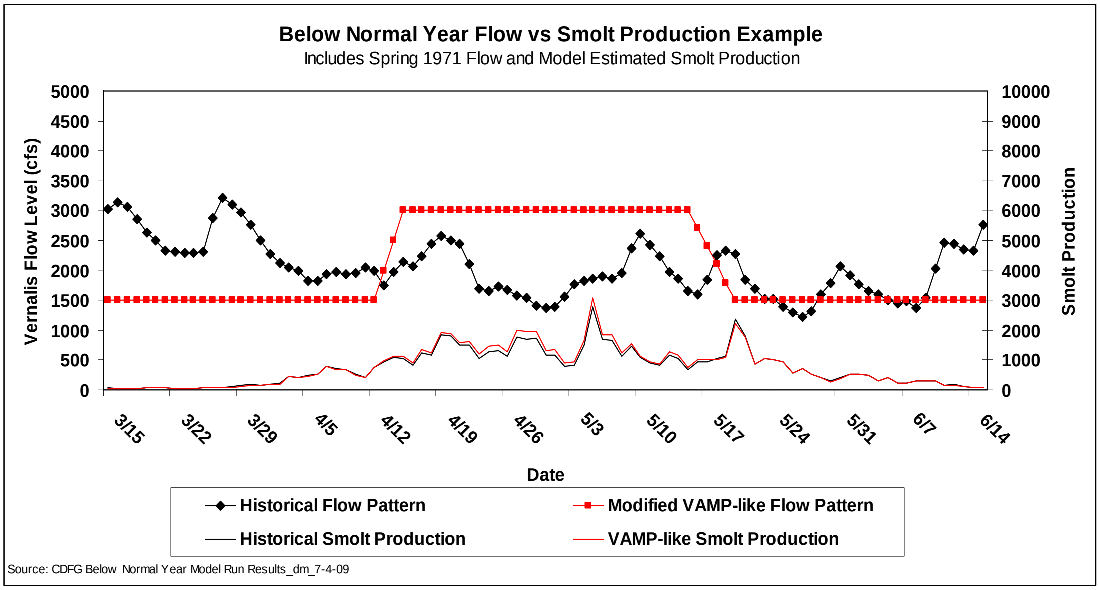
Below normal years included in the modeled scenarios were 1971 and 2003. Base (historical) Chipps Island average was 74,703. Modifying the historical spring flows into a VAMP-like pattern (31-day pulse flow during the Apr. 15 to May 15 time period) increased the Chipps Island average slightly to 76,459 (2 percent). Modifying flow magnitude, using VAMP-like flow pattern (31-days), flows were increased to 8000, 8500, 9000, and 10,000 cfs. Chipps Island smolt production increased ranging from 55 percent (8,000 cfs) to 84 percent (10,000 cfs) as compared to the base. Modifying flow duration, using an extended VAMP-like flow pattern, from a 31-day pulse to 40, 50 and 60 days resulted in a predicted Chipps Island smolt production increase ranging from 128,966 at 40 days-8,000 cfs (73 percent increase above the base) to 203,723 at 60 days-10,000 cfs (173 percent increase above the base). Results for all below normal years are provided in Table 7. A flow rate of 8,500 for 50 days was chosen because this flow level-duration combination i) provides a substantial boost (106 percent) in Chipps Island predicted smolt abundance increase, and ii) the overall water cost is relatively minimal (as compared to other scenarios).

For reference, an example of changing a below normal year flow pattern from a non-VAMP-like flow pattern to a VAMP-like flow pattern, with predicted Chipps Island smolt production, is provided in Figure 11. The recommended below normal year flow schedule, with predicted Chipps Island smolt production estimate, is compared to the VAMP-like modified historical flow pattern (for year 1971) (Figure 12).

Table 7 Model Scenario Results-Below Normal Year

Below Normal Years-SJR Salmon Model Run Summary																
Includes Water Years: 1970-1 and 2002-3 (2 Years)																
		VAMP-	Increase Magnitude (cfs)				Duration (8500 cfs)			Duration (9000 cfs)			Duration (10000 cfs)			
Category	Base	Like	8000	8500	9000	10000	40 Day	50 Day	60 Day	40 Day	50 Day	60 Day	40 Day	50 Day	60 Day
Juvenile Salmon to Mossdale	687,867	687,867	784,623	795,263	806,048	828,057	835,967	886,545	940,163	850,623	906,016	964,995	880,711	946,251	1,016,645
Add'l Mossdale Juveniles	n/a	n/a	96,756	107,396	118,180	140,189	148,100	198,678	252,295	162,756	218,149	277,128	192,844	258,383	328,777
Juvenile Salmon to Chipps	74,703	76,459	115,451	120,539	125,859	137,224	135,799	153,518	167,611	142,982	162,925	178,933	158,452	183,361	203,723
Add'l Chipps Juveniles	n/a	1,756	40,749	45,837	51,156	62,522	61,096	78,816	92,908	68,279	88,222	104,230	83,750	108,658	129,021
Percent Increase	n/a	0	55%	61%	68%	84%	82%	106%	124%	91%	118%	140%	112%	145%	173%
Adult Salmon Escaping (Brood Year)	11,161	11,337	14,850	15,273	15,707	16,613	16,501	17,864	18,906	17,061	18,564	19,719	18,233	20,031	21,433
Add'l Adult Salmon	n/a	176	3,689	4,111	4,546	5,452	5,340	6,703	7,745	5,900	7,402	8,558	7,072	8,870	10,272
Percent Increase	n/a	2%	33%	37%	41%	49%	48%	60%	69%	53%	66%	77%	63%	79%	92%

