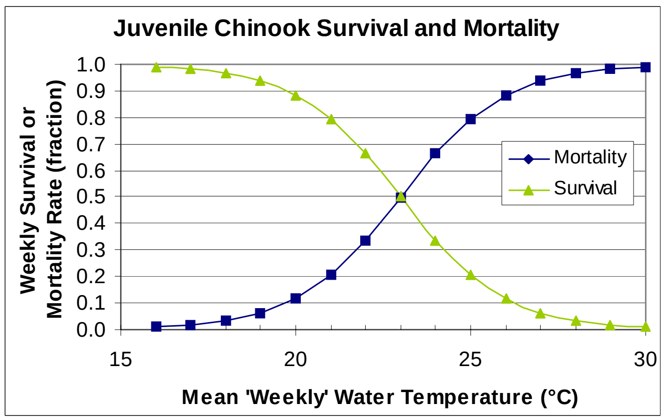
FINAL DRAFT 11-28-05

San Joaquin River
Fall-run Chinook Salmon
Population Model



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San Joaquin Valley Southern Sierra Region
November 2005[2]

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[1] Graphic from Stanislaus River Water Temperature Peer Review Panel Report (Deas 2004)
[2] Report authored by Dean Marston CDFG-SJVSSR Staff Environmental Scientist.

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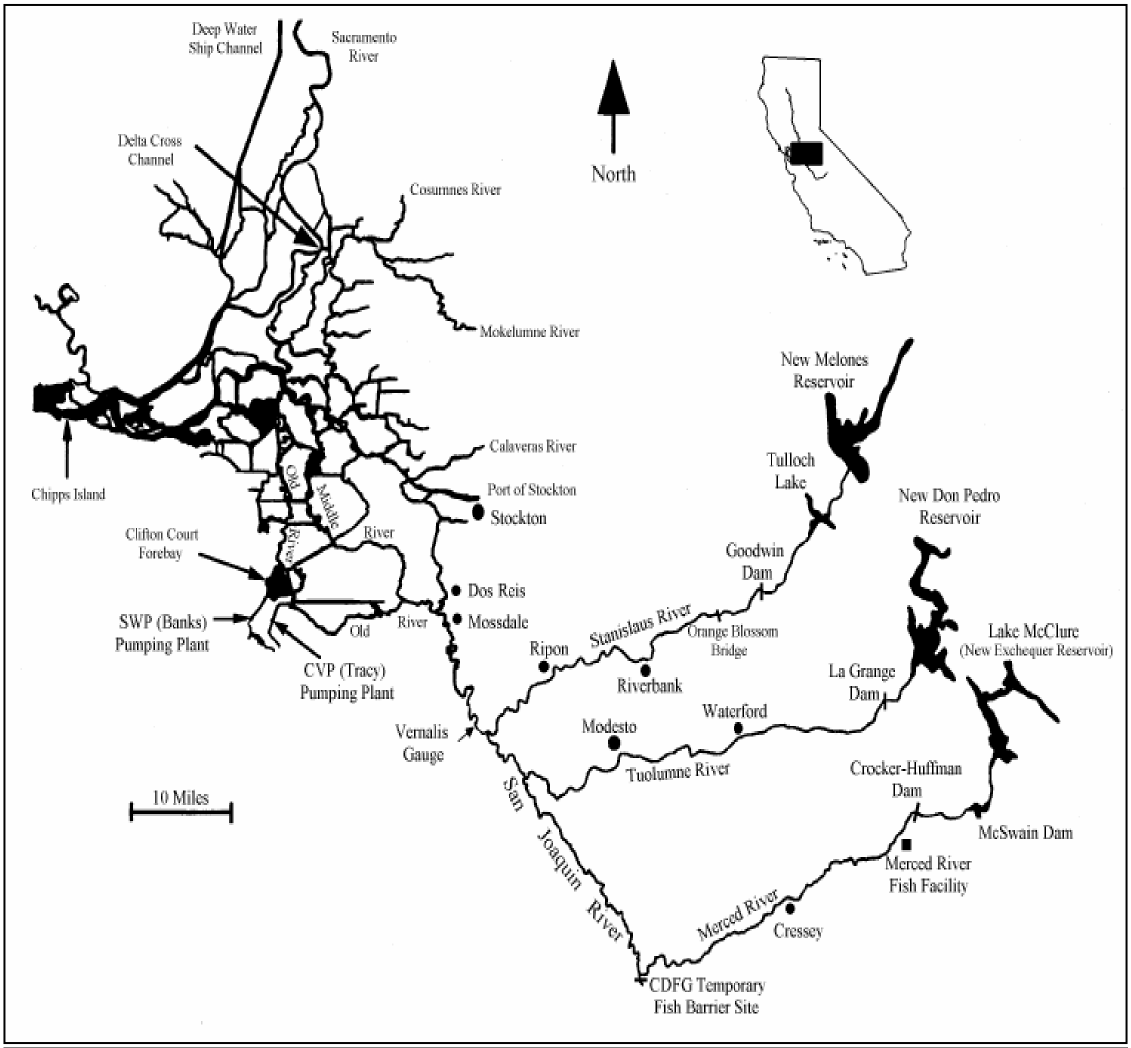
Lower San Joaquin River Basin Map[3]



[3] Map obtained from the U.S. Fish and Wildlife Service.

Executive Summary

In early 2005 it became necessary for the Department of Fish and Game (Department), the Trustee Agency for the fall-run Chinook salmon populations in the San Joaquin River (SJR), to provide comments to the State Water Resources Control Board (SWRCB) regarding the adequacy of the Board's Spring SJR at Vernalis flow objectives as identified in the SWRCB's 1995 San Francisco Bay/Sacramento-San Joaquin Delta Estuary Water Quality Control Plan (1995 WQCP).

In responding to the SWRCB's request for comments on the 1995 WQCP, the Department evaluated the 1995 WQCP by asking four key questions: 1) What is the current status of the SJR fall-run Chinook salmon population?; 2) What level of protection is being afforded salmon smolts out-migrating from the SJR into the South Delta?; 3) What is the status of the Vernalis Adaptive Management Plan (VAMP) experiment?; and 4) What influence does spring flow have on fall-run Chinook salmon production in the SJR?

In March 2005 the Department provided comments to the SWRCB in essence stating the 1995 WQCP SJR spring Vernalis flow objectives were not adequate for the long-term protection of fall-run Chinook salmon beneficial uses in the SJR because: 1) the SJR salmon population trend continues to be below the 1967-1991 historic average upon which the narrative Doubling Goal was established; 2) salmon smolts are not afforded the level of protection as envisioned by the 1995 WQCP; 3) the VAMP experiment is not working because it has not been implemented as designed; and 4) spring outflow is the primary factor controlling fall-run Chinook salmon populations in the SJR. In summary, the reason for the 1995 WQCP Vernalis flow objective inadequacy is in large part due to: 1) the diminished magnitude of the Vernalis flow objective; 2) the narrowness of the pulse flow protection window; 3) the infrequent occurrence of elevated flow objective levels; and 4) the frequent occurrence of reduced flow objective levels. As a result of these concerns, the Department asked the SWRCB to conduct a peer review process of VAMP. The SWRCB declined the Department's recommendation and instead challenged the Department to submit to the SWRCB its Vernalis flow recommendations.

The Department evaluated various parameters that have been identified as influencing abundance of escapement of fall-run Chinook salmon into the SJR, such as ocean harvest, Delta exports and survival, abundance of spawners, and spring flow magnitude, duration and frequency. The Department found that the non-flow parameters have little, or no, relationship to fall-run Chinook salmon population abundance in the SJR and that spring flow magnitude, duration, and frequency all had significant influence upon SJR fall-run Chinook salmon abundance in the SJR. The Department used the significant relationship between Vernalis spring flow volume, duration, frequency, and SJR fall-run Chinook salmon abundance to construct a simple regression-based spreadsheet SJR fall-run Chinook salmon population abundance prediction model. The Department then used this model to determine the Vernalis spring flow objectives that could: 1) accomplish the 1995 WQCP Narrative Doubling Goal for fall-run Chinook salmon in the SJR; 2) improve the escaping salmon replacement ratio; and 3) accomplish objectives 1) and 2) at the lowest water demand.

In June 2005, the Department submitted to the SWRCB a letter detailing the Department's Vernalis San Joaquin River fall-run Chinook Salmon Population Model (Model) and its Vernalis flow objective recommendations. In this letter the Department recommended, with the caveat that peer review should occur prior to implementation, that Vernalis flow levels should be tied to SJR water year types, and include the following Vernalis flow magnitude and durations: 1) Wet = 20,000 cfs and 90 day window; 2) Above Normal = 15,000 cfs and 75 day window; 3) Below Normal = 10,000 cfs and 60 day window; 4) Dry = 7,000 and 45 day window; and 5) Critical = 5,000 and 30 day window. The Model suggests that these Vernalis flow objectives would accomplish the Narrative Doubling Goal, improve the fall-run Chinook salmon replacement ratio, and would, as compared to other possible flow objective windows that could accomplish attainment of the Narrative Doubling Goal, result in the lowest water demand. Implementation of any flow recommendations should be accompanied by comprehensive monitoring to ascertain the reliability of the flow-related production increases suggested by this Model.

Recognizing that water in the SJR is a precious commodity and that artificial propagation of fall-run Chinook salmon may be an effective management tool, if operated under narrow guidelines to reduce genetic and large scale ecological level impacts, the Department has added to the Model a feature that allows for hatchery production of fall-run Chinook salmon to augment wild production in the SJR. Model scenarios using hatchery production suggest that the Narrative Doubling Goal and enhanced replacement ratio can occur at substantially less water cost than that indicated for scenarios that did not have hatchery augmentation. Before additional hatcheries are actually constructed and operable, it would be prudent to 1) develop hatchery management plans to avoid genetic (i.e. phenotypic) degradation of SJR fall-run Chinook salmon and 2) prove in advance of, or concurrent with, hatchery development that hatchery production is greater than wild production.

This report provides a description of the process the Department used to develop, and apply, its Model in the formulation of spring Vernalis flow objectives that were submitted to the SWRCB. Upon completion of this report, the Department will seek formal peer review of its Model and results.

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Introduction

In early 2005 the California State Water Resources Control Board (SWRCB) held public workshops as part of its Triennial Review process, to evaluate the effectiveness of water quality objectives contained in the 1995 San Francisco Bay/Sacramento-San Joaquin Delta Estuary Water Quality Control Plan (1995 WQCP). The SWRCB solicited comments to amend several 1995 Plan areas including: 1) Delta Outflow Objectives; 2) River Flow Objectives: San Joaquin River at Airport Way Bridge, Vernalis: February - April 14 and May 16 - June; 3) Export Limit Objectives; 4) San Joaquin River at Airport Way Bridge, Vernalis: 31 Day Pulse Flow Objectives for April 15-May 15; and 5) Narrative Salmon Protection Objective. This report focuses on spring flow at Vernalis and its importance to fall-run Chinook salmon production in the San Joaquin River.

The SWRCB's Triennial Review of the 1995 WQCP created the need for the Department to evaluate Vernalis Adaptive Management Plan's (VAMP) effectiveness in assuring adequate protection for salmon beneficial uses in the SJR. In responding to the SWRCB's request for comments on the 1995 WQCP, the Department evaluated the 1995 WQCP by asking four key questions: 1) What is the current status of the SJR fall-run Chinook salmon population?; 2) What level of protection is being afforded salmon smolts out-migrating from the SJR into the South Delta?; 3) What is the status of the VAMP experiment?; and 4) What influence does spring flow have upon fall-run Chinook salmon production in the SJR?

Upon reviewing relevant information to answer these questions, the Department concluded, and presented information to the SWRCB, that the current Vernalis flow objectives contained within the 1995 Plan are inadequate to provide long-term salmon beneficial use protection in the San Joaquin River basin (CDFG March 2005). In response to Question #1 (e.g., salmon population status), SJR fall-run Chinook salmon escapement population continues to be well below the 1967-1991 historic average upon which the narrative Doubling Goal was established. Figure 1 shows the 1967 to 1991 SJR escapement average is 18,211,[4] and the 1992 to 2004 SJR escapement average is 14,190. These escapement trends demonstrate that the SJR salmon escapement population has not made substantive improvement towards accomplishment of the 1995 WQCP Narrative Doubling Goal of 36,000 escaping salmon into the SJR, rather the escapement trend is declining. The declining trend continues the 1995 WQCP, VAMP, and millions of dollars of physical habitat restoration in the SJR east-side tributaries not withstanding[5]. In response to Question #2 (e.g., window of protection for smolt out-migration), overlaying a typical VAMP 31 day window of protection over a composite juvenile salmon out-migration pattern for the years 1988 through 2004 (Figure 2[6]) reveals that approximately 50% of juvenile salmon are receiving protection under

[4] Escapement data source is CDFG's Grand Tab (e.g. version June 2005).
[5] The SJR 2005 annual escapement estimate may not exceed 5,000 which continues the declining trend.
[6] Figure 2 is based upon an updated Mossdale Smolt outmigration estimate by Ken Johnson (2005) and includes all years from 1988 through 2005.

VAMP, rather then the 75% that was envisioned when the 1995 WQCP, and the SJRA/VAMP[7], were promulgated and implemented.

In response to Question #3 (e.g., status of VAMP experiment), the VAMP experiment is near the half-way point in terms of completion (e.g., 5 of 12 years completed[8]). At this approximate half-way point in VAMP, flow studies have occurred in the following Vernalis flow objective levels: 3200 cfs (3 tests), 4450 (1 test); 5700 (0 tests); and 7000 (0 tests). One non-VAMP flow level study has occurred at 6100 cfs and is considered an "official" VAMP study test. The VAMP study, as identified in Appendix B of the SJRA, stipulated that VAMP studies were to occur at the extreme Vernalis Spring flow objective levels first to remove, to the extent possible, statistical uncertainty. However, to date, three VAMP studies have occurred at the bottom end of the flow range (e.g., 3200 cfs) while no studies have occurred at the upper flow range level (e.g., 7000). Lack of tests in the upper flow range levels has resulted in continued statistical uncertainty. The primary purpose of the VAMP study is to remove uncertainty in the relationship, at mid-level flow ranges, between smolt survival and Delta inflow and Delta export. With only six years now remaining in VAMP, special attention must be given to evaluating smolt survival, in combination with Delta Export, at the upper flow range level.

In response to Question #4 (e.g., Delta inflow and salmon production), the Department concluded that SJR adult salmon production[9] as a function of daily average flow at Vernalis for the March 15th through June 15th time frame (Figure 3) suggests that salmon production is strongly correlated (e.g., directly connected) with spring flow level at Vernalis[10].

The Department also asserted that the principle determinant of salmon production, and therefore the focus of salmon management, in the SJR is the smolt rather than fry stage because: 1) Fry contribution to escapement is unknown; 2) Even though fry migrate in large numbers in wet years, and wet are years linked to tremendous adult escapements,

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[7] The SJRA is a negotiated settlement agreement between SJR water suppliers, water purveyors, and both State and Federal Fishery Agencies that calls for specific spring South Delta (e.g. SJR at Vernalis) river flows and Delta export pumping rates. The San Joaquin River Group Authority provides the flows necessary to attain the Vernalis flow objectives. State and Federal agencies ensure that Delta exports rates are met. The Vernalis Adaptive Management Plan (e.g. VAMP) is a scientific study that evaluates the effects of Delta inflow, and outflow, upon fall-run Chinook salmon smolt survival.

[8] At the time the SWRCB conducted its 1995 WQCP Workshops in 2005 five VAMP studies had been completed. At the time of this report six VAMP studies have now been completed and this past spring's study occurred out-side the VAMP flow evaluation level (e.g., flows at Vernalis exceeded 7,000 cfs).

[9] The term "adult salmon" used here includes both grilse (age 2) and adult (age 3) salmon.

[10] SJR salmon cohort data was supplied by Dr. Carl Mesick (Carl Mesick Consultants). The "ratio method" Dr. Mesick used to reconstruct brood year production cohorts is provided in the U.S. Fish and Wildlife Service Report entitled "Relationships Between Fall-Run Chinook Salmon Recruitment to the San Joaquin River tributaries and Streamflow, Delta Exports, the Head of the Old River Barrier, and Tributary Restoration Projects From 1972 to 2002." This report is a provincial draft and therefore not citable. However, Dr. Mesick has given his permission to cite it here as this report is part of a Public Records Act Request served upon the Department by the San Joaquin River Group.

wet years also produce tremendous smolt abundance; 3) Low dissolved oxygen is problematic in the SJR at the Stockton Deep Water Ship Channel (SDWSH) in some years during Jan/Feb time frame when fry out-migrate reducing the likelihood that fry contribute substantially to escapement; 4) smolts from all years return as in-river escaping adults[11]; and 5) there is a strong correlation between smolt production and adult cohort production[12] (Figure 3). Regarding management actions for fry, the Department stated to the SWRCB (CDFG 2005a) that it would support VAMP-like experiments to provide for the protection of fry, in combination with ascertaining fry contribution to escapement, if flow (e.g., Vernalis Flow Objectives) for fry protection was provided in addition to, rather than at the expense of, WQCP objectives established for smolt beneficial use protection.

Additional published information reviewed by the Department since commenting to the SWRCB in March 2005 suggests that juvenile salmon from the Central Valley may derive less benefit from estuarine residence than do more northerly populations (e.g., reference to Columbia and Klamath River Estuaries) (MacFarlane et. al 2002). The authors determined that juvenile salmon in the San Francisco Estuary grew little while in the estuary but gained weight rapidly in the ocean. These findings suggest that the Delta may not be a productive rearing ground for juvenile salmon and that getting them through the Delta and into the ocean may be the more prudent (e.g. beneficial) management action. This could require, to the extent possible, cessation of late winter/early spring "freshets" in east-side SJR salmon producing tributaries to prevent fry emigration and foster in-tributary fry to smolt transformation coupled with management actions (e.g. such as elevated spring flow) that foster shorter migration time periods into, and thru, the Delta.

The Department also submitted information to the SWRCB that elevated water temperature, as can occur in late spring during relatively low Vernalis flow levels, is of concern to the Department given the linkage between elevated water temperature and potential juvenile salmon mortality. Low spring time Vernalis flow levels are more susceptible to reaching water temperature ranges lethal to juvenile salmon than higher Vernalis flow levels (Figures 4 and 5). Elevated water temperature can result in substantial smolt mortality (Figure 6), as evidenced by the relationship between mean weekly water temperature and weekly salmon smolt mortality rate (Deas 2004)[13]. Spring flows in the three principal east-side tributaries (e.g., Stanislaus, Tuolumne, and

[11] Based on recovery of adult salmon that were coded-wire-tagged as smolts in the SJR.
[12] There are two metrics used to measure adult abundance, one is escapement the other is cohort. Escapement is the number of salmon returning to a river to spawn in one year. It is a single "slice-in-time" measure of adult production that occurred over five successive brood production years and is comprised of salmon aged from one to five years. Cohort is the number of salmon that return to spawn that originated from a single brood production year. Cohort is also comprised of salmon aged from one to five years, but differs from escapement in that all of the salmon are produced in a single year whereas escapement includes salmon produced over multiple years.
[13] The data used to develop the relationship between mean weekly water temperature and weekly mortality rate for Chinook salmon smolts originated in "Baker, P.F., T.P. Speed, and F.K. Ligon. 1995. Estimating the influence of temperature on the survival of Chinook salmon smolts migrating through the Sacramento-San Joaquin River Delta of California. Can. J. Fish. Aquat. Sci. 52:855-863."

Merced Rivers) are directly associated (e.g., strongly correlated) with spring flow levels at Vernalis. Figure 7 reveals that combined spring flows in the east-side tributaries are strongly correlated with Vernalis flow levels (r-squared value of 0.97). The strong regression correlation relationship between spring flow at Vernalis as a function of SJR Water Year Type Index[14] as depicted in Figure 8 (r-squared value of 0.89) suggests that the SJR is a system that is operated on a consistent, repetitive, and uniform pattern. Figure 9 shows the relationship between spring flow at Vernalis as a function of SJR Water Year Type Index for pre-VAMP (e.g. 1967 to 1999) and post-VAMP (e.g. 2000 to 2004) time periods. It is presently unknown if there is a statistical difference between the two time period regression relationships. There is also a strong correlation relationship between individual SJR east-side tributary spring flow magnitude and SJR Water Year Type Index as depicted in Figures 10 (e.g. Stanislaus River), 11 (e.g. Tuolumne River), and 12 (e.g. Merced River).

Water temperature in the east-side tributaries during the spring is also of concern to the Department. Water temperatures in the Stanislaus (Figure 13), Tuolumne (Figure 14), and Merced rivers (Figure 15) during the late spring time period, depending upon flow and ambient air temperatures, can change 15 degrees from the upper spawning habitat reaches to their confluence with the SJR. From these graphs it is evident that higher flow levels can substantially reduce the amount of thermal warming, as water moves downstream, as compared to lower flow levels. Low flow levels in the east-side tributaries have the potential to contribute to substantial (e.g., 50%) water temperature related mortality when overlaying weekly temperature mortality (Figure 6) upon east-side tributary water temperature (Figures 13 thru 15)[15]. Juvenile smolt survival versus water temperature in the Tuolumne River (Figure 16), per salmon smolt survival versus flow and water temperature studies, also suggest that as water temperature warms smolt

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[14] Per the California Department of Water Resources' California Data Exchange Center (CDEC 2005) SJR Water Year Type refers to the official water category designation used to differentiate wetter and drier water years based upon San Joaquin River Runoff and is the sum of Stanislaus River inflow to New Melones Lake, Tuolumne River inflow to New Don Pedro Reservoir, Merced River inflow to Lake McClure, and San Joaquin River inflow to Millerton Lake (in maf). The SJR Water Year Type formula is:
San Joaquin Valley Water Year Index = 0.6 * Current Apr-Jul Runoff Forecast (in maf) + 0.2 * Current Oct-Mar Runoff in (maf) + 0.2 * Previous Water Year's Index (Note: if the Previous Water Year's Index exceeds 4.5, then 4.5 is used). This index, originally specified in the 1995 SWRCB Water Quality Control Plan, is used to determine the San Joaquin Valley water year type as implemented in SWRCB D-1641. Year types are set by first of month forecasts beginning in February. Final determination for San Joaquin River flow objectives is based on the May 1 75% exceedence forecast.
San Joaquin Valley Water Year Hydrologic Classification:

Year Type:	Water Year Index:
Wet	Equal to or greater than 3.8
Above Normal	Greater than 3.1, and less than 3.8
Below Normal	Greater than 2.5, and equal to or less than 3.1
Dry	Greater than 2.1, and equal to or less than 2.5
Critical	Equal to or less than 2.1

[15] The overall mortality that would result attributable to warm water temperatures would depend upon the magnitude, and duration, of elevated water temperature and the fraction of total out-migrating juvenile salmon exposed to the elevated water temperatures.

survival drops substantially (e.g. 60-80% survival at 52°F compared to 30% survival at 67°F).

The Department suggested to the SWRCB that it was timely, given the approximate mid-point VAMP time frame, to have the SWRCB convene a peer review process to assess the adequacy of VAMP to accomplish its intended objectives which are: 1) progress towards achievement of the Narrative Doubling Goal; 2) define cumulatively or separately how flow, exports, and/or barriers affect salmon survival; and 3) provide an equivalent level of protection to the 1995 WQCP. The SWRCB advised the Department that is was not interested in convening a peer review process and wanted the Department to provide them with its Vernalis flow objective recommendation.

In response to this SWRCB request, the Department developed a simple spreadsheet flow-based SJR Fall-run Chinook Salmon Population Prediction Model (Model). The Department submitted its preliminary Vernalis flow objective recommendations to the SWRCB in June 2005 (CDFG June 2005). This paper describes the process the Department used in developing and applying its model, and the refinements made to the Model since June 2005. The model described herein differs slightly from the one described in CDFG June 2005. The current version of the Department's Model: 1) uses data sets that were derived entirely from SJR salmon monitoring studies; 2) limits flow dependent predictions to the range contained within data sets used to develop the Model[16]; 3) uses salmon smolt out-migration patterns that are water year type specific; 4) allows for use of Head of Old River Barrier (HORB) or non-HORB smolt survival versus flow relationships; and 5) allows confidence intervals (95%) to be calculated. Model refinements <u>did not</u> produce model results that warranted changing the Department's preliminary Vernalis Flow Objective recommendation to the SWRCB in June 2005.

<u>Methods</u>

The Department evaluated several variables that have been hypothesized as being "cause and effect" related to production of fall-run Chinook salmon in the SJR. These variables include: 1) Delta Exports; 2) Ocean Harvest; 3) Adult spawner density; and 4) Spring Flow. The time period for fall-run Chinook escapement tracking (e.g., Model simulation) is from 1967 through 2000. This time period was chosen because it includes the 1967-1991 time period used to develop the Narrative Doubling Goal Objective in the 1995 WQCP and includes the most recent years for which SJR escapements can be reconstructed[17].

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[16] The Model predicts outside the regression relationship data set for escapement and cohort variables (e.g. when escapement estimates are above 39,447, when Chipps smolt estimates are above 1,058,351, and when SJR cohort estimates are above 48,491). Flow dependent estimates are within the maximum flow data set values used for Mossdale smolt abundance, and Delta survival, predictions.

[17] SJR salmon escapements are typically comprised of individuals from five reproductive year classes. Technically speaking the latest brood year for which a "full" escapement can be reconstructed is 1999 as five year old salmon returning to spawn that originated in Brood Year (BY) 1999 (e.g., egg deposition year) would return to spawn in 2004 (last year's escapement). However since annual escapements have a low percentage of five year old salmon reconstruction through BY 2000 has been included.

Delta Exports

It has long been surmised, due to salvage of many juvenile salmon at both the State and Federal Delta export facilities in the spring months, that entrainment of juvenile salmon at the export facilities in the spring months has impacted fall-run Chinook salmon populations in the SJR. A statistically significant regression correlation relationship exists between the ratio of Delta exports and Delta inflow, from the SJR in April-June, and in-river escapement of fall-run salmon two and one-half years later (Figure 17). If the measurement metric of production cohort is used, instead of escapement 2.5 years later, the curvilinear regression correlation relationship improves (r-square value rises from 0.44 to 0.58) (Figure 18). This seems to suggest that both flow and exports are influencing salmon production in the SJR basin. However, in every instance where salmon production was high, Vernalis flows are in excess of 10,000 cfs. Conversely when salmon production was low, Vernalis flow levels are less than 2,000 cfs (Figure 18). The question becomes is it the flow, or the exports?

In an attempt to answer this question, the Department took a closer look at smolt survival data that has been collected in recent years (data from P. Brandes USFWS). Smolt survival data collected during VAMP shows that juvenile survival increases as exports increase (Figure 19). In addition smolt survival as a function of the export to Vernalis flow ratio[18] has a low correlation (Figure 20)[19], indicating that Delta export level, relative to Delta inflow level, does not influence juvenile salmon survival on a regular, normal, or repetitive pattern. When exports are combined with Vernalis flow in a multiple regression against juvenile survival (both with the Head of Old River Barrier in or out), a strong positive regression occurs (as both exports and Vernalis flow increase, juvenile salmon survival increases (Figures 21 and 22)). For both cases, with either the HORB in or out, export level has a slightly stronger positive influence upon survival than does inflow level. What is surprising about this occurrence is not that export level influences survival, but that there is a positive, rather than a negative, response in juvenile survival as export level increases. It is noted that due to VAMP, when exports are up, Vernalis flows are increased with export level tied to Vernalis Flow level. This is a noteworthy Delta system operational change, as prior to VAMP there was no correlation between South Delta spring inflow level (e.g. Vernalis flow) and spring Delta export level (unpublished data). Here again, the variable that seems to be controlling salmon production (e.g. survival) is spring Delta inflow not spring Delta export.

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[18] Defined as Delta export level divided by Vernalis flow level.

[19] The low correlation depicted in Figure 20 should not be confused with higher correlations depicted in Figures 17 and 18, as Figures 17 and 18 use adult salmon as the evaluation metric while Figure 20 uses juvenile salmon as the evaluation metric. It is unknown why Delta export to Delta inflow ratio has an apparently different influence upon salmon production when viewed from a juvenile salmon perspective as compared to an adult salmon perspective. The juvenile salmon relationship includes a smaller data set, and covers a narrower portion of the overall Delta export to Delta inflow ratio range, than does the adult salmon relationship. Perhaps the fact the Delta flow level alone has a positive correlation influence upon both juvenile and adult production indicates that flow level is the controlling influence upon SJR salmon production.

When Delta exports are subtracted from Vernalis flow levels (Figure 23) and escapement is regressed against this difference, a statistically significant regression correlation results. There is no correlation between exports and adult salmon escapement in the Tuolumne River two and one-half years later (Figure 24). When spring Vernalis flow and spring Delta exports are regressed against salmon escapement two and one-half years later, no improvement in the flow to salmon escapement correlation occurs (VAMP 2005), suggesting that spring flow level, not exports, is the variable limiting salmon production in the South Delta.

To summarize the relationship between exports, flow, and SJR salmon production the primary relationship suggesting that exports influence SJR salmon production is that when the ratio of exports to Vernalis flow decreases both escapement and cohort production increases. The relationships that suggest that flow, not export, is the primary factor influencing SJR salmon production are: 1) when the ratio of spring exports to spring Vernalis flow decreases, Vernalis flow greatly increases and SJR salmon production greatly increases; 2) when the ratio of spring exports to spring Vernalis flow increases, Vernalis flow greatly decreases and SJR salmon production substantially decreases; 3) juvenile salmon survival increases when spring Vernalis flow increases; 4) spring export to spring Vernalis flow ratio has little influence upon juvenile salmon survival; and 5) as the difference between spring Vernalis flow level and spring export flow level increases, escapement increases.

In conclusion, while the influence of Delta export upon SJR salmon production is not totally clear, overall it appears that Delta exports are not having the negative influence upon SJR salmon production they were once thought to have. Rather it appears that Delta inflow (e.g. Vernalis flow level) is the variable influencing SJR salmon production, and that increasing flow level into the Delta during the spring months results in substantially increased salmon production..

<u>Ocean Harvest</u>

It has also long been postulated that ocean harvest is a controlling influence upon long-term in-river salmon escapement population trends in the SJR. However, comparing the Central Valley Harvest[20] Index to Sacramento and San Joaquin River salmon escapements (Figures 25) suggests that ocean harvest is not a variable influencing the long-term trend in SJR salmon escapement. Unlike in the Sacramento River basin, no noticeable increase in SJR salmon escapement occurred when substantial changes in ocean sport and commercial fish regulations restricted ocean harvest in recent years. Additionally, regressing the Central Valley Harvest Index against annual SJR escapement produces a weak, but statistically significant, regression correlation (Figure 26). The relationships depicted in Figure 25 and 26 suggest that factors other than ocean harvest, such as in-Delta or in-river conditions, are controlling the long-term SJR salmon escapement trend. With Delta condition influence upon long term SJR escapement trend being determined by Delta inflow, which in turn is largely controlled

[20] The Central Value Harvest Index is the ratio of Central Valley produced salmon harvested in ocean sport and commercial salmon fisheries to Central Valley in-river salmon escapement.

by east-side SJR tributary flow[21], the focus shifts to in-river, specifically in east-side SJR tributary, conditions.

In-river Adult Salmon Density

It has long been surmised that elevated abundance of spawners in the tributaries results in density dependent mortality. Figure 27 shows some potential types of spawner recruit in response to increased spawner abundance. A Ricker type density dependent mortality relationship has been assumed to govern SJR salmon populations. The assumption is that when female salmon abundance increases to a certain level, production begins to decline because density dependent mortality occurs due to spawning superimposition (e.g., one female salmon digging up the eggs previously deposited by another female salmon). Upon closer evaluation of spawner abundance and both subsequent juvenile and adult salmon abundance data, a different picture emerges. Irrigation district personnel have conducted seining surveys for salmon fry for approximately 20 years in the Tuolumne River. Recently, a report summarizing the results of this data collection was prepared and submitted to the Federal Energy Regulatory Commission (TID/MID 2005). The fry seining surveys revealed that fry density increased with increasing spawner abundance rather than decreasing which would have been expected if spawner abundance was at the level where density dependent mortality governs salmon abundance in the Tuolumne River (Figure 28). Additionally, when spawner abundance is regressed with average spring Tuolumne River flow (e.g., as measured at Modesto) against adult salmon cohort production, a strong regression correlation occurs (Table 1). This same strong correlation relationship between salmon abundance and spring outflow magnitude also occurs when SJR female abundance and Vernalis flow magnitude is regressed against subsequent salmon cohort production (Table 2). Both the increased fry density with increased spawner density, and increased cohort abundance with increased spawner abundance are contrary with the density dependent hypothesis[22]. Habitat for spawning does not appear to be limiting production at the spawner abundance levels observed in recent decades. That spring flow, when combined with fall escapement abundance, results in a strong regression correlation with subsequent adult returns suggests that spring outflow from the tributaries is the factor controlling salmon abundance in the east-side salmon producing tributaries.

Spring Flow

Spring flow has long been hypothesized to be the primary factor controlling salmon production in the SJR basin. Regression correlations between spring tributary flow and east-side tributary salmon escapements two and one-half years later have been used as a foundation to support this hypothesis (Loudermilk 1997). The use of multi-age spawner escapement data has confounded regression correlations. Recently, both Dr. Mesick, and the Tuolumne River irrigation districts have produced production (e.g., brood year)

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[21] That SJR flow at Vernalis is largely controlled by SJR east-side tributary flow is documented later in this report and justified by regression relationships depicted in Figures 43 thru 46.

[22] It is currently unknown what escapement level, if any, would result in density dependent mortality.

cohorts for the Tuolumne River[23]. When previous year Tuolumne River fall escapement and current year Tuolumne River spring outflow are regressed against either Dr. Mesick's cohort or the Tuolumne River Irrigation District cohort, a strong statistically significant correlation results (r-square of 0.74 or greater)[24]. Combining adult production cohorts for the SJR east-side tributaries and regressing this data against average April and May spring flow at Vernalis resulted in a strong statistically significant correlation (Figure 3). When Vernalis spring flow magnitude and duration ratio is regressed against smolt production at Mossdale, a statistically significant relationship results (Figure 29). This suggests that the combination of spring Vernalis flow magnitude, and duration, strongly influence salmon production in the SJR. If the length of the smolt protection window (e.g., number of days) is regressed with average flow against smolt out-migration abundance, a strong correlation results (Table 3). As reported above, the SJR flow at Vernalis is strongly correlated with SJR Water Year Type Index, and SJR salmon cohort abundance is strongly correlated with spring Vernalis flow magnitude and duration. Thus it is not a surprise that there is a strong correlation between SJR cohort abundance and SJR Water Year Type Index (Figure 30). These findings support the statements regarding the linkage between spring Vernalis flow magnitude, duration, and frequency and SJR salmon escapement abundance, in the Department's comments to the SWRCB in March 2005.

These findings that spring Vernalis flow magnitude, duration, and frequency are strongly associated with SJR salmon abundance, in combination with the lack of substantial cause and effect relationships between either Delta exports, ocean harvest, and/or density dependence related to spawner abundance, indicate that is it appropriate to develop a conceptual SJR salmon population prediction model that includes spring Vernalis flow magnitude, duration, and frequency, and excludes ocean harvest, Delta exports, and in-river spawner abundance (e.g., referencing density dependent mortality).

