CALFED Staff Report: Summary Review of Prior Delta Conveyance Reports

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This Staff Report was prepared for the Delta Vision Blue Ribbon Task Force under the direction of

P. Joseph Grindstaff
Deputy Secretary, Resources Agency
Director, CALFED Bay-Delta Authority

Leo Winternitz,
Acting Chief Deputy Director, CALFED Bay-Delta Program

and

Terry Macaulay, P.E.
Supervising Engineer, Strategic Planning, CALFED Bay-Delta Program

By

Nancy Ullrey,
Lead Editor

Water Supply Reliability, Seismic and Flood Durability, and Schedule, Cost and Funding Sections by:
Sergio Guillen, P.E., Supervising Engineer, CALFED Bay-Delta Program
Loren Bottorff, P.E., Consultant

Ecosystem Health and Resilience Section by:
John Shelton, CALFED Bay-Delta Program
Dorian Fougeres, CALFED Bay-Delta Program
Terry Mills, Consultant

Water Quality Section by:
Sam Harader, CALFED Water Quality Program Manager
Patricia Fernandez, P.E., CALFED Water Quality Program
Nancy Ullrey, CALFED Bay-Delta Program

Summary

Over the past 40 years, state, federal, and local agencies, as well as academics have conducted numerous studies about the best way to move water through or around the Delta. For this summary report, CALFED staff reviewed more than 100 reports—30 of which specifically focused on various conveyance options—that dealt with Delta water conveyance and potential effects on water quality and ecosystem health and resilience.

Based on a review of these reports, it appears that most focus on the amount of water than can be moved and for what cost, but little work has been done to evaluate the effects on the Delta environment or the impacts of climate change and sea level rise. We note, however, that several studies now underway are addressing these issues.

General conclusions based on this review suggest:

1. The operational criteria of a conveyance system is critical to determining if it will meet the environmental, water quality, and water supply reliability needs of the state.
2. Based on the reports we reviewed, none of the conveyance options stand out as a clear choice capable of fully meeting all the performance standards laid out by the Task Force. Some conveyance options do well in some areas, but not in others; some conveyance options do moderately well across all areas.
3. Few of the existing reports include operational criteria or specifically integrate much of the new and relevant scientific data about the Delta ecosystem.
4. Cost estimates developed were for the conceptual designs for particular studies. Most of the reports did not include cost estimates for operation, maintenance and mitigation. Cost estimates presented here are not current and are not comparable among reports.

Other conclusions to specific topics are presented later in this section.

History

In *Our Vision for the California Delta*, the Delta Vision Blue Ribbon Task Force recommended that a process "be launched to urgently assemble available information (including expert judgment where needed) on design features, cost, and performance of alternative conveyance options against specified criteria to allow selection of a preferred alternative by June 2008." The Task Force also requested that five performance standards be used as criteria in summarizing and evaluating all the conveyance options:

1. water supply reliability,
2. seismic and flood durability,
3. ecosystem health and resilience,
4. water quality, and
5. projected schedule, cost, and funding.

In this summary report, the list of possible Delta conveyance options we used reflects the options analyzed in prior conveyance studies. The primary documents used to develop the descriptions for the through-Delta, isolated facility (eastern route), and dual-conveyance options were: the *Conservation Strategy Options Evaluation Report,* the *Delta Conveyance Improvement Studies Summary report,* the *Isolated Facility: Incised Canal Bay-Delta System, Estimate of Construction Costs,* and the *CALFED Final Programmatic Environmental Impact Statement/Environmental Impact Report.*

Two conveyance option descriptions, the Delta Corridors Project and the western route isolated facility, were submitted by stakeholders to the Task Force in 2007.

These and other prior reports generally suggested five conveyance options, and the CALFED staff focused on these five options for their review. Not all potential conveyance options were used in this review. For example, reduced exports were considered an operational decision and therefore are not included as a separate conveyance option in this review.

Concurrent Efforts

In addition to this summary report, the Department of Water Resources (DWR) is conducting two concurrent efforts about conveyance options:

First, as part of the Task Force recommendation, DWR conducted an effort to assess a dual conveyance system as the preferred direction, focused on understanding the optimal combination of through-Delta and isolated facility improvements. DWR's report is in a separate document.

Second, in March 2008, DWR began the environmental review process of four possible Delta conveyance alternatives:

1. no new conveyance facility,
2. a dual conveyance facility,
3. an isolated facility, and
4. an "armoring the Delta" through-Delta conveyance.

That environmental analysis is scheduled to be completed in 2010.

The five conveyance options used in this review, described later in this report, are:

1. current through-Delta conveyance,
2. Delta Corridors Project (a potential element of an "armoring the Delta" through-Delta conveyance),
3. an isolated facility (eastern route),
4. an isolated facility (western route), and
5. a dual conveyance facility.

Other reports also were reviewed for this report. Most of the documents reviewed were written in the last 10 years, but some date back 40 years. The scope and the quality of these documents vary widely, depending on when they were written.

Our Review

The review of available information began after the November 2007 Task Force meeting and includes some information that was available in early 2008. Most of the reports we reviewed mention the potential beneficial and negative effects of the conveyance options only. It is possible that many of the potential negative effects mentioned in these prior reports could be mitigated through operations or other means once a conveyance option is designed and operated.

Part of the review was to look for gaps in existing data. Sea level rise and climate change are two factors that were included in only a few of the prior reports, primarily the *Delta Risk Management Strategy (DRMS),* DWR's *Progress in Incorporating Climate Change into Management of California's Water Resources,* and *Envisioning Futures for the Sacramento-San Joaquin Delta.*

Information about the effects of sea level rise on water supply reliability is limited and currently is being studied more thoroughly. DRMS does include cost estimates regarding the impact of sea level rise on levees.

Other data gaps listed later in this report are the expert staff assessments of information missing in the prior studies that could be relevant to current conveyance option discussions.

This report structure is aligned with the five performance standards set out by the Task Force. This summary section highlights key findings and data gaps. The second section describes the approach used in writing the report and descriptions of the conveyance options.

The next five sections provide more detail about potential impacts of the conveyance options on the performance standards. Attached to this report is an annotated bibliography.

Key Findings Summarized from Prior Studies

The CALFED staff reviewed prior reports of various conveyance options using the five performance standards proposed by the Task Force; other studies supplemented staff evaluation of the conveyance options. The key findings are listed in the same order as the performance standard in Recommendation 8 by the Task Force.

It is important to remember that this report is based on prior studies and expert opinion regarding potential impacts, *not* a new analysis of any specific alternative conveyance system. As such, this report provides one important source of information for assessing the likely performance of alternatives.

Water Supply Reliability. Past reports conclude that new options for conveyance can improve water supply reliability by diverting better quality water, by reducing conflicts with the ecosystem, or by reducing exposure to levee failure.

Few studies integrated surface and groundwater storage strategies into their evaluations. The ability to store surface and groundwater storage can generally improve conveyance system performance by allowing the flexibility to move and store water during optimal conditions, however, most studies did not take this into consideration.

Optimal conditions could include periods of high water flow, conditions that provide for better water quality, or other conditions that result in decreased impacts to aquatic resources as a result of conveyance operations.

Past deliveries cannot accurately predict future deliveries, so estimates of water supply are based on computer models that depend on assumptions about conditions. As new information is provided or assumptions change, the models must change. This makes comparing water supply reliability of the conveyance options difficult because these were evaluated at different times and each used different assumptions about future conditions. Estimates are always limited because of the uncertainty regarding future conditions.

> **Data Gap:** The main data gap for water supply reliability is an evaluation that compares all conveyance options on an equal basis. *The Bay Delta Conservation Plan Environmental Impact Statement/Environmental Impact Report* is expected to address this data gap.

Seismic and Flood Durability. Scientists and engineers have not yet decided what future conditions should be used in conveyance design to account for potentially larger floods and sea level rise that could increase flood risk in the California Delta. Estimates of seismic vulnerability of Delta levees are not universally accepted. A recent study shows that the risk of failure in the central Delta due to flooding is unacceptably high and is expected to increase over time.

> **Data Gaps:** The main data gaps for seismic and flood durability are an understanding of seismic and flood forces and a decision about an acceptable level of risk to the system. The *Delta Risk Management Strategy* final report is intended to fill this data gap.

Ecosystem Health and Resilience. Environmental impacts of any of the conveyance options depend upon the design, placement, and operations of the facilities. The conveyance options considered for this review do not have enough specific design or operational information to determine their likelihood in promoting a healthy and resilient ecosystem; however, they all have the potential to do so if designed and operated with that goal in mind.

Conveyance options that feature through-Delta components will continue to have fishery impacts at the pumps, although some of these options also have opportunities to enhance habitat or ecological processes. Isolated facilities, regardless of their alignment, sever the direct relationship between in-Delta water quality and export water quality, which could have both beneficial and detrimental effects on the ecosystem. A dual conveyance system could, with careful design and operations, reduce the negative impacts of either of the two isolated facility options or the through-Delta option.

> **Data Gap:** The most significant information gap for assessing estuarine health and resilience is the lack of specific design and operation criteria for any of the conveyance options. Given the complexity of the Bay-Delta system, progress in evaluating conveyance options and assessing ecosystem health and resiliency requires well-funded, well-designed, and supported monitoring components to adaptively

manage the ecosystem. Much of the relevant scientific information about the California Delta ecosystem is new, largely developed through the CALFED Science Program, and this new information was not incorporated into prior analyses of conveyance options. *The Bay Delta Conservation Plan Environmental Impact Statement/Environmental Impact Report* is expected to fill many of these data gaps.

Water Quality. Improving environmental water quality and export (drinking) water quality are incompatible goals in many ways, and most conveyance system options focus on export water quality over environmental and in-Delta agricultural water quality. Water flows affect water quality, and those conveyance options that would reduce or change the source of water flows into the Delta could increase concentrations of contaminants like salt and selenium.

An isolated facility using a river intake could have excellent export water quality and could leave poorer quality water in the Delta; a dual conveyance facility could have potential for improved export water quality and could have less impact on in-Delta water quality, depending on operations.

Even with adequate flows, it can be difficult to predict water quality impacts on the ecosystem. A well-designed and appropriately funded monitoring program should be a part of any management plan for the chosen conveyance option.