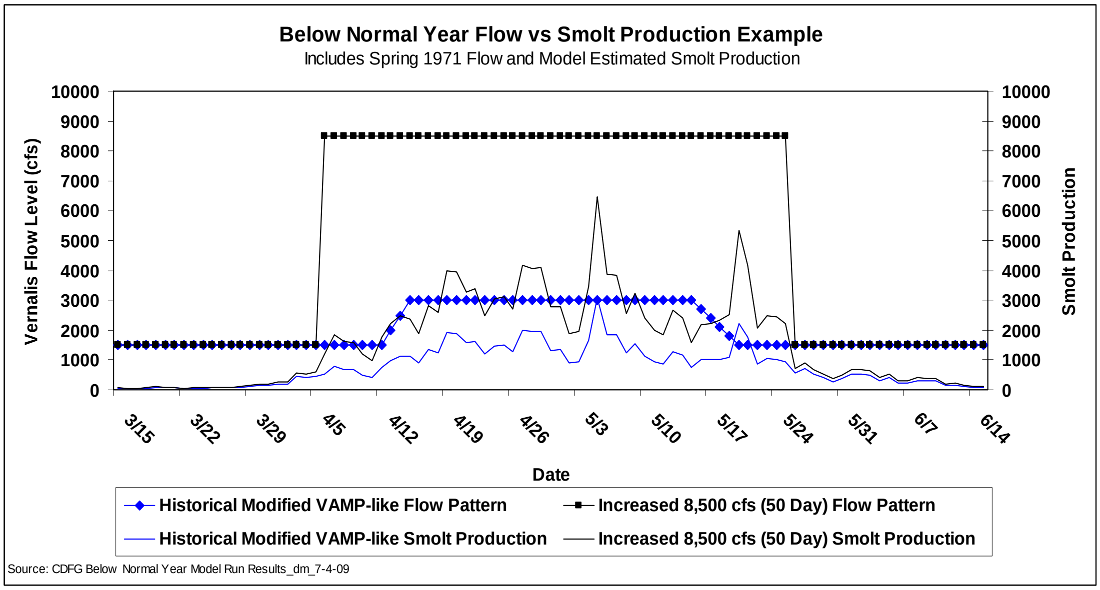
Notes: See Table 5 notes for category definitions



Source: CDFG Below Normal Year Model Run Results_dm_7-4-09

Figure 11 Below Normal Year Example-Changing Historical Flow to VAMP-like Flow

Notes: This graph compares smolt production using historical spring flow pattern to that using the same spring flow volume occurring historically but re-shaped to a VAMP-like flow pattern. Dry year 2002-3 not chosen because flows already VAMP-like. Reshaping the historical hydrograph into a VAMP-like shape does improve smolt survival (production) to Chipps Island albeit slightly (2 percent).



Source: CDFG Below Normal Year Model Run Results_dm_7-4-09

Figure 12 Below Normal Year Example-Changing VAMP-like Flow to 8,500 Max (50 Days)

Notes: This graph compares smolt production using historical spring flow volume re-shaped to a VAMP-like flow pattern to the scenario where spring flow volume is raised to 8,500 cfs for 50 days. Increasing the VAMP period flow from about 3,000 cfs (31 day average) to 8,500 cfs (50 day average) is estimated to improve smolt survival (production) to Chipps Island by about 106 percent and adult escaping salmon production by about 60 percent as compared to the historical base flow condition.