Model Development

<u>Conceptual Model</u>

The Model predicts salmon escapement abundance by: 1) predicting how many salmon smolts will arrive at Mossdale as a function of prior year escapement and current year Vernalis spring outflow (e.g., daily average flow from March 15th thru June 15th); 2) apportioning seasonal smolt abundance at Mossdale on a daily percent of total basis using water year type index specific smolt out-migration patterns; 3) predicting how many salmon smolts will survive from Mossdale to Chipps Island using either a HORB-in or a HORB-out smolt survival relationship; 4) predicting how many adult salmon will return to the SJR from the number of salmon smolts arriving at Chipps Island; and 5) predicting how many salmon return to spawn as one, two, three, four, and five year old

[23] Dr. Mesick also produced production brood year cohorts for the Stanislaus and Merced Rivers.

[24] Regression correlations between spawner abundance, spring outflow, and cohort abundance for the Tuolumne River using cohorts derived by the Department (e.g. via Dr. Mesick's ratio method) or by the Turlock and Modesto Irrigation Districts are documented in the Department's Letter to the Federal Energy Regulatory Commission dated 11-22-05.

salmon. Figure 31 depicts the conceptual model showing the process used in the model to numerically track salmon life history as a function of Vernalis flow.

Mossdale Smolt Production

The first estimation parameter the model predicts is the total number of smolts that will arrive at Mossdale as a function of number of SJR salmon escaping into east-side SJR tributaries in the previous fall-run escapement coupled with current year spring Vernalis Spring out-flow. Table 4 shows the data set used to develop the multi-regression linear relationship between combined SJR east-side tributary escapement, Vernalis flow, and smolt abundance at Mossdale. The year 1989 was not used due to being an out-lier value whose Mossdale smolt abundance estimate was not consistent with other years. Why the 1989 smolt abundance estimate is high relative to other years is currently unknown. Removing the 1989 smolt abundance estimate provides a multi-linear regression correlation relationship with an r-squared value of 0.89 ($p<0.001$). This strong correlation suggests that a strong relationship between the combination of fall escapement and spring outflow, and smolt abundance exists. It should be noted that the relationship between smolt abundance at Mossdale and Vernalis flow alone, for the years 1988 through 2004 (with 1989 removed) produces a linear relationship with an r-squared value of 0.88 which is significant at the .001 level (Figure 32). Between the two variables (e.g. previous fall escapement and current spring outflow), spring outflow has greater than twice the influence upon smolt abundance prediction than does escapement abundance. Spring Vernalis flow has a powerful influence upon smolt production in the SJR.

SJR Smolt Out-migration

Once the annual total number of smolts estimated to pass Mossdale is calculated, the annual smolt migration is apportioned across a 93 day time period from March 15 through June 15 using the water year type cumulative exceedence smolt out-migration pattern observed historically for each water year type (Figure 33)[25]. Only three cumulative exceedence relationships are used in the model (wet, composite, and dry), as wetter year types (Wet and Above Normal) had similar cumulative exceedences as did the drier year types (Dry and Critical). The composite cumulative exceedence is used for the Below Normal water year type. Wetter water year types have a lower slope than do drier water year types. This suggests that spring flow volume in the east-side tributaries and at Vernalis influences not only how many salmon smolts will emigrate from the SJR but determines the migration pattern as well. In wetter water year types, with higher spring flow levels, more smolts tend to leave the SJR later in the year (e.g., well into June). The number of smolts out-migrating from the SJR in wetter water year types is also higher than in drier water year types. This may be due to higher flow levels providing a bigger buffer against increasing water temperature as air temperature rises than lower flow levels (Figures 13 thru 15). It may also mean that habitat conditions in the east-side tributaries present in elevated flows (e.g. prolonged flood

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[25] The composite exceedence relationship depicted in Figure 33 is slightly different than that depicted in Figure 2. This is due to 1989 and 1995 being removed from the relationship depicted in Figure 33. 1989 was removed for being a data outlier, 1995 was removed because the Mossdale Trawl began late (e.g. as compared to other years).

plain inundation), is an important factor in determining smolt abundance. In drier water year types when lower spring flow levels occur smolt abundance and out-migration time period are curtailed due to lower spring flow magnitude and duration. Water temperatures also reach intolerable levels earlier in the spring due to lower spring flow levels.

Delta Survival

Once the annual smolt abundance is apportioned on a daily basis in each year (e.g., 1967 through 2000), using either a HORB-in or HORB-out, a Delta smolt survival relationship (Figure 34) is applied[26]. At present, the Model does not have the actual dates of HORB-in "hard wired" in its smolt survival calculation sequence (see Table 5 for HORB-in dates between 1967 and 2000). Therefore the historical model run operates all years from 1967 to 2000 without a HORB[27]. The Model allows the user to choose which survival relationship is used (e.g., HORB-in or HORB-out) and what dates within the year the HORB will operate[28]. Once chosen, the HORB-in relationship is applied to all years. The number of smolts arriving at Mossdale, combined with Vernalis flow level, determine the number of smolts reaching Chipps Island each day. The number of smolts reaching Chipps Island on a daily basis is used to estimate the number of smolts surviving migration through the Delta, continuing to the ocean, and returning to the SJR as escaping adults.

Cohort Abundance

Cohort abundance is determined from a regression relationship between the annual calculated number of smolts arriving at Chipps and the estimated production year cohort (data for years 1988 through 2000 with 1989 being removed for reasons described above). A HORB-in relationship was used for the year 2000[29]. Figure 36 shows the regression relationship between smolts at Chipps Island and eventual cohort

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[26] There are several Delta smolt survival relationships in existence. The reader is referred to VAMP annual reports for a full explanation of the various smolt survival relationships. The smolt survival estimates used in the model and referred herein are "absolute survival" survival estimates and are based on marked hatchery smolts released at Durham Ferry and/or Mossdale, and Jersey Point and recovered at Chipps Island. It should be noted that Delta smolt survival can also be measured by recovery of marked fish caught in ocean fisheries. Survival rates estimated from ocean re-captures have substantially greater survival rate percentages than those based upon Delta, or Chipps Island, recoveries (compare Figures 34 and 35). In both cases, a statistically significant relationship between Vernalis flow level and subsequent smolt survival exists (VAMP 2005). Use of ocean fishery recovery-based Delta smolt survival relationship in the Model would decrease the Vernalis spring flow water volume needed to accomplish the Narrative Doubling Goal because at any given flow a higher rate of Delta survival would result in more smolts surviving to Chipps Island and an increase in the estimated number of salmon returning to spawn several years later.

[27] It is not believed that the Model's inability to have a operational HORB for historical base model runs substantially changes the overall results with use of a time period base average escapement as the metric for comparative evaluation of escapement trend between 1967 and 2000, since only a few years had an operable HORB during this time frame (e.g. 1992, 1994, 1996, 1997 and 2000).

[28] This is a new Model feature and may alter slightly Model results from those reported herein.

[29] A full accounting of years, and specific dates within years (Table 5), was not obtained until after the model was developed and applied. Applying HORB-in survival relationship, which has higher smolt survival than HORB-out, for all dates between 1988 and 2000 could change the regression correlation and model projections.

production[30]. The correlation for the relationship between estimated number of smolts surviving to Chipps and subsequent return of adults to in-river escapement is moderate with a statistically significant ($p<0.001$) r-square value of 0.51[31]. With positive regression correlations: 1) between Vernalis spring flow and Mossdale smolt abundance; 2) between Vernalis spring flow and Delta smolt survival; and 3) between Delta smolt survival abundance (e.g. at Chipps) and cohort production; it appeared possible to link SJR salmon escapement production on an inter-annual basis, for the years 1967 though 2000, as a function of spring Vernalis flow magnitude, duration, and frequency once a method for reconstructing escapements, on annual basis, was developed.

Escapement Reconstruction

The advent of marking methods (e.g., coded wire tagging of juvenile salmon) and other aging techniques (e.g., scales/otoliths) has allowed differentiation of age composition in multi-year age class escapements to occur. Once cohort brood year production estimates are calculated, correlation of these estimates with environmental variables, such as flow, can occur. Development of the model described herein has used two methods to estimate escapement age class structure. These methods are: 1) the use of a composite average for each age class of coded wire tag recoveries from Central Valley salmon for the years 1974 through 1994; and 2) the use of a composite average of results from a preliminary reading of scales obtained from SJR escaping salmon for the years 1981 through 2000 (Table 6). A comparison of regression relationships between Vernalis spring flow and cohort production for each of the two cohort reconstruction methods is provided in Figure 37. Both cohort reconstruction methods produced very strong correlations (e.g. R-square correlations greater than 0.90). This indicates that either method could be used to predict SJR cohort production. The model described herein uses the SJR salmon escapement scale reading method as the basis for SJR cohort prediction and escapement reconstruction.

Once the brood year production cohort is predicted, cohort abundance needs to be distributed across several age classes to that escapement estimation can occur. Escapement age composition, comprised of age one though age five year classes, varies annually. The Model's use of averages to calculate each age class means that percent age composition for each cohort does not change from one year to the next. However, the age composition of each annual escapement does[32]. Age composition percentage is

[30] The cohort numbers used in this model do not match those described in Mesick 2005. The reason for this is that data included in an earlier version of Dr. Mesick's work was used to develop the regression relationships described herein. Due to time constraints, updating the regressions and the Model using Dr. Mesick's latest cohort reconstruction values has not yet occurred.

[31] In CDFG's June 2005 Letter to the SWRCB this regression correlation r-square value was identified as 0.61. This was due to the SJR cohort being derived from Central Valley-wide coded wire tag return data. Use of only the SJR origin salmon age data to develop SJR cohorts resulted in a lower correlation value. Figure 37 compares SJR Scale derived age cohorts and Central Valley coded wire tag return derived production cohorts and flow, and shows that with either method there is a strong correlation.

[32] Recent analysis suggests that within-year escapement year class percentages can be estimated using either Dr. Mesick's "ratio" method or by regression (wherein percent female escapement is combined with average spring flow volume magnitude and regressed against two year old salmon abundance, thence two old salmon abundance is regressed against three year old salmon abundance, thence three year old

applied directly to the cohort.   An example of cohort reconstruction is provided in Table 7. It is noted that age composition is applied directly to cohort number, then annual escapement abundance is reconstructed for each year by summing the abundance of the age one thru age five year classes that contribute to it.[33]

Hatchery Augmentation

Hatchery production, as a mitigation tool, to replace wild production is a common management practice in the Pacific Northwest[34]. Due to genetic health concerns, hatchery operating protocols have been developed to reduce catastrophic effects[35]. If additional production were desired through hatchery augmentation, then predicting increased hatchery origin production requires subjecting hatchery origin juvenile salmon to the same flow related environmental variables, such as water temperature exposure, that wild spawned salmon experience. It is currently unknown how hatchery augmentation influences escapement in the SJR, as not all Merced River Hatchery (MRH) production is permanently marked upon release for later recovery and analysis[36]. In recent years, MRH production has comprised between 17% and 41% of annual Merced River escapement (Johnson 2004). It is hypothesized that because hatchery origin juvenile salmon have a higher condition factor (e.g., lipid content) due to hatchery feed, and are larger at time of out-migration than wild juvenile salmon, they may be able to better withstand the rigors of out-migration and smoltification than wild spawned salmon[37]. This hypothesis remains untested.

Nevertheless, hatchery augmentation is included in the Model so the Department can evaluate whether hatchery production can off-set, to some degree, the water demand needed to obtain targeted SJR escapement production goals. The Model estimates

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salmon abundance is regressed against four year old salmon abundance, and four year old salmon abundance is regressed against five year old salmon abundance). Due to time constraints neither of these methods has been incorporated into the Model.

[33] For example the 1972 escapement is comprised of age one fish from 1971, age two fish from 1970, age three fish from 1969, age four fish from 1968, and age five fish from 1967.

[34] Hatchery production, when used as a surrogate, for wild production is a highly contentious issue and is too voluminous to address in sufficient detail here. The author neither advocates for, nor against, use of hatcheries as a management tool in the San Joaquin River basin. Hatchery augmentation is provided herein simply as a planning tool component that can be evaluated, along with spring flow, to help managers understand the dynamics of salmon production in the San Joaquin River. Whether or not hatchery production does in fact replace wild production should be thoroughly evaluated prior to, or concurrent with, hatchery construction, and implementation, within the San Joaquin River.

[35] A recent genetic study of fall-run Chinook salmon in Central California rivers showed that northern (Sacramento) and southern (San Joaquin) fall-run chinook salmon populations are genetically homogeneous (Williamson 2004).

[36] Concurrent permanent marking (e.g. coded-wire-tag or otolith thermal marking), and both release and recovery, of wild and hatchery produced salmon (smolts) would help evaluate whether or not production potential (adult male and female salmon) taken from the wild, and placed into a hatchery, actually results in production of more escaping adults than if the production potential were left in the wild.

[37] One apparent "advantage" hatchery production (smolts) has over wild production is that hatchery production can, to some degree (i.e. thru diet), be timed to accommodate elevated (improved) spring outflow conditions. At present, diet cannot be manipulated to speed up development rates of wild juvenile salmon. It is noted that water temperature affects development rates of both wild and hatchery produced juvenile salmon.

hatchery production augmentation by simulating presence of new hatcheries on the Stanislaus and Tuolumne rivers (e.g., at same level of production of the Department's Merced River Hatchery) and provides for an increase in the production capacity of the MRH (e.g., average annual production increases by one-half). Table 8 provides the estimated number of smolts per female that could be produced if hatcheries were in operated on the Stanislaus and Tuolumne rivers.

The conceptual model for hatchery augmentation includes: 1) estimate the fraction of in-river escaping salmon that would migrate into the hatchery (Figure 38); 2) estimate the female fraction of total hatchery escapement ratio (Figure 39); 3) estimate the number of smolts that would be produced by the number of salmon migrating into the hatchery (Table 8); 4) estimate salmon smolt survival as a function of spring flow in each SJR east-side tributary (Figure 40); 5) estimate hatchery smolt survival through the South Delta (Figure 34); 6) estimate the adult salmon production cohort for each brood year (Figure 36); and 7) add hatchery cohort production to wild cohort production; 8) reconstruct combined wild[38] and hatchery produced SJR salmon escapement; and 9) subtract hatchery escapement from wild escapement for future year cohort production and escapement prediction.

<u>Model Operating Constraints</u>

The parameters under which the Model was operated include: 1) attainment of the 1995 WQCP Narrative Doubling Goal; 2) improving the replacement ratio of three year old escaping salmon[39]; and 3) minimizing water demand.

<u>Model Calibration/Validation</u>

Two approaches for calibration and validation are common in building and testing computer simulation models: 1) Calibrate with a subset of the data and validate with the remaining subset; and 2) use the entire data set and build a model that is based upon the most complete data set possible to capture the fullest range of variability. The second method was employed in Model development and use. The calibration parameters used include: 1) duplicate the historical escapement pattern; 2) duplicate the time period escapement average; 3) duplicate the replacement ratio; 4) remain within the 95% confidence interval coefficient variability for each of the regression equations described herein[40].

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[38] For purposes of this model, existing Merced River Hatchery production is not distinguishable from wild in-river spawned salmon production.

[39] Replacement ratio is one method used as a population health barometer. As used here, replacement ratio is the escapement in any one year divided by the escapement which produced it three years earlier. Calculating replacement ratio in this manner assumes that three year old salmon represent the largest fraction of escaping salmon across all years. With the ability to reconstruct cohorts a potentially more representative barometer of population health trend may be to calculate replacement rate by dividing the cohort by the escapement that produced it and track this over time (e.g., trend). Due to time constraints this has not been done.

[40] It may be possible to take the 34 year model time period and break it into two models that did not have overlapping (e.g., shared) production year cohorts. One model consisting of the years 1967 to 1978 could serve as the calibration model while the second model, consisting of the years 1989 to 2000, could serve as the validation model. How to address the "in between" model years in terms of production would be challenging as "between model year production would influence results for the validation model.

Figure 41 provides a comparison between Model predicted escapement and historical escapement. The aforementioned calibration parameters were accomplished. The Model appears to track the historical escapement trends fairly well. The large discrepancies (e.g., lag time) between predicted and observed SJR salmon escapement population levels at the beginning of the model simulation time period (e.g., 1967 through 1970) is common to population prediction models (e.g., Bill Loudermilk and Noah Hume personal communication).

Confidence intervals (95% level) have been calculated and are presented in Figure 41. At present, the confidence intervals cascade (e.g., are additive) with confidence interval variability additive thru the Model calculation sequence. As currently calculated, no matter how narrow the confidence intervals were, they would cascade across regression calculations. It has been suggested that confidence intervals should not be included as model output due to this aberrant, and potentially mis-interpreted, effect (Dan Odenweller personal communication).

<u>Model Assumptions</u>

The Model assumes that: 1) Spring time flow at Vernalis, which is primarily contributed to by spring time flow from the east-side salmon producing tributaries, is the primary factor influencing salmon production in the San Joaquin River; 2) Zero flow, zero survival is a real data point; 3) Salmon smolts out-migrate in greater abundance and in a different pattern in wetter years as compared to drier water year types; 4) The maximum smolt survival versus Vernalis flow rate which can occur is 95%; 5) The regressions which predict production based upon smaller sized data sets reflect the same regression relationship that would be evident if larger sized data sets were in existence (e.g., regression equations which predict outside the data set(s) used to develop them reflect reality[41]); 6) Adult salmon return rate is constant over time (e.g., does not vary); and 7) Adult age cohort percent composition for each age class is constant over time (e.g., does not vary).

<u>Model Scenarios</u>

The Model is versatile and can be used to predict salmon escapement abundance for a variety of flow scenarios. To limit the total number of scenarios and yet capture the range of operational alternatives, 11 scenario summaries[42] were selected to give managers a sense of the salmon escapement production that could be possible under a broad array of SJR Vernalis Flow Objective alternatives (Table 9). In summary, the scenarios selected fit into one of four categories: 1) Vernalis flow objective varies (2000 cfs to 7000 cfs) by water year type and the time period for applying the objective (i.e. window of protection) remains constant across water year types at either 30, 45, 60, 75,

[41] The author has stated in both the Department Technical Briefing (10-14-05) and California Water and Environmental Modeling Forum Meetings (11-04-05) that no estimates were calculated out-side the existing data set range. The author in making these statements was referencing regressions equations using Vernalis flow.

[42] The actual number of scenarios run is approximately 35, for summary purposes these 35 scenarios are grouped and compared in 11 separate tables.

or 90[43] days (scenarios 1 and 2); 2) Vernalis flow objective remains constant across water year types (5,000, 10,000 or 15,000 cfs) and the window of protection remains constant across water year types at 30, 45, 60, 75, or 90 days (scenarios 3, 4, and 5); 3) Vernalis flow objective is variable across water year types (5,000 cfs Critically Dry years in increments up to either 10,000, 15,000, or 20,000 in Wet years) and the window of protection remains constant across water year types at 30, 45, 60, 75, or 90 days (scenarios 6, 7, and 8); and 4) Vernalis flow objective is variable across water year types (5,000 cfs (Critically Dry years) in increments up to either 10,000, 15,000, or 20,000 (Wet years)) and the window of protection varies in accordance to water year type (30 day window for Critically Dry years, 45 day window for Dry years, 60 day window for Below Normal years; 75 day window for Above Normal years, and 90 day window for Wet years) (scenarios 9 and 10). Use of hatchery augmentation can occur for each of these scenarios, however due to time constraints use of hatchery augmentation was conducted only for one scenario (scenario 11) for which the Vernalis flow objective is variable across water year types (2,000 cfs Critically Dry years in increments up to 12,000 cfs in Wet years) and the same year-type-specific windows of protection as scenario 10).

Model Input

The Model has seven input parameters that are user adjustable. These parameters include: 1) adjustable regression coefficients for Mossdale smolt abundance, Delta survival, and Chipps survival to escapement (i.e. Cohort abundance); 2) salmon cohort age return rate (age composition[44]); 3) HORB-in or HORB-out Delta Survival; 4) set SJR water year type flow levels at Vernalis; 5) choose which water year types, if any, to allow hatchery augmentation to occur; 6) choose which years to allow Vernalis flows to vary[45]; and 7) determine flow window duration[46].

Model Output—Water

The Model has several output parameters which include: 1) Average additional water by water year type[47]; 2) Average spring percent of total water[48]; 3) Average spring percent

[43] The "90" day window referenced herein is actually 93 days counting the dates from March 15 through June 15.

[44] Age composition, in terms of %, to apply to cohorts for purposes of reconstructing annual escapement is adjustable for each age classification. Once a percent is chosen for each age class it remains constant for all model years.

[45] In some water year types, depending upon the flow rate selected, the model selected flow rate can be less than the historical flow rate. Therefore, the user can decide what years they want to allow flow rates to vary.

[46] Flow window duration refers to the duration of days a pulse flow occurs in the SJR at Vernalis. The window is user adjustable for each water year type and can be set to include a maximum of 93 days between March 15 and June 15 annually.

[47] Average additional water refers to the additional amount of water that has been added for each water year type in the model run as compared to the average amount of water, by water year type, that passed Vernalis historically.

[48] Average spring percent total water refers to the amount of spring SJR water passing Vernalis in relation to total October thru July run-off into New Melones, New Don Pedro, New Exchequer, and Friant Reservoirs.

change[49]; 4) Vernalis minimum flow level for each water year type and window of duration for each water year type; and 5) SJR east-side tributary flow summary[50].

Model Output—Salmon
The Model provides several output parameters for salmon including: 1) annual and average annual model estimated escapement; 2) estimated SJR east-side tributary escapement[51]; 3) replacement ratio; and 4) hatchery augmentation.

Model Results

Salmon Production
Results for each Model run are provided in Tables 10 through 20, with an overall summary of results provided in Table 21. In all scenarios, expanding the magnitude of spring outflow resulted in increased salmon production for all water year types. In all scenarios, expanding the window of protection resulted in increased salmon production. The greatest increment in salmon production is associated with increasing the window of protection from 30 days to 60 days. When the window of protection is further increased, in 15 day increments, the incremental increase in modeled salmon production decreases because 1) each 15 days adds a smaller percentage to the window of protection and 2) the 60 day window of protection is roughly centered on the out-migration season and the expanded window is incorporating the tails of the temporal distribution when fewer fish are present (Figure 53).

Results of the model runs indicate that the scenario which provided the greatest salmon production gain at the least water cost (21 escaping salmon per 1,000 additional acre-feet of water), without hatchery augmentation, is Scenario 10 which varied both the minimum flow levels and windows of protection according to water year type. If hatchery augmentation is included, the number of escaping salmon per 1,000 additional acre-feet of water increases from 21 to 80 (i.e. 20,857 additional salmon divided by 256,205 average annual additional acre-feet multiplied by 1,000, equals approximately 80).
Simulating hatchery augmentation at a level comparable to existing MRH levels on the Merced River suggests that substantial decreases in water cost may result without sacrificing progress towards achieving the Narrative Doubling Goal[52]. For scenario 11,

[49] Average spring percent change refers to the relative increase in spring flow at Vernalis as compared to that which occurred with historic Vernalis flow levels.
[50] SJR tributary flow summary includes calculating what additional flow volumes would occur, based on historical patterns, if spring Vernalis flow levels were changed. Figures 43 thru 46 provide the regression correlation between spring Vernalis flow to combined spring SJR east-side tributary flow, and spring east-side tributary flow to spring Stanislaus River, spring Tuolumne River flow, and spring Merced River flow.
[51] Predicted escapement for the 1967 to 2000 time period for the Stanislaus, Tuolumne, and Merced Rivers was determined by regressing the total combined historical SJR escapement against the historical escapement for the Stanislaus, Tuolumne, and Merced Rivers (Figures 47 thru 49). Model predicted, versus historical, escapements for the Stanislaus, Tuolumne, and Merced Rivers is provided in Figures 50 thru 52).
[52] The reader is referred to the report section entitled “Hatchery Augmentation” for caveats associated with use of hatchery production as a management tool and reliance upon hatchery augmentation as a

when simulated hatchery augmentation occurs in all water year types, the ratio of wild to hatchery salmon escapement peaks at a ratio of 4.2:1, declines to a low of 0.7:1 with a geometric mean ratio for all years of 1.3:1.

Replacement Ratio

The replacement ratio is influenced primarily by Vernalis flow magnitude. In scenarios one and two where VAMP flows are modeled, the replacement ratio essentially remains unchanged, even if the smolt window of protection is increased. This suggests that the current Vernalis flows objectives, for both magnitude and duration, are insufficient to accomplish substantive progress towards improving the overall long-term SJR salmon production trend. If Vernalis flow magnitude increases to levels of 10,000 cfs or above, the replacement ratio begins to rise, suggesting that SJR population may experience fewer near extinction population episodes during drier years than was experienced historically. As the smolt protection window duration increases, in combination with Vernalis flow magnitude increases, the replacement ratio increases substantially.

Water

With respect to water, the additional water cost associated with increased salmon production is provided in Tables 10 through 20. Comparison by water year type of Model predicted flow versus historical flow for Model Scenario #10 (e.g., CDFG flow recommendation to SWRCB) for the SJR at Vernalis, Stanislaus River at Ripon, Tuolumne River as Modesto, and Merced River at Stevinson are provided in Figures 54 thru 57). Model results suggest that up to one-third of the basin's total available water on an annual basis may be necessary to accomplish the Narrative Doubling Goal[53]. However, Model results suggest that substantial salmon production increases could be achieved with far less water cost (e.g., through hatchery augmentation[54]). Scenarios which increased Vernalis flow magnitude and the smolt window of protection in progressively wetter water year types (Scenarios 9 and 10) resulted in the greatest salmon production gain at the least additional water cost.

Discussion

SJR fall-run Chinook salmon populations continue to decline, despite substantial changes in ocean harvest. The apparent non-influence of Delta exports upon SJR

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surrogate for wild production. Whether predicted hatchery production would actually occur, at levels indicated by the Model, is unknown. Hatchery production is susceptible to the same environmental stressors (temperature exposure etc.) associated with low spring flow levels in the SJR east-side tributaries, and in the SJR at Vernalis, as wild production. Just as flow magnitude, and window of protection, work together as variables influencing wild salmon production in the SJR, it is possible that some sort of, yet to be defined, dynamic is present between wild and hatchery production. For example, it may be that hatchery production can improve wild production (escaping adults) in drier water year types but not in wetter years.

[53] Assuming the inland, as compared to ocean, recovery based Delta smolt survival versus flow survival trend is accurate. Less water would be required if the ocean recovery based Delta survival trend better describes Delta survival.

[54] Figures 58 thru 61 show the estimated additional water projected to be needed to attain the 1995 WQCP Narrative Doubling Goal in the SJR during the spring at Vernalis and in the SJR east-side tributaries if hatchery augmentation is utilized.

salmon production is perplexing given the entrainment of juvenile salmon that has occurred historically. It appears that mortality, whether it results from ocean harvest, Delta exports, predation, or some other mechanism does not materially influence SJR salmon production on a regular, consistent, repetitive basis as suggested by the low regression correlation between salmon production and these variables.

The variable which appears to have the most influence at present upon SJR salmon production is spring flow in east-side tributaries, and consequent spring Vernalis flow levels. Delta survival calculated using ocean recoveries of marked hatchery smolts is consistently higher than survival from inland recoveries. If the ocean recovery survival trend reflects the true smolt survival versus flow relationship, substantially less water would be required to accomplish the 1995 WQCP Narrative Doubling Goal than is presently suggested by the Model which uses survival rates based on inland (Delta) recoveries.

The relationships between: 1) flow in the tributaries and flow at Vernalis; 2) water temperature, and flow levels at both Vernalis and in east-side tributaries; and 3) the relationship between both adult salmon production and juvenile salmon out-migration survival in SJR salmon producing east-side tributaries as a function of spring flow, suggests that salmon production in the SJR is strongly associated with spring flow conditions (e.g., spring flow magnitude, duration, and frequency) in each east-side SJR tributary. Water temperature trend data suggests that increasing Vernalis flow magnitude and duration would result in decreased water temperature and associated water temperature mortality in east-side tributaries and in the south Delta, given the direct strong correlation between combined east-side tributary flow level and Vernalis flow level.

Overall, the Model suggests that substantial salmon production gains are possible if Vernalis flow objectives were increased and the smolt production window of protection were prolonged. In 2003, accomplishing the 1995 WQCP Narrative Doubling Goal appeared doubtful with flow alone stemming from Judge Candee’s decision in Andersen et. al. vs. State Water Resources Control Board et. el. because no known prediction method was available to quantify flow related salmon production increases over time. This model provides a tool to meet that need. Flow recommendations can now be developed. Of course implementation of any flow recommendations would have to be accompanied by comprehensive monitoring to ascertain the reliability of the flow-related production increases suggested by this Model.

The underlying smolt outmigration patterns used in this Model suggest that Vernalis flow magnitude and duration affect not only smolt abundance at Mossdale, but also the out-migration pattern as well. Wet years result in 1) more smolts out-migrating from the SJR into the south Delta and 2) a longer out-migration time period. The Model suggests that substantial gains in salmon production can be achieved if 1) the window of protection were expanded from 30 days to at least 60 days and 2) the increased window of protection occurred later in the out-migration time period (e.g., into late May and early June).

The Model suggests that hatchery augmentation has the capacity, occurring within well defined hatchery operation protocols designed to avoid ecological level impacts, to diminish the additional flow volume needed to accomplish attainment of the 1995 WQCP Narrative Doubling Goal. Monitoring of hatchery production, through marking and recapture of hatchery production, would be necessary to determine if Model projected production increases are valid. Use of hatchery fish, under a conservation style planning and operation framework wherein hatchery production is used to augment natural production not replace it, is a viable, but untested, management tool currently used in the Merced River. Before additional hatcheries are actually constructed and operable, it would be prudent to 1) develop hatchery management plans to avoid genetic (i.e. phenotypic) degradation of SJR fall-run Chinook salmon and 2) prove in advance of, or concurrent with, hatchery development that hatchery production is greater than wild production (e.g. on at least a smolt to escaping adult basis).

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List of Tables

Table 1. Adult Stock Density and Modesto Spring Flow vs. Tuolumne Cohort Production.

Tuolumne Stock Density, Modesto Flow, and Cohort Production			
Year	# of Escaping Females	Flow At Modesto (Apr&May daily avg)	Production Cohort
1973	1174	411	1225
1974	633	593	572
1975	960	280	1654
1976	867	154	813
1977	279	2380	1529
1978	871	697	2636
1979	603	2601	17624
1980	341	358	2217
1981	6271	7100	19458
1982	4276	9844	44864
1983	3709	786	9395
1984	4654	363	1501
1985	22580	3950	19373
1986	3554	594	1303
1987	4573	257	125
1988	3467	263	70
1989	663	252	88
1990	31	406	545
1991	35	337	410
1992	57	779	765
1993	280	481	1700
1994	257	7513	12326
1995	401	3558	3259
1996	1593	1376	9105
1997	4207	4704	22000
1998	4037	1997	5310
1999	4016	1624	6560
Multiple Regression			
#Females (x1) & Modesto Flow (x2) vs. Cohort (y)			
R-squared Value 0.78 (p<0.001)			
Equation: ((#Females*0.3966)+(Modesto Flow*3.2486)+(-644.004))			
	Lower 95%	Upper 95%	
y-Intercept	-3320.6	2032.592	
X1 Variable	-0.08342	0.876681	
X2 Variable	2.429051	4.068183	

Yellow = Years where # of Females and elevated flow produce increased cohort production.
Blue = Years where # of Females and elevated flow produce decreased cohort production.

Table 2. Adult Stock Density and Vernalis Spring Flow vs. SJR Cohort Production.

SJR Stock Density, Vernalis Flow, and Cohort Production			
Escapement Year	**SJR Females**	**Spring Vernalis Flow**	**Production Cohort**
1981	7,486	16,954	58,798
1982	8,784	34,178	91,991
1983	2,313	4,049	22,052
1984	20,264	2,322	6,055
1985	38,125	16,209	42,824
1986	10,719	2,596	2,513
1987	2,707	1,983	344
1988	11,705	1,900	765
1989	1,758	1,362	1,098
1990	227	1,237	3,267
1991	282	1,101	3,677
1992	528	3,213	4,221
1993	1,068	1,840	6,722
1994	2,078	20,719	27,594
1995	1,804	8,497	7,164
1996	2,316	4,759	18,221
1997	9,135	18,776	48,491
1998	6,173	5,762	18,471
1999	6,285	5,441	21,608
Multiple Regression			
SJR Females (x1) & Vernalis Flow (x2) vs. Cohort (y)			
R-squared Value = 0.87 (p<0.001)			
Equation: ((#Females*0.137)+(VNS Flow*2.481124)+(-624.576))			
	Lower 95%	Upper 95%	
y-intercept	-7345.2	6096.044	
X1 Variable	-0.39739	0.672242	
X2 Variable	1.943222	3.019027	

Yellow = Years where # of Females and elevated flow produce increased cohort production.
Blue = Years where # of Females and elevated flow produce decreased cohort production.