> **Data Gaps:** The main data gaps for water quality are a lack of detailed operating scenarios and modeling, including integration of water projects upstream of the Delta; information about the linkage between drinking water quality and Delta food web productivity; better understanding of the effects of pesticides and other toxic substances; better water quality monitoring for key constituents; and modeling for the effects of sea level rise on water quality.

Projected Schedule, Cost, and Funding. None of the conveyance options go beyond the conceptual stage and consequently none of the studies provide good cost estimates for today's needs. Estimates for the various concepts range from a low of $2.8 billion to almost $9 billion. These estimates are based on different sizes of facilities, different assumptions, and were conducted at different times, and, therefore are not comparable across the options. Most available estimates are only for construction costs and do not include operation and maintenance costs or any other costs related to ecosystem enhancement and mitigation.

> **Data Gap:** The main data gap for the projected schedule, cost and funding is a single evaluation that compares all conveyance options on an equal basis.

Potential Recommendations

Based on their review, CALFED staff provides the following recommendations to the Task Force as they consider current conveyance option studies:

- Few past conveyance studies include ecosystem health and resilience as criteria for design or facility operation. Any conveyance option that progresses through the design and implementation phases should include ecosystem health and resilience as a design and operation component.
- Few past conveyance studies include information about integrating conveyance operation with surface or groundwater storage management. Surface and groundwater management should be integrated into any future conveyance study.
- None of the past conveyance studies include an assessment and monitoring program in its evaluation. A comprehensive and integrated monitoring, assessment, and reporting program should be included into any future conveyance option study.
- Few past conveyance studies thoroughly addressed sea level rise and climate change as it could impact water quality and water system infrastructure. The effects of sea level rise and climate change on water quality for human and environmental use and water system infrastructure should be integrated into any future conveyance study.

Approach and Conveyance Option Descriptions

This section briefly describes the approach used to complete this report and provides more information about the conveyance options.

Approach

Over the past 40 years, hundreds of documents record the reasons for and beliefs about water conveyance options through or around the California Delta.

In preparing this summary review of prior reports, the CALFED staff reviewed the most useful and relevant information. The primary documents used for the through-Delta, isolated facility (eastern route), and dual-conveyance options were: the *Conservation Strategy Options Evaluation Report,* the *Delta Conveyance Improvement Studies Summary report,* the *Isolated Facility: Incised Canal Bay-Delta System, Estimate of Construction Costs,* and the *CALFED Final Programmatic Environmental Impact Statement/Environmental Impact Report.* Other reports also were reviewed.

All of the documents reviewed for this report covered the last 40 years of conveyance studies. The scope and the quality of these documents varies widely, depending on when they were written. Two other conveyance options used, *Delta Corridors* and the western isolated facility, were submitted to the Delta Vision Blue Ribbon Task Force by members of the public.

Other information was used to determine the potential effects of a conveyance option, such as, changes in water quality. Staff consulted with key stakeholders and technical experts to make sure the best available information was being used.

After reviewing the information against the criteria established by the Task Force, a draft report was reviewed by technical staff and consultants from each subject area before completing the final report.

Given the number and length of prior reports reviewed, staff decided to use citations and annotate the bibliography. Because many of the same prior reports were used for each section, but focused on different subjects, staff also decided to use a modified *Chicago Manual of Style* citation system for the report.

Citations have a prefix followed by a number that corresponds to the appropriate annotated bibliography entry. Citations for the Water Supply Reliability; Seismic and Flood Durability; and Schedule, Cost and Funding sections begin with the prefix ENG. Citations for the Ecosystem Health and Resilience, and Water Quality sections begin with EHR and WQ, respectively. The annotated bibliography is in Attachment A.

Conveyance Options Used in the Review

Five conveyance options were reviewed: existing through-Delta, Delta Corridors, isolated facility (eastern route), isolated facility (western route), and dual conveyance. The following is a brief description of each conveyance option.

Through-Delta Conveyance. Through-Delta conveyance is the current method of moving water from the Sacramento River across the Delta (via the Delta Cross Channel) to export pumps in the south Delta. There are many alternative configurations for improving through-Delta conveyance. Alternative configurations include improving channel conveyance capacities by dredging, constructing barriers or other changes to Delta flow patterns or other extensive changes to the physical shape of existing channels.

Delta Corridors. This concept was submitted to the Task Force in July 2007. This approach is an enhanced version of through-Delta conveyance that uses the existing channels, along with a variety of flow control structures, to carefully direct flow through a multitude of channels for specific water supply, water quality, and ecosystem uses. The Sacramento River through-Delta flow would be siphoned under the San Joaquin River outflow channels to reach the south Delta export pumps. Delta Corridors could be a potential element of an "armoring the Delta" conveyance option.

Isolated Conveyance Facility (eastern route). An eastern isolated conveyance facility would divert high quality water from a screened intake on the Sacramento River and transport it around the eastern Delta perimeter to the export pumps in the south Delta. The conveyance facility could be a canal (lined or unlined), a pipeline, or a combination of both.

Isolated Conveyance Facility (western route). This alternative was submitted to the Task Force in July 2007. As described in "An Alternative Vision for the Sacramento-San Joaquin Delta - Peer Swan," a western isolated conveyance facility would use the Sacramento Ship Channel to move water to Rio Vista, at which point it would be conveyed via siphons, tunnels and pipelines to the export pumps in the south Delta.

Dual Conveyance. This alternative is a combination of the through-Delta conveyance and an isolated facility. Dual conveyance provides the flexibility of moving water through the Delta, around the Delta, or a combination of both depending on use needs and water flows. DWR is currently conducting modeling to evaluate this and other alternatives.

Water Supply Reliability

This section reviews available information about various conveyance options and their potential effects on water supply reliability. A brief description of water supply reliability is followed by a discussion of key findings and data gaps.

There is no universally accepted definition of water supply reliability.

> DWR defines "water delivery reliability" as how much a water agency can count on a certain amount of water being delivered to a specific place at a specific time.
>
> Source: *State Water Project Water Supply Reliability Report, 2007*

Individual households may view their water supply as highly reliable as long as water flows when they turn on the taps. Determining water supply reliability is much more complex for water agencies. Water agencies determine water supply reliability based on the mix of available water sources; water quality of the sources; timing and variability of use; projected growth in use; hydrology; available facilities (conveyance, and surface and groundwater storage); water use efficiency measures; environmental constraints and other regulatory requirements; and estimates of future weather patterns.

The California Delta is generally one of several sources for supply. For some users of Delta water, the Delta provides a small portion of their water supply. For others, the Delta provides all or a major portion of their water supply.

Since it is not practical for Delta studies to portray the reliability of Delta water for each contracting water agency, a composite measure is used to explain the variability of Delta water availability. This is usually described as the frequency that different quantities of water can be delivered from the Delta. DWR uses the term "water delivery reliability" in referring to water that is available from the California Delta for the State Water Project (SWP) (ENG 1).

Water supply reliability also depends on all other criteria in this report. A conveyance system that is vulnerable to seismic conditions and floods is less reliable for water supply because there is a greater chance of its being shut down during emergencies (ENG 2).

A conveyance system coexisting with an unhealthy ecosystem is more prone to environmental constraints that can reduce Delta exports, much like what happened in June 2007 when pumping was curtailed to protect Delta smelt near the south Delta export pumps (ENG 2). A conveyance system that delivers poorer quality water or is vulnerable to salinity increases from sea level rise has less water supply reliability because the degree of use and reuse (the utility) of the water is lower.

Key Findings and Data Gaps

Past deliveries cannot accurately predict future deliveries, so estimates depend on computer models with defined assumptions about conditions. All estimates depend on assumptions of existing and future conditions and, as new information becomes available, modeling assumptions change. This means estimates from different studies are not directly comparable.

Sometimes assumptions must change significantly over a short time to accommodate new regulations or new insights about future conditions like climate change. Because of the uncertainty with future conditions, estimates always have limited accuracy. Table WS-1 shows the differences in three estimates of Delta water supply delivery reliability for through-Delta conveyance, all made since 2002 (ENG 1, 3, 4).

Surface and groundwater storage can generally improve conveyance system performance especially if the conveyance system is large enough to move water in or out of storage when conditions are optimal. For example, a large capacity conveyance system in the California Delta coupled with new storage south of the Delta could export more water during optimal conditions.

Optimal conditions could include periods of high water flow, conditions that provide for better water quality, or other conditions that result in decreased impacts to aquatic resources as a result of conveyance operations. Since 2000, DWR and U.S. Bureau of Reclamation (Reclamation) have invested heavily in studying five new surface storage projects and in cost-sharing local groundwater projects (ENG 5, 6). These studies should provide a wealth of knowledge about potential storage operations and costs that can be coupled with future work on Delta conveyance.

There are no up-to-date references that provide estimates of water supply reliability for all Delta conveyance options. The *CALFED Final Programmatic EIS/EIR* (ENG 7) and related documents provide water export estimates for several conveyance options using the best information available in 1997 and 1998, but much has changed since then. DWR provides the most up-to-date estimates of Delta water reliability for the existing through-Delta conveyance facility in the 2*007 Draft State Water Project Delivery Reliability Report* (ENG 1).

TABLE WS-1. SWP "TABLE A" DELIVERY FROM THE DELTA UNDER CONDITIONS CURRENT AT THE TIME OF THE REPORT

[IN THOUSANDS OF ACRE-FEET ANNUALLY (TAF/YEAR)]

Study of Current Conditions	Average Delivery[1]		Maximum Delivery[1]		Minimum Delivery[1]	
	TAF/year	% Maximum Table A[2]	TAF/year	% Maximum Table A[2]	TAF/year	% Maximum Table A[2]
2002 Report	2,962	72%	3,845	93%	804	19%
2005 Report	2,818	68%	3,848	93%	159	4%
2007 Report	2,595	63%	3,711	93%	243	6%

[1] Delivery estimates based on different periods of record: 1922-1994 for 2002 and 2005 reports; 1922-2003 for 2007 Draft Report.