3.6.4 Above Normal Water Years

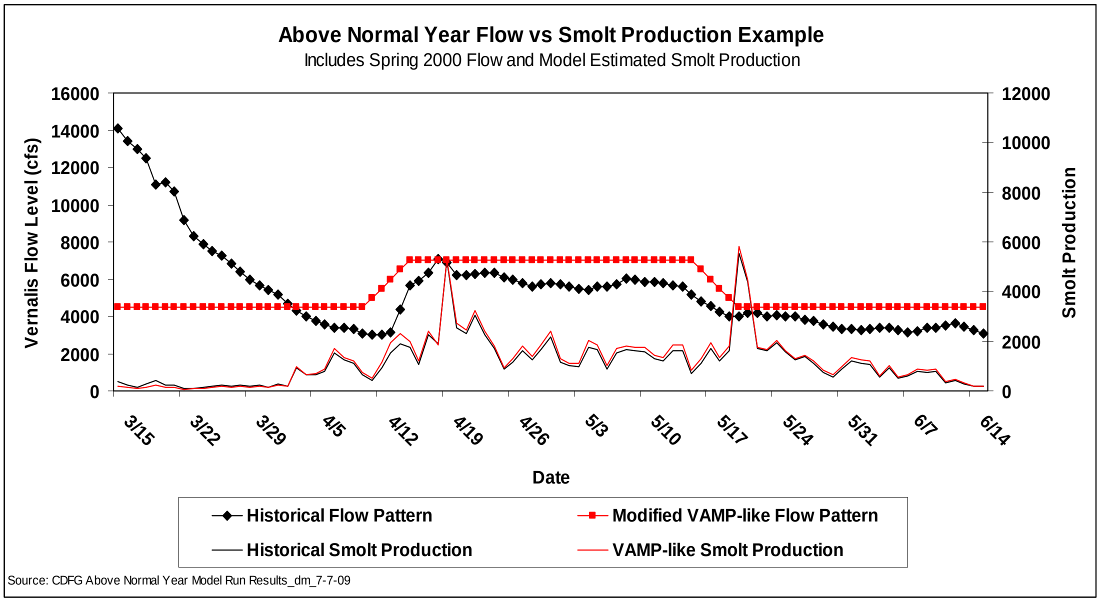
The modeled above normal years included six years ('70, '73, '79, '84, '99, and '00). Base (historical) Chipps Island average was 89,610. Modifying the historical spring flows into a VAMP-like pattern (31-day pulse flow during the Apr. 15 to May 15 time period) increased the Chipps Island average slightly to 97,606 (9 percent). Modifying flow magnitude, using VAMP-like flow pattern, flows were increased to 10000, 11000, and 12000 cfs. Chipps Island smolt production increases ranged from 40 percent (10,000 cfs) to 62 percent (12,000 cfs) as compared to the base. Modifying flow duration, using an extended VAMP-like flow pattern, from a 31-day pulse to 40, 50 and 60 days resulted in a predicted Chipps Island smolt production increase ranging from 59,592 to 141,784 at 40 days-10,000 cfs (58 percent increase above the base) to 232,370 at 60 days-12,000 cfs (159 percent increase above the base). Results for all above normal years are provided in Table 8. A flow rate of 10,000 for 60 days was chosen because this flow level-duration combination i) provides a substantial boost (102 percent) in Chipps Island predicted smolt abundance increase, and ii) the overall water cost is relatively minimal (as compared to other scenarios).

For reference, an example of changing an above normal year flow pattern from a non-VAMP-like flow pattern to a VAMP-like flow pattern, with predicted Chipps Island smolt production, is provided in Figure 13. The recommended above normal year flow schedule, with predicted Chipps Island smolt production estimate, is compared to the VAMP-like modified historical flow pattern (for year 2000) (Figure 14).

Table 8 Model Scenario Results-Above Normal Years

Above Normal Years-SJR Salmon Model Run Summary														
Includes Water Years: 1969-70, 1972-3, 1978-9, 1983-4, 1998-9 and 1999-00 (6 Years)														
		VAMP-	Increase Magnitude			Duration (10000 cfs)			Duration (11000 cfs)			Duration (12000 cfs)		
Category	Base	Like	10000	11000	12000	40 Day	50 Day	60 Day	40 Day	50 Day	60 Day	40 Day	50 Day	60 Day
Juvenile Salmon to Mossdale	726,557	726,557	797,207	818,975	841,337	833,608	885,012	939,700	863,094	924,314	989,996	893,623	965,361	1,042,984
Add'l Mossdale Juveniles	n/a	n/a	70,650	92,418	114,780	107,051	158,455	213,143	136,537	197,757	263,439	167,066	238,803	316,427
Juvenile Salmon to Chipps	89,610	97,606	125,243	134,948	145,454	141,784	164,111	181,018	155,809	183,709	205,227	171,174	205,447	232,370
Add'l Chipps Juveniles	n/a	7,996	35,633	45,338	55,844	52,174	74,501	91,408	66,199	94,099	115,617	81,563	115,837	142,760
Percent Increase	0	9%	40%	51%	62%	58%	83%	102%	74%	105%	129%	91%	129%	159%
Adult Salmon Escaping (Brood Year)	12,507	13,247	15,596	16,370	17,186	16,912	18,595	19,811	17,976	19,997	21,475	19,100	21,486	23,253
Add'l Adult Salmon	n/a	740	3,089	3,863	4,679	4,405	6,088	7,304	5,469	7,490	8,968	6,593	8,979	10,746
Percent Increase	0	6%	25%	31%	37%	35%	49%	58%	44%	60%	72%	53%	72%	86%

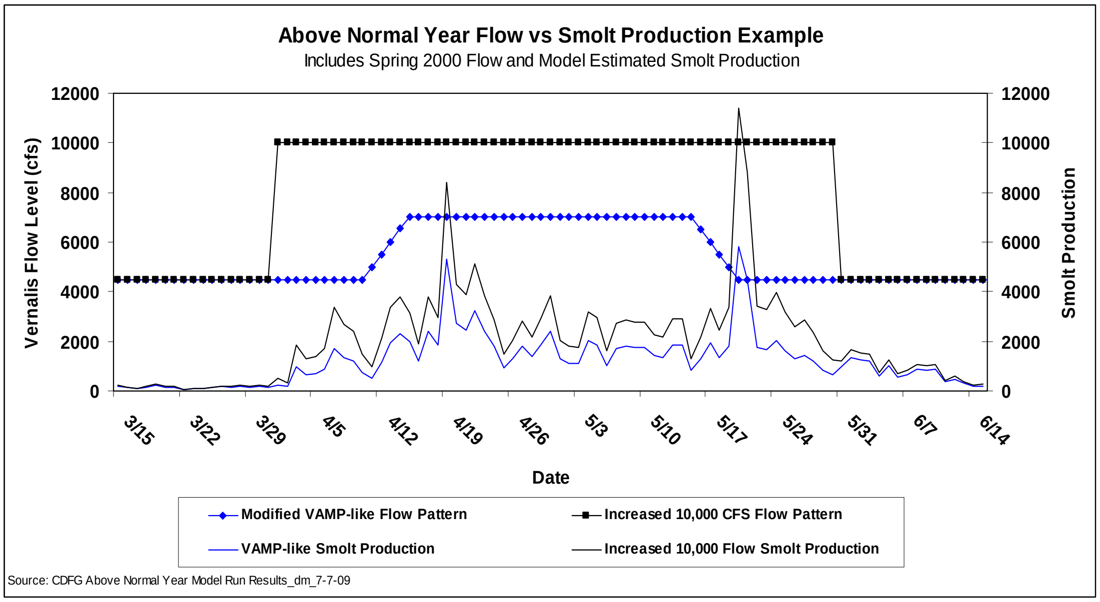
Notes: See Table 5 notes for category definitions