Table 3. Vernalis Flow Magnitude/Duration and Juvenile Salmon Out-migration

Vernalis Window Flow Magnitude/Duration and Juvenile Salmon Production							
WY Type	**Year**	**Start Date**	**End Date**	**# Days**	**Flow (average daily)**	**Ratio (Flow/days)**	**Juveniles Outmigrating**
C	1988	6-Apr	2-Jun	57	1936	34	1050122
C	1990	14-Apr	5-Jun	52	1296	25	256212
C	1991	5-Apr	22-May	47	1086	23	522441
C	1992	2-Apr	20-May	48	1277	27	265375
W	1993	2-Apr	19-May	47	3668	78	254092
C	1994	7-Apr	11-May	34	1993	59	417637
W	1995	17-May	10-Jun	24	21808	909	3078016
W	1996	6-Apr	12-Jun	67	7249	108	1145994
W	1997	4-Apr	8-Jun	65	4599	71	588882
W	1998	7-Apr	6-Jun	60	21080	351	2456575
AN	1999	15-Apr	10-Jun	56	5504	98	318432
AN	2000	3-Apr	1-Jun	59	4884	83	470538
D	2001	14-Apr	27-May	43	3671	85	752964
D	2002	9-Apr	23-May	44	2943	67	682884
BN	2003	10-Apr	19-May	39	2992	77	519659
D	2004	5-Apr	18-May	43	2936	68	321974
Multiple Regression							
# Days (x1) & Average Flow (x2) vs. Juvenile Salmon Out-migration (y)							
R-squared Value 0.89 (p<0.001)							
Equation ((#days*-6125.28)+(Average Flow*117.38)+467018.5)							
	Lower 95%			*Upper 95%*			
Intercept	-287591.6			1221629			
X1Variable	-20528.3			8278			
X2Variable	91.6			143			

Table 4. San Joaquin River Escapement, Vernalis Spring Flow, vs. Juvenile Salmon Abundance

Mossdale Smolt Abundance Estimate					
Year	SJR Prior Year Escapement	3/15-6/15 Mean Daily Vernalis Flow (cfs)	Mossdale Smolts	Lower 95%	Upper 95%
1988	25,169	1,983	1,188,584	-287,769	1,328,383
1990	20,583	1,362	263,932	-329,065	1,102,553
1991	658	1,237	537,397	-213,986	573,347
1992	590	1,101	280,395	-229,154	547,659
1993	1,373	3,213	269,035	7,631	938,788
1994	2,826	1,840	453,245	-158,983	734,558
1995	5,126	20,719	3,361,384	1,987,903	4,110,843
1996	4,368	8,497	1,155,319	593,221	1,943,583
1997	8,962	4,759	635,517	135,354	1,403,635
1998	16,394	18,776	2,844,637	1,692,196	4,056,179
1999	16,088	5,762	438,979	203,931	1,761,309
2000	17,347	5,441	484,703	159,034	1,737,004
2001	39,447	2,853	848,488	-280,931	1,844,658
2002	26,659	2,382	733,839	-251,782	1,436,393
2003	25,625	2,467	550,446	-235,312	1,425,041
2004	15,109	2,575	333,080	-154,622	1,176,360

Multiple Regression		
SJR Escapement (x1) & Vernalis Flow (x2) vs. Mossdale Smolt Abundance (y)		
R-squared value = 0.89 (p<0.001)		
Equation: ((Escapement*9.47722)+(Flow*145.1225)+(-6051.58))		
	Lower 95%	Upper 95%
y-intercept	-351341.864	339238.7127
X1 Variable	-6.497540131	25.45198408
X2 Variable	114.5089275	175.7360296

Table 5. Historical Spring Head of Old River Barrier Operation Dates

Spring Head of Old River Barrier (HORB)[55]					
Year	Installation Started	Installation Completed	Removal Started	Removal Completed	Notes
1992	15-Apr	1-May	2-Jun	8-Jun	
1993	No HORB				
1994	21-Apr	1-May	18-May	20-May	
1995	No HORB				
1996	6-May	11-May	16-May	3-Sep	Breached on 5/16 on an emergency basis
1997	9-Apr	16-Apr	15-May	19-May	
1998	HORB Status Unknown				
1999	HORB Status Unknown				
2000		16-Apr	16-May		
2001		26-Apr	26-May		
2002		15-Apr	24-May		
2003		15-Apr	16-May		
2004		15-Apr	21-May		

Note: Dates approximate for 2003 and 2004

[55] Data obtained from U.S. Fish and Wildlife Service (P. Brandes).

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Table 6. Preliminary SJR Fall-run Chinook Salmon Age Distribution.

CDFG Preliminary Scale Analysis Age Determination for SJR Fall-run Chinook Salmon												
Year	**Age 1**	**Age 2**	**Age 3**	**Age 4**	**Age 5**	**Total**	**Year**	**Age 1**	**Age 2**	**Age 3**	**Age 4**	**Age 5**
1981	3	113	40	3		159	1981	1.89%	71.07%	25.16%	1.89%	0.00%
1982	1	6	31	2		40	1982	2.50%	15.00%	77.50%	5.00%	0.00%
1983		20	24	11		55	1983	0.00%	36.36%	43.64%	20.00%	0.00%
1984	2	27	28			57	1984	3.51%	47.37%	49.12%	0.00%	0.00%
1985	1	25	49	6	1	82	1985	1.22%	30.49%	59.76%	7.32%	1.22%
1986	2	18	16	21	2	59	1986	3.39%	30.51%	27.12%	35.59%	3.39%
1987	1	94	36	7	2	140	1987	0.71%	67.14%	25.71%	5.00%	1.43%
1988	1	36	181	5		223	1988	0.45%	16.14%	81.17%	2.24%	0.00%
1989		38	342	328	3	711	1989	0.00%	5.34%	48.10%	46.13%	0.42%
1990		17	31	19		67	1990	0.00%	25.37%	46.27%	28.36%	0.00%
1991		5	36	7		48	1991	0.00%	10.42%	75.00%	14.58%	0.00%
1992	3	95	71	22	2	193	1992	1.55%	49.22%	36.79%	11.40%	1.04%
1993	3	67	154	17		241	1993	1.24%	27.80%	63.90%	7.05%	0.00%
1994	1	50	201	22	1	275	1994	0.36%	18.18%	73.09%	8.00%	0.36%
1995		49	86	12	1	148	1995	0.00%	33.11%	58.11%	8.11%	0.68%
1996	2	248	274	41		565	1996	0.35%	43.89%	48.50%	7.26%	0.00%
1997		41	172	13	1	227	1997	0.00%	18.06%	75.77%	5.73%	0.44%
1998		96	142	102		340	1998	0.00%	28.24%	41.76%	30.00%	0.00%
1999		195	212	21	1	429	1999	0.00%	45.45%	49.42%	4.90%	0.23%
2000	2	78	562	64	1	707	2000	0.28%	11.03%	79.49%	9.05%	0.14%
								Age				
							Summary	**1**	**2**	**3**	**4**	**5**
							Mean	0.87%	31.51%	54.27%	12.88%	0.47%
							Max	3.51%	71.07%	81.17%	46.13%	3.39%
							Min	0.00%	5.34%	25.16%	0.00%	0.00%
							Median	0.36%	29.36%	49.27%	7.66%	0.07%

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Table 7. Escapement Reconstruction Template Example.

Escapement Year	Reconstructed Escapement	Smolt Production Year	Cohort #	Age Cohort %'s				
				Age 1	Age 2	Age 3	Age 4	Age 5
				0.05%	30.00%	55.35%	14.00%	0.60%
1967		1968	276	0	83	153	39	**2**
1968		1969	98603	49	29,581	54,577	**13,804**	592
1969		1970	1403	1	421	**776**	196	**8**
1970		1971	1119	1	**336**	620	**157**	7
1971		1972	461	**0**	138	**255**	64	3
1972	**14,919**	1973	2638	1	**791**	1,460	369	16
1973	1,547	1974	3645	**2**	1,094	2,018	510	22
1974	**1,213**	1975	3304	2	991	1,829	463	20

Note: **Cohort % are applied to Cohort #, and the sum of colored boxes under Age Cohort % equals the same shaded box number in the Reconstructed Escapement column.**

Table 8. Merced Hatchery Estimated Smolts Per Female.

Merced Hatchery Smolts Per Female									
Year	**In-River Escapement**	**Hatchery (MRH) Escapement**	**MRH (%) to In-River Escapement**	**Females**	**% Females Hatchery Escapement**	**Total Eggs**	**Eyed Eggs**	**Eggs Per Female**	***Smolts Per Female**
1987	3,168	958	23%	156	16%	609133	445850	2858	2286
1988	4,135	457	10%	206	45%	1069258	790799	3839	3071
1989	345	82	19%	32	39%	172053	103795	3244	2595
1990	36	46	56%	14	30%	59919	23273	1662	1330
1991	78	41	34%	9	22%	48075	19310	2146	1716
1992	618	368	37%	41	11%	203454	121742	2969	2375
1993	1,269	409	24%	153	37%	740020	559721	3658	2927
1994	2,646	943	26%	282	30%	1569937	1047887	3716	2973
1995	2,320	602	21%	196	33%	977637	650031	3316	2653
1996	3,291	1,141	26%	361	32%	1736391	1267974	3512	2810
1997	2,714	946	26%	397	42%	1985782	1661035	4184	3347
1998	3,292	799	20%	304	38%	1210055	1037789	3414	2731
1999	3,129	1,637	34%	383	23%	1862840	1573540	4108	3287
2000	11,130	1,946	15%	937	48%	5,299,480	3,855,560	4115	3292
2001	9,181	1,663	15%	703	42%	2947812	1799565	2560	2048
2002	8,800	1,838	17%	797	43%	3348582	2059305	2584	2067
2003	4,110	549	12%	248	45%	1249075	947082	3819	3055
Average	**3545**	**849**	**24%**	**307**	**34%**	**1475853**	**1056721**	**3277**	**2621**
Estimated Average Smolts Per Year									***804763***

*Note: Assumes a 20% loss between Eyed Egg and Smolt Stage.

Table 9. Model Scenarios

Model Scenarios			
Scenario	**Flow Range**	**Window Duration**	**Notes**
1	5-7K	31 Days	No HORB
2	5-7K	31 Days	HORB
3	5K	30, 45, 60, 75, 90 Days	Duration & magnitude constant
4	10K	30, 45, 60, 75, 90 Days	Duration & magnitude constant
5	15K	30, 45, 60, 75, 90 Days	Duration & magnitude constant
6	5-10K	30, 45, 60, 75, 90 Days	Duration constant & magnitude variable
7	5-15k	30, 45, 60, 75, 90 Days	Duration constant & magnitude variable
8	5-20K	30, 45, 60, 75, 90 Days	Duration constant & magnitude variable
9	5-15K	Variable with WY Type	Duration & magnitude variable
10	5-20K	Variable with WY Type	Duration & magnitude variable
11	5-20K	Variable with WY Type	Same as #10 & includes Hatchery Supplementation

Note: Scenarios 3 thru 10 all include HORB-in for the identified window of protection time period (e.g. 30 to 90 days).

Table 10. Results Model Scenario #1 Model Results.

Scenario #1: 1967 to 2000 CDFG Vernalis Flow Adult Salmon Production Model Results--VAMP Flow Levels (No HORB)											
Water Year Type	**Minimum Flow**	**Fish Summary**					**Water Summary***				
		*Smolt Protection Window (# of days)***					*Smolt Protection Window**				
		30	*45*	*60*	*75*	*90*	*30*	*45*	*60*	*75*	*90*
		Adult Salmon Escapement					**Additional Water (AF)**				
W	7000	17,097	17,440	17,702	17,907	18,084	46,108	69,530	94,989	117,564	145,702
AN	5700						127,262	188,187	241,688	287,975	327,367
BN	4450						149,141	223,663	304,628	372,705	436,161
D	3200						89,747	140,220	186,564	227,815	268,987
C	2000						36,228	55,703	74,877	93,693	113,112
Weighted Average (*According to Number of Each Water Year Type*)							**65,978**	**99,659**	**132,492**	**161,792**	**192,181**
Yr Type	**Flow**	**Percent Increase Adult Escapement*****					**Percent Additional Water******				
W	7000	3.5%	5.6%	7.2%	8.4%	9.5%	1.7%	2.5%	3.4%	4.2%	5.2%
AN	5700						13.7%	19.0%	23.2%	26.5%	29.0%
BN	4450						28.3%	37.2%	44.6%	49.7%	53.6%
D	3200						21.7%	30.2%	36.5%	41.2%	45.3%
C	2000						11.6%	16.8%	21.3%	25.3%	29.0%
Weighted Average (*According to Number of Each Water Year Type*)							**9.6%**	**13.5%**	**16.7%**	**19.4%**	**21.8%**
Yr Type	**Flow**	**1:1 Replacement Ratio Geometric Mean--All Yr Types**					**Additional Percent of Total Available Water*******				
W	7000	1.12	1.12	1.12	1.12	1.12	0.7%	1.0%	1.3%	1.6%	1.9%
AN	5700						2.1%	3.1%	4.0%	4.8%	5.5%
BN	4450						3.1%	4.7%	6.4%	7.8%	9.1%
D	3200						2.8%	4.4%	5.8%	7.1%	8.4%
C	2000						2.1%	3.3%	4.4%	5.5%	6.6%
Weighted Average (*According to Number of Each Water Year Type*)							**1.6%**	**2.5%**	**3.3%**	**4.0%**	**4.7%**

Notes:

* Does not account for VAMP Water (e.g., up to 110 TAF single step years)

** May 1 is the central point for all Smolt Protection Window time periods

*** Defined as modeled adult escapement increase as compared to modeled historical baseline (38,000 is the Narrative Doubling Goal)

**** Defined as percent water increase as compared to historical flows (AF)

***** Defined as amount of water (% WY Type Total Apr-July) used for fishery beneficial use (1967-2000 Average = 18.0%)

Table 11. Scenario #2 Model Results.

Scenario #2: 1967 to 2000 CDFG Vernalis Flow Adult Salmon Production Model Results--VAMP Flow Levels (with HORB)											
		Fish Summary					**Water Summary***				
		*Smolt Protection Window (# of days)***					*Smolt Protection Window**				
Water Year Type	**Minimum Flow**	*30*	*45*	*60*	*75*	*90*	*30*	*45*	*60*	*75*	*90*
		Adult Salmon Escapement					**Additional Water (AF)**				
W	7000	17,888	18,297	18,613	18,850	19,057	46,108	69,530	94,989	117,564	145,702
AN	5700						127,262	188,187	241,688	287,975	327,367
BN	4450						149,141	223,663	304,628	372,705	436,161
D	3200						89,747	140,220	186,564	227,815	268,987
C	2000						36,228	55,703	74,877	93,693	113,112
Weighted Average (*According to Number of Each Water Year Type*)							**65,978**	**99,659**	**132,492**	**161,792**	**192,181**
Yr Type	**Flow**	**Percent Increase Adult Escapement*****					**Percent Additional Water******				
W	7000	8.3%	10.8%	12.7%	14.1%	15.4%	1.7%	2.5%	3.4%	4.2%	5.2%
AN	5700						13.7%	19.0%	23.2%	26.5%	29.0%
BN	4450						28.3%	37.2%	44.6%	49.7%	53.6%
D	3200						21.7%	30.2%	36.5%	41.2%	45.3%
C	2000						11.6%	16.8%	21.3%	25.3%	29.0%
Weighted Average (*According to Number of Each Water Year Type*)							**9.6%**	**13.5%**	**16.7%**	**19.4%**	**21.8%**
Yr Type	**Flow**	**1:1 Replacement Ratio Geometric Mean--All Yr Types**					**Additional Percent of Total Available Water*******				
W	7000	1.12	1.12	1.12	1.12	1.12	0.7%	1.0%	1.3%	1.6%	1.9%
AN	5700						2.1%	3.1%	4.0%	4.8%	5.5%
BN	4450						3.1%	4.7%	6.4%	7.8%	9.1%
D	3200						2.8%	4.4%	5.8%	7.1%	8.4%
C	2000						2.1%	3.3%	4.4%	5.5%	6.6%
Weighted Average (*According to Number of Each Water Year Type*)							**1.6%**	**2.5%**	**3.3%**	**4.0%**	**4.7%**

Notes:

* Does not account for VAMP Water (e.g., up to 110 TAF single step years)

** May 1 is the central point for all Smolt Protection Window time periods

*** Defined as modeled adult escapement increase as compared to modeled historical baseline (38,000 is the Narrative Doubling Goal)

**** Defined as percent water increase as compared to historical flows (AF)

***** Defined as amount of water (% WY Type Total Apr-July) used for fishery beneficial use (1967-2000 Average = 18.0%)

Table 12. Scenario #3 Model Results.

Scenario #3: 1967 to 2000 CDFG Vernalis Flow Adult Salmon Production Model Results--5000 Flow Levels (with HORB)											
Water Year Type	**Minimum Flow**	**Fish Summary**					**Water Summary***				
		*Smolt Protection Window (# of days)***					*Smolt Protection Window**				
		30	*45*	*60*	*75*	*90*	*30*	*45*	*60*	*75*	*90*
		Adult Salmon Escapement					**Additional Water (AF)**				
W	5000	18,668	19,442	20,056	20,522	20,935	14,931	23,062	33,470	40,242	51,838
AN	5000						98,981	141,510	177,759	210,403	238,730
BN	5000						181,861	272,742	370,067	454,504	535,410
D	5000						196,710	300,724	400,609	493,929	587,843
C	5000						207,330	313,713	419,670	523,389	633,128
Weighted Average (*According to Number of Each Water Year Type*)							**106,988**	**160,911**	**214,255**	**263,721**	**315,972**
Yr Type	**Flow**	**Percent Increase Adult Escapement*****					**Percent Additional Water********				
W	5000	13.0%	17.7%	21.4%	24.2%	26.7%	0.6%	0.9%	1.2%	1.5%	1.9%
AN	5000						11.0%	15.0%	18.2%	20.8%	23.0%
BN	5000						32.5%	41.9%	49.5%	54.6%	58.6%
D	5000						37.7%	48.1%	55.2%	60.3%	64.4%
C	5000						42.8%	53.1%	60.3%	65.4%	69.6%
Weighted Average (*According to Number of Each Water Year Type*)							**18.9%**	**24.0%**	**27.6%**	**30.3%**	**32.6%**
Yr Type	**Flow**	**1:1 Replacement Ratio Geometric Mean--All Yr Types**					**Additional Percent of Total Available Water***********				
W	5000	1.12	1.12	1.12	1.12	1.12	0.2%	0.3%	0.5%	0.5%	0.7%
AN	5000						1.7%	2.4%	3.0%	3.5%	4.0%
BN	5000						3.8%	5.7%	7.7%	9.5%	11.2%
D	5000						6.1%	9.4%	12.5%	15.3%	18.2%
C	5000						10.3%	15.5%	20.7%	25.8%	31.2%
Weighted Average (*According to Number of Each Water Year Type*)							**3.9%**	**5.9%**	**7.9%**	**9.8%**	**11.7%**

Notes:

* Does not account for VAMP Water (e.g., up to 110 TAF single step years)

** May 1 is the central point for all Smolt Protection Window time periods

*** Defined as modeled adult escapement increase as compared to modeled historical baseline (38,000 is the Narrative Doubling Goal)

**** Defined as percent water increase as compared to historical flows (AF)

***** Defined as amount of water (% WY Type Total Apr-July) used for fishery beneficial use (1967-2000 Average = 18.0%)

Table 13. Scenario #4 Model Results.

Scenario #4: 1967 to 2000 CDFG Vernalis Flow Adult Salmon Production Model Results--10,000 Flow Levels (with HORB)											
Water Year Type	**Minimum Flow**	**Fish Summary**					**Water Summary***				
		*Smolt Protection Window (# of days)***					*Smolt Protection Window**				
		30	*45*	*60*	*75*	*90*	*30*	*45*	*60*	*75*	*90*
		Adult Salmon Escapement					**Additional Water (AF)**				
W	10000	20,687	22,908	24,903	26,622	28,215	111,506	166,613	224,810	285,927	353,992
AN	10000						367,361	553,508	731,939	895,979	1,039,789
BN	10000						479,311	718,917	964,967	1,198,129	1,437,675
D	10000						494,160	746,899	995,509	1,237,554	1,490,108
C	10000						504,780	759,888	1,014,570	1,267,014	1,535,393
Weighted Average (*According to Number of Each Water Year Type*)							**316,595**	**476,445**	**635,797**	**792,068**	**953,273**
Yr Type	**Flow**	**Percent Increase Adult Escapement*****					**Percent Additional Water******				
W	10000	25.2%	38.7%	50.8%	61.2%	70.8%	4.0%	5.8%	7.7%	9.6%	11.7%
AN	10000						31.5%	40.9%	47.8%	52.8%	56.5%
BN	10000						55.9%	65.6%	71.9%	76.0%	79.2%
D	10000						60.3%	69.7%	75.4%	79.2%	82.1%
C	10000						64.6%	73.3%	78.6%	82.1%	84.7%
Weighted Average (*According to Number of Each Water Year Type*)							**33.0%**	**39.2%**	**43.4%**	**46.6%**	**49.2%**
Yr Type	**Flow**	**1:1 Replacement Ratio Geometric Mean--All Yr Types**					**Additional Percent of Total Available Water*******				
W	10000	1.13	1.13	1.14	1.14	1.15	1.5%	2.3%	3.0%	3.8%	4.7%
AN	10000						6.1%	9.2%	12.2%	14.9%	17.3%
BN	10000						10.0%	15.0%	20.1%	25.0%	30.0%
D	10000						15.3%	23.2%	30.9%	38.4%	46.2%
C	10000						24.3%	36.5%	48.8%	60.9%	73.8%
Weighted Average (*According to Number of Each Water Year Type*)							**10.2%**	**15.4%**	**20.5%**	**25.6%**	**30.8%**

Notes:

* Does not account for VAMP Water (e.g., up to 110 TAF single step years)

** May 1 is the central point for all Smolt Protection Window time periods

*** Defined as modeled adult escapement increase as compared to modeled historical baseline (38,000 is the Narrative Doubling Goal)

**** Defined as percent water increase as compared to historical flows (AF)

***** Defined as amount of water (% WY Type Total Apr-July) used for fishery beneficial use (1967-2000 Average = 18.0%)

Table 14. Scenario #5 Model Results.

Scenario #5: 1967 to 2000 CDFG Vernalis Flow Adult Salmon Production Model Results--15000 Flow Levels (with HORB)											
Water Year Type	**Minimum Flow**	**Fish Summary**					**Water Summary***				
		*Smolt Protection Window (# of days)***					*Smolt Protection Window**				
		30	*45*	*60*	*75*	*90*	*30*	*45*	*60*	*75*	*90*
		Adult Salmon Escapement					**Additional Water (AF)**				
W	15000	25,398	31,328	36,932	41,898	46,447	251,987	375,975	513,492	661,267	812,575
AN	15000						664,811	999,683	1,326,839	1,639,604	1,937,956
BN	15000						776,761	1,165,092	1,559,867	1,941,754	2,339,940
D	15000						791,610	1,193,074	1,590,409	1,981,179	2,392,373
C	15000						802,230	1,206,063	1,609,470	2,010,639	2,437,658
Weighted Average (*According to Number of Each Water Year Type*)							**549,410**	**825,109**	**1,104,607**	**1,384,046**	**1,672,122**
Yr Type	**Flow**	**Percent Increase Adult Escapement*****					**Percent Additional Water******				
W	15000	53.8%	89.7%	123.6%	153.7%	181.2%	8.6%	12.3%	16.1%	19.8%	23.2%
AN	15000						45.4%	55.5%	62.4%	67.2%	70.8%
BN	15000						67.3%	75.5%	80.5%	83.7%	86.1%
D	15000						70.9%	78.6%	83.0%	85.9%	88.0%
C	15000						74.4%	81.3%	85.3%	87.9%	89.8%
Weighted Average (*According to Number of Each Water Year Type*)							**41.5%**	**47.9%**	**52.3%**	**55.8%**	**58.7%**
Yr Type	**Flow**	**1:1 Replacement Ratio Geometric Mean--All Yr Types**					**Additional Percent of Total Available Water*******				
W	15000	1.14	1.16	1.17	1.18	1.19	3.4%	5.0%	6.7%	8.6%	10.5%
AN	15000						11.1%	16.7%	22.1%	27.3%	32.3%
BN	15000						16.2%	24.3%	32.6%	40.5%	48.9%
D	15000						24.6%	37.0%	49.3%	61.4%	74.1%
C	15000						38.4%	57.6%	76.9%	96.1%	116.4%
Weighted Average (*According to Number of Each Water Year Type*)							**16.9%**	**25.3%**	**33.8%**	**42.2%**	**51.0%**

Notes:

* Does not account for VAMP Water (e.g., up to 110 TAF single step years)

** May 1 is the central point for all Smolt Protection Window time periods

*** Defined as modeled adult escapement increase as compared to modeled historical baseline (38,000 is the Narrative Doubling Goal)

**** Defined as percent water increase as compared to historical flows (AF)

***** Defined as amount of water (% WY Type Total Apr-July) used for fishery beneficial use (1967-2000 Average = 18.0%)

Table 15. Scenario #6 Model Results.

Scenario #6: 1967 to 2000 CDFG Vernalis Flow Adult Salmon Production Model Results--5-10,000 Flow Level (with HORB)											
Water Year Type	**Minimum Flow**	**Fish Summary**					**Water Summary***				
		*Smolt Protection Window (# of days)***					*Smolt Protection Window**				
		30	*45*	*60*	*75*	*90*	*30*	*45*	*60*	*75*	*90*
		Adult Salmon Escapement					**Additional Water (AF)**				
W	10000	19,345	20,653	21,795	22,768	23,649	111,506	166,613	224,810	285,927	353,992
AN	9000						307,871	464,273	612,959	747,254	861,038
BN	8000						360,331	540,447	727,007	900,679	1,076,769
D	7000						315,690	479,194	638,569	791,379	948,749
C	5000						207,330	313,713	419,670	523,389	633,128
Weighted Average (*According to Number of Each Water Year Type*)							**202,864**	**305,849**	**408,335**	**507,741**	**608,589**
Yr Type	**Flow**	**Percent Increase Adult Escapement*****					**Percent Additional Water******				
W	10000	17.1%	25.0%	31.9%	37.8%	43.2%	4.0%	5.8%	7.7%	9.6%	11.7%
AN	9000						27.8%	36.7%	43.4%	48.3%	51.8%
BN	8000						48.8%	58.9%	65.8%	70.5%	74.0%
D	7000						49.3%	59.6%	66.3%	70.9%	74.5%
C	5000						42.8%	53.1%	60.3%	65.4%	69.6%
Weighted Average (*According to Number of Each Water Year Type*)							**25.1%**	**31.7%**	**36.5%**	**40.2%**	**43.3%**
Yr Type	**Flow**	**1:1 Replacement Ratio Geometric Mean--All Yr Types**					**Additional Percent of Total Available Water*******				
W	10000	1.13	1.13	1.13	1.14	1.14	1.5%	2.3%	3.0%	3.8%	4.7%
AN	9000						5.1%	7.7%	10.2%	12.5%	14.4%
BN	8000						7.5%	11.3%	15.2%	18.8%	22.5%
D	7000						9.8%	14.9%	19.8%	24.6%	29.4%
C	5000						10.3%	15.5%	20.7%	25.8%	31.2%
Weighted Average (*According to Number of Each Water Year Type*)							**5.6%**	**8.5%**	**11.3%**	**14.0%**	**16.8%**

Notes:

* Does not account for VAMP Water (e.g., up to 110 TAF single step years)

** May 1 is the central point for all Smolt Protection Window time periods

*** Defined as modeled adult escapement increase as compared to modeled historical baseline (38,000 is the Narrative Doubling Goal)

**** Defined as percent water increase as compared to historical flows (AF)

***** Defined as amount of water (% WY Type Total Apr-July) used for fishery beneficial use (1967-2000 Average = 18.0%)

Table 16. Scenario #7 Model Results.

Scenario #7: 1967 to 2000 CDFG Vernalis Flow Adult Salmon Production Model Results--5-15,000 Flow Level (with HORB)											
Water Year Type	**Minimum Flow**	**Fish Summary**					**Water Summary***				
		*Smolt Protection Window (# of days)***					*Smolt Protection Window**				
		30	*45*	*60*	*75*	*90*	*30*	*45*	*60*	*75*	*90*
		Adult Salmon Escapement					**Additional Water (AF)**				
W	15000	20,939	23,524	25,929	28,083	29,977	251,987	375,975	513,492	661,267	812,575
AN	12000						486,341	731,978	969,899	1,193,429	1,398,084
BN	9000						419,821	629,682	845,987	1,049,404	1,257,222
D	7000						315,690	479,194	638,569	791,379	948,749
C	5000						207,330	313,713	419,670	523,389	633,128
Weighted Average (*According to Number of Each Water Year Type*)							**293,953**	**441,924**	**593,693**	**745,404**	**897,498**
Yr Type	**Flow**	**Percent Increase Adult Escapement*****					**Percent Additional Water******				
W	15000	26.8%	42.4%	57.0%	70.0%	81.5%	8.6%	12.3%	16.1%	19.8%	23.2%
AN	12000						37.8%	47.8%	54.8%	59.9%	63.6%
BN	9000						52.6%	62.5%	69.1%	73.5%	76.9%
D	7000						49.3%	59.6%	66.3%	70.9%	74.5%
C	5000						42.8%	53.1%	60.3%	65.4%	69.6%
Weighted Average (*According to Number of Each Water Year Type*)							**28.9%**	**36.4%**	**42.1%**	**46.5%**	**50.2%**
Yr Type	**Flow**	**1:1 Replacement Ratio Geometric Mean--All Yr Types**					**Additional Percent of Total Available Water*******				
W	15000	1.14	1.15	1.16	1.17	1.18	3.4%	5.0%	6.7%	8.6%	10.5%
AN	12000						8.1%	12.2%	16.2%	19.9%	23.3%
BN	9000						8.8%	13.1%	17.7%	21.9%	26.2%
D	7000						9.8%	14.9%	19.8%	24.6%	29.4%
C	5000						10.3%	15.5%	20.7%	25.8%	31.2%
Weighted Average (*According to Number of Each Water Year Type*)							**6.9%**	**10.4%**	**14.0%**	**17.4%**	**20.9%**

Notes:

* Does not account for VAMP Water (e.g., up to 110 TAF single step years)

** May 1 is the central point for all Smolt Protection Window time periods

*** Defined as modeled adult escapement increase as compared to modeled historical baseline (38,000 is the Narrative Doubling Goal)

**** Defined as percent water increase as compared to historical flows (AF)

***** Defined as amount of water (% WY Type Total Apr-July) used for fishery beneficial use (1967-2000 Average = 18.0%)

Table 17. Scenario #8 Model Results.

Scenario #8: 1967 to 2000 CDFG Vernalis Flow Adult Salmon Production Model Results--5-20,000 Flow Level (with HORB)											
Water Year Type	**Minimum Flow**	**Fish Summary**					**Water Summary***				
		*Smolt Protection Window (# of days)***					*Smolt Protection Window**				
		30	*45*	*60*	*75*	*90*	*30*	*45*	*60*	*75*	*90*
		Adult Salmon Escapement					**Additional Water (AF)**				
W	20000	22,866	27,090	31,091	34,678	37,912	423,021	633,355	866,934	1,113,632	1,374,458
AN	12000						486,341	731,978	969,899	1,193,429	1,398,084
BN	9000						419,821	629,682	845,987	1,049,404	1,257,222
D	7000						315,690	479,194	638,569	791,379	948,749
C	5000						207,330	313,713	419,670	523,389	633,128
Weighted Average (*According to Number of Each Water Year Type*)							**364,379**	**547,903**	**739,228**	**931,672**	**1,128,861**
Yr Type	**Flow**	**Percent Increase Adult Escapement*****					**Percent Additional Water********				
W	20000	38.4%	64.0%	88.2%	109.9%	129.5%	13.6%	19.1%	24.4%	29.3%	33.9%
AN	12000						37.8%	47.8%	54.8%	59.9%	63.6%
BN	9000						52.6%	62.5%	69.1%	73.5%	76.9%
D	7000						49.3%	59.6%	66.3%	70.9%	74.5%
C	5000						42.8%	53.1%	60.3%	65.4%	69.6%
Weighted Average (*According to Number of Each Water Year Type*)							**31.0%**	**39.2%**	**45.5%**	**50.5%**	**54.6%**
Yr Type	**Flow**	**1:1 Replacement Ratio Geometric Mean--All Yr Types**					**Additional Percent of Total Available Water***********				
W	20000	1.15	1.17	1.19	1.20	1.22	5.5%	8.2%	11.1%	14.1%	17.3%
AN	12000						8.1%	12.2%	16.2%	19.9%	23.3%
BN	9000						8.8%	13.1%	17.7%	21.9%	26.2%
D	7000						9.8%	14.9%	19.8%	24.6%	29.4%
C	5000						10.3%	15.5%	20.7%	25.8%	31.2%
Weighted Average (*According to Number of Each Water Year Type*)							**7.8%**	**11.7%**	**15.7%**	**19.7%**	**23.7%**

Notes:

* Does not account for VAMP Water (e.g., up to 110 TAF single step years)

** May 1 is the central point for all Smolt Protection Window time periods

*** Defined as modeled adult escapement increase as compared to modeled historical baseline (38,000 is the Narrative Doubling Goal)

**** Defined as percent water increase as compared to historical flows (AF)

***** Defined as amount of water (% WY Type Total Apr-July) used for fishery beneficial use (1967-2000 Average = 18.0%)

Table 18. Scenario #9 Model Results.

<table>
<tr><td colspan="12">Scenario #9: 1967 to 2000 CDFG Vernalis Flow Adult Salmon Production Model Results--15,000 Flow & Variable Days (with HORB)</td></tr>
<tr><td rowspan="4">Water Year Type</td><td rowspan="4">Minimum Flow</td><td colspan="5">Fish Summary</td><td colspan="5">Water Summary*</td></tr>
<tr><td colspan="5">Smolt Protection Window (# of days)**</td><td colspan="5">Smolt Protection Window*</td></tr>
<tr><td>30</td><td>45</td><td>60</td><td>75</td><td>90</td><td>30</td><td>45</td><td>60</td><td>75</td><td>90</td></tr>
<tr><td colspan="5">Adult Salmon Escapement</td><td colspan="5">Additional Water (AF)</td></tr>
<tr><td>W</td><td>15000</td><td colspan="5" rowspan="5">27,904</td><td></td><td></td><td></td><td></td><td>812,575</td></tr>
<tr><td>AN</td><td>12000</td><td></td><td></td><td></td><td>1,178,401</td><td></td></tr>
<tr><td>BN</td><td>10000</td><td></td><td></td><td>963,143</td><td></td><td></td></tr>
<tr><td>D</td><td>7000</td><td></td><td>477,050</td><td></td><td></td><td></td></tr>
<tr><td>C</td><td>5000</td><td>206,646</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="7">Weighted Average (According to Number of Each Water Year Type)</td><td colspan="5">681,695</td></tr>
<tr><td>Yr Type</td><td>Flow</td><td colspan="5">Percent Increase Adult Escapement***</td><td colspan="5">Percent Additional Water****</td></tr>
<tr><td>W</td><td>15000</td><td colspan="5" rowspan="5">68.9%</td><td></td><td></td><td></td><td></td><td>23.2%</td></tr>
<tr><td>AN</td><td>12000</td><td></td><td></td><td></td><td>59.6%</td><td></td></tr>
<tr><td>BN</td><td>10000</td><td></td><td></td><td>71.8%</td><td></td><td></td></tr>
<tr><td>D</td><td>7000</td><td></td><td>59.5%</td><td></td><td></td><td></td></tr>
<tr><td>C</td><td>5000</td><td>42.8%</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="7">Weighted Average (According to Number of Each Water Year Type)</td><td colspan="5">40.5%</td></tr>
<tr><td>Yr Type</td><td>Flow</td><td colspan="5">1:1 Replacement Ratio Geometric Mean--All Yr Types</td><td colspan="5">Additional Percent of Total Available Water*****</td></tr>
<tr><td>W</td><td>15000</td><td colspan="5" rowspan="5">1.17</td><td></td><td></td><td></td><td></td><td>10.5%</td></tr>
<tr><td>AN</td><td>12000</td><td></td><td></td><td></td><td>19.7%</td><td></td></tr>
<tr><td>BN</td><td>10000</td><td></td><td></td><td>20.1%</td><td></td><td></td></tr>
<tr><td>D</td><td>7000</td><td></td><td>14.8%</td><td></td><td></td><td></td></tr>
<tr><td>C</td><td>5000</td><td>10.2%</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="7">Weighted Average (According to Number of Each Water Year Type)</td><td colspan="5">12.8%</td></tr>
</table>

Notes:

* Does not account for VAMP Water (e.g., up to 110 TAF single step years)

** May 1 is the central point for all Smolt Protection Window time periods

*** Defined as modeled adult escapement increase as compared to modeled historical baseline (38,000 is the Narrative Doubling Goal)

**** Defined as percent water increase as compared to historical flows (AF)

***** Defined as amount of water (% WY Type Total Apr-July) used for fishery beneficial use (1967-2000 Average = 18.0%)

Table 19. Scenario #10 Model Results.