[2] Table A is the limit of SWP water contracts and equals 4,133 TAF/year

Sources: *State Water Project Reliability Reports, 2002, 2005, and Draft 2007.*

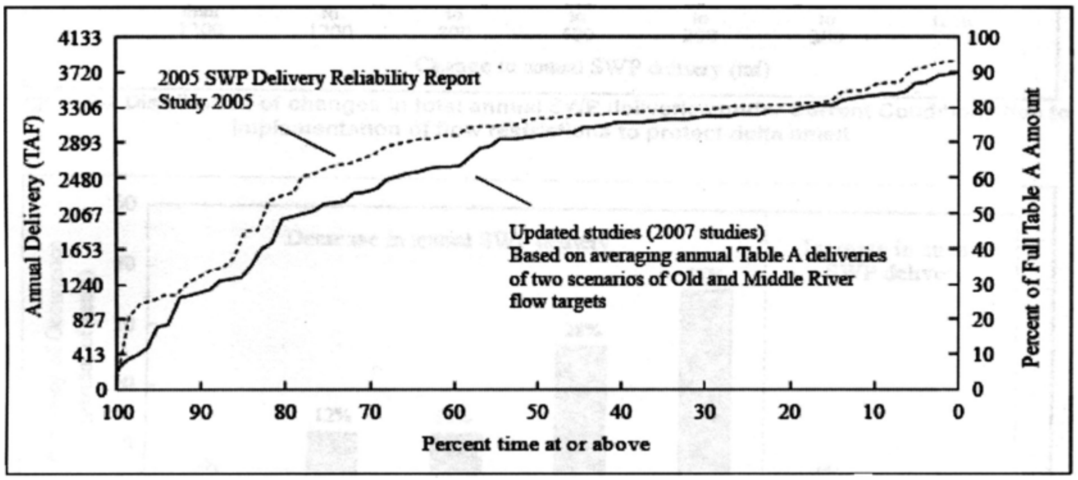
Another factor that will effect future water supply reliability is the recent court order regarding Delta smelt issued by federal Judge Oliver Wanger (the Wanger decision) (ENG 8). Interim export restrictions cited in this recent court order will be used until a new Biological Opinion is completed by September 2008 (ENG 8).

The main data gap for Delta water supply reliability is a single evaluation that compares all conveyance options on an equal basis.

Existing Through-Delta Conveyance. DWR prepared SWP Delivery Reliability reports (ENG 1, 3, 5) in 2002, 2005, and 2007 for the existing through-Delta conveyance. Each report provides an estimate of delivery reliability based on "current conditions" as of the date of the report (see Table WS-1). Although no similar estimates are available for the Central Valley Project (CVP), the table shows that water delivery reliability from the California Delta generally has decreased over the past few years.

Figure WS-1 shows the same results for the 2005 and 2007 reports as a probability curve. The figure shows the percent of time that an annual delivery is at or above the values on the left side of the graph. The lower curve for

FIGURE WS-1. SWP DELTA "TABLE A" DELIVERY RELIABILITY UNDER CONDITIONS CURRENT AT THE TIME OF THE REPORT



Source: *2007 Draft State Water Project Delivery Reliability Report.*

the 2007 study represents a less reliable water supply then the upper curve. The figure shows that for probabilities above 40 percent, the updated annual "Table A" deliveries can be 250 to 500 thousand acre-feet (TAF) less than the earlier estimates.

One important thing that Table WS-1 and Figure WS-1 illustrate is that the best estimates made in one year may not hold when conditions change a short time later. The main changes from the 2002 report to the 2005 report were the result of operational changes under the 2004 Long-Term Central Valley Project Operations Criteria and Plan (OCAP). The two biggest changes from the 2005 report to the 2007 report are Delta pumping restrictions imposed by the Wanger decision and consideration of climate change. All three reports also include estimates of delivery reliability for 20 years (see Table WS-2).

The values in Table WS-2 are higher than the values in Table WS-1 because estimated water demands are higher in the future. The ranges shown in Table WS-2 for 2007 cover the ranges of climate change estimates.

Modified Through-Delta Conveyance. Over the past few decades, planners have considered many ways to modify through-Delta conveyance, mainly to improve water quality or ecosystem conditions that could indirectly improve water supply reliability (also see the Water Quality and Ecosystem Health and Resilience sections). The CALFED through-Delta facility, the re-operation of the Delta Cross Channel, and the Franks Tract Project (channel gates for water quality and ecosystem improvements) have been studied,

TABLE WS-2. SWP "TABLE A" DELIVERY FROM THE DELTA UNDER FUTURE CONDITIONS

[IN THOUSANDS OF ACRE-FEET ANNUALLY (TAF/YEAR)]

Study of Current Conditions	Average Delivery[1]		Maximum Delivery[1]		Minimum Delivery[1]	
	TAF/year	% Maximum Table A[2]	TAF/year	% Maximum Table A[2]	TAF/year	% Maximum Table A[2]
2002 Report for 2021	3,130	76%	4,133	100%	830	20%
2005 Report for 2025	2,818	77%	4,133	100%	187	5%
2007 Report for 2027	2,724--2,850	66%--69%	4,133	100%	255-293	6%--7%

[1] Delivery estimates based on different periods of record: 1922-1994 for 2002 and 2005 reports; 1922-2003 for 2007 Draft Report.

[2] Table A is the limit of SWP water contracts and equals 4,133 TAF/year

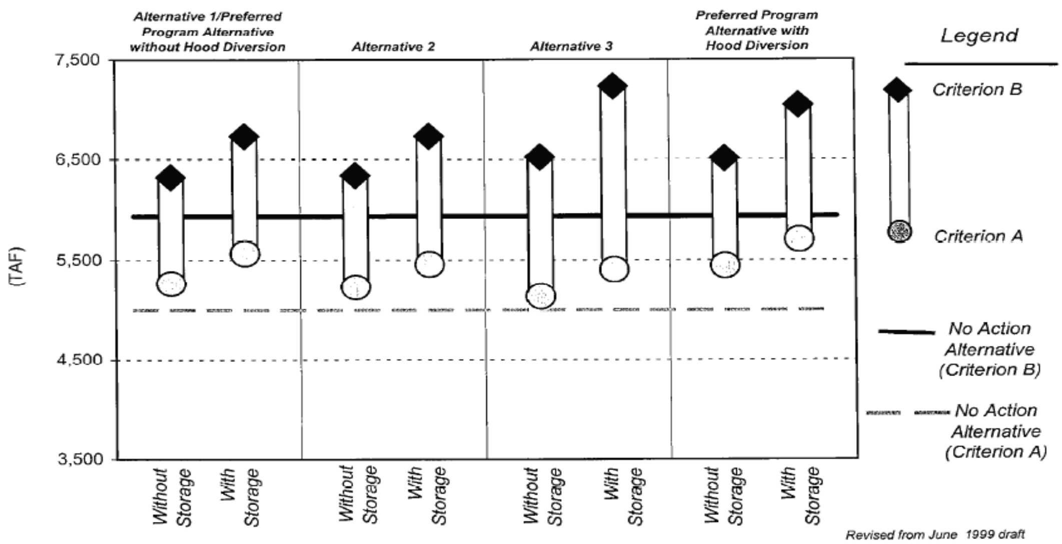
Sources: *State Water Project Reliability Reports, 2002, 2005, and Draft 2007.*

but study results do not indicate significant water supply improvements (ENG 9). Modifications that improve Delta levee stability can improve water supply reliability by reducing the chances that an emergency could reduce Delta water exports or reduce the time exports would be curtailed (ENG 2).

In some cases, proposals for physical modifications to Delta conveyance were also tied to operational changes to increase permitted exports of the SWP south Delta pumps from 6,680 cubic feet per second (cfs) to 8,500 cfs or 10,300 cfs (ENG 7, 10, 11). These modifications, intended to accommodate increases in permitted SWP pumping, do show direct improvements in water export volumes.

For example, Figure WS-2 compares possible Delta exports for two CALFED alternatives from model runs conducted in 1997 and 1998. Since Delta operating conditions have changed significantly since then, these figures should be viewed only as an indication of how water supply can vary by alternatives.

FIGURE WS-2. AVERAGE ANNUAL DELTA EXPORTS AT BANKS AND TRACY UNDER ALL PROGRAM ALTERNATIVES FOR THE LONG-TERM PERIOD FROM 2000 CALFED PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT/ENVIRONMENTAL IMPACT REPORT



Source*: CALFED Final Programmatic Environmental Impact Statement/Environmental Impact Report*.

Alternative 1 is existing through-Delta conveyance with south Delta channel improvements, barriers and operational changes. Alternative 2 is similar to Alternative 1 with a 10,000 cfs diversion near Hood to improve water quality. Alternative 3 considers a dual conveyance with an isolated facility in the 5,000 cfs to 15,000 cfs range. The preferred program alternative is similar to Alternative 2 with operational changes.

Criterion A uses 1995 levels of water demand to simulate extensive water use efficiency in the service areas. Criterion B uses projected increased water demand in the service area. Therefore, each alternative in the figure is shown with a range of possible water exports (ENG 7).

Figure WS-2 also suggests that storage can improve any water supply reliability alternative. Each alternative in the figure is shown with and without new storage.

Delta Corridors. The Delta Corridors Project is a modified through-Delta conveyance alternative. Although no detailed operations studies have been performed, initial estimates indicate that the Delta Corridors Project could export about 150 TAF to 250 TAF additional water annually compared to the existing through-Delta conveyance (ENG 12, 13).

Since this alternative includes a water supply corridor (Middle River) and an ecosystem corridor, more detailed model runs may show that most water supply exports lost due to the Wanger decision could be recovered. Since the Middle River corridor would be separated from the ecosystem corridor, it also may be possible to safely export more water by removing the 6,680 cfs pumping limit from the SWP and allow pumping up to 10,300 cfs.

Isolated Conveyance Facility (eastern route). The water supply available from an isolated conveyance facility depends on its size, the regulations that are in place, and how the facility is operated. The most recent available estimates for water supply from an isolated facility were conducted for Bay Delta Conservation Plan (BDCP) (ENG 14, 15). BDCP simulations indicate the potential for reduced CVP and SWP exports in the range of 100 TAF to 800 TAF annually compared to existing conditions (i.e., pre-Judge Wanger decision), depending on the level of Rio Vista flow requirements, X2 objectives (X2 is a Delta outflow objective measured as the location of low salinity [2 parts per thousand]), and salinity requirements. With less restrictive requirements, water supply could nearly equal existing amounts.

With more restrictive requirements, the water supply could be significantly lower. However, since the flow to the south Delta pumps would be separate from Delta channels, it may be possible to safely export more water by increasing SWP pumping to 10,300 cfs. Any major change in conveyance in the California Delta from the existing configuration will require thorough review and possible revision of existing requirements.