Source: CDFG Above Normal Year Model Run Results_dm_7-7-09

Figure 13 Above Normal Year Example-Changing Historical Flow to VAMP-like Flow

Notes: Notes: This graph compares smolt production using historical spring flow pattern to that using the same spring flow volume occurring historically but re-shaped to a VAMP-like flow pattern. Reshaping the historical hydrograph into a VAMP-like shape does improve smolt survival (production) to Chipps Island albeit slightly.



Source: CDFG Above Normal Year Model Run Results_dm_7-7-09

Figure 14 Above Normal Year Example-Changing VAMP-like Flow to 10,000 Max (60 Days)

Notes: This graph compares smolt production using historical spring flow volume re-shaped to a VAMP-like flow pattern to the scenario where spring flow volume is raised to 10,000 cfs for 60 days. Increasing the VAMP period flow from about 7,000 cfs (31 day average) to 10,000 cfs (60 day average) is estimated to improve smolt survival (production) to Chipps Island by about 102 percent and adult escaping salmon production by about 58 percent as compared to the historical base flow condition.

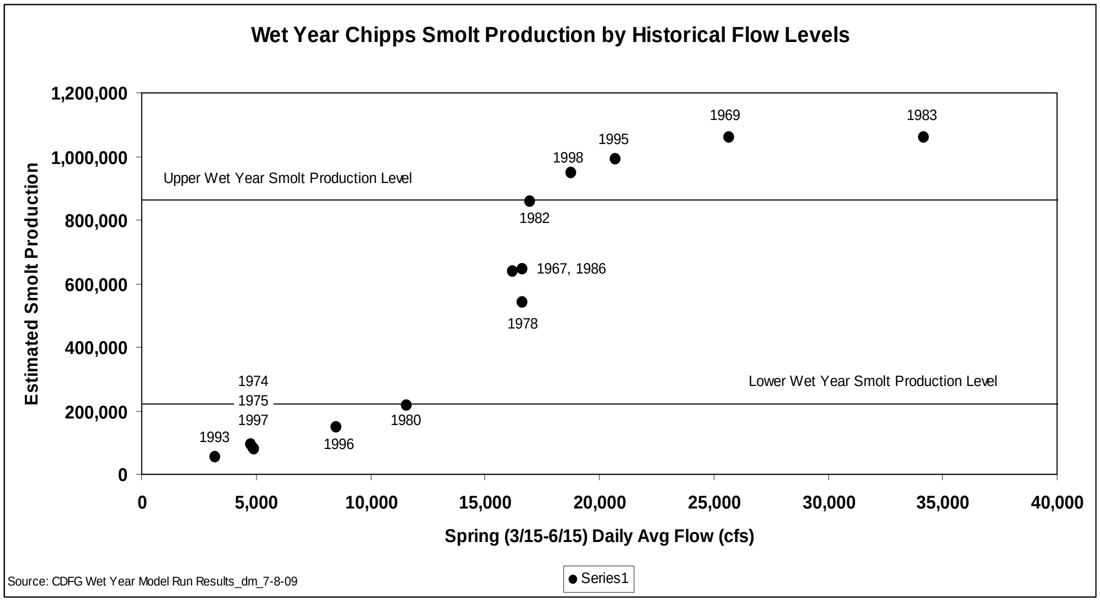
3.6.5 Wet Years

There are 14 wet years included in the modeling scenarios between the 1967 to 2004 time period ('67, '69, '74, '75, '78, '80, '82, '83, '86, '93, '95, '96, '97, and '98). However, only six wet years have been included in model scenarios ('74, '75, '80, '93, '96, and '97). The reason for this is that in the other wet years the average daily spring pulse flow was typically greater than 15,000 cfs and in some cases was more than 25,000 cfs). Figure 6.7-9 shows the historical (base case) average spring flow level for each wet water year type along with Chipps Island smolt production. It was determined that flows in the wettest of the wet years, where flood control releases were occurring, would not have flow levels reduced. Therefore only those wet years where daily average spring flows were less than 15,000 cfs were chosen for use in modeling scenarios.