Scenario #10: 1967 to 2000 CDFG Vernalis Flow Adult Salmon Production Model Results--20,000 Flow & Variable Days (with HORB)											
		Fish Summary					**Water Summary***				
		*Smolt Protection Window (# of days)***					*Smolt Protection Window**				
Water Year Type	**Minimum Flow**	*30*	*45*	*60*	*75*	*90*	*30*	*45*	*60*	*75*	*90*
		Adult Salmon Escapement					**Additional Water (AF)**				
W	20000	37,181									1,374,458
AN	15000									1,624,576	
BN	10000								963,143		
D	7000							477,050			
C	5000						206,646				
Weighted Average (*According to Number of Each Water Year Type*)							**991,795**				
Yr Type	**Flow**	**Percent Increase Adult Escapement*****					**Percent Additional Water******				
W	20000	125.1%									33.9%
AN	15000									67.0%	
BN	10000								71.8%		
D	7000							59.5%			
C	5000						42.8%				
Weighted Average (*According to Number of Each Water Year Type*)							**46.2%**				
Yr Type	**Flow**	**1:1 Replacement Ratio Geometric Mean--All Yr Types**					**Additional Percent of Total Available Water*******				
W	20000	1.22									17.3%
AN	15000									27.1%	
BN	10000								20.1%		
D	7000							14.8%			
C	5000						10.2%				
Weighted Average (*According to Number of Each Water Year Type*)							**17.0%**				

Notes:

* Does not account for VAMP Water (e.g., up to 110 TAF single step years)

** May 1 is the central point for all Smolt Protection Window time periods

*** Defined as modeled adult escapement increase as compared to modeled historical baseline (38,000 is the Narrative Doubling Goal)

**** Defined as percent water increase as compared to historical flows (AF)

***** Defined as amount of water (% WY Type Total Apr-July) used for fishery beneficial use (1967-2000 Average = 18.0%)

Table 20. Scenario #11 Model Results.

Scenario #11: 1967 to 2000 Salmon Production Model Results--20,000 Flow & Variable Days (with HORB & Hatchery)											
		Fish Summary					**Water Summary***				
		*Smolt Protection Window (# of days)***					*Smolt Protection Window**				
Water Year Type	**Minimum Flow**	*30*	*45*	*60*	*75*	*90*	*30*	*45*	*60*	*75*	*90*
		Adult Salmon Escapement					**Additional Water (AF)**				
W	12000	37,105									526,159
AN	5700									278,010	
BN	4450								302,804		
D	3200							138,076			
C	2000						35,993				
Weighted Average (*According to Number of Each Water Year Type*)							**300,392**				
Yr Type	**Flow**	**Percent Increase Adult Escapement*****					**Percent Additional Water******				
W	12000	124.6%									16.4%
AN	5700									25.8%	
BN	4450								44.5%		
D	3200							29.8%			
C	2000						11.5%				
Weighted Average (*According to Number of Each Water Year Type*)							**19.2%**				
Yr Type	**Flow**	**1:1 Replacement Ratio Geometric Mean--All Yr Types**					**Additional Percent of Total Available Water*******				
W	12000	1.21									6.9%
AN	5700									4.7%	
BN	4450								6.3%		
D	3200							4.3%			
C	2000						2.1%				
Weighted Average (*According to Number of Each Water Year Type*)							**4.9%**				

Notes:

* Does not account for VAMP Water (e.g., up to 110 TAF single step years)

** May 1 is the central point for all Smolt Protection Window time periods

*** Defined as modeled adult escapement increase as compared to modeled historical baseline (38,000 is the Narrative Doubling Goal)

**** Defined as percent water increase as compared to historical flows (AF)

***** Defined as amount of water (% WY Type Total Apr-July) used for fishery beneficial use (1967-2000 Average = 18.0%)

Table 21. Model Results Summary.

Model Scenario Results Summary									
Scenario	Vernalis Flow (1000 cfs)	Duration (days)	Predicted Escapement (25 year avg)	Additional Predicted Escapement (25 year avg)	Replacement Ratio	Average Annual acre-feet	Percent Addition al Water	Percent of Water Available	Salmon per 1000 acre-feet
1	2-7K	60	17,702	1,184	1.12	132,492	17%	3%	9
2	(HORB) 2-7K	60	18,613	2,095	1.12	132,492	17%	3%	16
3	5K	60	20,056	3,538	1.12	214,255	28%	8%	17
4	10K	60	24,903	8,385	1.14	635,797	43%	21%	13
5	15K	60	36,932	20,414	1.17	1,104,607	52%	34	18
6	5-10K	60	21,795	5,277	1.13	408,335	37%	11%	13
7	5-15K	60	25,929	9,411	1.16	593,693	42%	14%	16
8	5-20K	90	37,912	21,394	1.22	1,128,861	55%	24%	19
9	5-15K	variable	27,904	11,386	1.17	681,695	41%	13%	17
10	5-20K	variable	37,181	20,663	1.22	991,795	46%	17%	21
11	2-12K	variable	37,105	20,687	1.21	256,208	19%	5%	80

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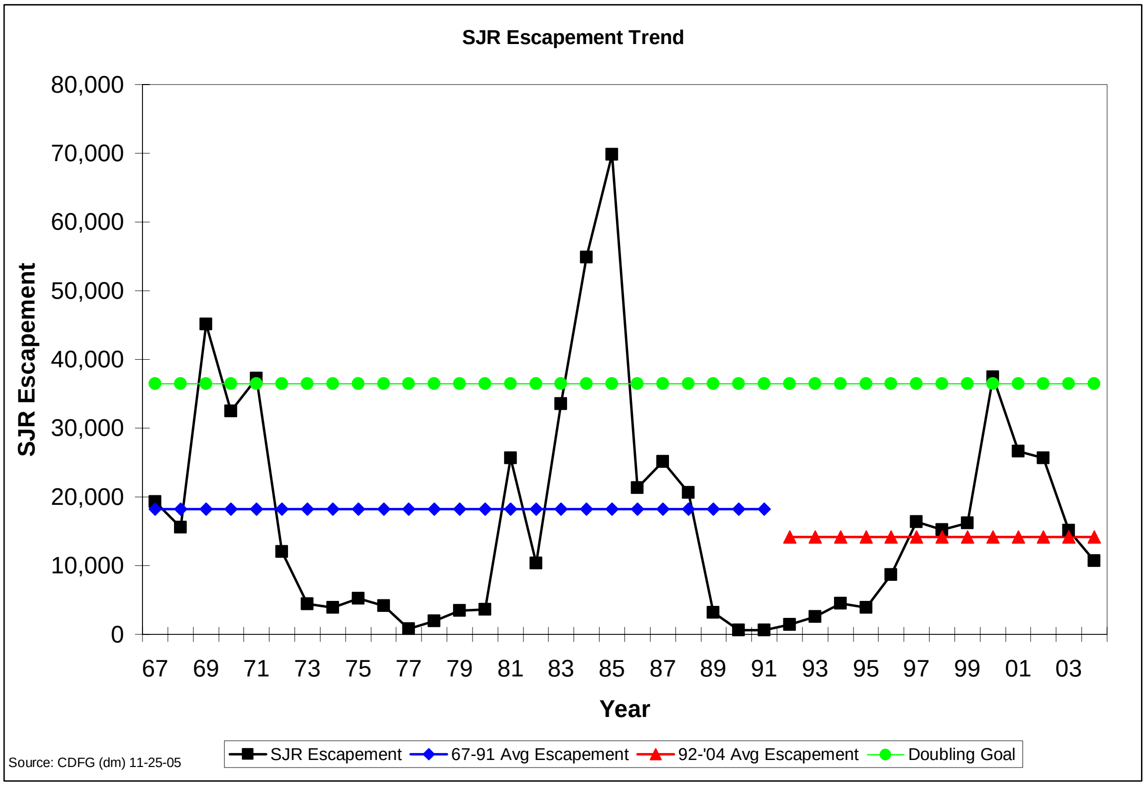

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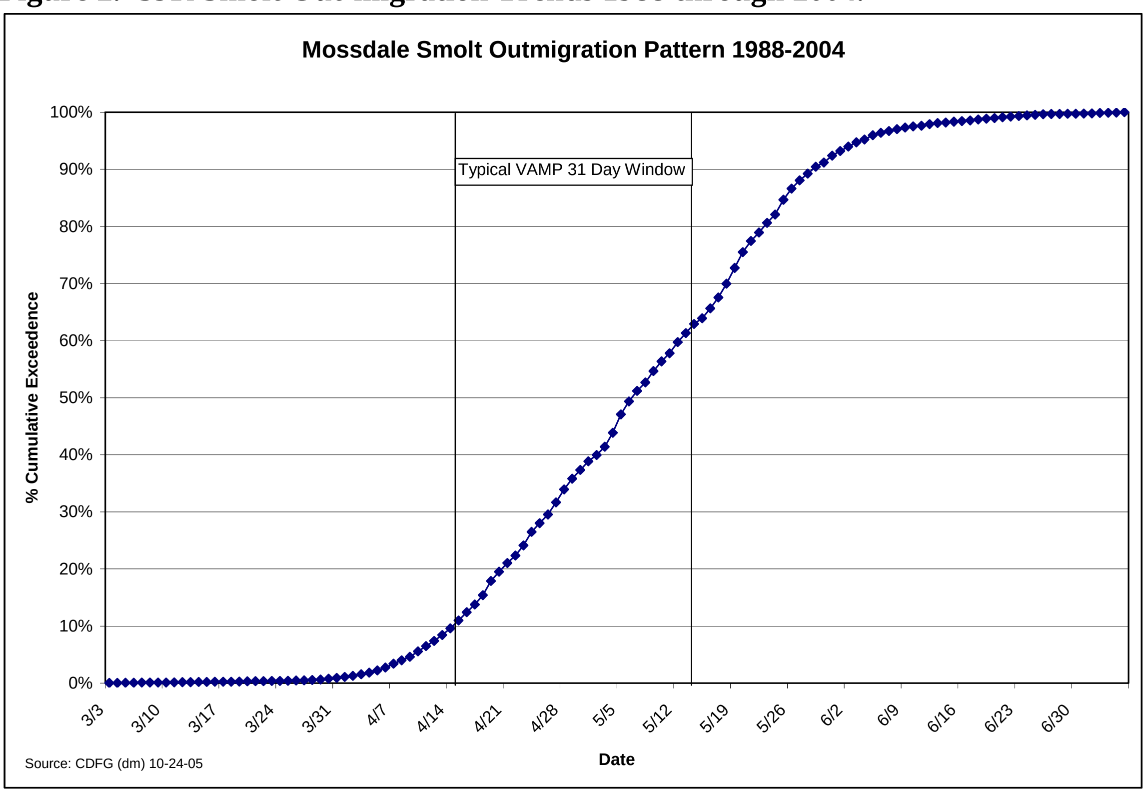

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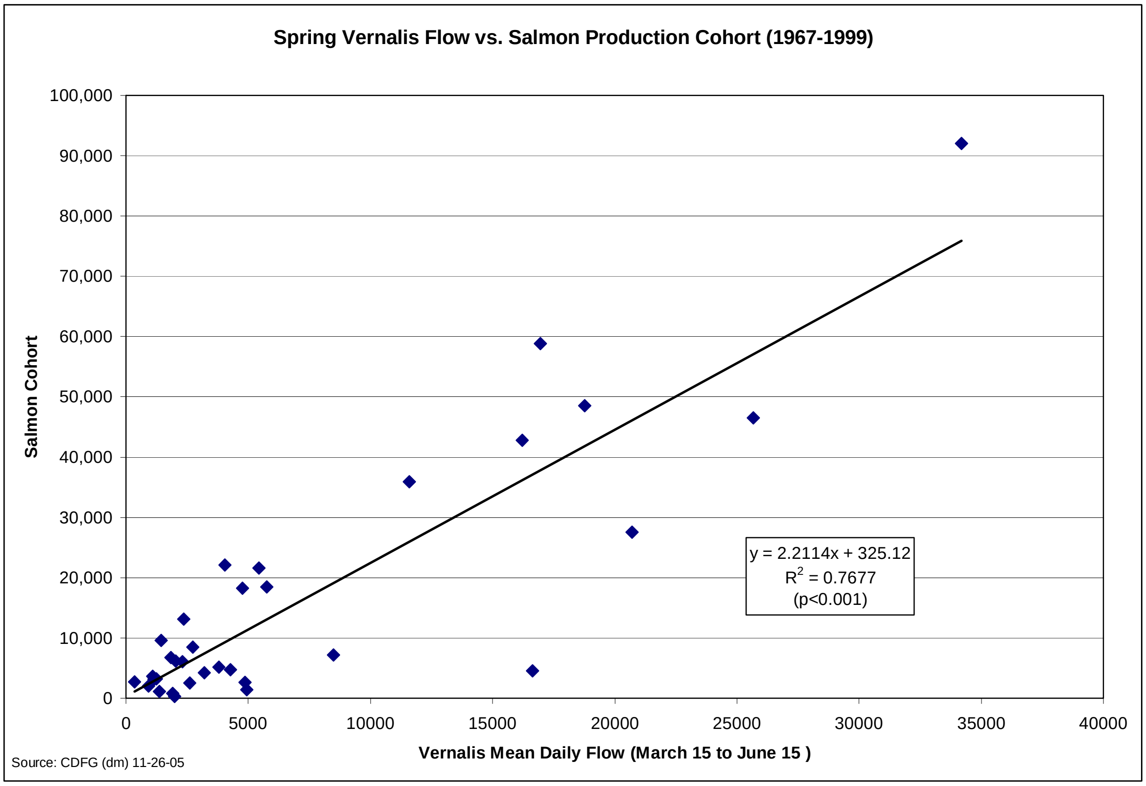

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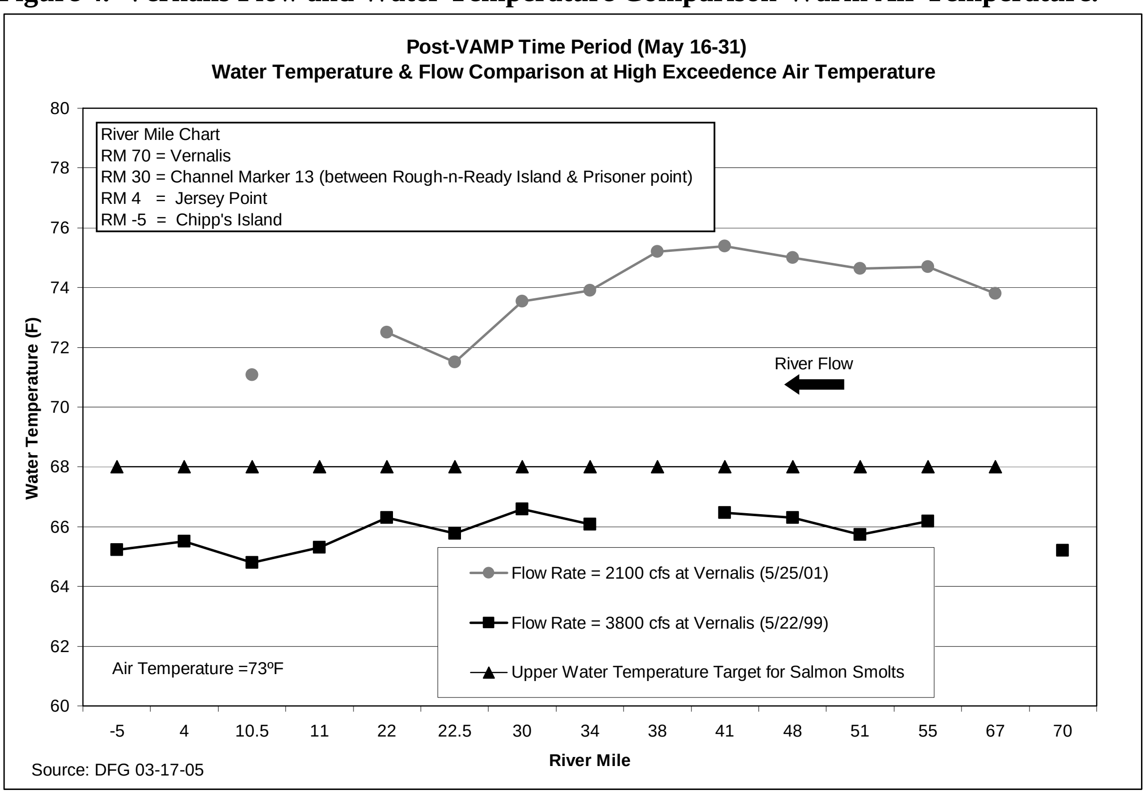

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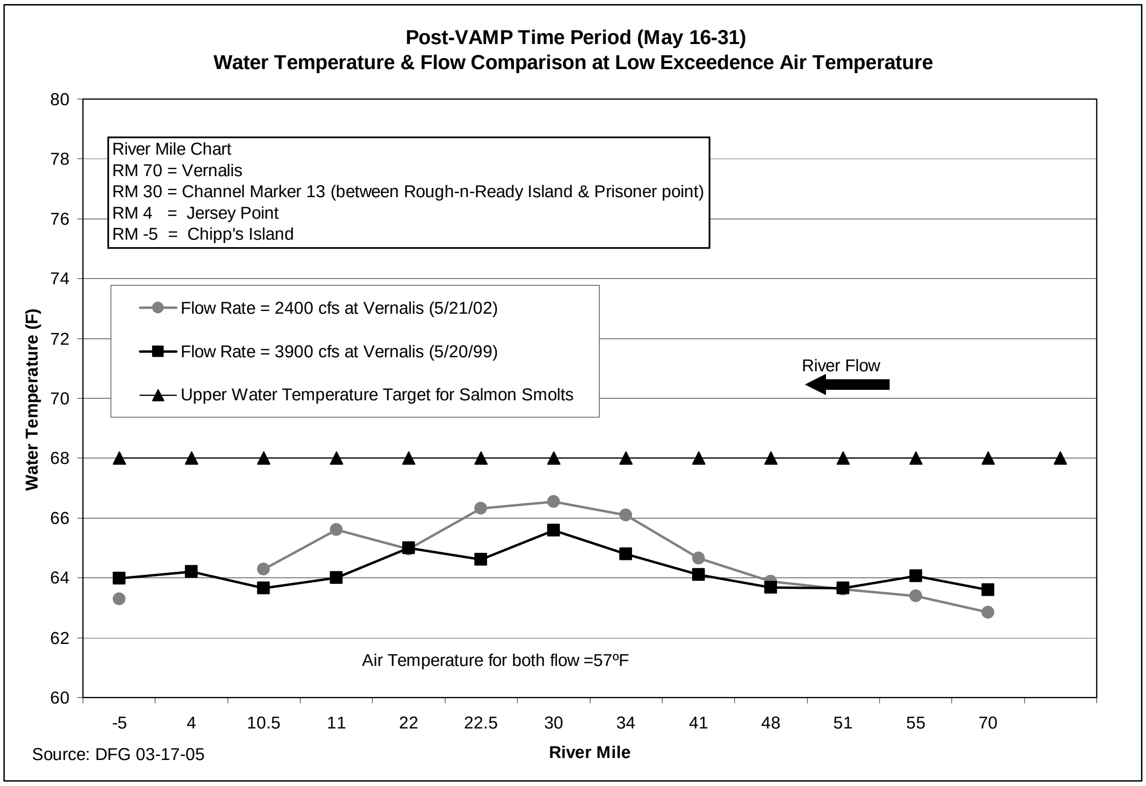

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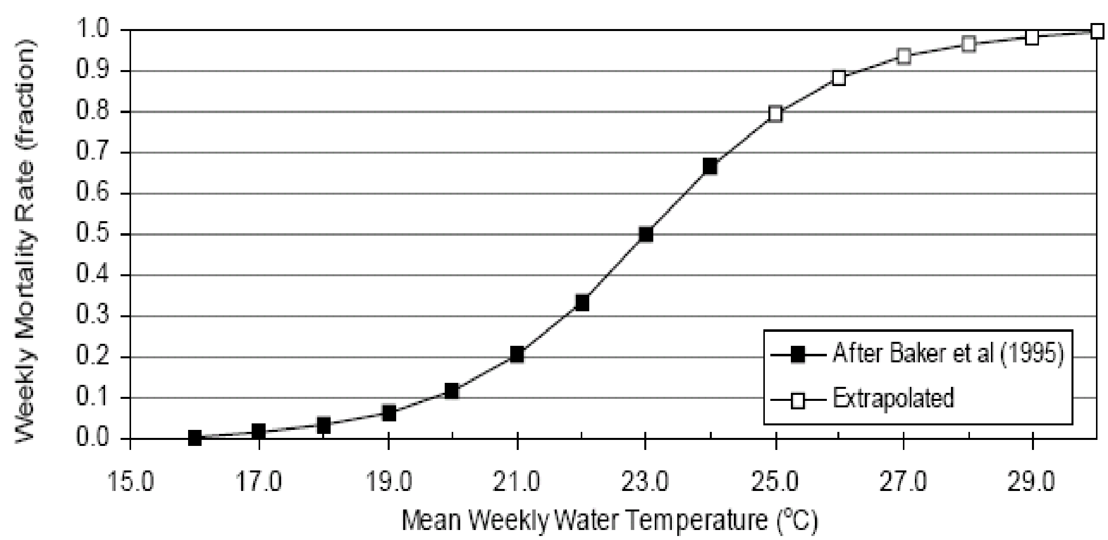

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Source: CALFED Stanislaus Water Temperature Model Peer Review Panel Report--2004

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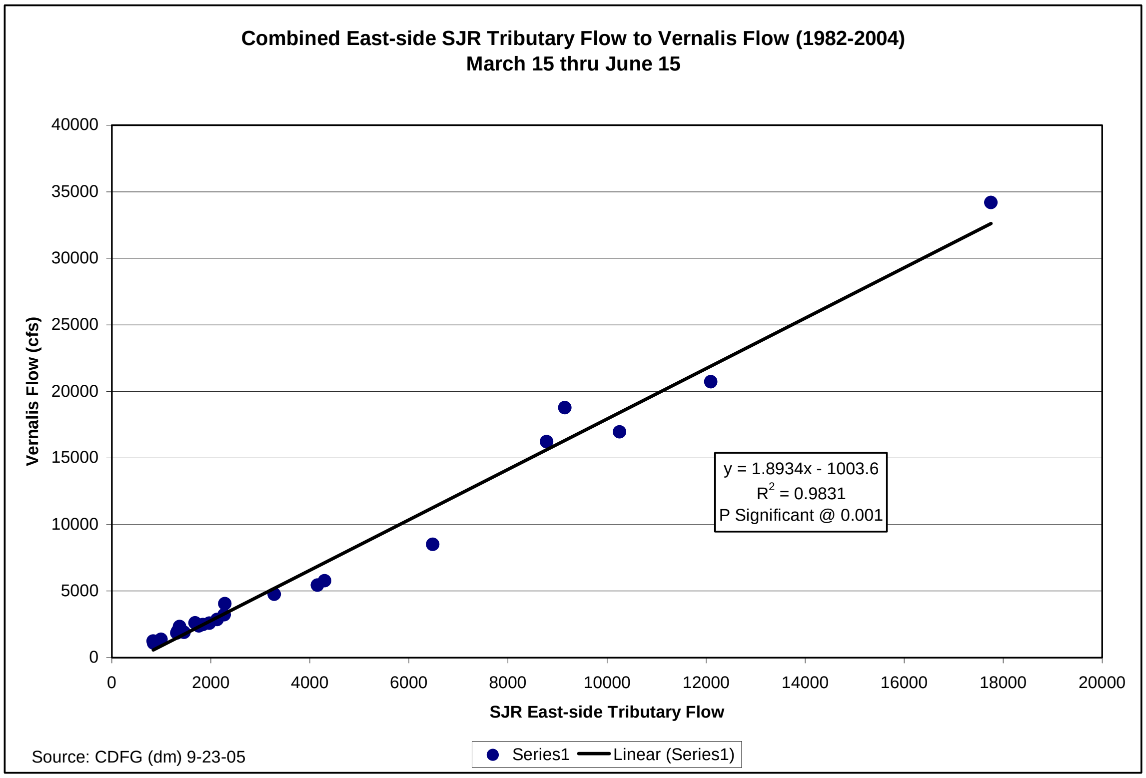

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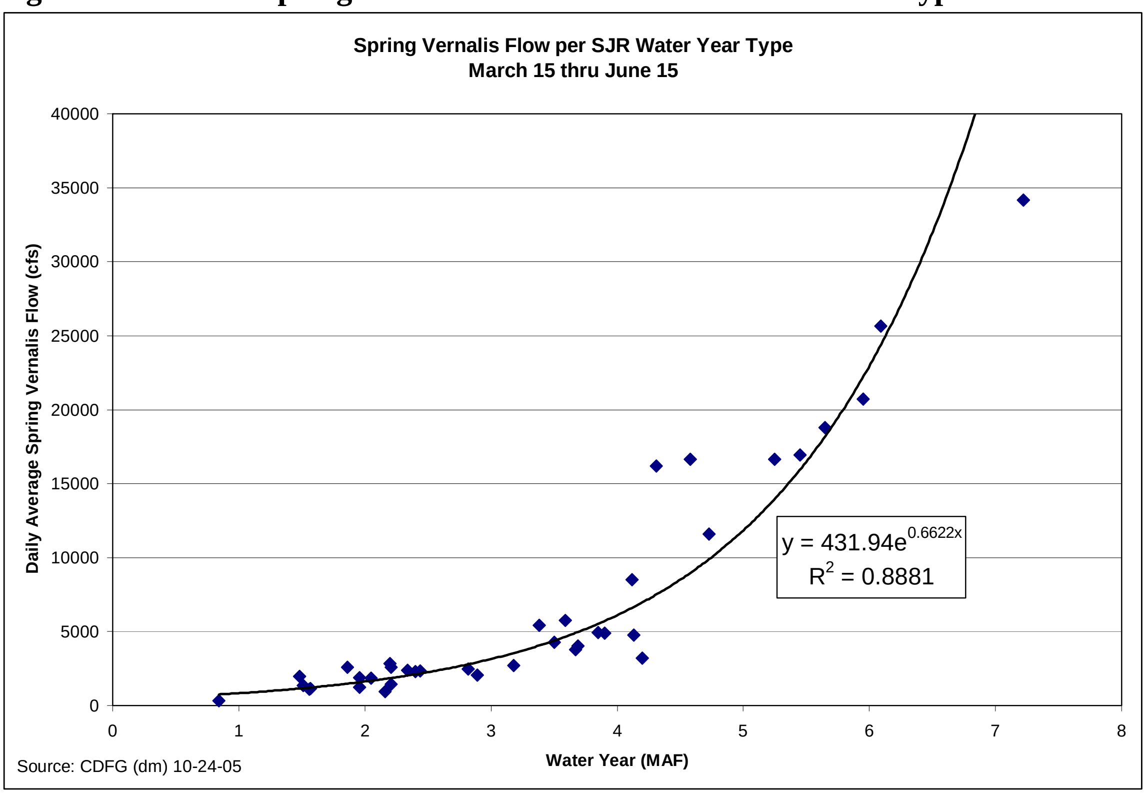

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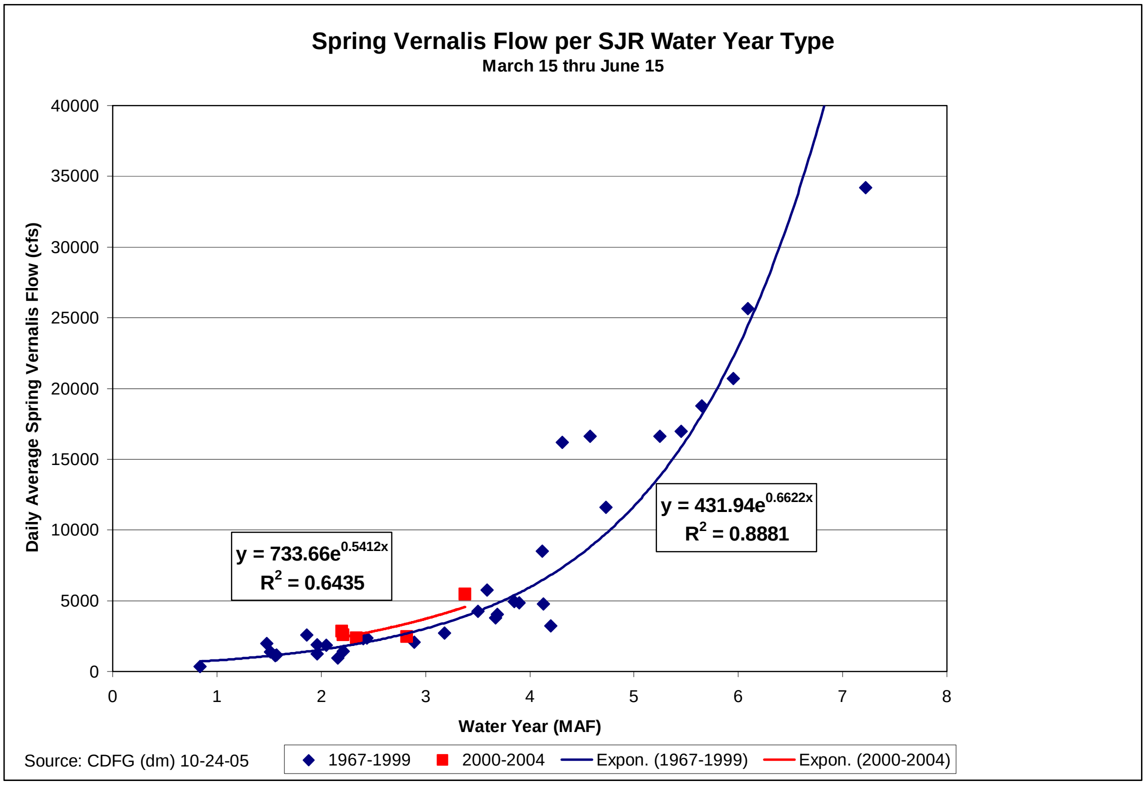

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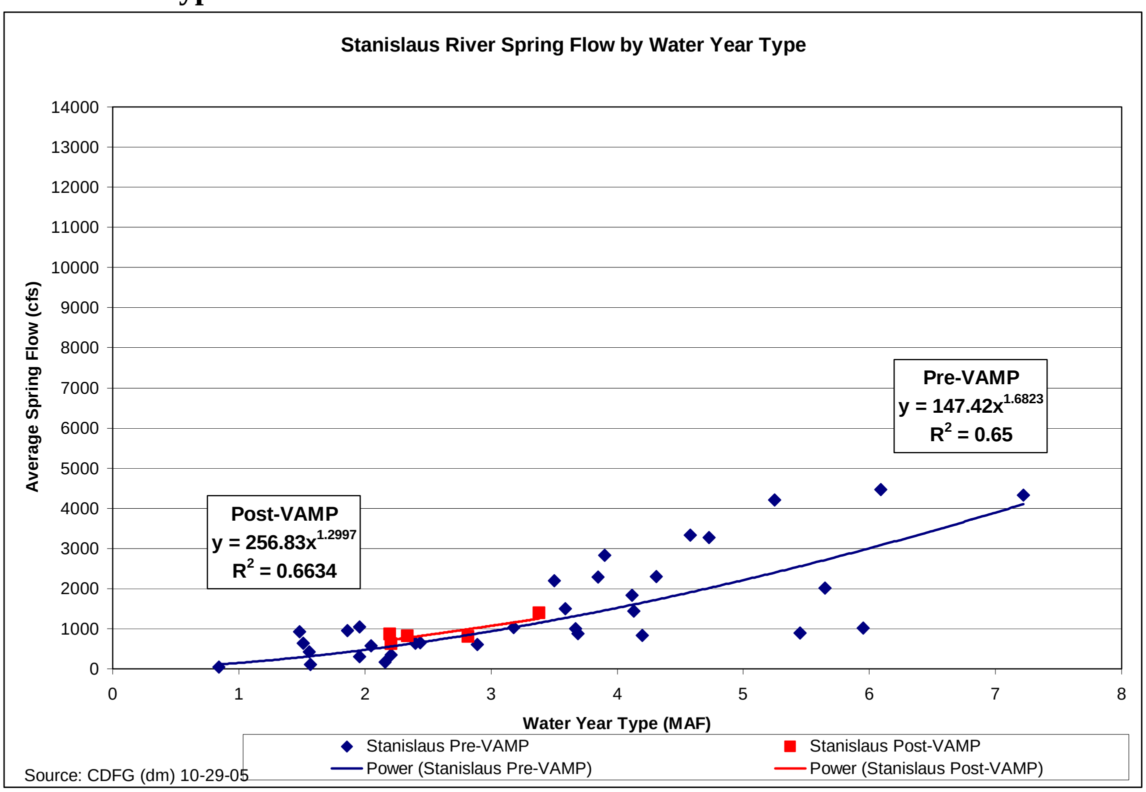

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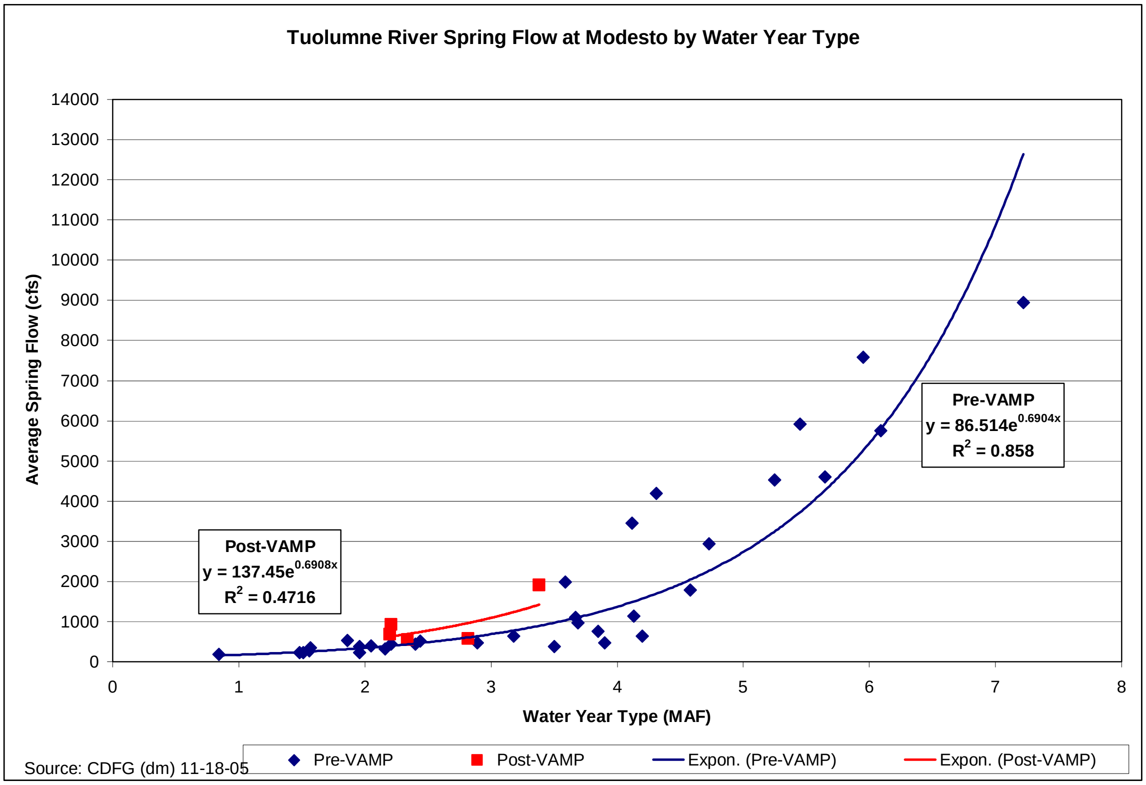