Isolated Conveyance Facility (western route). Existing reports (ENG 16, 17) that consider an isolated facility on the west side of the Delta do not make specific estimates of water supply reliability. One conveyance proposal (ENG 17) concludes that such a facility could reduce the risks to water supply reliability due to subsidence, rising sea levels, flooding, and seismic activity. The improvement in water quality at the pumps by diverting high quality water just below the American River could also improve water supply reliability because the facility could be less susceptible to sea level rise that threatens through-Delta conveyance (ENG 17).

Since detailed studies of water supply reliability have not been conducted, it is reasonable to assume that water supply reliability for the western isolated conveyance facility would be similar to the reliability for the eastern isolated facility.

Dual Conveyance. The water supply reliability of a dual conveyance system depends on the features and sizes of modified through-Delta conveyance and features, the size of the isolated conveyance, and operational requirements that are yet to be determined. DWR is conducting an assessment of dual conveyance that will provide estimates to the Task Force about water supply reliability for at least one possible configuration of dual conveyance. An example of how a dual conveyance could be configured is noted the BDCP Option 3 (ENG 14).

Option 3 evaluates a variation of the Delta Corridors Project concept to move in-Delta flows, and provides the opportunity to divert San Joaquin River flows when environmental conditions allow. The BDCP report does not select a size for an isolated conveyance facility which could range from 5,000 cfs to 15,000 cfs in its analysis (ENG 14). The BDCP analysis acknowledges that the water supply provided by the facility depends on the level of Rio Vista flow requirements, X2 objectives, and salinity requirements. The amount and direction of Middle River flow toward or away from the bay (QWEST) restrictions is also a factor. The BDCP report provides a preliminary estimate of 70 TAF to 500 TAF increase in CVP and SWP exports over pre-Wanger decision conditions.

The greater operating flexibility of two flow paths provides opportunities to draw water from either facility and to capture some flows from the San Joaquin River and other Delta tributaries that would be missed by an isolated facility. Preliminary estimates from BDCP indicate that approximately 20 percent of the total CVP and SWP exports would be derived from the through-Delta portion of the conveyance.

Dual conveyance also could improve water supply reliability because it could be significantly less vulnerable to earthquakes and floods (see Seismic and Flood Durability Section). In addition, dual conveyance could improve water supply reliability since it could operate with less influence from water quality requirements (see Water Quality Section). It appears that the dual conveyance could also improve water reliability since it may be less influenced by ecosystem constraints on diversions (see Ecosystem Health and Resilience Section).

Seismic and Flood Durability

This section reviews available information about various conveyance options and their potential influence on seismic risk and flood durability of the state's water system. A brief introduction is followed by key findings and data gaps, and the potential affects of each conveyance option.

The vulnerability of Delta levees to high water during large flood events has been known since the first attempts to build levees in the 1850s (ENG 18). One hundred and sixty-six failures have flooded islands and tracts since 1900 (ENG 18, 19). Water managers now realize that this past performance may not be an accurate guide for the future, since climate change may increase winter flows into the California Delta and rising sea level presents an additional flooding threat (ENG 18, 19).

The potential for levee failures from seismic events is less obvious because no Delta levees have failed due to earthquakes (ENG 18, 19). However, since the late 1970s, water managers have become more aware of the threat (ENG 20, 21). Since the late 1990s, several reports have successively quantified the risks of Delta levee failures from earthquakes (ENG 18, 22, 23).

The Delta Risk Management Strategy risk analysis considers:

- The frequency with which different sizes of earthquakes and floods occur.
- How land subsidence can affect a levee.
- The condition and vulnerability of different Delta levees to earthquakes and floods.
- How hazards and levee vulnerability combine to cause levee failures including how many levees are likely to fail during the same earthquake or flood.
- The water supply, economic, and ecosystem consequences of levee failure.
- How these factors are likely to change in the future.

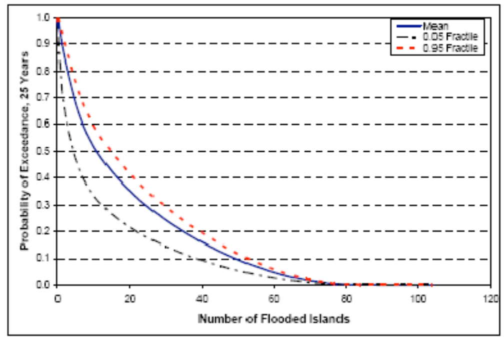
Note: The level of risk is determined by considering combinations of these factors.

Key Findings and Data Gaps

Scientists and engineers are only beginning to understand the potential affects of climate change on floods that may enter the Delta, and they have not yet concluded what future flood and sea level conditions should be taken into account in conveyance design. Likewise, estimates of seismic vulnerability of Delta levees are not universally accepted. However, based on information presented in the most recent study for DRMS (ENG 18, 19), risks to the Delta water system are unacceptably high from both flood and seismic events.

While no report addresses the seismic and flood vulnerability of all conveyance options, some options can be expected to perform better than others. Most relevant references focus on existing through-Delta conveyance. Given the new information from DRMS, future conveyance options should consider seismic and flood forces and establish acceptable risk levels in designing the conveyance facilities to withstand these events.

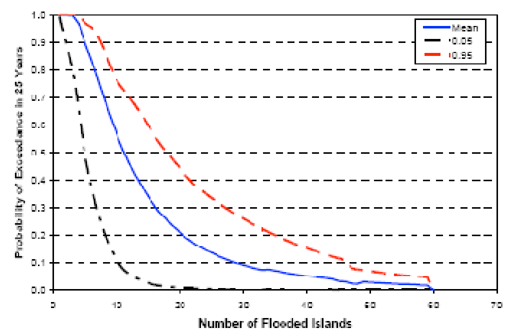
FIGURE SFD-1. PROBABILITY IN A 25-YEAR EXPOSURE PERIOD OF A NUMBER OF SIMULTANEOUS LEVEE FAILURES FROM A SEISMIC EVENT.



Source: *Draft Summary Report Phase 1: Risk Analysis, Delta Risk Management Strategy.*

Existing Through-Delta Conveyance. A CALFED independent science panel reviewed DRMS preliminary findings (ENG 24). The review led to a reevaluation of some DRMS analyses. The results of the reevaluation will be incorporated into the final report to be completed in summer 2008. While specific numbers may change, the essence of the findings is expected to remain the same (ENG 25).

FIGURE SFD-2. PROBABILITY IN 25-YEARS OF EXPOSURE FOR THE INDICATED NUMBER OF SIMULTANEOUS ISLAND FAILURES (OR MORE) FROM A FLOOD EVENT.



Source: *Draft Summary Report Phase 1: Risk Analysis, Delta Risk Management Strategy.*

The DRMS report provides preliminary estimates about the probability of multiple islands flooding simultaneously from an earthquake during the next 25 years, as shown in the Figure SFD-1. The vertical scale ranges from 0 to 1, with 0 meaning little chance of 70 or more simultaneous island failures and 1 meaning a very high chance of a few failures. For example, there is about a 40 percent chance that 20 or more islands will flood simultaneously as a result of an earthquake sometime over the next 25 years.

Levee breaches during the late spring, summer, or early fall can draw saline water into the Delta from Suisun Bay and render water unusable for state and federal water projects, Contra Costa Water District, and in-Delta uses (ENG 2). DRMS estimates that seismic levee failures that flood 30 islands could disrupt water exports for 16 to 23 months due to salt intrusion.

DRMS also provides preliminary estimates about the probability of multiple islands flooding simultaneously from a larger flood during a 25-year period. This probability is shown in Figure SFD-2. There is about a 20 percent chance that 20 or more islands will flood during a single flood during a 25-year period (ENG 18, 19).

When a levee failure occurs during high flood flows, fresh stormwater tends to fill flooded islands. This contrasts with levee failures during low river flow when salt water from the Suisun Bay is drawn into the Delta to fill the flooded islands, such as what happened with the 2004 Jones Tract flooding (ENG 2). (The Jones Tract flooding did not impact water exports because of the time of year the break occurred. Water quality was degraded, but was still within acceptable standards.) The export disruptions were found to be negligible for failures under flood conditions, assuming that the levees are repaired as quickly as possible under a sensible priority system (ENG 18). There may be lasting impacts on Delta hydrodynamics if levee failures are not repaired, however, and post-failure exports may be impaired during the lower flow periods common during most of the year (ENG 18).

Modified Through-Delta Conveyance. As discussed in Delta Vision (ENG 26) and other reports (ENG 2), the existing through-Delta conveyance system cannot continue to meet water supply reliability needs. This conclusion stems from the threat of sea level rise, earthquakes, and potentially larger floods due to climate change that can damage the existing levees and render the existing conveyance system unusable, at least temporarily.

Many potential modifications to the existing system have been considered to improve these conditions. Since these modifications could reduce risk to different degrees, they are not directly comparable and are listed below to illustrate various concepts.

- **Pre-event Strategy** – The Metropolitan Water District of Southern California (MWD) considered constructing levee and flow barriers to block salt water from entering the south Delta in a major emergency, allowing water exports to be resumed about two months after a levee failure (ENG 27). With rising sea level, this may only be a potential interim measure rather than a long-term action (ENG 28).

- **Post-event Strategy** – Rather than construct facilities before an emergency, as in the Pre-event Strategy, MWD preferred pre-positioning materials and equipment in advance of an emergency so a temporary freshwater pathway could be constructed when and where needed (ENG 27). MWD estimated that water exports could be resumed about six months after an emergency. DWR currently is pre-positioning material in the California Delta (ENG 29). With rising sea level, this action may be a potential interim measure rather than a long-term action.

- **Upgrading Delta Levees –** Rebuilding all or some Delta levees to reduce the risk of catastrophic failure was considered as a potential method to reduce the risk to through-Delta conveyance. DRMS considered upgrading Delta levees to Public Law (PL) 84-99 standards, to urban levee standards, and seismic recovery levels (stronger levees that could be repairable after an earthquake) (ENG 25, 30).

- **Armored Pathway Through-Delta Conveyance** – This concept proposes to make extensive levee improvements along a conveyance pathway from the Sacramento River to Clifton Court Forebay. Although it could provide improved protection, it could be very expensive, and has been generally eliminated from serious consideration (ENG 31, 32).

Most other modified through-Delta conveyance options do not reduce seismic or flood vulnerability in a meaningful way.