By graphing modeled historical Chipps Island smolt production for all wet years an interesting discovery was found. There is a sigmoidal relationship between Chipps Island smolt production and average spring Vernalis flow level. The center of the flow range (approximately 16,000 cfs), which includes 4 years ('67, '78, 82, and '86), while having similar flow levels, produces substantially different Chipps Island smolt production estimates (Figure 15). The reason for this is believed to be the combination of magnitude and flow duration occurring during the time when most smolts are out-migrating. Year 1982 had the highest peak, and longest elevated duration, flow occurring over the largest portion of smolt out-migration than the other years.

Continuing with wet year model results, the base (historical) Chipps Island average was 111,421. Modifying the historical spring flows into a VAMP-like pattern (31-day pulse flow during the Apr. 15 to May 15 time period) increased the Chipps Island average slightly to 125,507 (13 percent). Modifying flow magnitude, using VAMP-like flow pattern, flows were increased to 15000, 20000, and 25000 cfs. Chipps Island smolt production increases ranged from 61 percent (15,000 cfs) to 214 percent (25,000 cfs) as compared to the base. Modifying flow duration, using an extended VAMP-like flow pattern, from a 31-day pulse to 50, 60 and 70 days resulted in a predicted Chipps Island smolt production increase ranging from 198,658 at 50 days-15,000 cfs (78 percent increase above the base) to 601,174 at 70 days-20,000 cfs (440 percent increase above the base). Results for all wet water years are provided in Table 9. A flow rate of 15,000 cfs for 70 days was chosen because this flow level-duration combination i) provides a substantial boost (191 percent) in Chipps Island predicted smolt abundance increase, and ii) the overall water cost is relatively minimal (as compared to other scenarios). Figure 15 shows that wet years ’74, ’75, ’80, ’93, ’96, and ’97 have very low (as compared to other wet years) Chipps Island smolt production estimates for historical flow conditions. This is likely due to the fact that these wet years have “drier year like” spring flow levels (e.g. even though a wet year occurred, flows more consistent with drier water year types occurred).

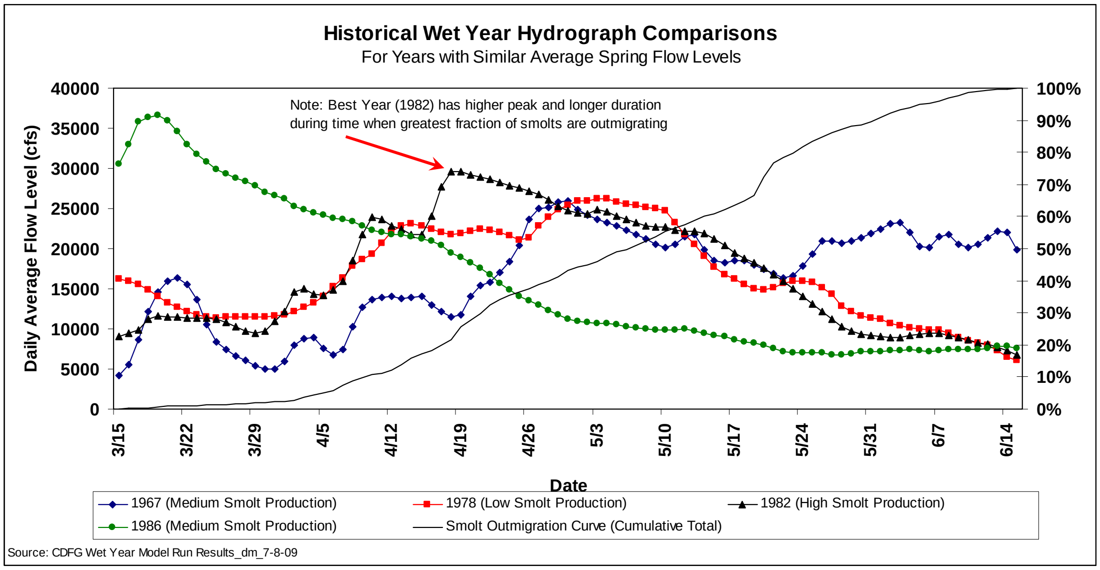
For reference, an example of changing a wet year flow pattern from a non-VAMP-like flow pattern to a VAMP-like flow pattern, with predicted Chipps Island smolt production, is provided in Figure 16. The recommended wet year flow schedule, with predicted Chipps Island smolt production estimate, is compared to the VAMP-like modified historical flow pattern (for year 1997)(Figure 17).



Source: CDFG Wet Year Model Run Results_dm_7-8-09

Figure 15 Wet Year Model Estimated Smolt Production at Chipps Island

Note: There is a very large discrepancy in the amount of estimated smolt production at Chipps Island for wet water year types. This is due to the very large difference in average spring flow levels occurring during wet years. For example, in 1996 (a wet year with low smolt production) the average spring flow (3/15-6/15) was about 8,500 cfs; whereas, in 1998 (a wet year with high smolt production) the average spring flow (3/15-6/15) was about 19,000 cfs. For years 1967, 1978, 1982, and 1986, all had average spring (3/15-6/15) flow levels of about 16,000 cfs. However, smolt production was not estimated to be consistent across these years. This is believed due to the difference in historical flow patterns which are presented in Figure 6.7-10 below. Also noted is that the model limits survival to the highest empirical flow range evaluated (25,000 cfs) therefore, it is believed that smolt production in 1983 was actually much higher than that estimated by the model