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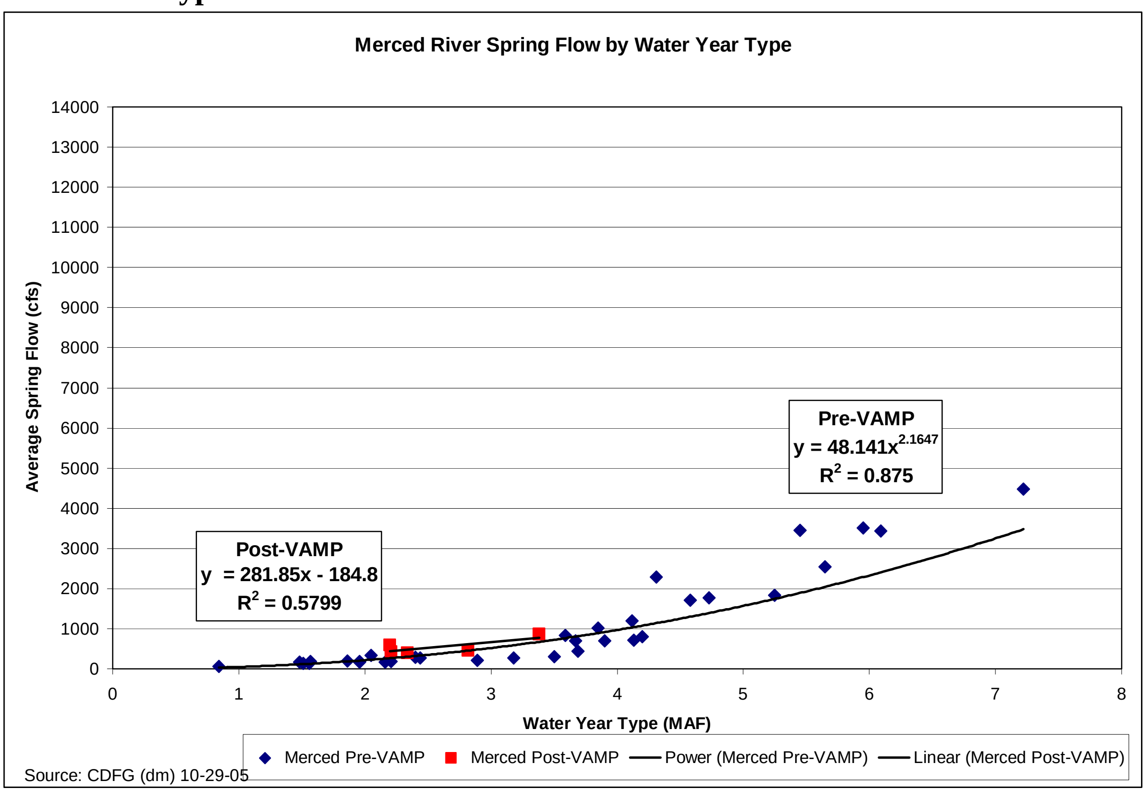

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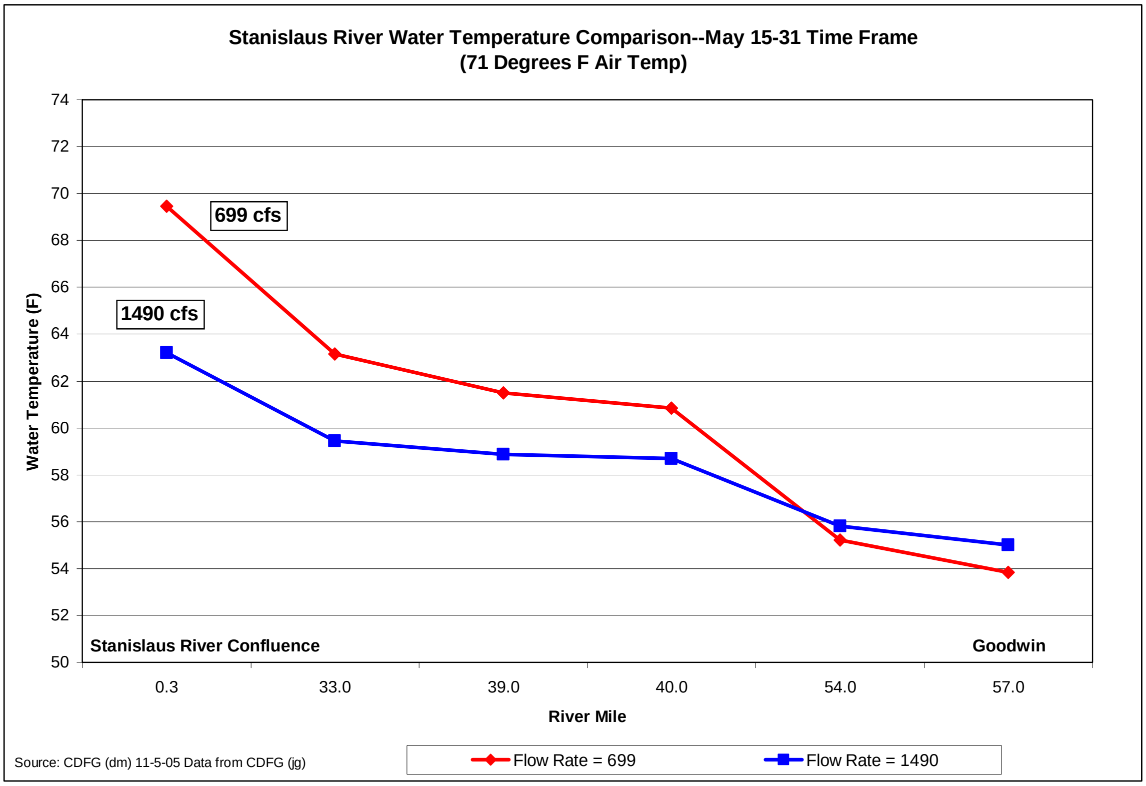

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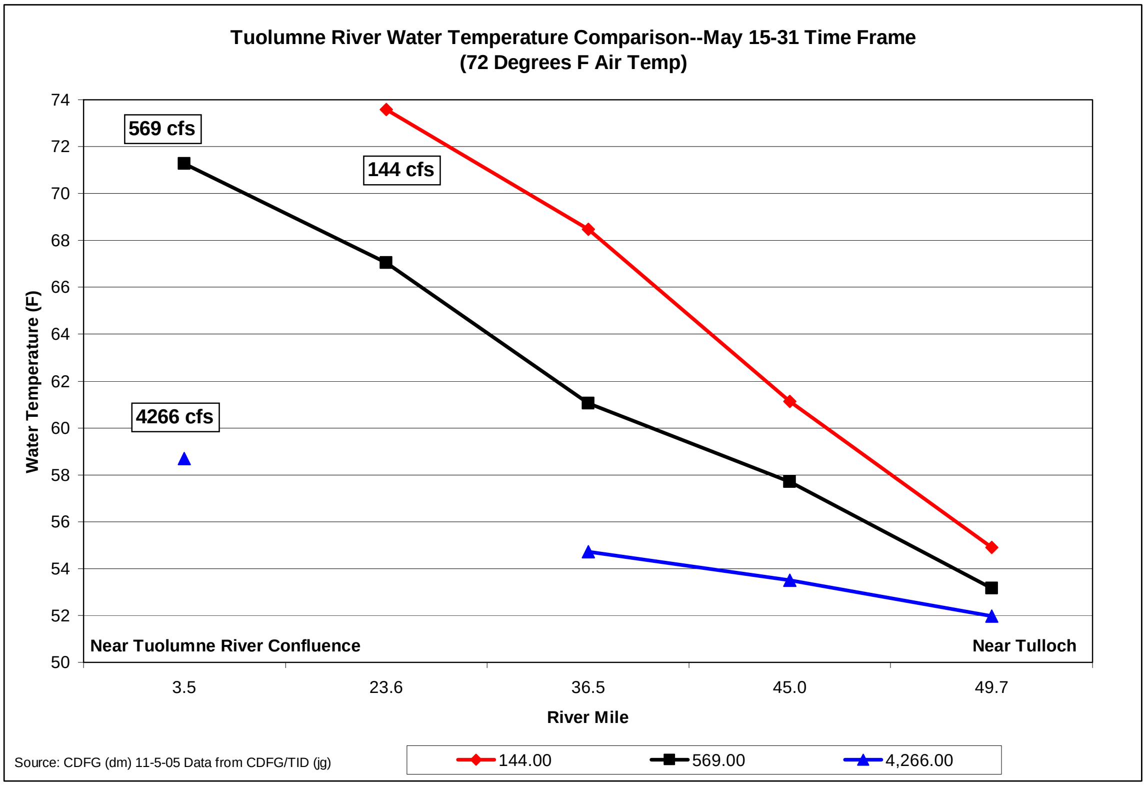

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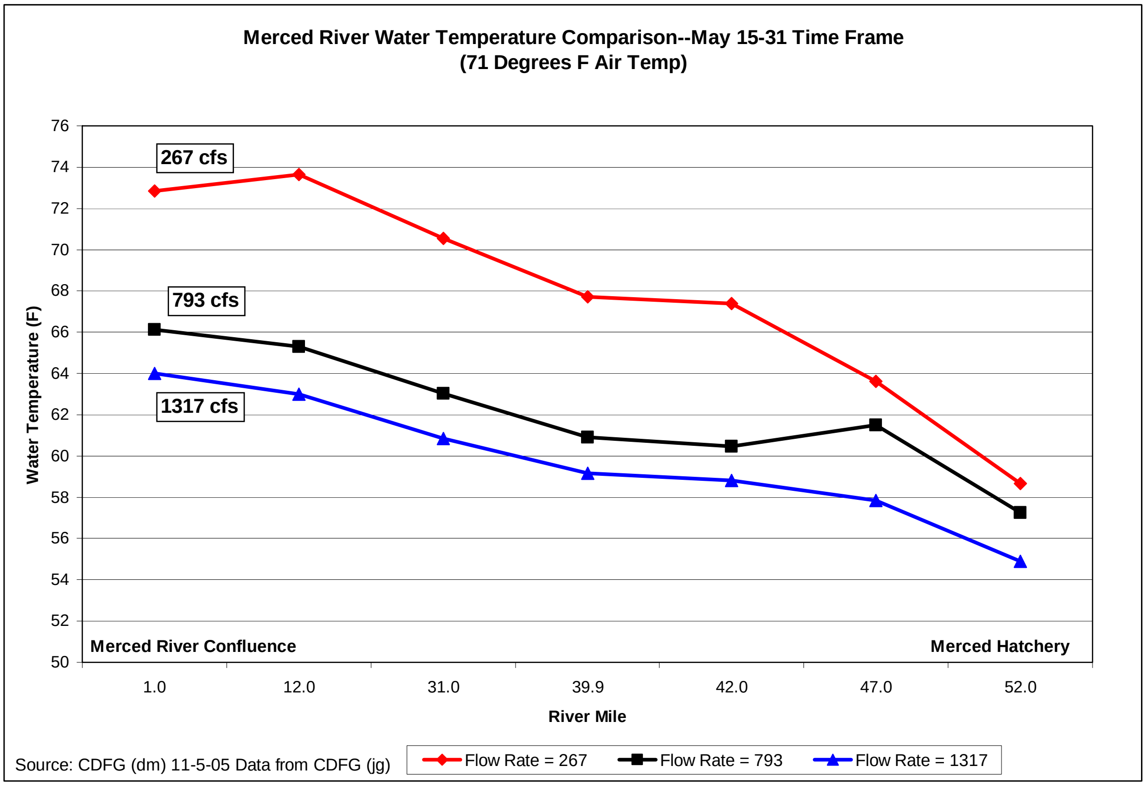

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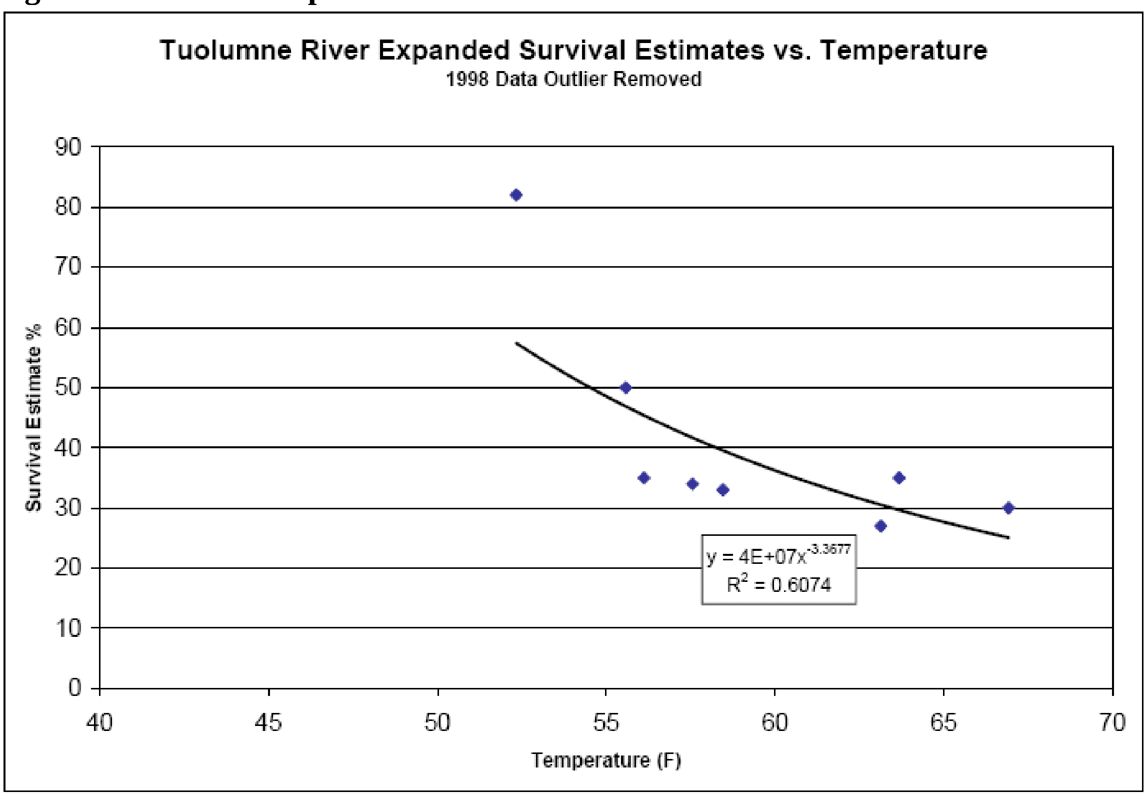

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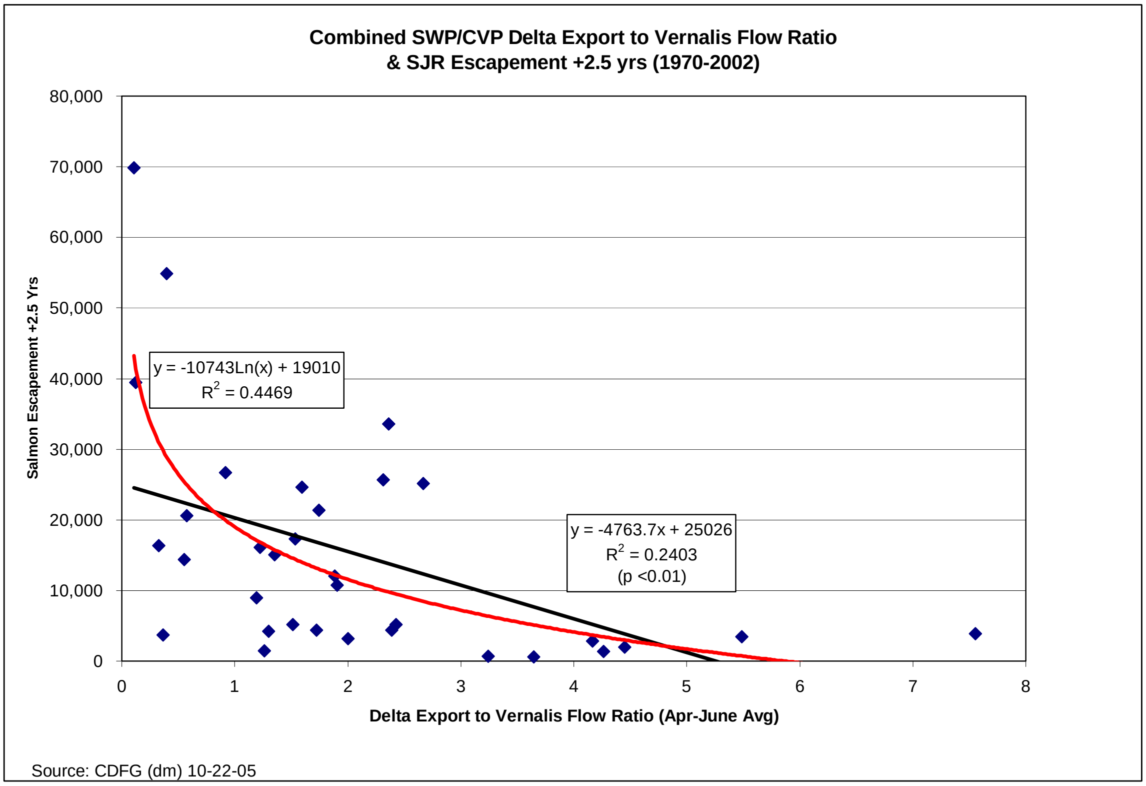

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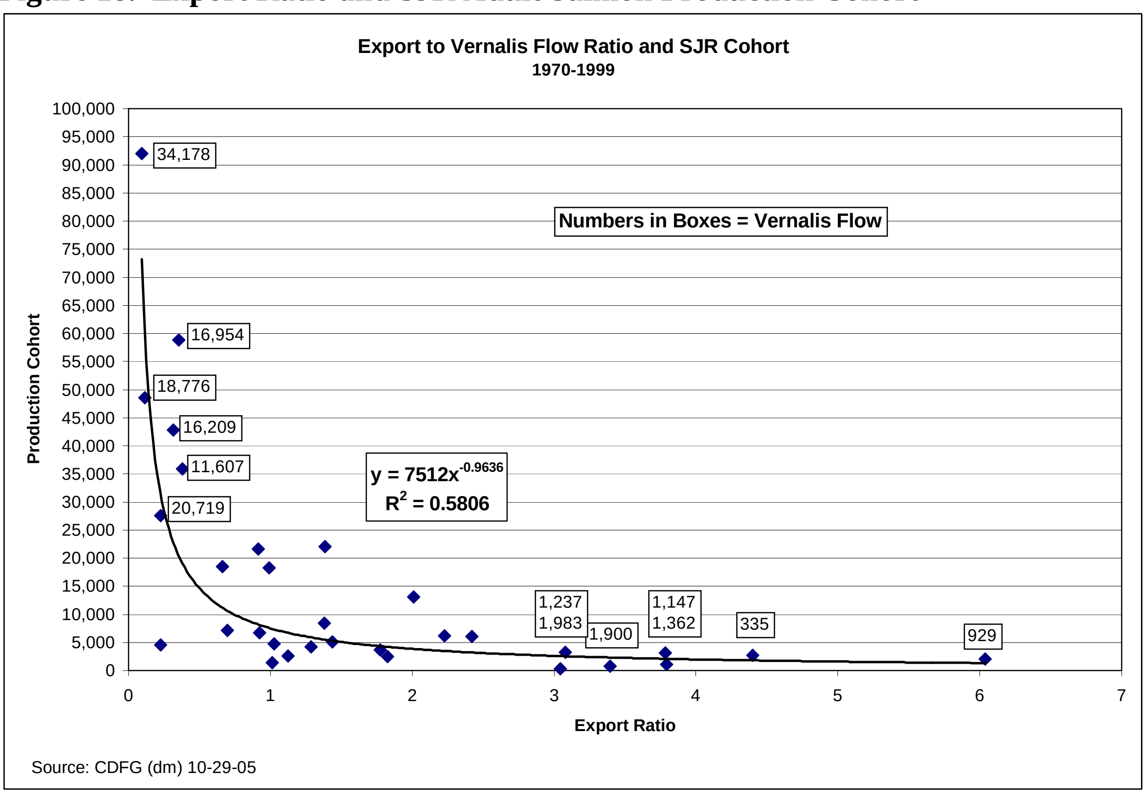

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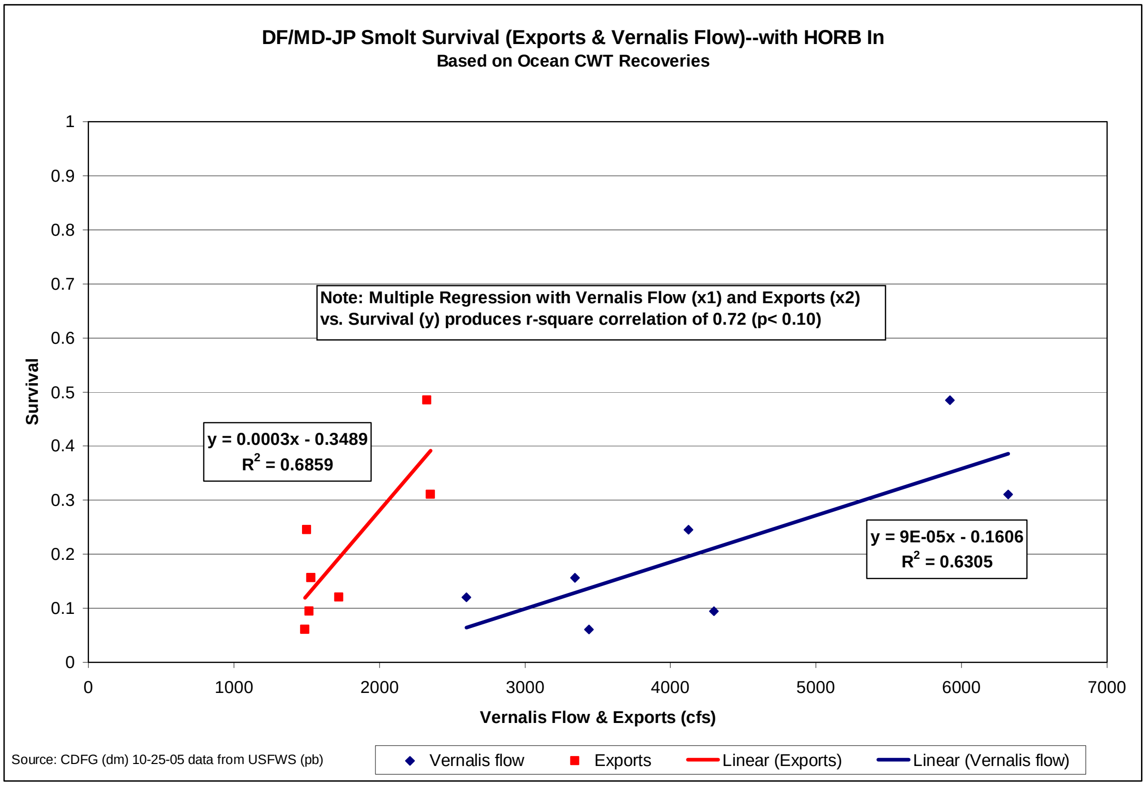

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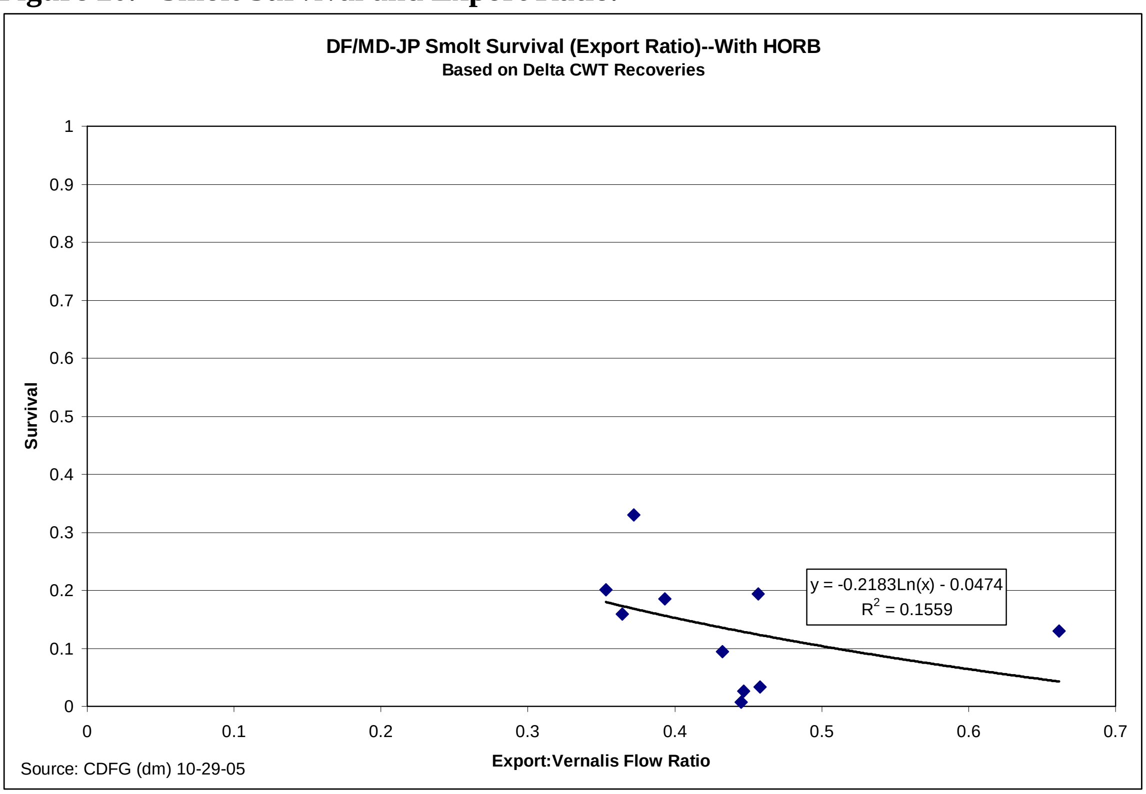

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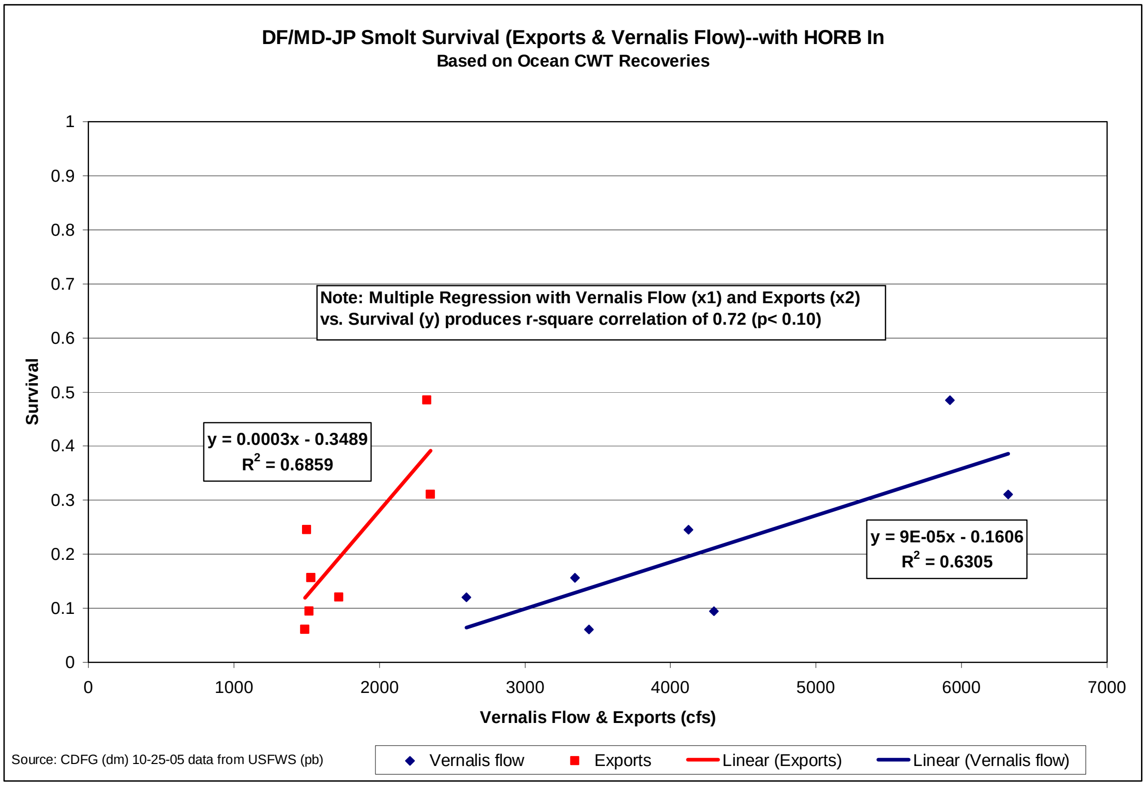

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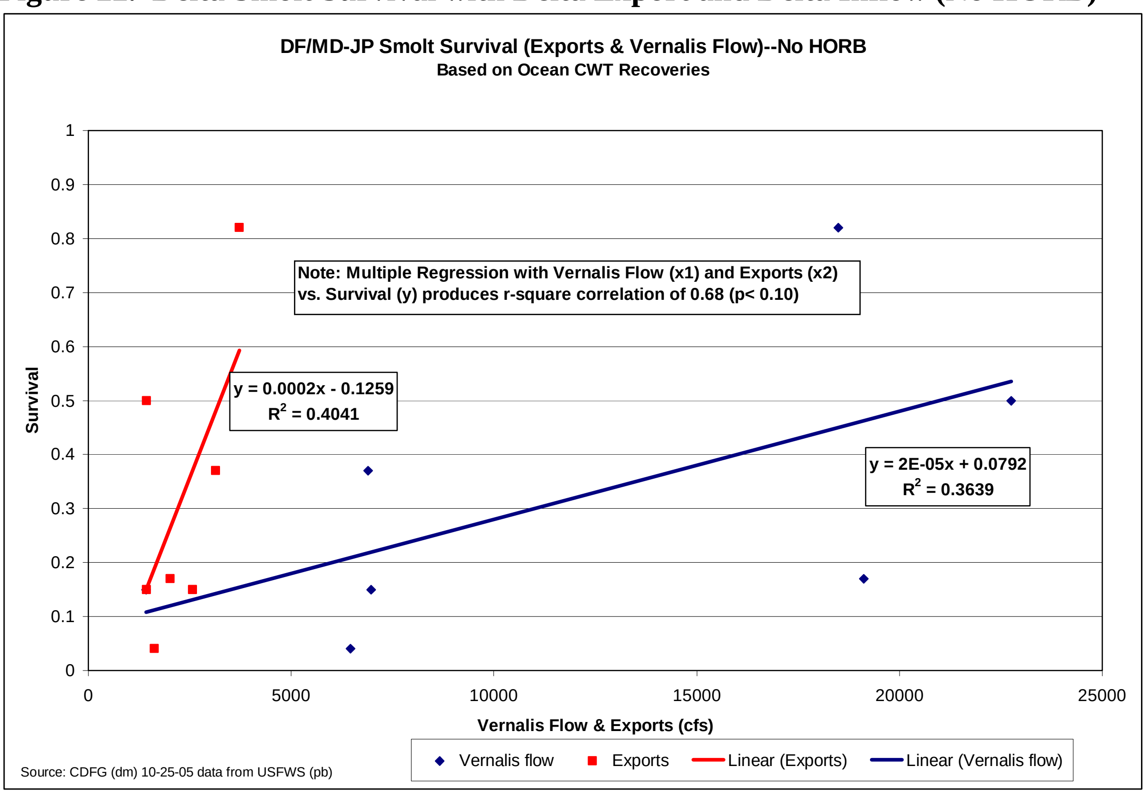

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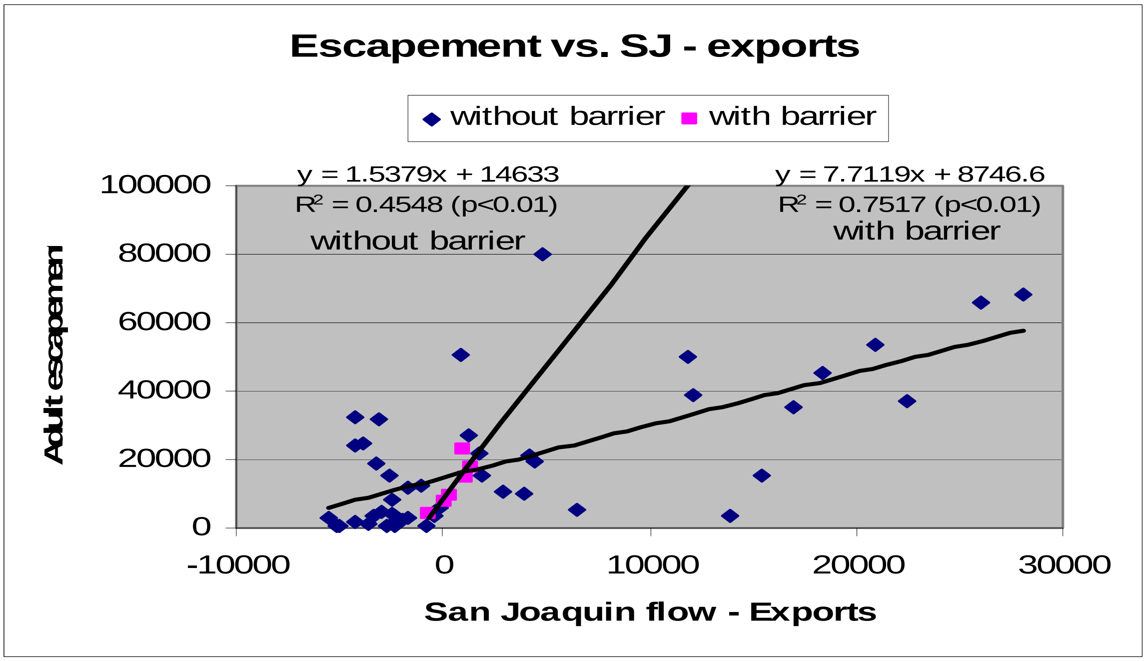