Delta Corridors. This project could reduce the risk of water supply interruptions from levee failures (from floods or seismic events) and islands flooding compared to through-Delta conveyance (ENG 12.) Separating Middle and Old river corridors could reduce the likelihood of salinity intrusion during levee breaks.

Isolated Conveyance Facility (eastern route). Isolating the conveyance system from Delta channels makes it significantly less vulnerable to levee failures and salt water intrusion during a major emergency. Urbanization in the eastern Delta could require moving the conveyance facility alignment further to the west from that planned in the 1980s (ENG 33). The most recent cost estimates by The Washington Group (now part of URS Corp.) moved portions of the alignment to avoid existing development (ENG 33). Some people are concerned that concepts for the isolated conveyance facility have not adequately addressed seismic events or flooding that can occur east of the facility from water draining toward the California Delta (ENG 34).

The 1999 isolated conveyance facility studies done by the CALFED Bay-Delta Program (ENG 35) and The Washington Group (ENG 33) were based on a below ground level (incised) cross section for the canal. DWR is revising the concept to a "cut and fill" cross section. A cut and fill cross section is constructed partly below ground and partly above ground to balance excavation quantities with fill for parallel levees. This could provide more of a barrier to water draining toward the Delta during heavy storms. None of these design concepts consider seismic and flooding issues.

Isolated Conveyance Facility (western route). Like the eastern route, the western route of an isolated conveyance facility could reduce seismic and flooding risks to the water supply compared with the existing conveyance system. The western route requires a major tunnel crossing of the Sacramento River and western Delta that may have increased seismic issues. The western route should not cause the same flood concerns as the eastern route. None of these concepts have detailed designs where seismic and flooding issues will be given due consideration.

Dual Conveyance. A dual conveyance system could be less vulnerable to seismic and flood events compared with the existing through-Delta conveyance. Two flow paths provide some redundancy during an emergency.

An example of how a dual conveyance system could be configured is in the Bay Delta Conservation Plan, Option 3 (ENG 14). The isolated conveyance facility could be designed to reduce the risks from earthquakes and floods, but costs could increase. The channels for the through-Delta conveyance are in the eastern Delta and are partially isolated with operable gates on channels leading to the central Delta. This through-Delta conveyance should be significantly less vulnerable to a major emergency from levee failure in the western Delta. Salt water drawn into the Delta to fill these flooded islands should have less impact on the through-Delta conveyance channels since the gates can be shut and improvements along a portion of the channels could make levees less susceptible to failure.

Ecosystem Health and Resilience

This section reviews available information about various conveyance options and their potential effects on Delta ecosystem health and resilience. After a brief introduction, key findings and data gaps are presented by the three topics listed as necessary for a resilient, regenerated ecosystem: physical habitat, ecological process, and stressors. This section also includes short discussions regarding trade-offs and recommended next steps.

Present understanding of Delta ecosystem functions are based primarily on its existing configuration, existing water management operations, and recent scientific evaluations.

The five conveyance options considered in this review include the ability to export various quantities of water through combinations of channel modifications, pipelines, tunnels, salinity barriers, operable flood gates, expansive fish screens, as well as creating and improving tidal and freshwater marshes, riparian corridors, migratory corridors for anadromous fish, and open water (pelagic) habitats. None of the conveyance options address the ecosystem's complexity or the need for science-based adaptive management.

Overall, the closer a proposed conveyance option mirrors the existing design and operation of the Delta, the better its potential impacts can be assessed. As the Blue Ribbon Task Force (EHR 11) stated, the current conveyance system and Delta configuration is not sustainable, especially in light of climate change and other future stressors. We are in a position that strongly suggests changes need to be made to the system to ensure ecosystem health and resilience.

Changes to the ecosystem are coming, regardless of human action or inaction (EHR 38). Some changes are easy to understand but hard to carry out, such as reducing the adverse affects of invasive species and pollutants; others are harder to understand but easier to carry out (at least theoretically), such as increasing freshwater flows from the major tributaries.

The Task Force said in their Delta Vision document, "in any ecosystem, ecological functions are a product of a given physical habitat structure and the ecological and physical processes that occur there, with additional influence from external stressors, such as pollution or powerful water pumping that alters currents. All of these elements are of critical importance in the Delta […]" (EHR 11).

The key findings and data gaps discussion is followed by more detailed discussion based on the Task Force's three critical elements: physical habitat, ecological process, and stressors.

Key Findings and Data Gaps

Environmental impacts from any of the conveyance options ultimately depend upon the design, placement, and operation of the facilities.

Through-Delta conveyance options usually include design options that allow for expanded flexibility and opportunities to restore habitats and enhance ecosystem functions of the Delta (EHR 34, 35). Through-Delta options (including the Delta Corridors Project) will continue to have impacts associated with the pumps in the south Delta. One adverse impact of through-Delta conveyance is redirecting fish from their natural habitats into the export facilities (entrainment) and the resulting loss of fish.

Both isolated facilities options (east and west alignments) also have expanded flexibility to modify in-Delta channel configurations and landforms to restore habitats and enhance ecosystem functions (EHR 42, 43). The isolated facilities options sever the direct connection between in-Delta water quality and export water quality, although the in-Delta water quality will be affected by timing and diversion rates at the intake facility (EHR 16). Both of the isolated facilities options will have impacts, some potentially significant, to terrestrial habitats that will be disturbed. Some of the disturbance would be in places bisected by the new facilities that will connect with the export facilities in the south Delta. An isolated facility would eliminate reverse flows in channels leading to the export facilities and eliminate the entrainment and the associated fish loss. A large screening or fish facility would be needed to prevent entrainment into the isolated facility (EHR 31, 34, 36).

The dual conveyance option can, with careful design and operations, address the negative impacts of either the stand-alone isolated facilities or a through-Delta conveyance system (EHR 31, 36).

An important design feature for any conveyance option is fish screens (EHR 40). The current facilities have direct impacts on several special status fish species (EHR 31, 36).

In general, the lack of specific design and operation criteria is a gap that prevents thorough analysis of potential ecosystem impacts from these various conveyance options.

Physical Habitat

The California Delta is a mosaic of many different kinds of physical habitat, both aquatic and terrestrial (EHR 16, 32, 33, 36). The Task Force said, "For the Delta as a whole, a resilient, regenerated ecosystem will contain" seven physical habitat attributes:

1. Seasonal and inter-annual patterns of freshwater flow into and through the Delta that will re-establish variable water conditions and floodplain inundation for the benefit of native species;
2. Channel configurations that are like tentacles and contribute to variable residence time and greater habitat complexity;
3. Tidal access to low-lying marginal lands to encourage tidal freshwater and saltwater marsh development;
4. Patterns of sediment transport, disposition, and erosion that maintain appropriate levels of turbidity as well as intertidal and shallow sub-tidal land forms;
5. Broad corridors of natural and semi-natural habitats connecting marsh to extensive upland;
6. Geometry and topography that allows all life forms expected in a delta-estuary system;
7. Marginal land reserves that will allow upslope migration of wetland types in response to sea level rise (EHR 11).

These seven physical habitat attributes integrate to varying degrees in the categories used in the following text: wetland habitats, riparian habitats, seasonally-inundated floodplains, and open water (pelagic) habitat.

The main focus of this section is aquatic habitat because this report deals with conveyance. Aquatic habitats are the integrated group of physical, chemical, and biological factors that species occupy (EHR 37). Maintaining appropriate habitat quality is essential to the long-term health of aquatic resources (EHR 31, 35, 36, 38). Historically, Delta habitats varied across years, seasons, and tidal cycles in terms of salinity, the amount of time water stayed in an area (water residence time), turbidity, water velocity, elevation, and other physical habitat conditions (EHR 8, 16).

This ecosystem was composed of large areas of tidal wetlands, both saline and freshwater, connected by branch-like (dendritic) channels that provided a complicated and dynamic food chain (EHR 26). The tributary rivers and streams had floodplain areas adjoining their channels that flooded on a regular basis (EHR 14).

Wetland Habitats. The California Delta has undergone tremendous modification in the last 150 years (EHR 5, 25). Most of the in-Delta tidal wetlands have been drained and separated from the open water system. This draining and separation means wetlands no longer interact with the open water habitats, and tides no longer flood the wetlands.

Almost all of remaining wetlands are on the boundary of the California Delta between the upland watershed and the open water (EHR 32, 33). Areas within the Yolo Bypass and Suisun Marsh contain most of these remaining wetlands. Researchers investigating the aquatic food web in the Bay-Delta observed the importance of both tidal marsh and floodplain preservation and restoration as relatively food-rich areas for species living in open water (EHR 20).

- *Potential Effects of Conveyance Options on Wetland Habitats*–Although the various conveyance options do not specifically address tidal wetlands, most could allow for some beneficial modifications over existing conditions. With the **through-Delta options,** some tidal wetlands could be established or recovered, but this could mean that the conveyance system would have to be operated differently to meet drinking water quality needs at the export facilities. Both of the **isolated facility options** could allow many of the channels to be reconfigured and the islands to be opened to tidal influence. Since most central and western islands are too subsided to provide tidal wetlands without on-going management, the most practical place to create tidal wetlands would be in the northern and southern Delta, in addition to the fringes of the Delta (EHR 25, 32, 33, 36). In order for these ecosystem improvements to be effective in the southern Delta, the water quality issues associated with low summer flows would need to be addressed. The **dual conveyance option** could provide some flexibility for establishing or recovering tidal wetlands, depending on the operations criteria and design (EHR 31).

Riparian Habitats. Riparian habitats are those areas adjacent to rivers and streams with a differing density, diversity, and productivity of plant and animal species. There is less riparian habitat in the Delta now compared to historic levels and this loss affects a wide variety of birds and other animals. The Swainson's hawk, a state-listed threatened species, is a good example of a species that depends on riparian habitat. There continues to be a conflict between levee maintenance and need for riparian habitat that has yet to be resolved.

- *Potential Effects of Conveyance Options on Riparian Habitats*–None of the conveyance options address riparian habitat impacts, yet all could have some impacts from installing and maintaining new facilities. Existing levee and channel configuration could be modified for improved riparian habitat with most of the options. The western isolated facility option suggested that several Delta islands could be acquired and managed for a variety of tidal marsh, wetland, riparian woodland, and riverine habitats (EHR 44).