Source: CDFG Wet Year Model Run Results_dm_7-8-09

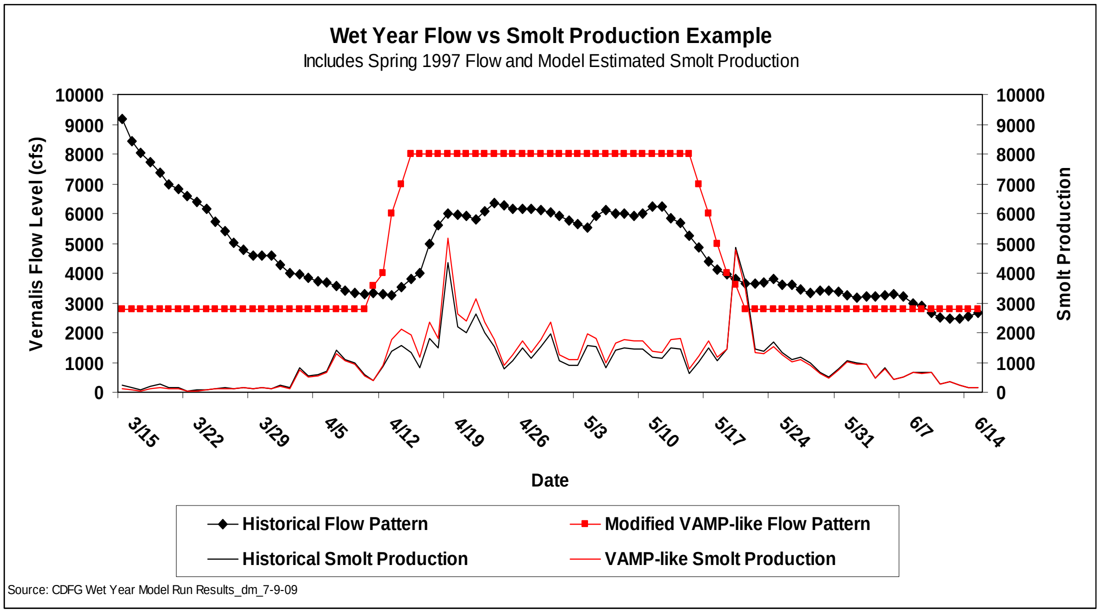
Figure 16 Historic Spring Wet Year Flow Patterns for Years with Similar Average Spring Flow Level

Note: Though the historical spring (3/15-6/15) hydrograph for the four wet years depicted (1967, 1978, 1982, and 1986) all have similar averages for the spring period (16,000 cfs), wet year 1982 is estimated to have produced a substantially greater number of smolts at Chipps Island than the other years. The reason for this difference in smolt production is believed to be caused by a much greater peak flow and longer duration allowing for greater smolt survival to occur when a greater fraction of smolts were out-migrating than that which occurred in other similar average spring flow wet years (1967, 1978, and 1986).

Table 9 Model Scenario Results-Wet Years

Wet Years-SJR Salmon Model Run Summary															
Includes Water Years: 1973-4, 1974-5, 1979-80, 1992-3, 1995-6 and 1996-7 (6 Years)															
		VAMP-	Increase Magnitude (cfs)				Duration (12500 cfs)			Duration (15000 cfs)			Duration (20000 cfs)		
Category	Base	Like	12500	15000	20000	25000	50 Day	60 Day	70 Day	50 Day	60 Day	70 Day	50 Day	60 Day	70 Day
Juvenile Salmon to Mossdale	712,747	712,747	781,420	826,188	945,315	1,081,618	865,439	919,570	983,167	954,158	1,036,544	1,133,104	1,185,689	1,345,266	1,535,891
Add'l Mossdale Juveniles	n/a	0	68,673	113,441	232,568	368,871	152,692	206,823	270,420	241,411	323,797	420,357	472,942	632,519	823,144
Juvenile Salmon to Chipps	111,421	125,507	155,786	179,801	254,269	350,188	198,658	218,308	239,740	252,700	286,982	324,629	419,672	504,473	601,174
Add'l Chipps Juveniles	n/a	14,087	44,365	68,380	142,848	238,767	87,237	106,888	128,319	141,279	175,561	213,208	308,251	393,052	489,754
Percent Increase	0	13%	40%	61%	128%	214%	78%	96%	115%	127%	158%	191%	277%	353%	440%
Adult Salmon Escaping (Brood Year)	14,131	15,199	17,798	19,598	24,501	30,058	20,984	22,330	23,734	24,525	26,627	28,815	33,853	38,057	42,515
Add'l Adult Salmon	n/a	1,068	3,667	5,467	10,370	15,927	6,853	8,199	9,603	10,394	12,496	14,684	19,722	23,926	28,384
Percent Increase	0	8%	26%	39%	73%	113%	48%	58%	68%	74%	88%	104%	140%	169%	201%

Notes: See Table 5 notes for category definitions
This table only includes those wet years from 1967 through 2004 that had a daily average spring flow levels (3/15 to 6/15) less than 15,000 cfs.