Note: Figure from Draft 2005 VAMP Annual Report

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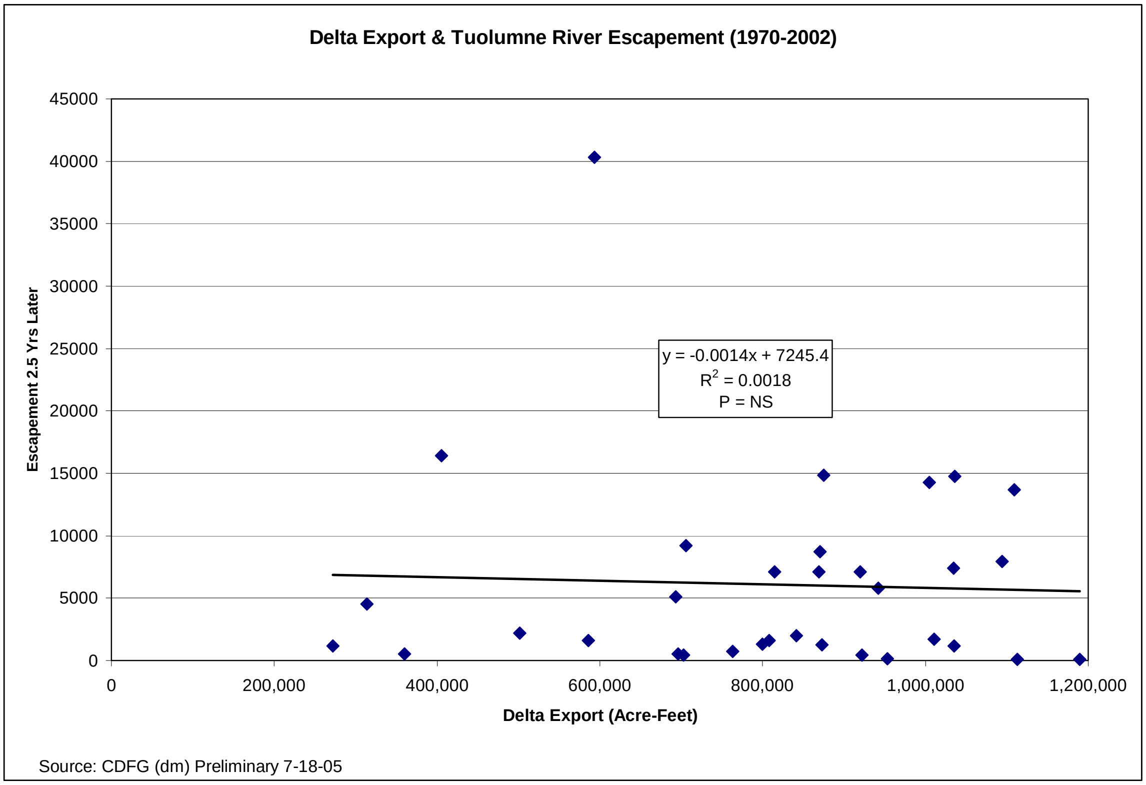

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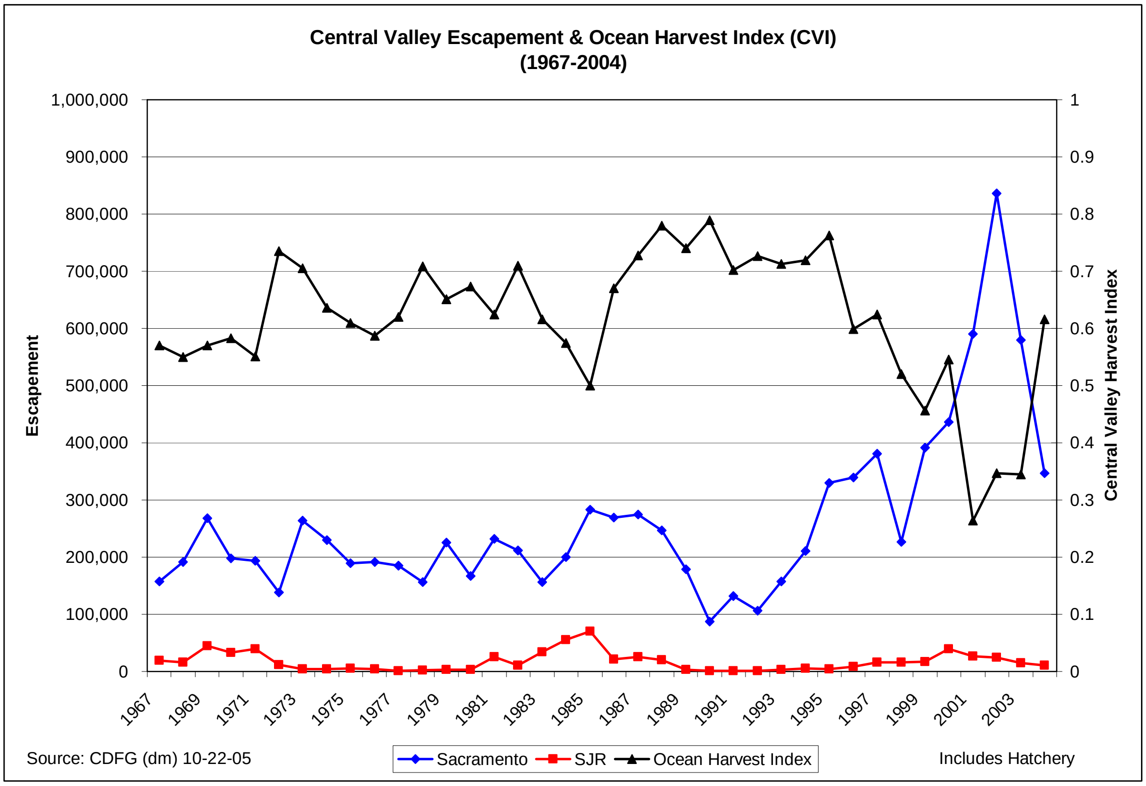

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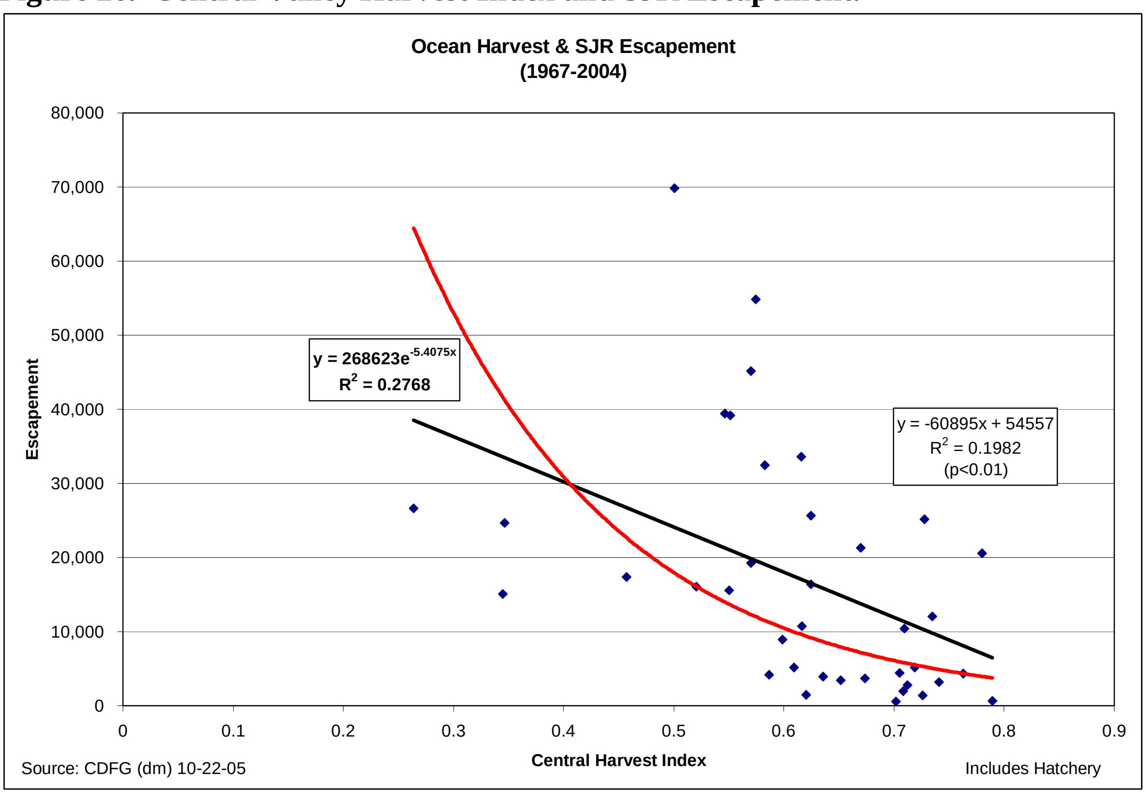

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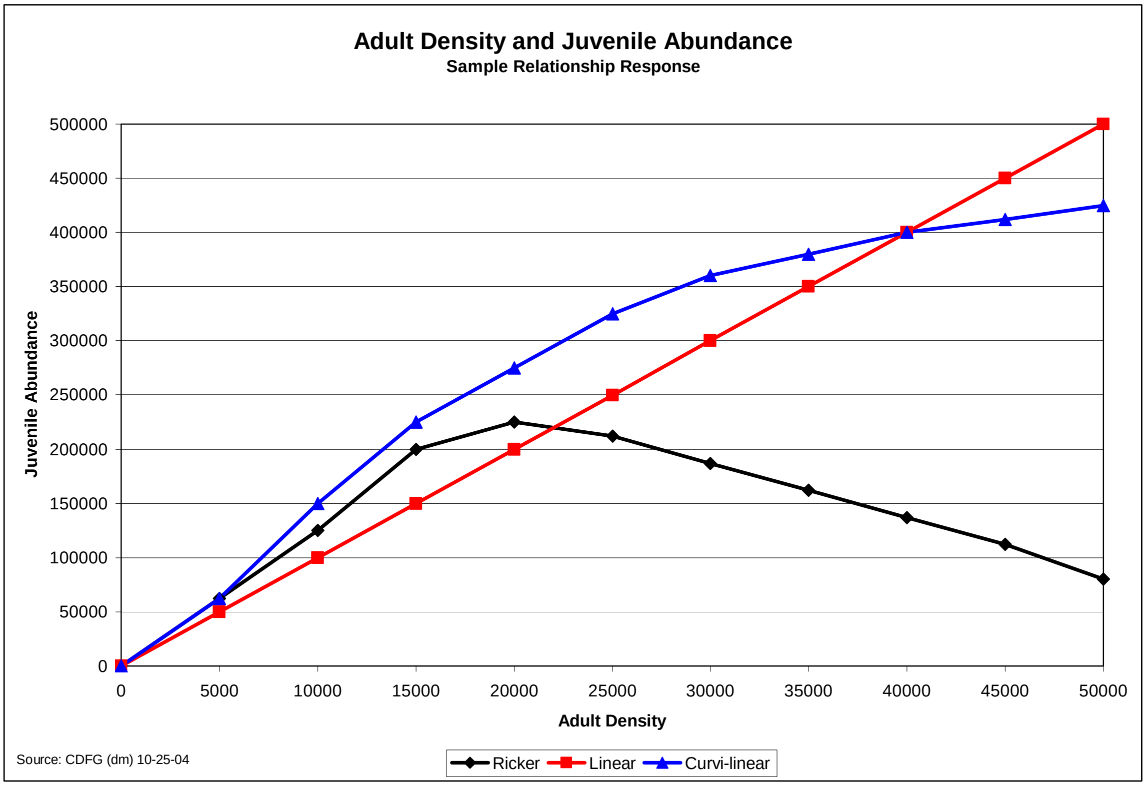

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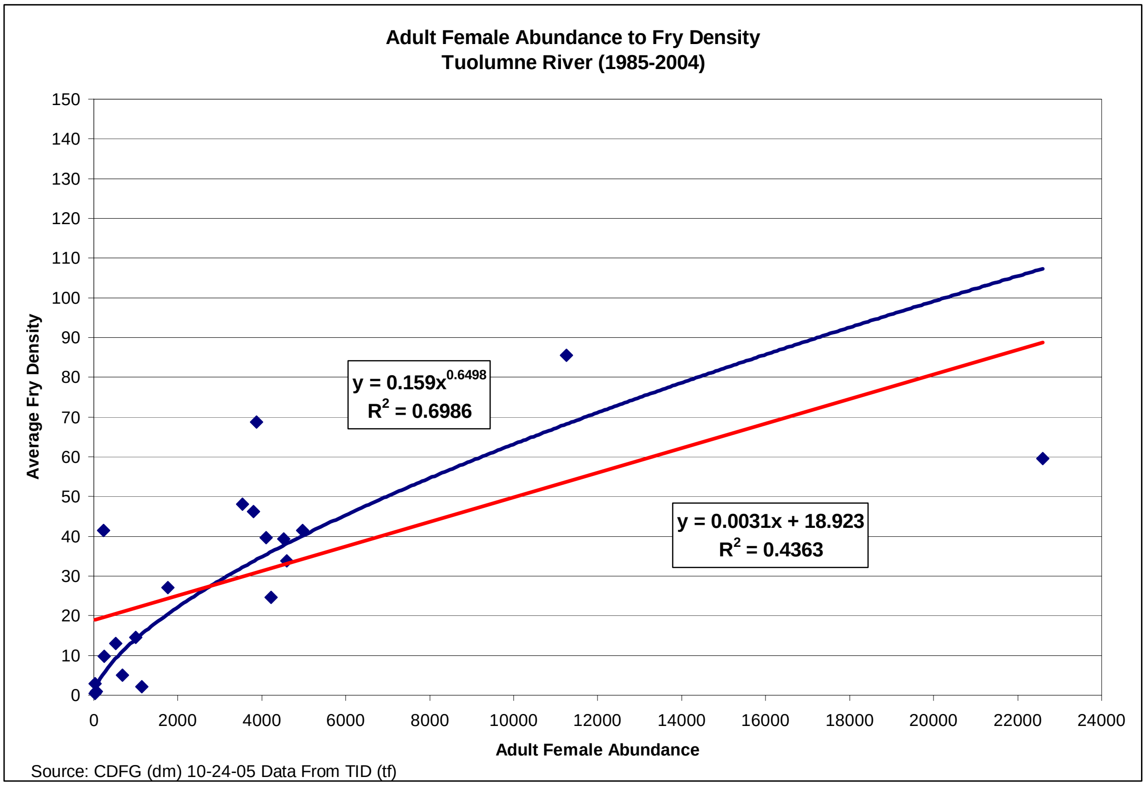

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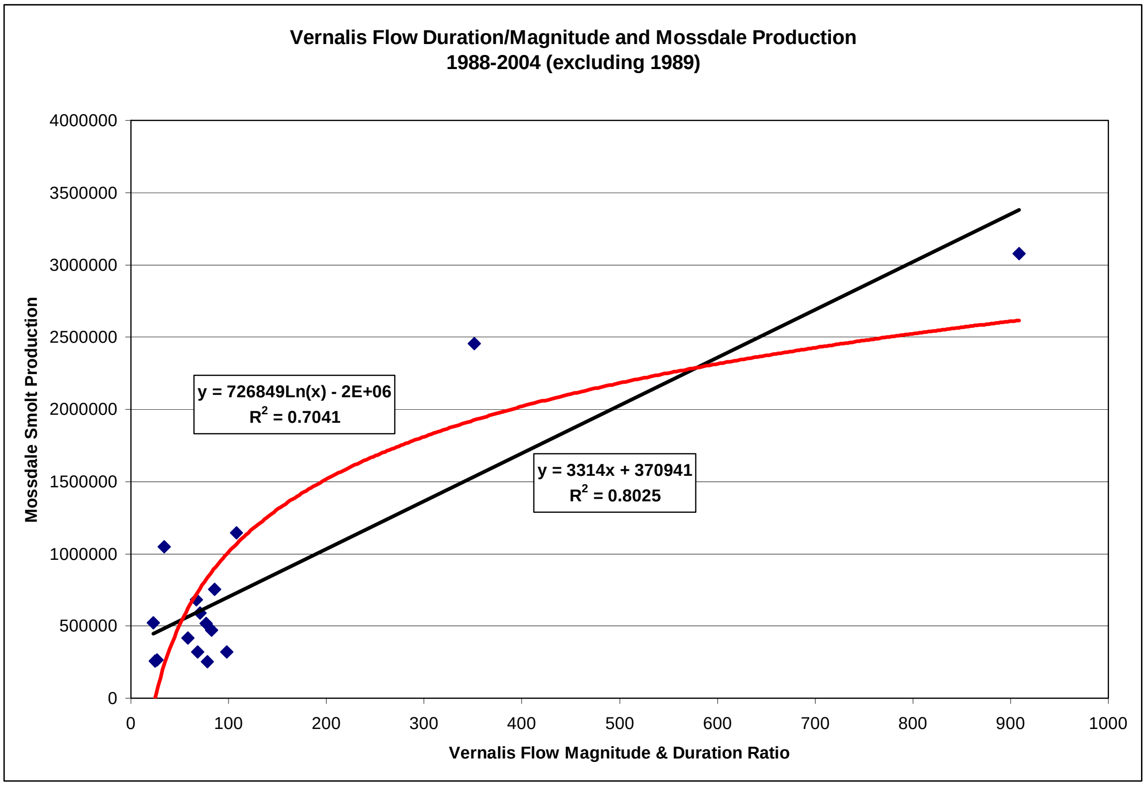

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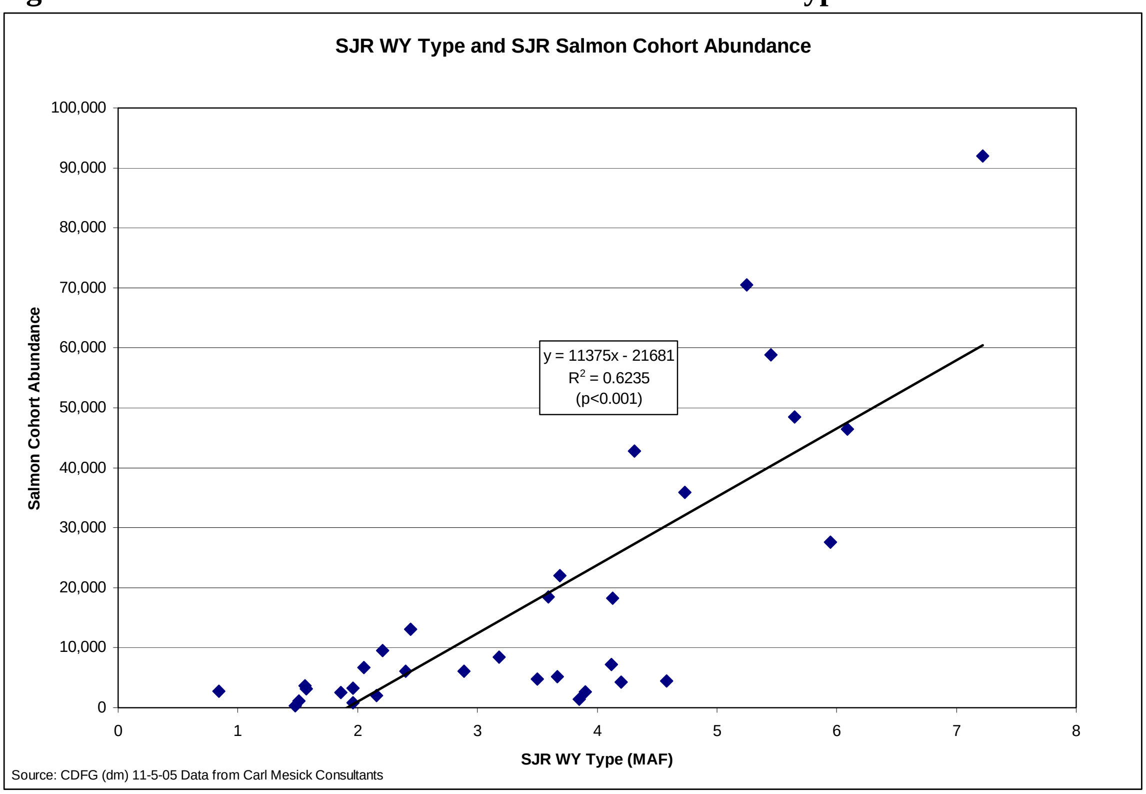

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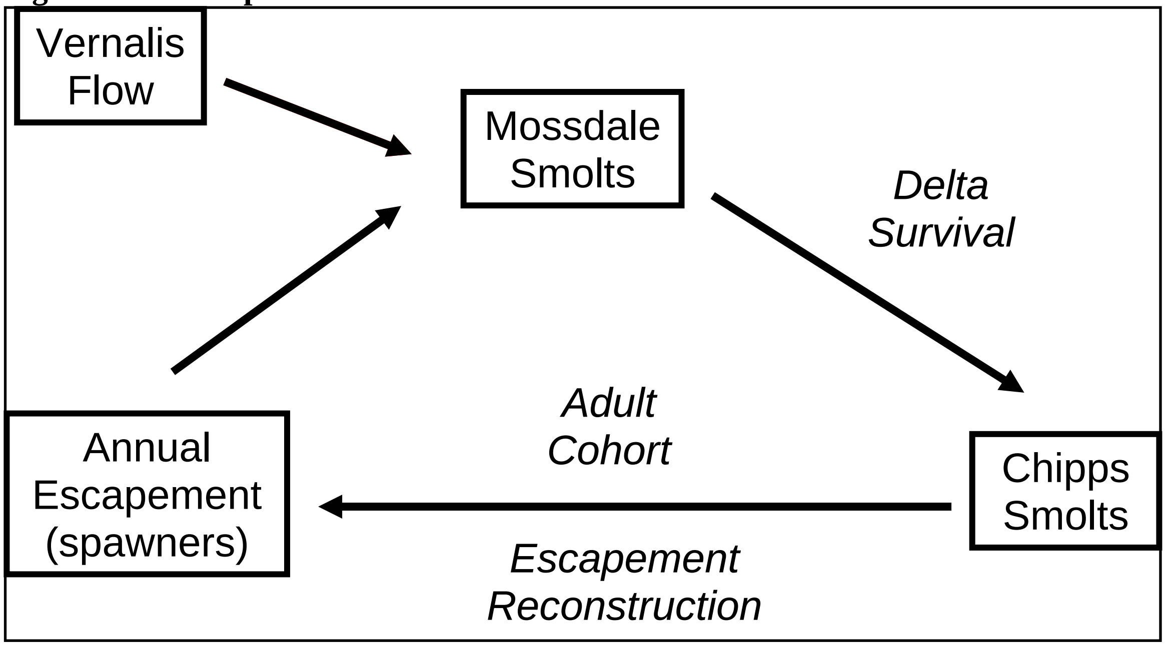

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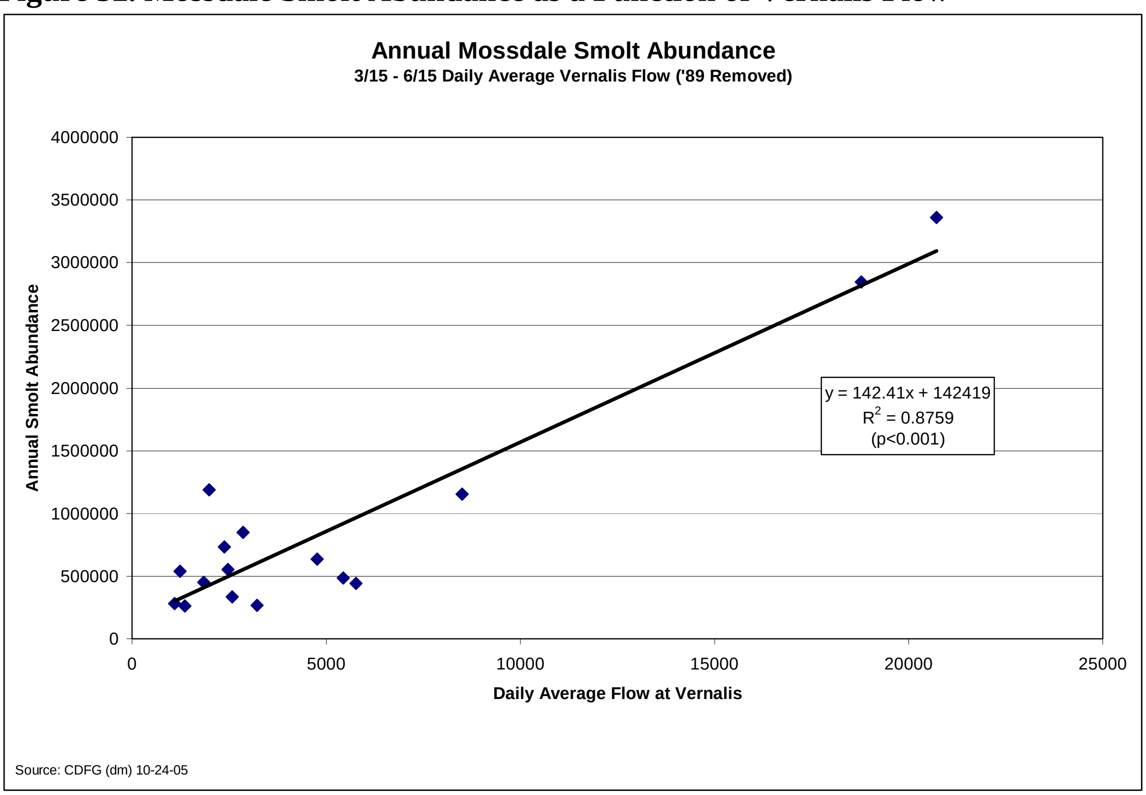

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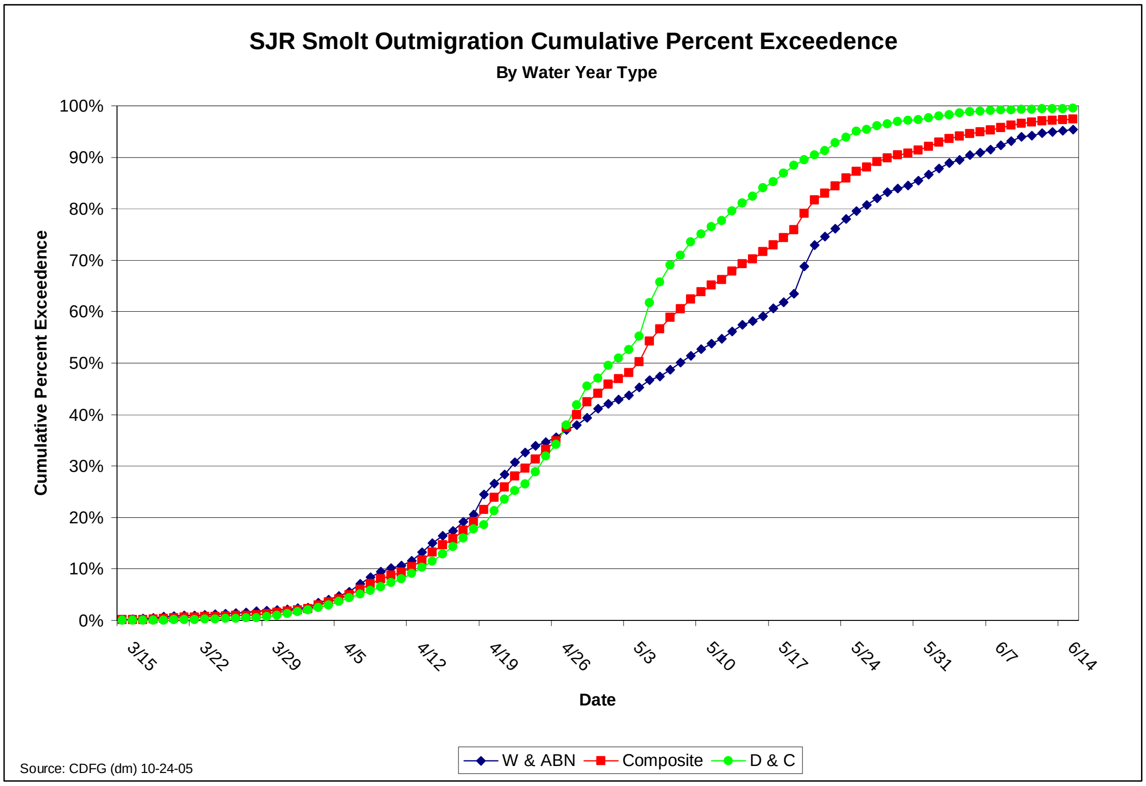

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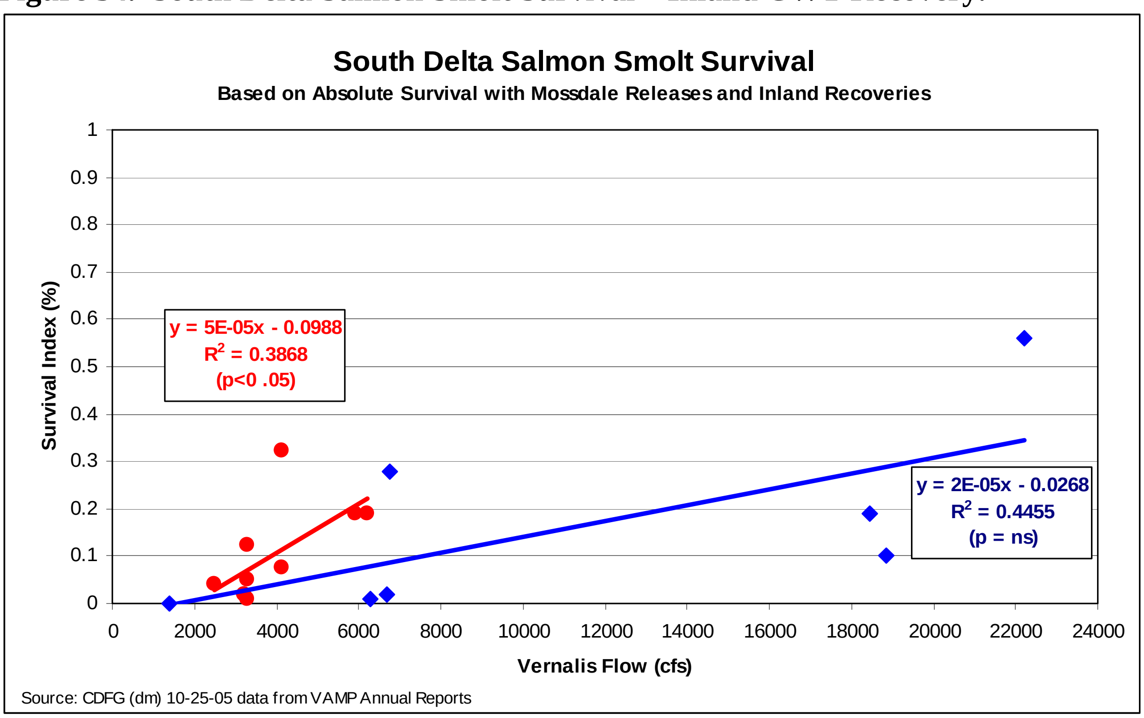

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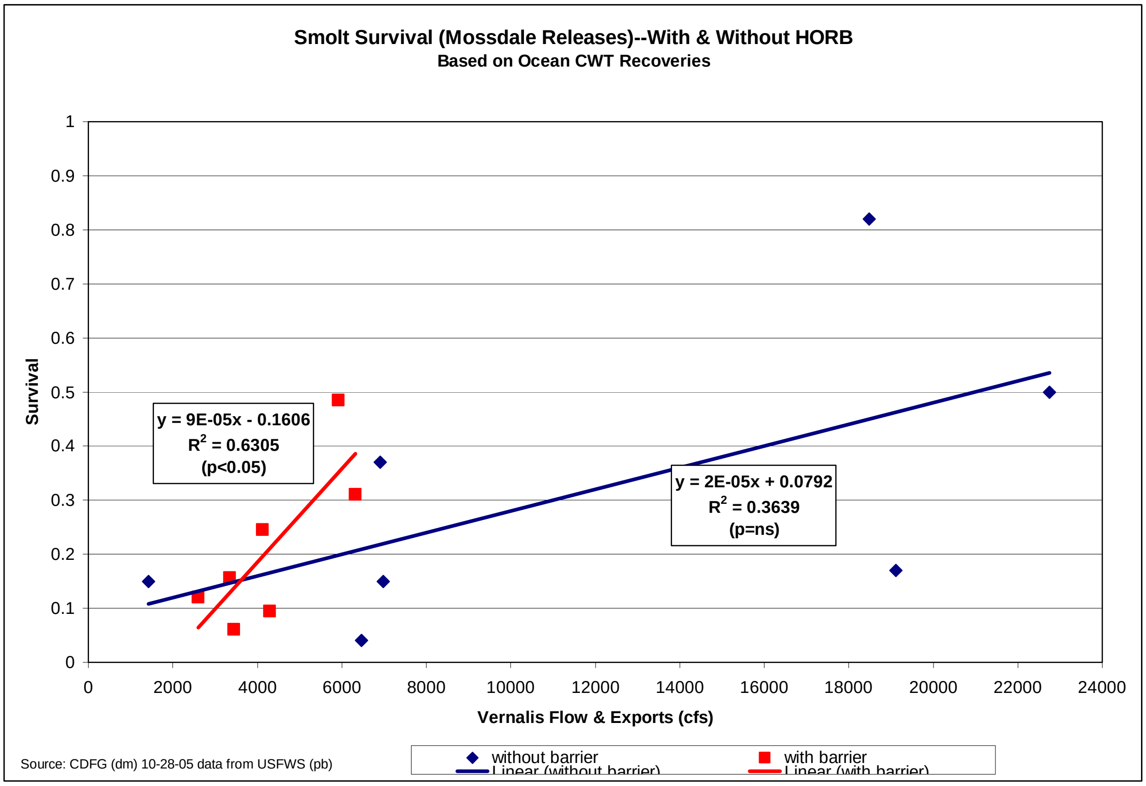

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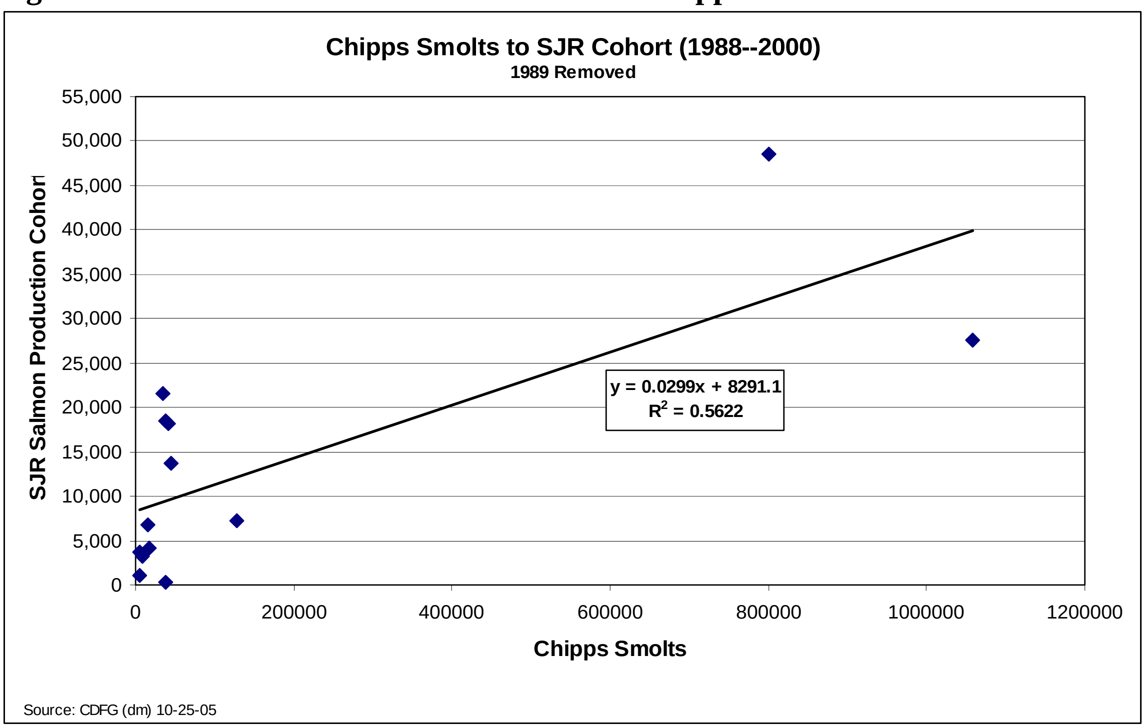