Seasonally-Inundated Floodplains. Winter flooding along river banks produce habitat called seasonally inundated floodplains. This habitat is critical to certain life stages of desired fish species. For example, studies and monitoring of Yolo Bypass show the ecosystem benefits available by connecting the Delta with its floodplains, which can increase the growth rate and survival of several important species (EHR 27, 29). Managing seasonally-inundated floodplains (e.g., Yolo Bypass) and providing safe fish migration corridors between spawning and rearing grounds is needed to promote frequent successful spawning of fish such as splittail (EHR 7, 17, 24).

- *Potential Effects of Conveyance Options on Seasonally-Inundated Floodplains*–None of the proposed conveyance options addressed this important ecosystem habitat. Any proposed conveyance option would have to account for this important connection with floodplains by avoiding impacts to existing connections and allowing or encouraging new connections.

Migratory Habitat for Anadromous Fish. Anadromous fish are those that spawn in fresh water but live in salt water; water bodies that provide passage between spawning areas and the ocean are considered migratory habitat for these fish. Migratory habitat for anadromous fish includes the lower portion of the Sacramento River and the maze of sloughs and channels in the California Delta. The San Joaquin River provides migratory habitat, passes through the California Delta, and empties into the Sacramento River. Because of the complexity of the migratory system, no single route exists for an out-migrating fish to the ocean, and the distance traveled after entering the California Delta toward the San Francisco Bay can vary (EHR 22). The water diversions and exports have drastically changed historic out-migration routes and reduced the likelihood of juvenile Chinook salmon successfully reaching the California Delta and the ocean. Data show that closing the Delta Cross Channel gates during juvenile Chinook outmigration contributed to their survival by keeping the fish out of the central Delta and away from the export facilities.

- *Potential Effects of Conveyances Options on Migratory Habitat for Anadromous Fish*–The **through-Delta** would provide less protection to young salmon from entrainment at SWP and CVP facilities, although the **dual conveyance option** could allow improved protection, depending upon how it is operated. The **Delta Corridors Project**, a form of through-Delta conveyance, would separate the San Joaquin River corridor from the export facilities, restore more natural functions of the riverine and estuarine migratory habitats, and eliminate entrainment of San Joaquin River fish. The **isolated facility options** could also improve migratory conditions for juvenile salmon.

Open Water (Pelagic) Habitat. Habitat for pelagic fishes is open water, away from shorelines and vegetated inshore areas except perhaps during spawning. Open water habitat includes large embayments such as Suisun Bay and the deeper areas in many larger Delta channels (EHR 37). Pelagic fish habitat provides a variety of physical and chemical properties that support growth, such as salinity, turbidity, temperature, suitably low levels of contaminants, and suitably high levels of prey production. Pelagic fish habitat in the estuary can be strongly influenced by variation in freshwater flow (EHR 4, 12, 14). There is a strong correlation between pelagic habitat and the place where seawater and freshwater meet in the estuary called the X2 zone. The abundance of numerous species increased when outflow from the California Delta into the estuary was high and the X2 zone moved seaward (EHR 12), suggesting that the quantity of pelagic habitat increases when outflows are high. Even though pelagic habitat increases in years of high outflow, there has been a long-term decline in fall open water habitat quality for Delta smelt and striped bass based on a 36-year record of concurrent midwater trawl and water quality sampling (EHR 10).

- *Potential Effects of Conveyance Options on Open Water (Pelagic) Habitat*–Pelagic habitat is reduced in years or times of low Delta outflow and is increased during high outflow. None of the conveyance options could significantly improve the quality or quantity of pelagic habitat. Except during periods of high (uncontrolled) outflow, the water management scenarios for each option are more important than the conveyance option itself in determining the quantity of outflow and the resulting quality and quantity of pelagic habitat.

Ecological Processes

The Task Force said three ecological processes are necessary:

1. Enhanced processes of food productivity and delivery to valued components of the ecosystem;
2. Restoration and expansion of ecosystems on which rare and threatened species depend;
3. Enhanced processes that strengthen competitive ability of native species (EHR 11).

This section discusses the first of these three ecological processes. The California Delta ecosystem is dynamic. Today's Delta will be different from tomorrow's Delta in terms of species assemblages, new exotic species, water operations, water quality, configuration (levees and channels), and hydrodynamics. Long-term climatic changes also will alter inflow patterns to the California Delta and water level elevations (EHR 36). Under existing operations and configuration, native fish species continue to decline, and Delta smelt may be on the verge of extinction (EHR 16). Recent investigations suggest that Delta pumping has a negative effect on several key Delta fish species; however, more freshwater inflows or reduced exports alone probably will not save these species because the highly altered ecosystem also is significant part of the problem (EHR 1, 4, 12).

Arthur et al. observed that "the greatest negative impacts are largely associated with altered flow patterns and hydrodynamic changes in the Delta resulting from direct transport of CVP/SWP export water through existing Delta channels. Impacts include […] significant alterations of Delta habitat (via decreased residence time and alteration of flow patterns) with corresponding reductions in some fish and their food web." (EHR 1)

The four most abundant pelagic fishes in the upper estuary are Delta smelt, longfin smelt, striped bass, and threadfin shad. Around 2000, abundance indices for these pelagic fishes began to decline sharply, despite hydrologic conditions that normally support self-sustaining fish production (EHR 39). These declines surprised many Delta researchers because these fish have different life histories and use Delta habitats differently. These differences suggest one or more Delta-wide factors are important in the declines (EHR 37).

One factor may be the decline in food web organisms (primary production); an important indicator of primary production is the amount of organic matter in the system. The California Delta is a net producer of organic matter in critically dry years. Because of water diversions from the California Delta, organic matter moving from the Delta to important downstream nursery areas in San Francisco Bay always is less than the organic matter entering the Delta from upstream sources. More floodplains offer a greater opportunity to increase organic matter into the system.

Another factor in the food web decline is a decrease in channel residence times—the amount of time water and fish stay in a particular channel—that is a result of more water being transported across the southern and central Delta to the export pumps. This residence time decrease is an additional impact to the loss of food web organisms, fish eggs, and larvae being pumped out of the Delta via the Delta-Mendota Canal and the California Aqueduct (EHR 1). Moving the major diversion points to the upper estuary could address these issues by allowing changes in the present channel configurations and water movement through those channels (EHR 1, 24, 26, 28).

A third factor is water clarity. Delta water clarity has increased over several decades (EHR 10, 36, 37, 41). The primary reasons seem to be: reduced sediment supply due to dams in the watershed; sediment washout from very high inflows during the 1982-1983 El Nino (EHR 12); and biological filtering by submerged aquatic vegetation (EHR 41). The increasing water clarity lessens pelagic fish habitat quality (EHR 10 and EHR 41) and suggests a connection between Brazilian waterweed proliferation (an invasive species) and pelagic habitat quality (EHR 41).

- *Potential Effects of Conveyance Options on Ecological Processes.*–An **isolated facility** could result in substantial nutrient loading increases during winter and autumn, but little change in spring and summer when food availability is more important to developing organisms. Flow and fish barriers in the channels could have significant effects, especially on phytoplankton, and in dry years by eliminating short-circuits in moving organic matter to diversion points (EHR 12, 41). Since annual primary production declines partially explain Delta species declines (EHR 10, 12), any conveyance option will need to address this issue if the Delta's ecosystem is to recover the functions required to support a healthy and resilient ecosystem. The ability for the proposed conveyance options to address sediment supply is very limited; however, there is some potential to address existing and future impacts of invasive species such as the Brazilian waterweed that do impact sediment transport within the California Delta.

Stressors

The Task Force listed five stressors that should be reduced or eliminated in the California Delta:

1. Reduced impact of chemical stressors of all types on Delta species and ecosystems;
2. Reduced impact of established non-native species on native species;
3. Reduced opportunity for invasion of new non-native species;
4. Reduced or eliminated entrainment of desired species and food organisms into water intakes;
5. Reduced or eliminated effects of export pumping on flow patterns in the Delta (EHR 11).

There are many stressors in the estuarine ecosystem; this review will look only at invasive species and entrainment. Water quality stressors, including pollutants, are covered in the Water Quality section of this report.

Invasive Species. The California Delta is highly invaded by nonnative organisms. Although most nonnative species do not become established, numerous large scale invasions have greatly altered the Delta ecosystem (EHR 9, 16, 17). Invasive species will continue to affect the system in many ways, including water clarity, changes in quality and quantity of primary producers (EHR 9), and direct competition and predation with other species (EHR 19). Restoration projects in and around the California Delta need to consider the potential impacts of nonnative invasive species to their goals and objectives.

- *Potential Effects of Conveyance Options on Invasive Species*–The conveyance options do not address impacts to invasive species. The **through-Delta option** gives the fewest choices for addressing potential new invasions or existing nonnative aquatic species since the current hydrology or something similar would need to be maintained. The **isolated facility options** could promote invasive species where new construction occurs and because of changes to existing hydrology and land form. For example, the western alignment, though not specific, could affect sensitive plant communities along the north perimeter of the California Delta where invasive plant species are a major concern. The eastern alignment may disrupt local runoff patterns within islands that could establish new populations or increase existing populations of invasive plants. These impacts could be mitigated with careful design, construction, and maintenance. Because invasive species issues are complicated and future threats are not well understood, the overall impacts of the proposed conveyance options are very difficult to determine.

Entrainment. An important stressor is the loss of desired species (take) at the export pumps (EHR 1, 3, 31). Major water diversions in the Delta include the SWP and CVP export facilities, power plants, and agricultural diversions. Of these, the patterns of agricultural diversions are the least likely to have changed during the pelagic fish decline (EHR 37). The pump intakes at the SWP and CVP are screened and the export facilities are operated to lessen take of desired species.

Potential Effects of Conveyance Options on Stressors–The **through-Delta option** would continue the take impacts, though potential changes to nearby channel hydrology could lessen these impacts, especially to protected species. Operational changes also could lessen the death rate (EHR 31, 36, 39). With both the **isolated facility options**, the intakes should be screened, which could lessen the impact on the species. The intake design and placement for either isolated facility options have not been specified. Depending on their placement and design, direct take could still be an important issue with either isolated facility option (EHR 31, 36). The **dual conveyance option** could allow for more flexibility in operations to address direct mortality (EHR 31.)

Trade-Offs

Developing and evaluating conveyance scenarios needs to address a wide range of ecological considerations. While none of the existing scenarios adequately address non-native invasive species impacts, water clarity, reduced pelagic habitat, and altered food web dynamics, there are opportunities to address these inadequacies as the scenarios are further discussed, modified, and developed.