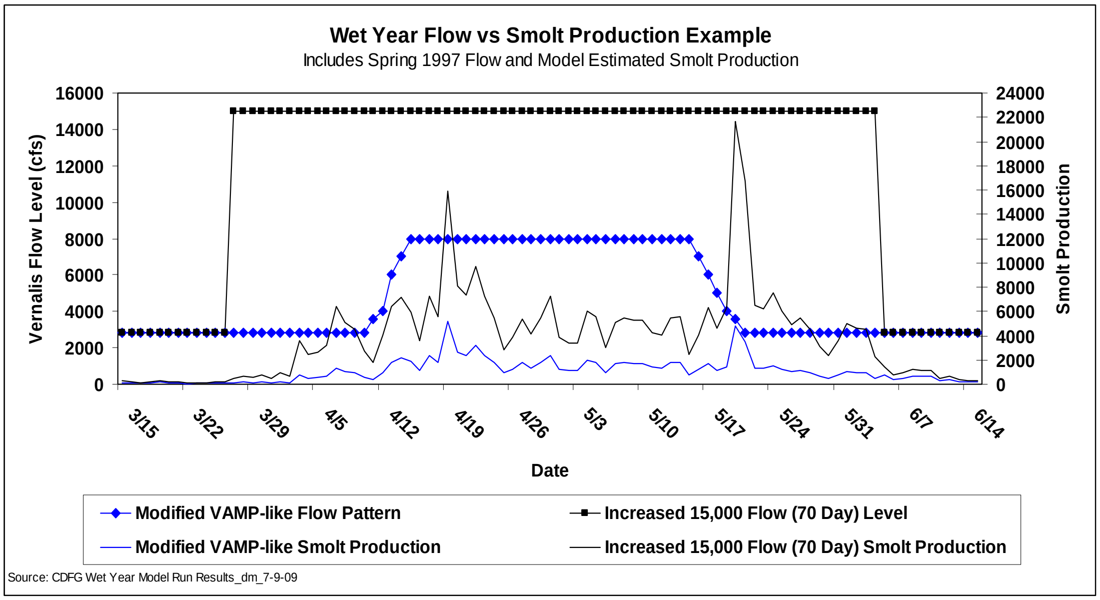

Wet Year Flow vs Smolt Production Example

Includes Spring 1997 Flow and Model Estimated Smolt Production

Source: CDFG Wet Year Model Run Results_dm_7-9-09

Figure 17 Wet Year Example-Changing Historical Flow to VAMP-like Flow

Notes: Notes: This graph compares smolt production using historical spring flow pattern to that using the same spring flow volume occurring historically but re-shaped to a VAMP-like flow pattern. Reshaping the historical hydrograph into a VAMP-like shape does improve smolt survival (production) to Chipps Island albeit slightly.


Wet Year Flow vs Smolt Production Example

Includes Spring 1997 Flow and Model Estimated Smolt Production

Source: CDFG Wet Year Model Run Results_dm_7-9-09

Figure 18 Wet Year Example-Changing VAMP-like Flow to 15,000 Max (70 Days)

Notes: This graph compares smolt production using historical spring flow volume re-shaped to a VAMP-like flow pattern to the scenario where spring flow volume is raised to 15,000 cfs for 70 days. Increasing the VAMP period flow from about 8,000 cfs (31 day average) to 15,000 cfs (70 day average) is estimated to improve smolt survival (production) to Chipps Island by about 191 percent and adult escaping salmon production by about104 percent as compared to the historical base flow condition.

3.7 Flows Needed at Vernalis to Improve Smolt Production at Chipps Island

Based on the modeling results, flows needed for the SJR at Vernalis are provided in Table 10 and depicted in Figure 19. The predicted Chipps Island smolt production from this flow schedule (Figure 20) accomplishes the doubling objective (e.g. Chipps Island smolt production is increased two-fold from 78,210 to more than 156,420).

Table 10 South Delta (Vernalis) Flows Needed to Double Smolt Production at Chipps Island (by Water Year Type)

	Water Year Type				
Flow Type	Critical	Dry	Below Normal	Above Normal	Wet
Base (cfs)	1,500	2,125	2,258	4,339	6,315
Pulse (cfs)	5,500	4,875	6,242	5,661	8,685
Pulse Duration	31	40	50	60	70
Total Flow (cfs)	7,000	7,000	8,500	10,000	15,000
Acre-Feet Total	614,885	778,772	1,035,573	1,474,111	2,370,768