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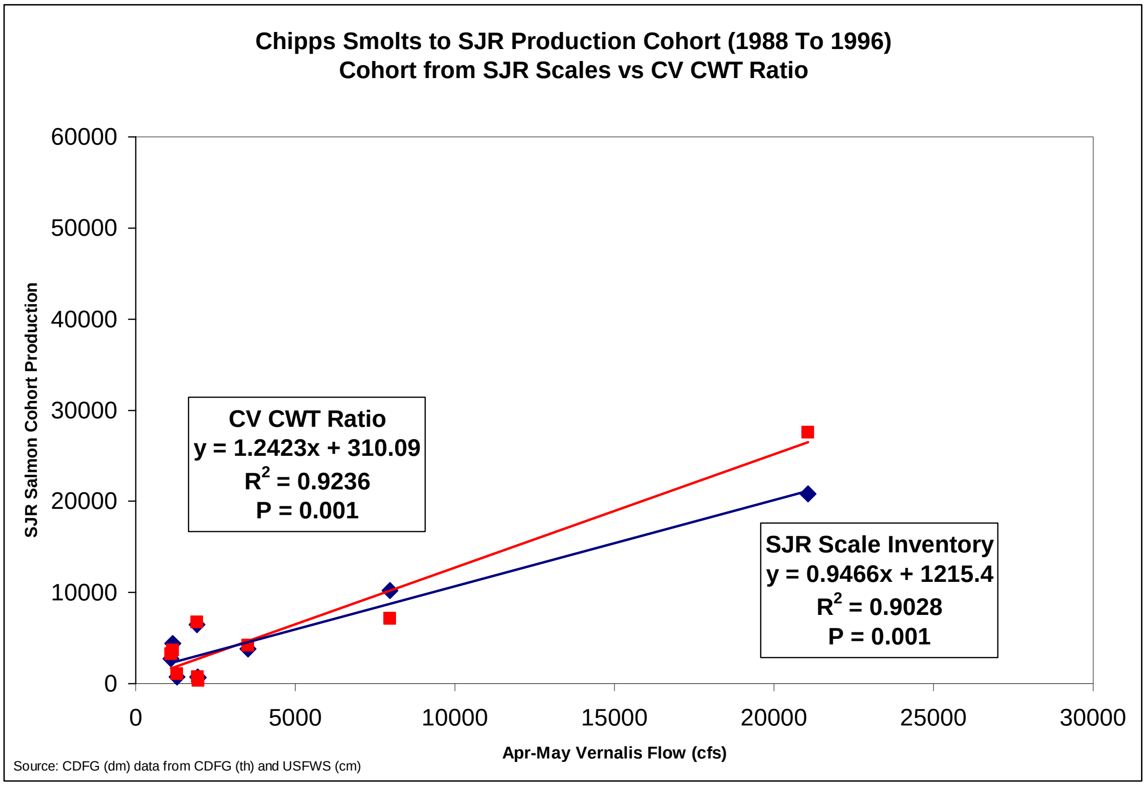

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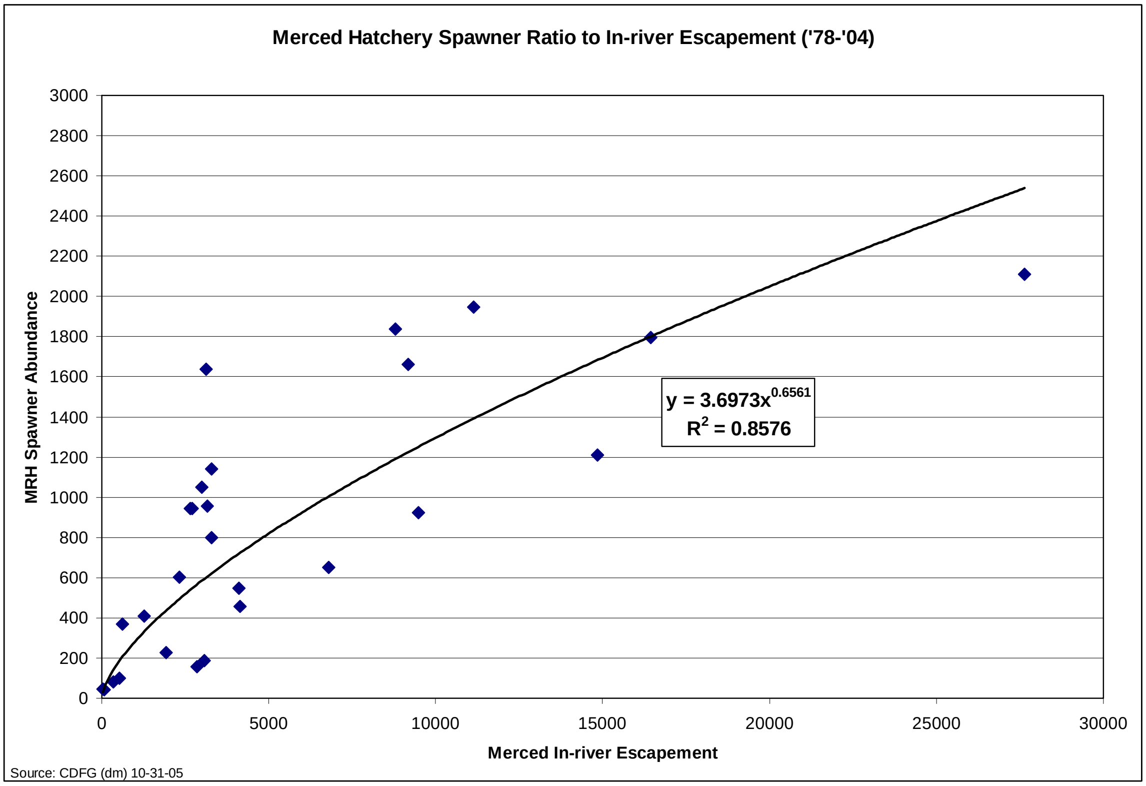

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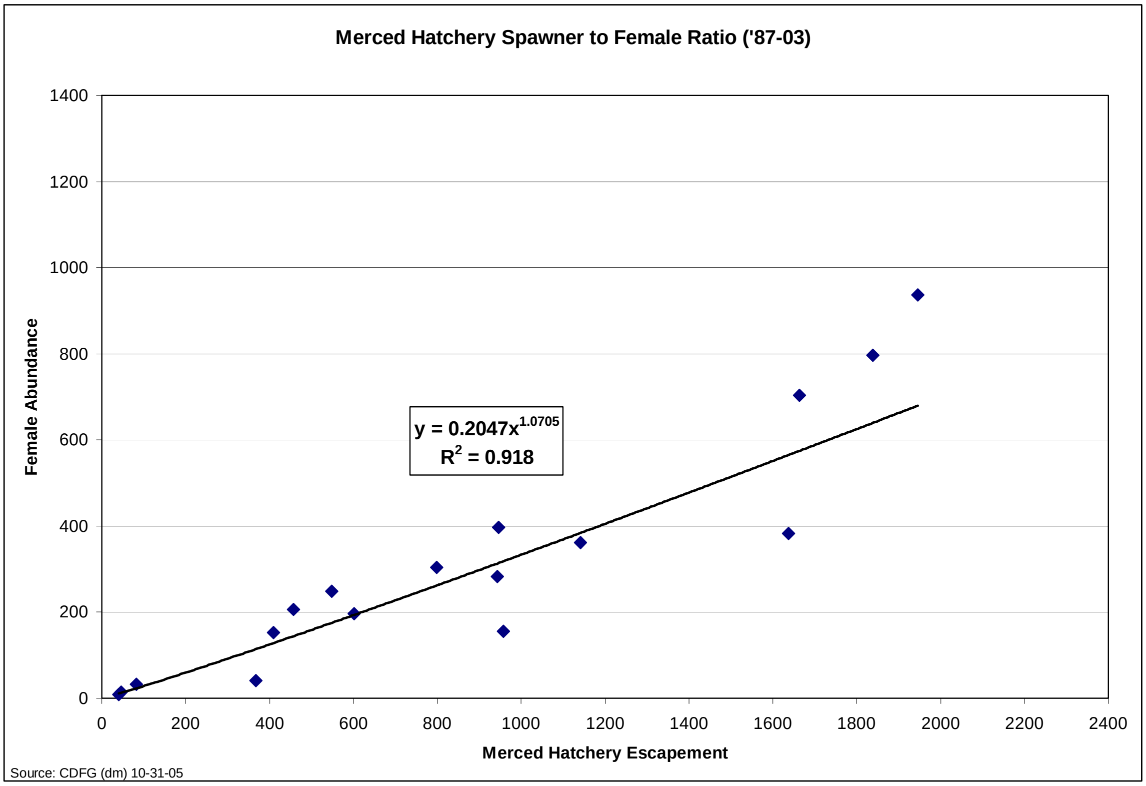

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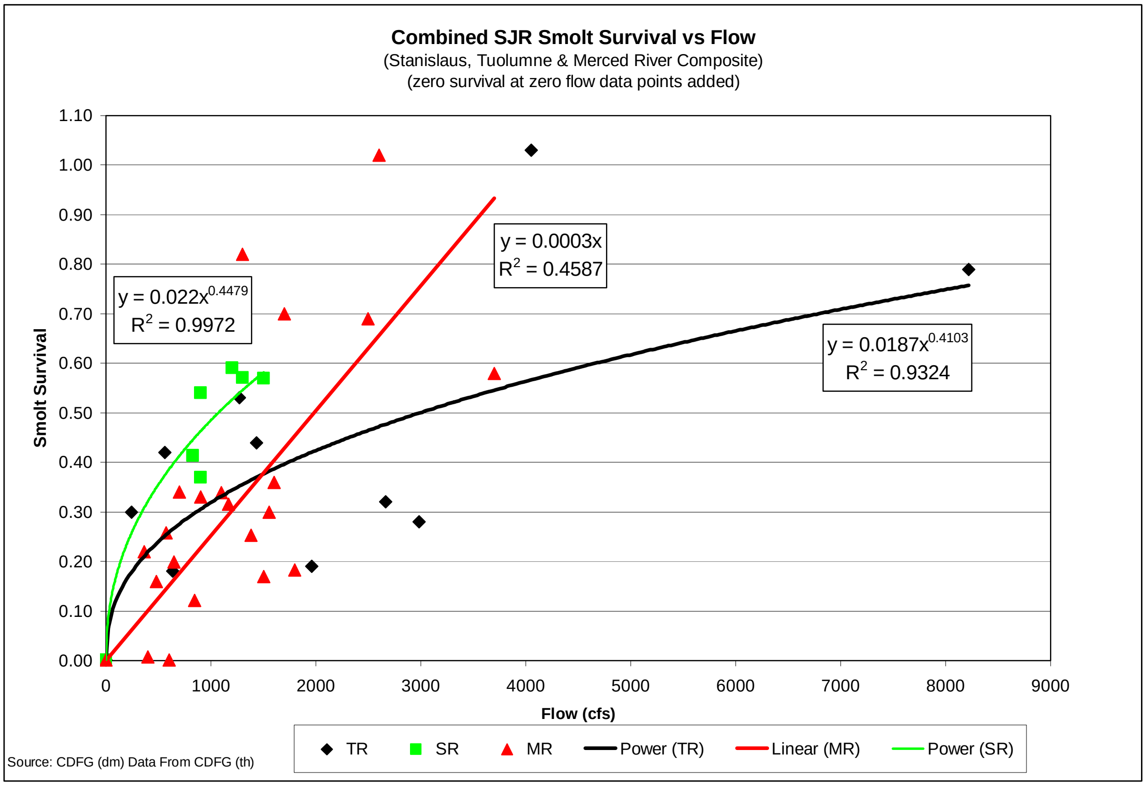

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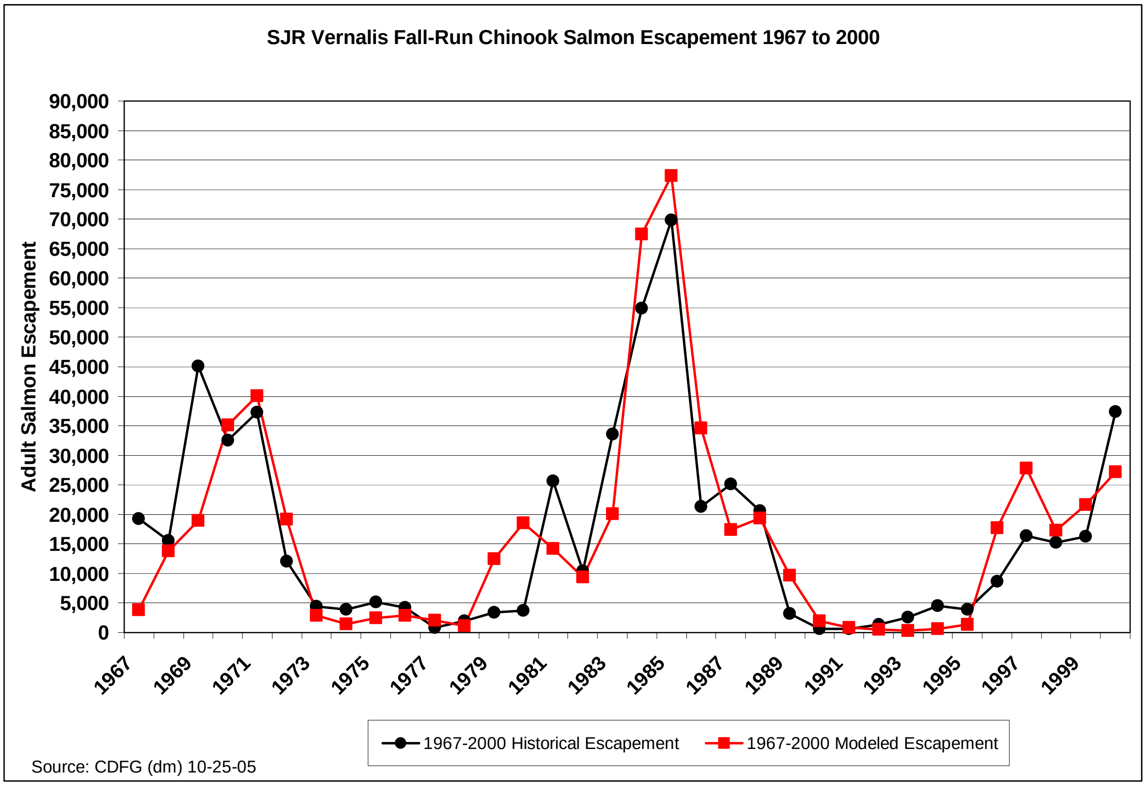

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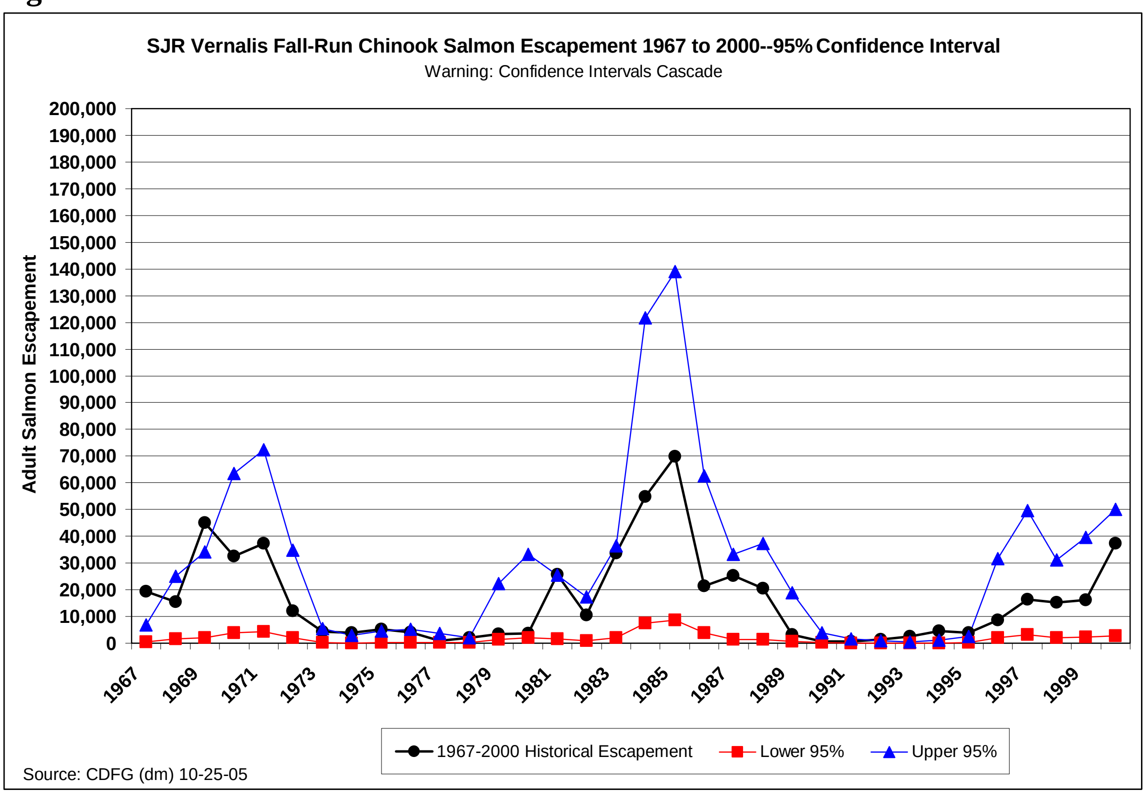

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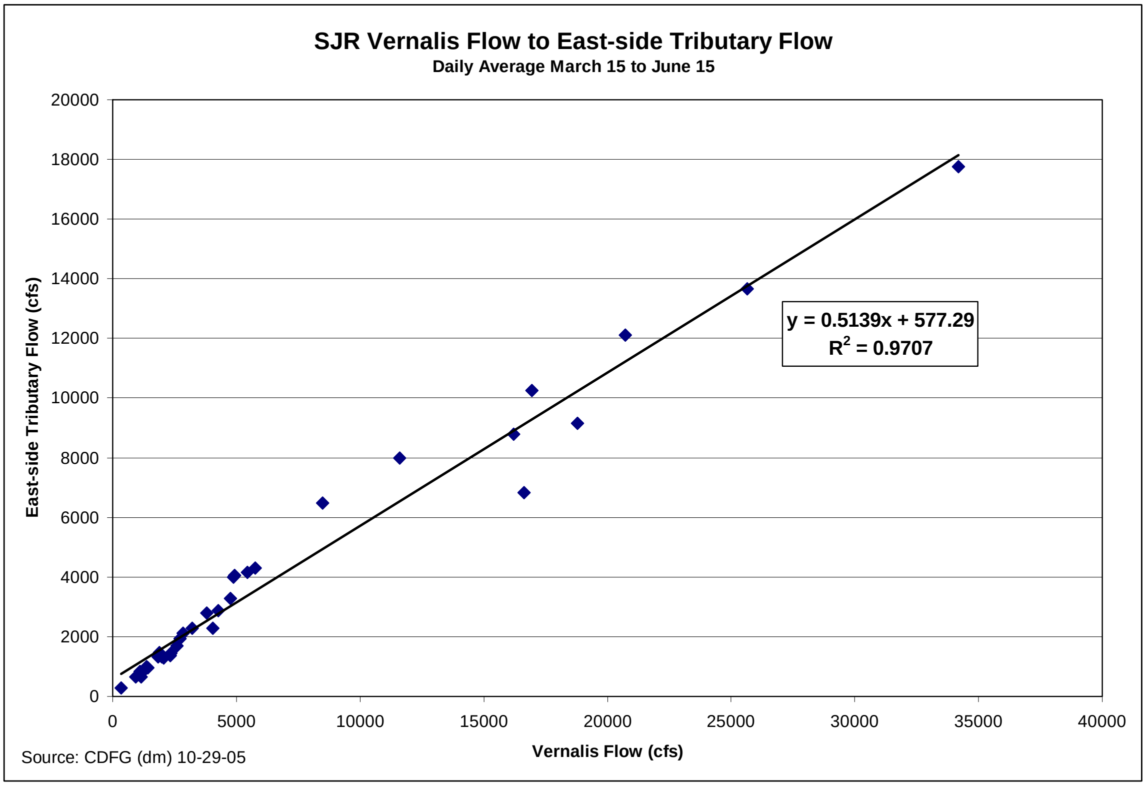

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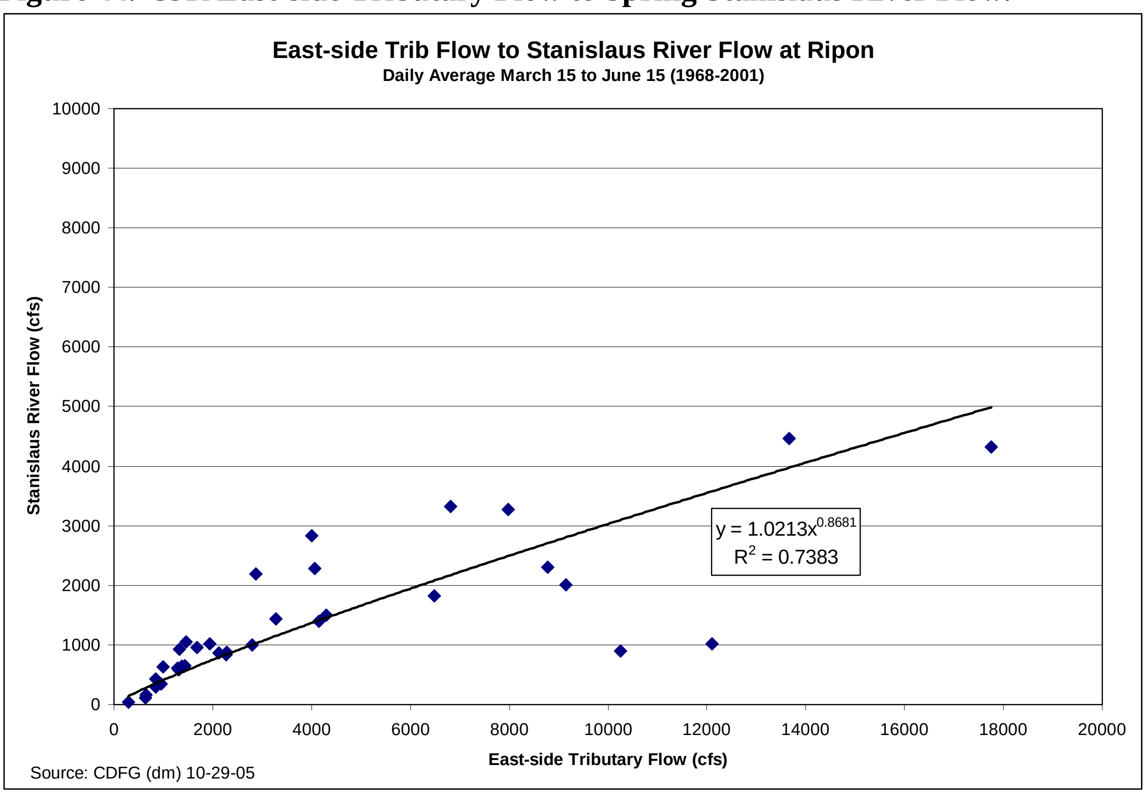

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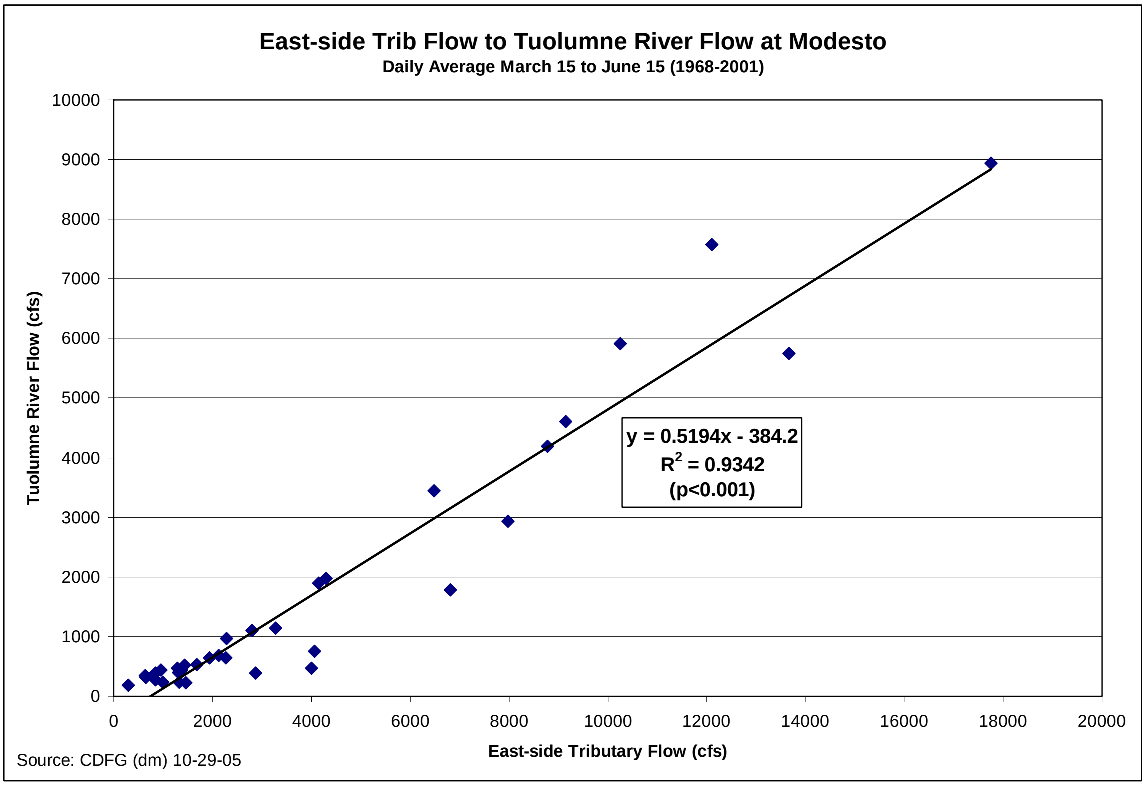

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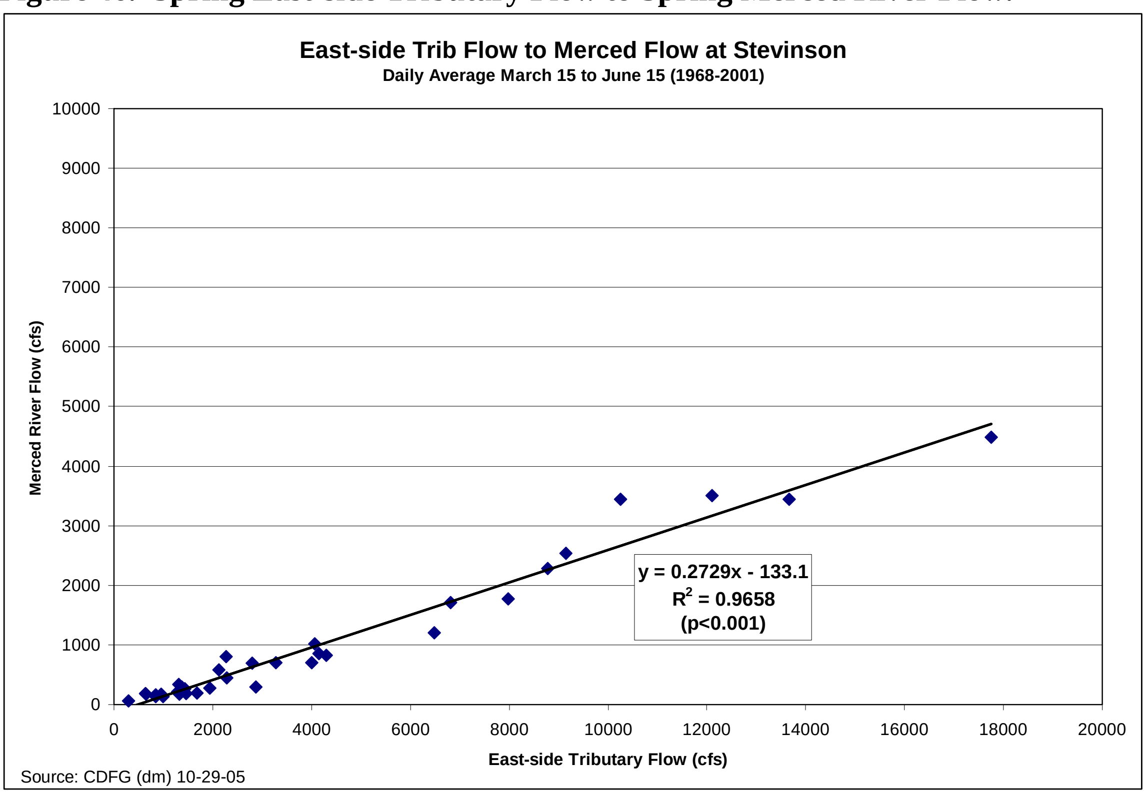

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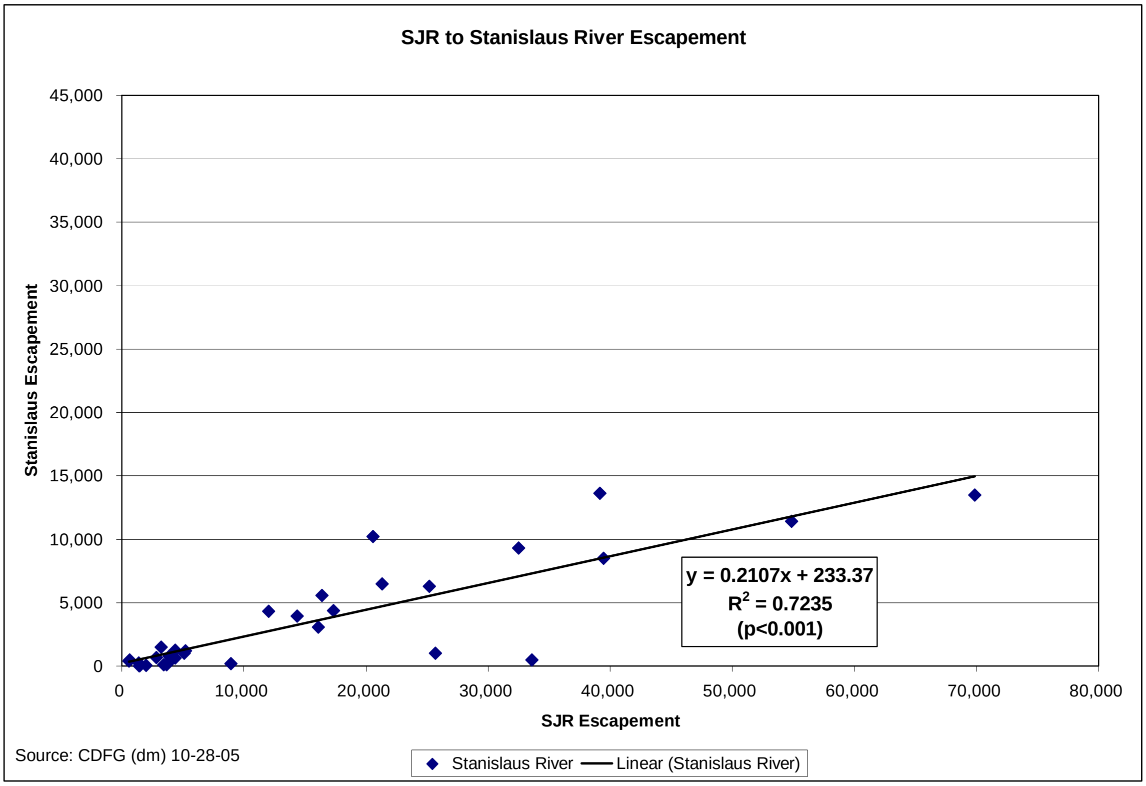

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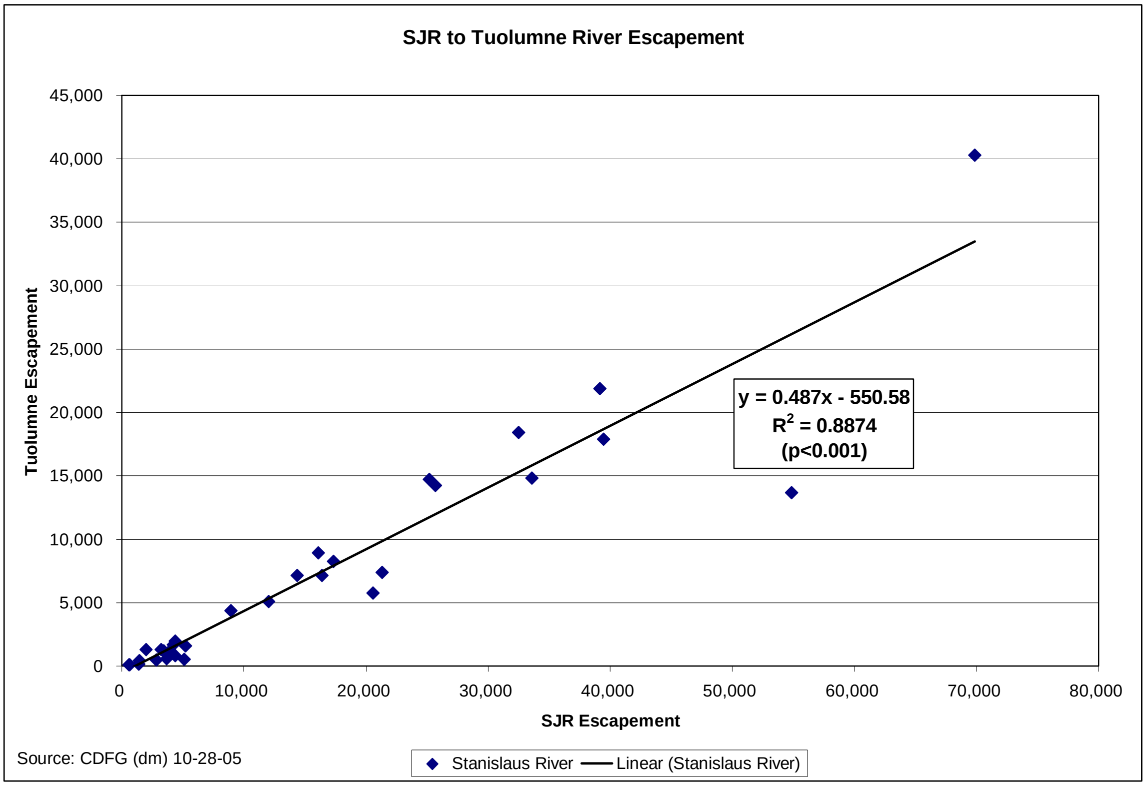