Greater variation in salinity levels in the Delta was suggested as a way to help pelagic fish (EHR 16). While greater salinity variability might be good for estuarine fish like Delta smelt and striped bass, for pelagic food web organisms, and for waterfowl, to focus simply on salinity variability is not enough. Habitat variability is necessary as well, and needs to include a broad range of attributes such as dendritic channel geometry that promotes more variability in water residence time, salinity gradients, and other water quality components (EHR 41). Lund et al. (EHR 16) also observed that a Delta that is variable across space and time is more likely to support native species than is an entirely fresh or brackish Delta.

While the conveyance options being considered lack the design and operation specificity to adequately assess their likelihood to provide or promote a healthy and resilient ecosystem in the Delta, they all have the potential to do this. The final outcome will depend on the ability of the designers and operators to minimize adverse impacts while providing much-needed ecosystem enhancements. The five scenarios are strong in suggesting conveyance options, but weak in suggesting corresponding options to improve the ecological processes and aquatic and terrestrial habitats of the Delta. Table EHR-1 highlights some of the ecological concerns with each conveyance option. Due to the California Delta's complex ecology, continued analysis and reassessment of implemented actions (e.g., adaptive management) is critical for eventual success.

Recommended Next Steps

To make good choices, decision makers need more information about long-term solutions for the California Delta. This information includes more detail about where a facility would be built, how large it would be, and how it would be operated (EHR 16, 31, 36). Without specific information, it is difficult to predict ecological impacts of any conveyance option. As evaluation of conveyance options for the California Delta continues in a thoughtful, deliberate manner, additional data will be required. Any chosen conveyance option needs to integrate new and relevant scientific data about the Delta ecosystem into its design and operation criteria. Ecosystem and conveyance facility management should be supported by proper data collection and analysis, in combination with computer modeling; levee replacement, island land management, and flood control also should receive greater attention in a problem-solving framework (EHR 16, 36).

EHR-1. SCENARIO COMPARISON			
Scenario	**Ecological Processes**	**Habitat**	**Stressors**
Through-Delta Conveyance	If future operations are similar to existing operations, then similar and significantly detrimental effects on ecological process would occur. Current operations reduce flow from San Joaquin River to critically low levels – San Joaquin could provide nutrients and zooplankton to Delta with better flow and less loss to pumps. Current channel configurations are designed and managed to keep water flowing through Delta for water supply – restricts ability to allow naturalized hydrogeological processes.	Potential to create aquatic and terrestrial habitats limited by need to continue operations of water conveyance through Delta and to protect current land forms. Does not promote pelagic habitat. Impairs migratory habitat for anadromous fish.	Has encouraged non-native species that adversely affect natives by greatly modifying landform, channel diversity and hydrology Current fish screens operations at pumps difficult to operate without "take." Present operations result in entrainment and loss of juvenile fish at the SWP and CVP export facilities. Requires extensive dredging that can resuspend chemical stressors within substrate.
Isolated Conveyance Facility (eastern route)	Reduces Delta inflow during dry periods. Diverts upstream organic input and sediment from Delta. Potential adverse affects on aquatic foodweb in north Delta. Potential for beneficial affects on aquatic foodweb in south Delta. Depending on design of existing channel crossing, closures of sloughs may inhibit fish passage and aquatic food web.	Potential to create aquatic and terrestrial habitats within Delta is enhanced without the need to continue water transport across Delta. Construction of facilities may disrupt existing terrestrial habitats, especially for waterfowl and upland birds. Facilities, depending on alignment, may hinder area specific wetland and upland habitat creation. Can expand or reduce open water (pelagic) habitat depending on outflow (X2). Can improve migratory habitat for anadromous fish.	Potential to create aquatic and terrestrial habitats within Delta is enhanced without the need to continue water transport across Delta. Construction of facilities may disrupt existing terrestrial habitats, especially for waterfowl and upland birds. Depending on alignment, facilities may hinder area specific wetland and upland habitat creation. Can expand or reduce open water (pelagic) habitat depending on outflow (X2). Can improve migratory habitat for anadromous fish.

EHR-1. SCENARIO COMPARISON, CONTINUED			
Scenario	**Ecological Processes**	**Habitat**	**Stressors**
Isolated Conveyance Facility (western route)	Similar in effects to Isolated Conveyance (eastern route)—reduces Delta inflow during low-flow periods. Potential adverse affects on aquatic food web in north Delta. Potential for beneficial affects on aquatic food web in south Delta.	Similar in effects to Isolated Conveyance (eastern route). Unquantified potential to create aquatic and terrestrial habitats. Can expand or reduce open water habitat depending on outflow (X2). Can improve migratory habitat for anadromous fish.	Could promote invasive species due to changes in hydrology or land form. Facilities construction may increase invasive terrestrial species. Could reduce fish entrainment at export facilities.
Delta Corridors	Potential to improve ecological functioning in lower San Joaquin River.	Unquantified potential to create aquatic and terrestrial habitats. Improves migratory habitat for San Joaquin Chinook salmon smolts.	Could promote invasive species due to changes in hydrology or land form. Fish screens at Delta Cross Channel could impair adult fish migrations.
Dual Conveyance	More operational opportunities to support ecological processes.	Unquantified potential to create aquatic and terrestrial habitats. Can expand or reduce open water habitat depending on outflow (X2).	Could promote invasive species due to changes in hydrology or land form. Requires barriers and extensive fish screens. Could reduce fish entrainment at export facilities.

Water Quality

This section reviews available information about various conveyance options and their potential effects on water quality. After a brief introduction, key findings are presented, followed by a discussion of drivers of change and water quality. This section also includes discussions regarding data gaps, trade-offs, and expected water quality outcomes by conveyance option.

Water Quality Constituents Reviewed for this Assessment

Salinity
Organic Carbon
Temperature
Dissolved Oxygen
Ammonia
Nutrients
Pesticides
Selenium
Bromide
Pathogens
Mercury

Source: *CALFED Water Quality Program.*

Different water uses have different water quality needs and standards. We have a good understanding of current water quality for many constituents of concern for drinking water supply, agricultural water supply, and the ecosystem (WQ 4, 6, 7, 11, 12, 13, 14, 34, 35, 36). Given the location, timing, and diversion amount of a proposed conveyance option, we can make well-informed predictions about changes in concentrations of these water quality constituents in the Bay-Delta system. Water quality assessments of conveyance options depend on computer models that simulate the complex hydrology and hydrodynamics of the California Delta and its watershed. The output of these models depends on the assumptions about the configuration and operation of a conveyance system.

This section describes how water quality might change with any one of five conveyance options. Variations on those options also are discussed when appropriate. Most of the descriptions are qualitative, but in some cases, quantitative estimates of water quality changes are cited. This assessment looked at water uses (drinking water and San Joaquin Valley agriculture, in-Delta agriculture, and ecosystem) and constituents of concern, water quality location, pollutant sources, water project operations, timing, and other factors. Water quality trends, climate change, and population change impacts are also considered.

Key Findings

- **Ecosystem water quality ≠ drinking water quality**

Water quality needs for ecosystem processes conflict with water quality needs for drinking water. Designing or managing the California Delta for ecosystem processes diminishes the Delta as a good source of drinking water, and vice versa (WQ 1, 4, 9, 34). Actions to improve ecosystem processes will increase some water quality constituents that are detrimental to drinking water or in-Delta agricultural quality. Each water use has its own particular water quality and water supply needs and preferences that may conflict with other uses.

Organic carbon and bromide contribute to disinfection byproduct (DBP) formation in municipal water supplies (WQ 6, 7, 8, 11). At the south Delta intakes, both are at concentrations higher than CALFED targets established to protect public health. Most regulated DBPs are considered probable or suspected human carcinogens. Standards for drinking water contaminants are a compromise based on treatment technology, cost, health risk from pathogenic microorganisms, and cancer risk. For one DBP (bromate), this meant setting a standard with a 1 in 5,000 lifetime cancer risk. The usual practice is to set a standard as close as possible to a 1 in 1,000,000 lifetime cancer risk, but no more than 1 in 10,000. Therefore, the standards are upper limits, and it is desirable from a public health standpoint to reduce DBP concentrations as much as possible. Reducing the concentration of organic carbon and bromide in water diverted from the California Delta would help municipal water suppliers in their efforts to provide safe drinking water.

Plans for ecosystem restoration in the California Delta include creating or restoring wetlands and floodplain habitat that will likely increase organic carbon concentrations (WQ 1). Increasing the variability of salinity in the Delta for the ecosystem would also impact drinking water quality. Salinity that would be harmless or even beneficial for the ecosystem could make water completely unusable for municipal or agricultural water supply (WQ 4). Increasing turbidity and the amount of algae in the water, considered beneficial for pelagic fish species, would also be problematic for drinking water by making treatment more difficult, and more costly, and by increasing public health risk (WQ 4, 9, 30).

A recent analysis by U. S. Geological Survey scientists estimated that restoring 30,000 acres of wetlands in the Delta could seasonally increase organic carbon by 0.5 milligrams per liter (WQ 37). During peak wetland carbon production, this could amount to roughly a 15 percent increase over current levels and could have a significant impact on drinking water treatment.

- **Dilution isn't the solution (but it has its benefits)**

For the Bay-Delta as a whole, wet years have better water quality (WQ 4). There is a strong correlation between inflow and average Delta salinity. Within the California Delta, the current through-Delta conveyance creates a broad zone of relatively low salinity dominated by Sacramento River water (WQ 4, 34, 35). Wastewater discharges, agricultural drainage, and poorer quality San Joaquin River inflow are diluted by this large flow of higher quality water. An isolated facility could reduce this volume of high quality inflow, thereby increasing the average concentration of many contaminants including selenium, salts, and nutrients from the San Joaquin River (WQ 2, 6, 19).

High Sacramento River flows also mask the significant pollutant contributions from urban runoff and wastewater treatment plant discharges from the Sacramento urban area. These discharges can be high in organic carbon, pathogens, and ammonia and should be addressed when planning alternative conveyance.