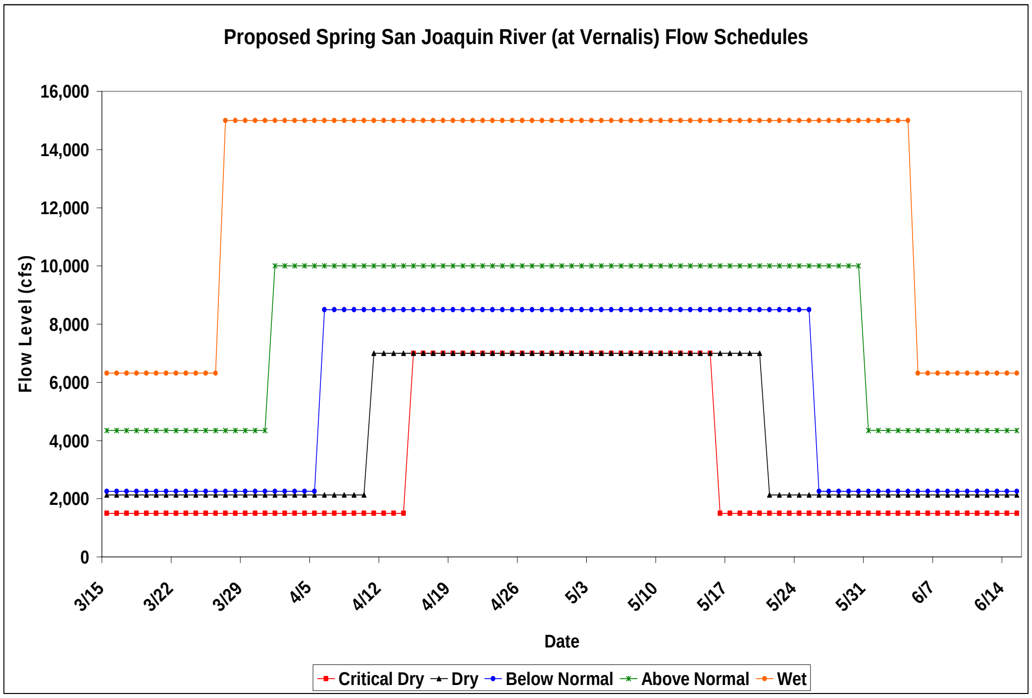


Figure 19 South Delta (Vernalis) Flows Needed to Improve Smolt Production at Chipps Island (by Water Year Type)

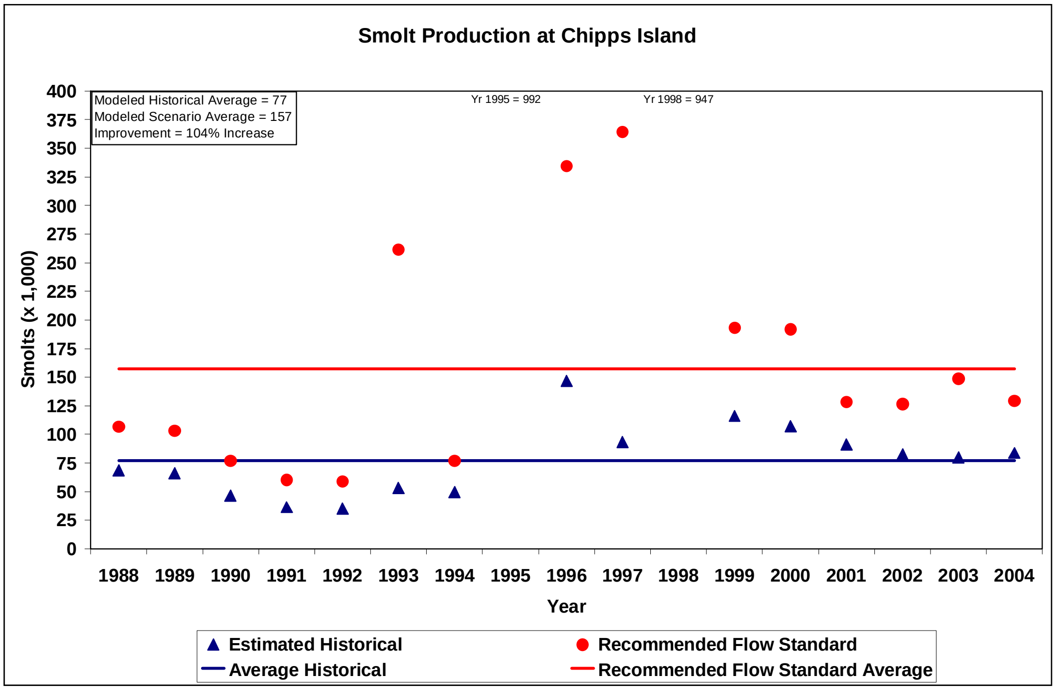


Figure 20 Modeled Chipps Island Salmon Production for Years 1988-2004.
Note: This figure shows the model predicted Chipps Island smolt production for the base (historical-blue diamonds) and recommended Vernalis flow standards (red circles). Smolt production is doubled at the recommended flow levels. The average for both data sets excludes the extremely wet years (and corresponding high smolt production) as these years (1995 and 1998) inflate the average (in both cases), and the spring flows were not changed in the scenarios evaluated.

The smolt production model determined flows to achieve smolt production doubling for the various water-year types for the San Joaquin River near Vernalis. The time period for the modeled flows spans 93 days from March 15 through June 15 for each water-year type, the time period determined from smolt out-migration monitoring that should provide sufficient flows necessary to cover all but the small percentage of unusually early or late migrants. The following tables show the magnitude and duration for the base- and pulse-flow smolt out-migration periods for each of the San Joaquin Valley water-year indices in cfs.

4 Conclusion

In conclusion, the empirical information that has been gathered over the last 20 years indicates that improving stream flow in the spring time period in the SJR east-side tributaries, resulting in increased SJR flows at Vernalis, is necessary to accomplish the State and Federal salmon doubling goal by doubling juvenile (smolt) abundance at Chipps Island. The flows identified to double smolt production (Table 10) are based upon empirical information generated from SJR basin studies. Alternate flows for different year types, flow magnitude, duration, and timing are presented in tables 5, 6, 7, 8, and 9.

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