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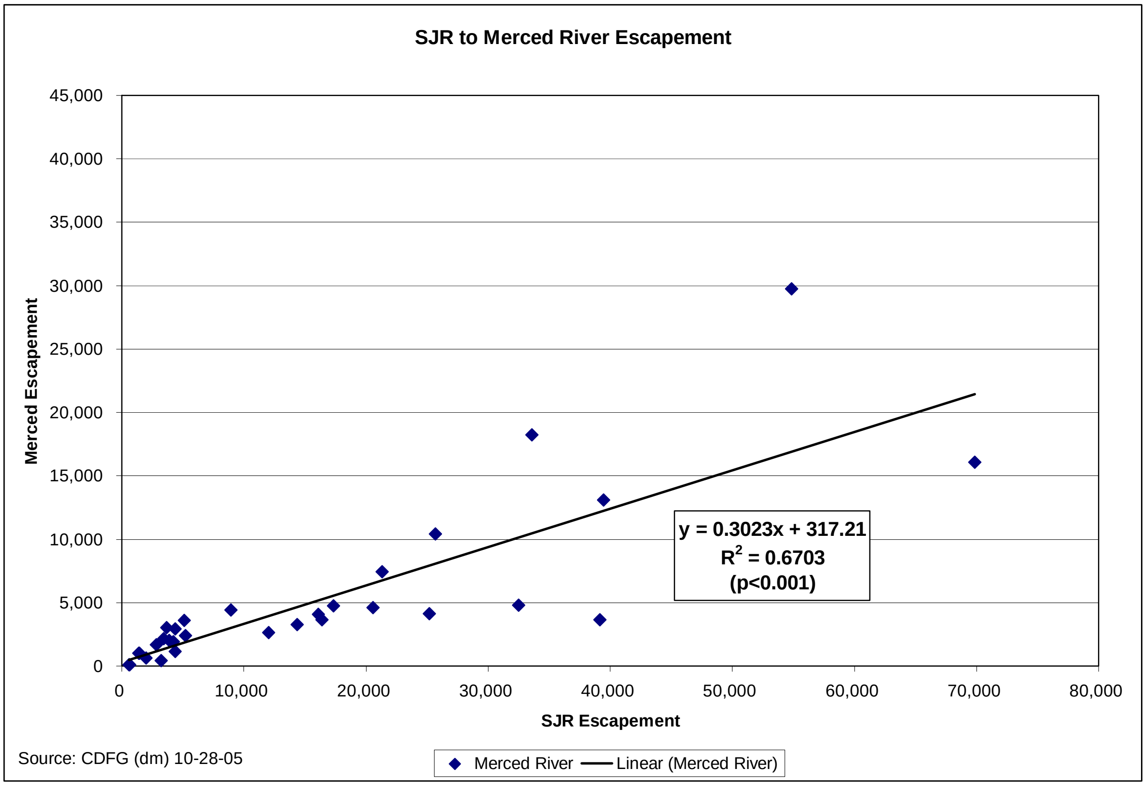

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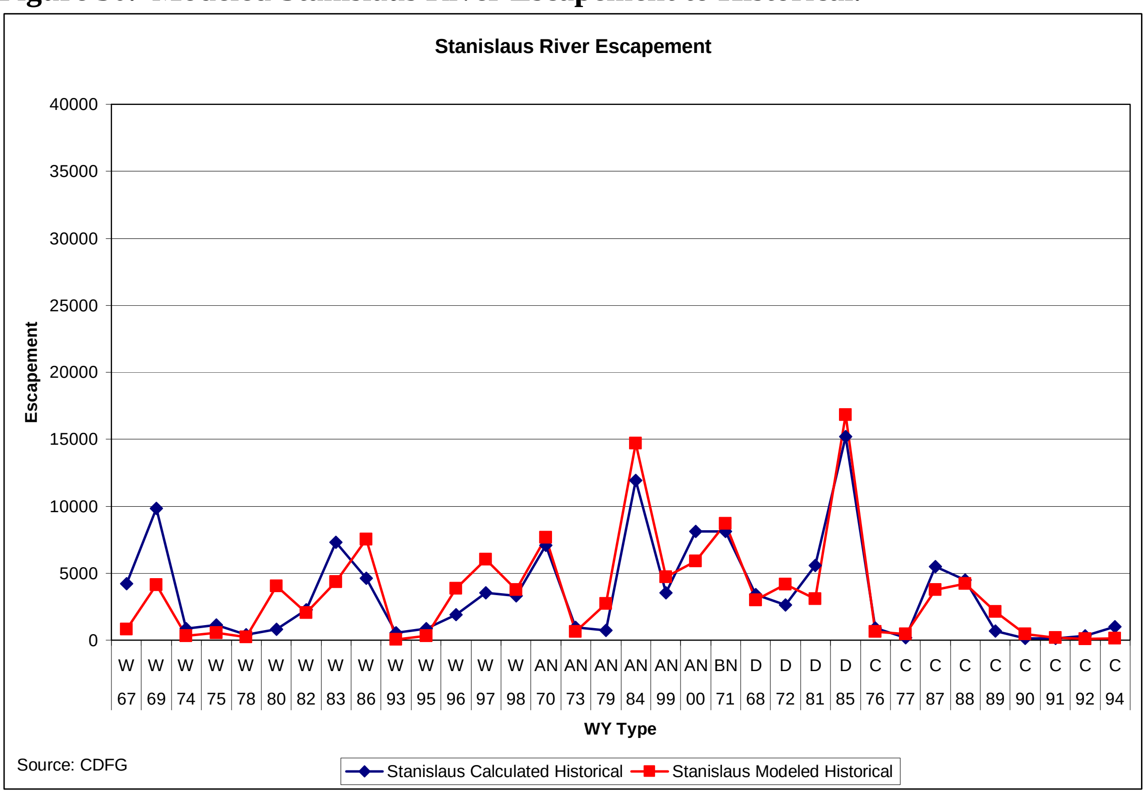

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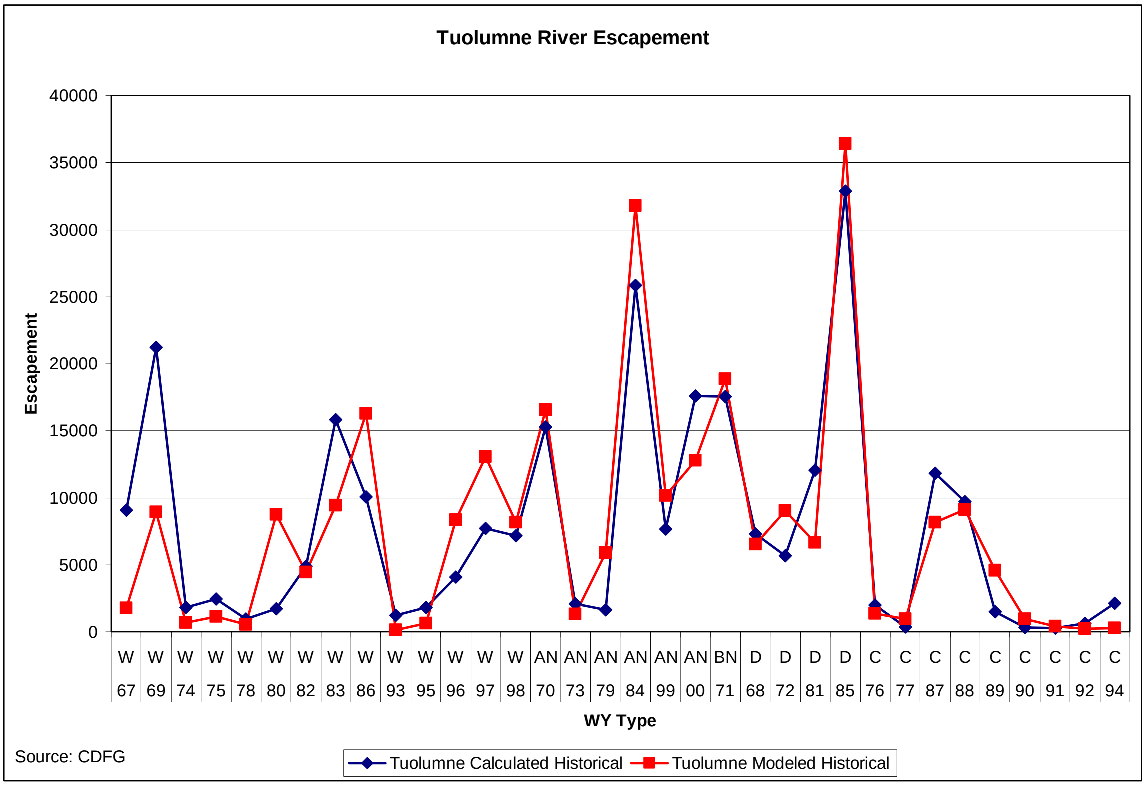

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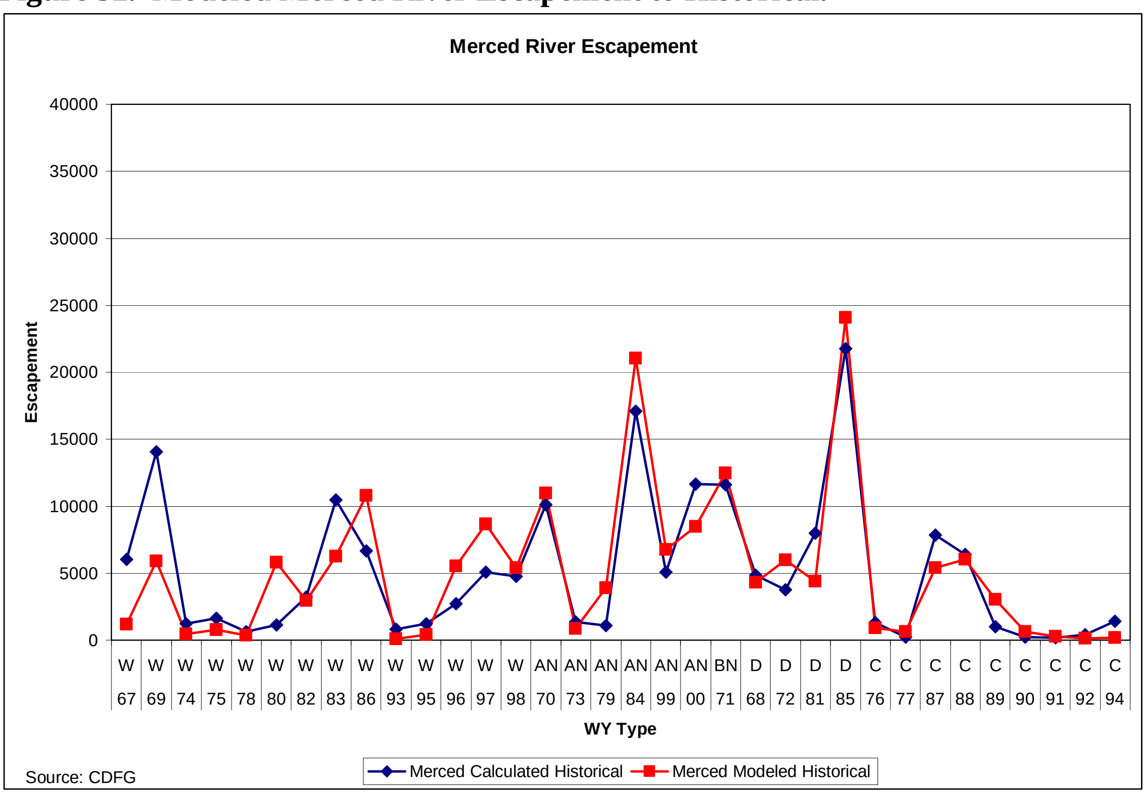

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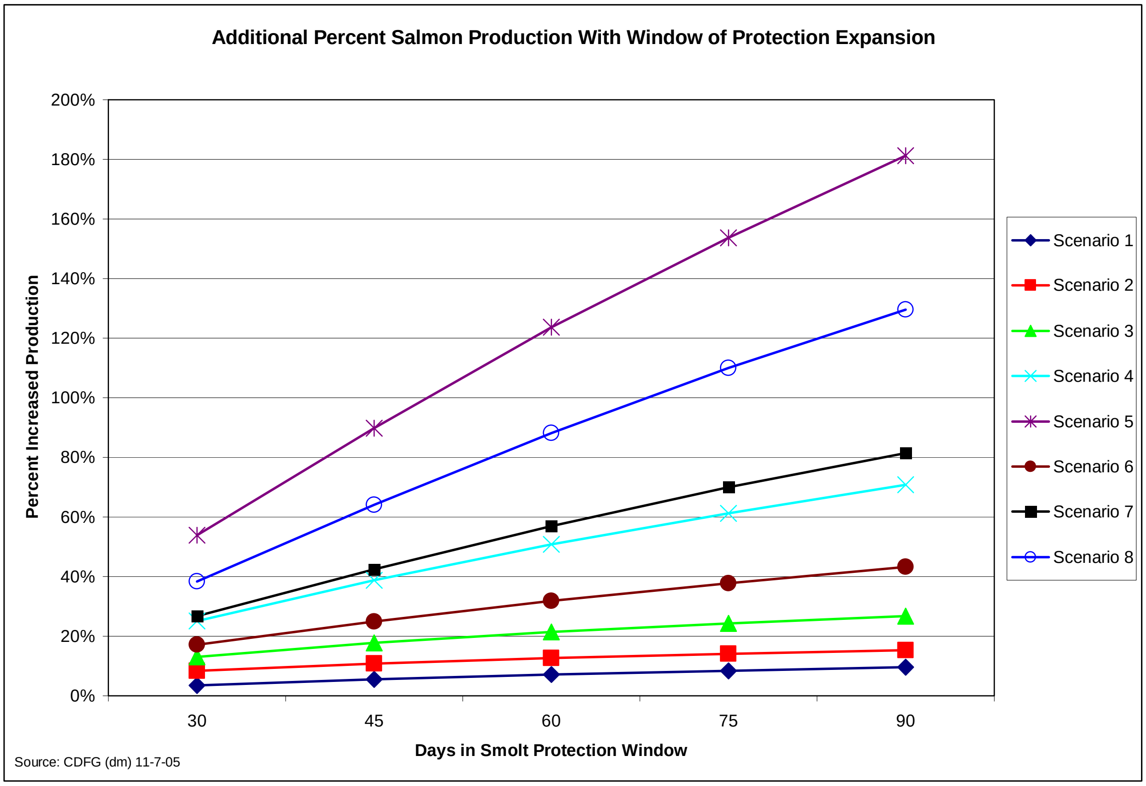

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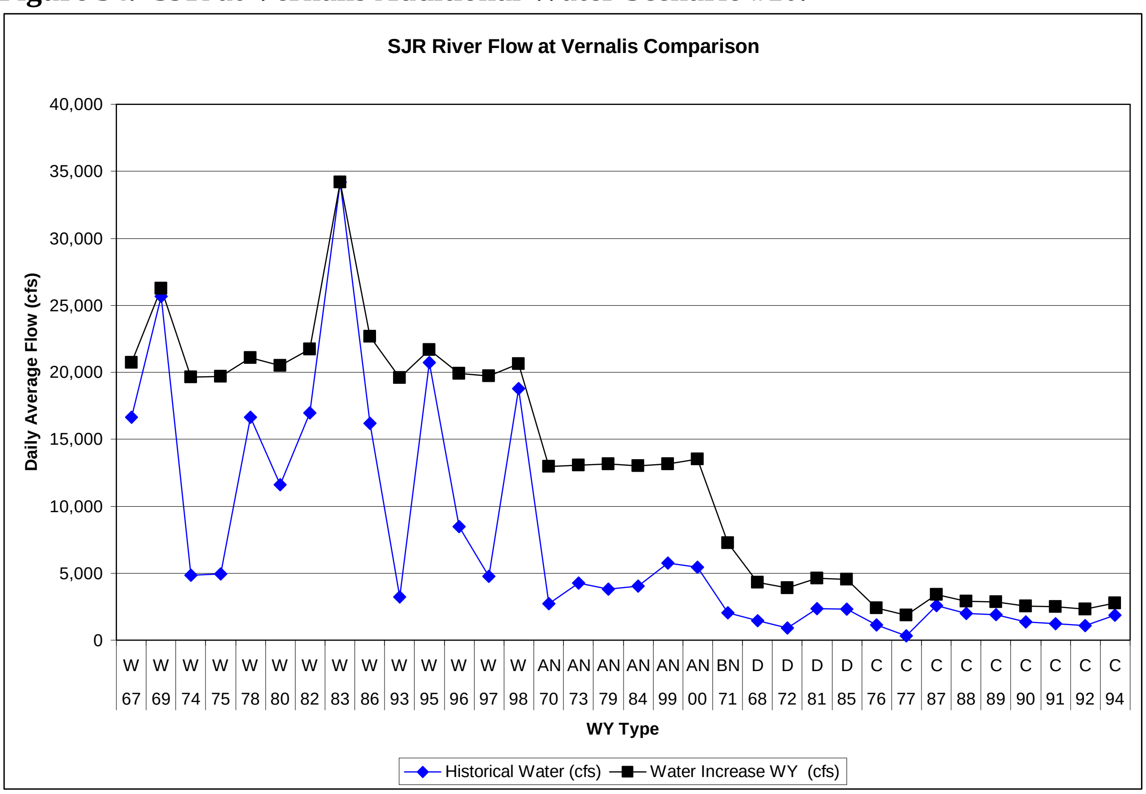

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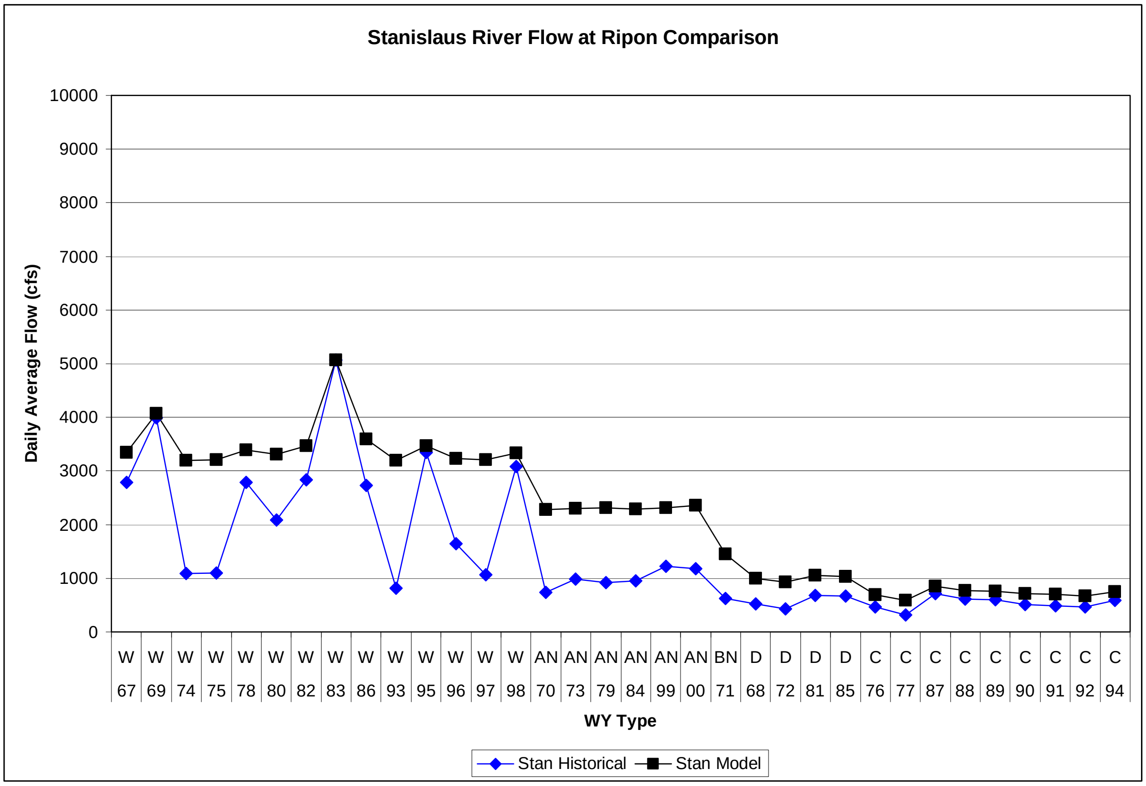

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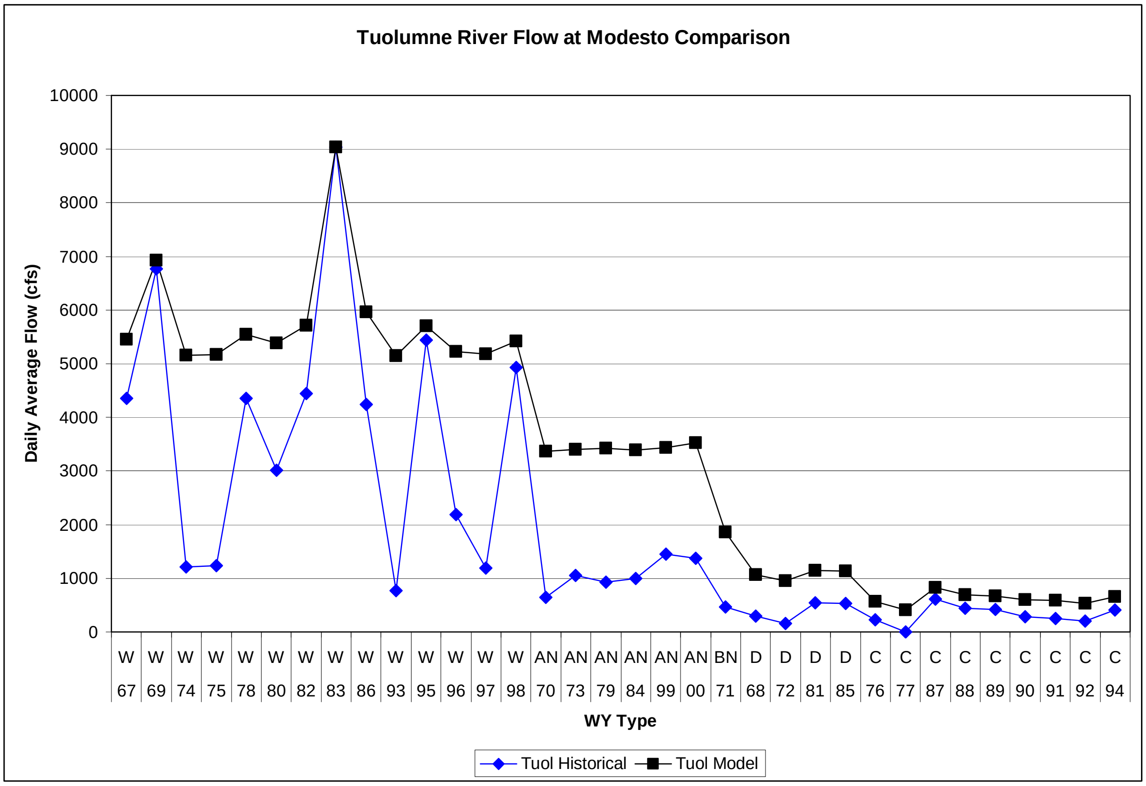

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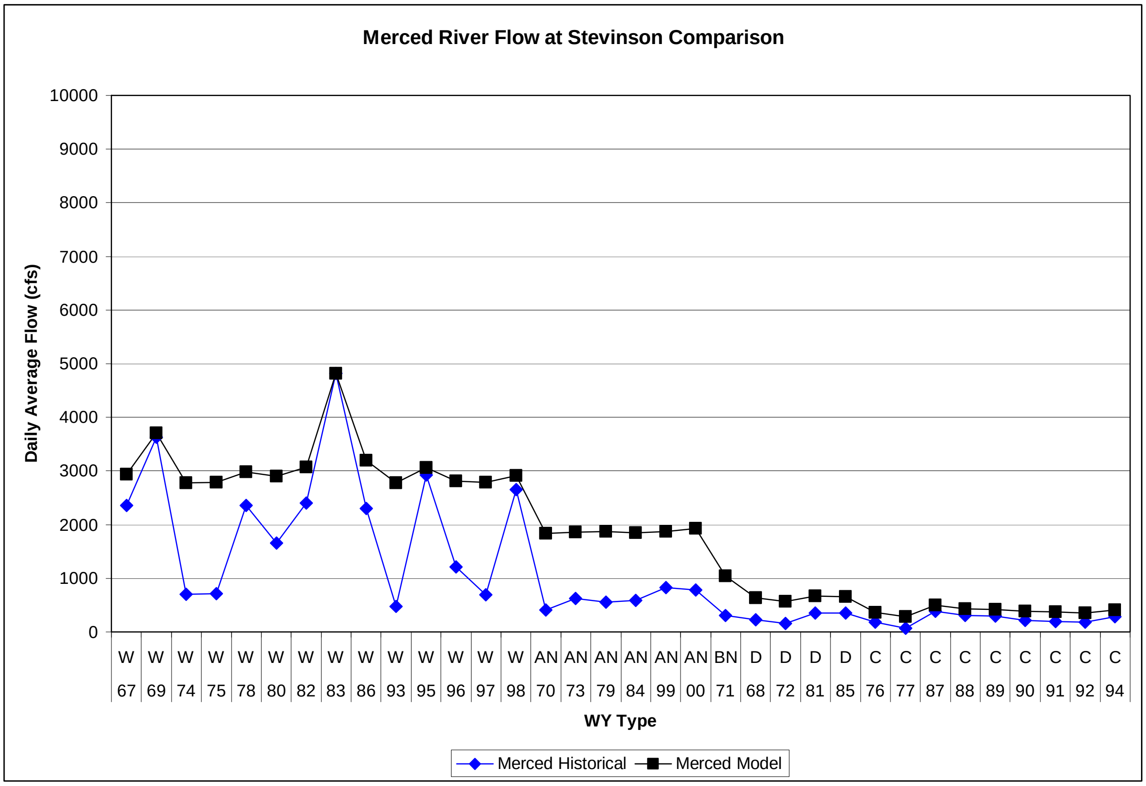

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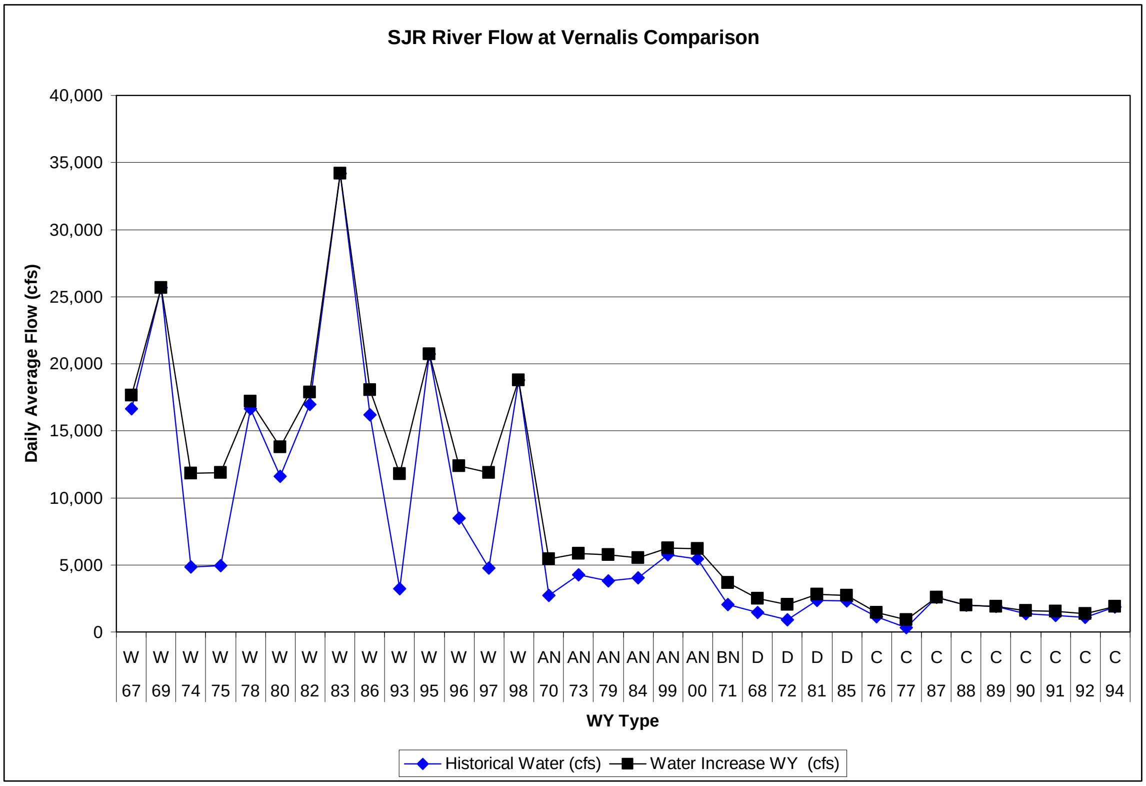

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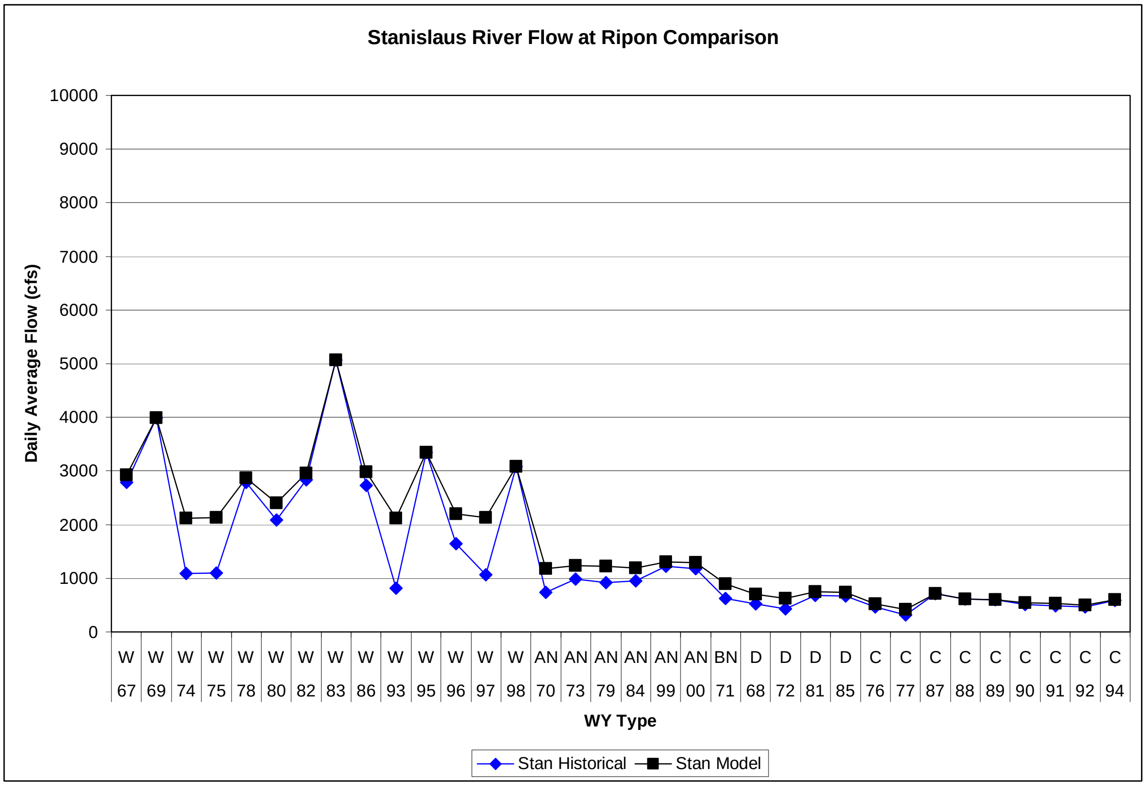

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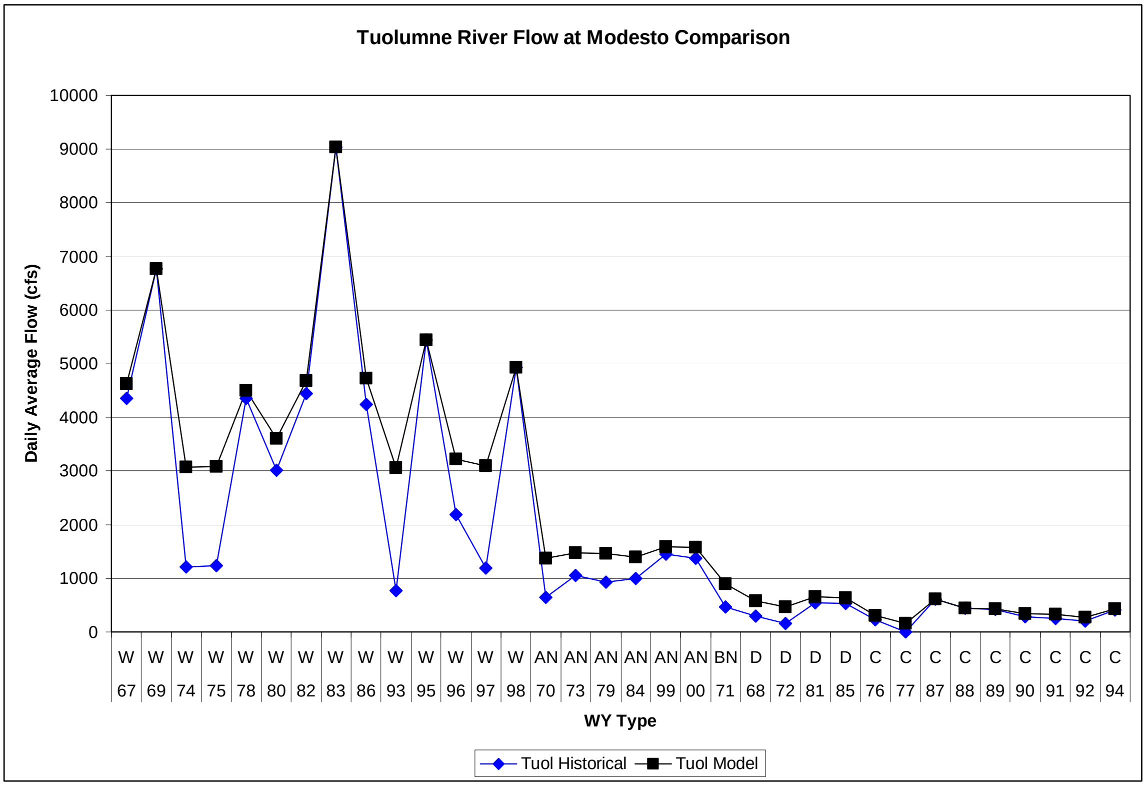

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