- **The method and operation of conveyance is important to local water quality within the California Delta**

Studies show that changes to barrier, gate, and export pumping operations can cause major changes in local water quality conditions within the Delta (WQ 20, 25). Computer modeling and chemical fingerprinting techniques show that, for much of the year, nearly all of the flow from the San Joaquin River is intercepted by the south Delta pumps (WQ 2, 7, 10, 12, 13). Many of the water quality problems linked to poor quality San Joaquin River water (such as low dissolved oxygen in the Stockton Ship Channel) are truncated in the central Delta by the cross-Delta flow of Sacramento River water (WQ 2, 16).

Operation of an isolated facility could increase the area within the California Delta dominated by San Joaquin River flows. This could be partially mitigated by the improved quality of water delivered to the San Joaquin Valley through the Delta-Mendota Canal, but this needs further study (WQ 2, 10). The effects of export water quality need to be considered on agricultural water use and water quality in the San Joaquin Valley, and water use and reuse in all water project service areas. Operation of an isolated facility could also increase residence time and increase the influence of other local water sources in the Delta.

- **River intakes allow operational flexibility**

An intake for an isolated facility near Hood on the Sacramento River could provide better drinking water quality than the existing south Delta intakes, but could provide even greater water quality benefits through operational flexibility. For water utilities with river intakes, one strategy to improve water quality is to simply let pulses of poorer water quality pass by their intakes. Monitoring shows that seasonal spikes of poorer quality water in the Sacramento River are often short lived lasting only a few days (WQ 7). This is not a viable strategy for the existing south Delta SWP and CVP intakes since low quality water pools around the intakes and water quality may even get worse when pumping stops. Coupled with additional storage, this strategy could be a powerful water quality improvement tool.

Most upstream drinking water suppliers using surface water employ this strategy to some extent including the cities of Sacramento and Redding. Some Delta diverters use variations of this approach shifting to other sources or stored water when water quality is poor (WQ 7).

- **Better source control is needed**

The California Delta has existing water quality impairments as evidenced by the State Water Resources Control Board's list of impaired water bodies, Total Maximum Daily Load actions, and other agency regulatory actions (WQ 16, 26, 29, 30, 32). Improving the quality of wastewater discharges, urban runoff, and agricultural drainage is essential to all of these efforts and would benefit multiple water uses. Urban runoff and wastewater discharges contribute to ammonia, dissolved oxygen, pesticide toxicity, and pathogen problems in the California Delta. An isolated facility could create a more direct connection between Sacramento wastewater and Delta municipal water supply because it would reduce the dilution effect. An isolated facility could also increase the impact of agricultural drainage for the same reason. A wide range of contaminants including selenium, pesticides, salinity, and nutrients contribute to Delta water quality woes and are best dealt with at the source.

- **Water quality impacts on ecosystems are difficult to predict**

Plant nutrients (various forms of nitrogen and phosphorous) are necessary for productive food chains, but high nutrient concentrations do not necessarily mean there is a productive food web (WQ 35). The California Delta probably has an excess of nutrients and these nutrients may be contributing to a variety of Delta water quality and ecosystem problems. In theory, increasing residence time would increase Delta food web productivity, but the combination of high nutrient concentrations, residence time, and temperature could lead to explosive algae growth followed by rapid die-off and low dissolved oxygen conditions (WQ 9, 35). Nutrients are a contributing factor in the Stockton Ship Channel dissolved oxygen depletion problem and may be a factor in the excessive growth of invasive aquatic plants (WQ 16).

Habitat requirements for individual species tend to be complex and the interrelationships between species are even more complex. Changes in basic water quality parameters such as temperature, salinity, and turbidity could cause changes in the location and population of key Delta species (WQ 9). Inputs of small amounts of certain toxic substances can also have far reaching impacts on ecosystems (WQ 6, 19). A well designed monitoring program will be needed to be able to detect water quality problems in their early stages and guide effective management responses.

Drivers of Change and Water Quality

Population Growth. The impact of population growth on the California Delta ecosystem is likely to extend beyond reduction in available habitat. Without increased levels of control, development in and around the California Delta will increase the amounts of pollutants common in urban runoff and wastewater discharges, including emerging contaminants such as endocrine disrupting compounds, pharmaceuticals, and personal care products.

There is a tradeoff: polluted runoff from current land uses in the Delta could be reduced, however, urban runoff contains high concentrations of many pollutants that are not part of those current land uses (WQ 16). Efforts to reduce urban stormwater are called stormwater controls; there is not much yet known about how effective large-scale stormwater control could be. The most conservative assumption is that urban runoff will continue to send pulses of stormwater that are high in metals, organic carbon, pathogens, pesticides, and other toxic compounds into receiving waters such, as the Sacramento River, at rates similar to those currently observed. Increasing population would result in increasing amounts of these pollutants.

Climate Change. A warmer climate could cause more precipitation to fall as rain rather than snow, shift the annual runoff peak to earlier in the year, increase peak flows and reduce runoff duration, as well as increase water temperatures. These changes could likely result in a system with greater winter flows and lower summer and fall flows (WQ 15). Water quality problems associated with high winter flows (turbidity and organic carbon) and low summer and fall flows (temperature, algae, dissolved oxygen, and salinity) could worsen (WQ 15). Reduced flows in the summer and fall could also increase the impact of agricultural drainage and wastewater discharges. Rising sea level will also increase salinity intrusion into the California Delta (WQ 15). Unless changes are made, increased salinity intrusion will likely increase the average salinity of exported water and reduce export volume as more water is needed to maintain freshwater conditions under current Delta salinity standards.

Seismic and Flood Risk. The California Delta is vulnerable to levee failures from a variety of causes including earthquakes and floods. The 2004 Jones Tract levee failure was well documented, and gives a hint of what water quality impacts can be expected from multiple levee failures. In the first three days of the break, an estimated 150,000 to 200,000 acre-feet of water, approximately 35 percent of the volume of all Delta channels, moved onto Jones Tract. Export pumping was immediately reduced and reservoir releases increased due to concerns that the Jones Tract failure could cause a surge in Delta salinities (WQ 11). Salinity after the break was higher than average, but within the normal annual range. The salinity levels were probably helped by the quick response from SWP and CVP operators and favorable hydrologic conditions. Dissolved organic carbon, however, was much higher than normal and increased during the pump-out, probably due to leaching from the flooded island's peat soils. Other constituents of concern associated with flooded islands include bacteria from flooded septic tank systems, taste and odor from algae blooms, and petroleum products and other chemicals from farming operations.

Analyses of the probability of Delta island levee failure due to an earthquake indicate that multiple island levee failures are possible, and that these could interrupt water supply for up to two years. In this scenario, there are two potential drivers of salinity intrusion: (1) the initial surge of salty water pulled into the Delta from Suisun Bay as the islands fill and (2) the continuing increase in tidal energy due to the larger volume of water moving in and out with each tide change.

Gaps

- Quantitative projections of water quality for any constituent cannot be made until more detailed operating scenarios and modeling are available. Depending on the pollutant, both diversion volumes and timing at each intake could make an important difference.

- A noticeable data gap is the lack of water quality modeling of alternatives that includes all pollutants of concern for the Delta, including salinity, nutrients, selenium, mercury, pesticides, pathogens, bromide, retention time, temperature, turbidity, dissolved oxygen, organic carbon, and effluent dilution ratios.

- Our understanding of the linkage between water quality and the Delta food web is incomplete. There is evidence that the California Delta has an excess of plant nutrients and signs that this is a pollution problem, but there is also evidence that productivity is very low. A thoughtful program of careful observation, monitoring, studies, and experiments is needed to create water quality conditions that support a healthy Delta ecosystem.

- Our understanding of pesticides, other toxic substances, and toxicity test results is also incomplete. Studies are under way to compile available information on toxics in the California Delta and its tributaries and to determine the sensitivity of key Delta species, but it is likely that more work will be needed.

- Water quality analyses are inadequate to monitor the impacts of mercury, selenium, and other bioaccumulative substances on the ecosystem and human health. Most of the information on fish tissue concentrations of these substances comes from short-term projects or studies. A comprehensive long-term fish tissue and bivalve tissue monitoring program for mercury, selenium, and other bioaccumulative substances is needed to guide management programs for these substances.
- Up-to-date and more extensive modeling of the effects of sea level rise on Delta salinity is needed. Will projected sea level rise in the next hundred years affect salinity at proposed isolated facility intake locations? More information also is needed regarding the impacts of earthquakes and levee failure on Delta water quality.

Trade-Offs

There are inherent conflicts between managing the California Delta for improved ecosystem values and managing the Delta for drinking water quality. Habitat changes beneficial for ecosystem function such as restored wetlands, increased algal productivity, increased turbidity, and perhaps variable salinity, could have serious negative impacts on drinking water quality (WQ 1).

A perennial Delta trade-off is the relationship between the quantity of water supply and water quality. The more fresh water diverted from the system, the saltier Delta water becomes (WQ 4).

Expected Water Quality Outcomes by Conveyance Option

Through-Delta. With the through-Delta conveyance option, current water quality conditions and problems could continue with gradual improvement on some fronts due to decreasing amounts of some pollutants and implementation of control programs (WQ 6, 16). Increased urban development will increase urban runoff and wastewater discharges.

A gradual reduction in mercury is expected over time as the legacy from mining activity very slowly works its way through the system and control actions take effect (WQ 6, 16). Banned substances such as DDT and PCBs should also gradually decrease. Salinity from salt accumulation in the San Joaquin Valley and increased seawater intrusion caused by sea level rise will gradually increase Delta salinity (WQ 12, 15).

Increased water diversions in the California Delta watersheds could also result in general water quality degradation due to increased consumptive use. The Franks Tract project, which proposes modifications to western Delta channel hydrodynamics through an operable barrier in either False River or Three Mile Slough, could reduce salinity intrusion. This and other modifications to through-Delta conveyance such as re-operation of the Delta Cross Channel or a 4,000 cfs screened diversion between the Sacramento River near Hood and the North Fork of the Mokelumne River, could reduce salinity at Clifton Court Forebay by approximately 3-17 percent (WQ 20).

Isolated Facility (eastern route). Water quality delivered to the export pumps through an isolated facility should be similar to what it could be at the new point of diversion. If this new diversion point is near the Sacramento River at Hood, exported water will be well below the organic carbon and bromide targets for drinking water. Salinity, measured as electrical conductivity (EC), will be less than half that of water currently exported from the south Delta (a reduction of more than 50 percent) (WQ 27).

An isolated facility diversion will reduce high quality flow into the northern, central, and southern Delta channels between Hood and the south Delta pumps. The resulting salinity effects depend on the volume and timing of the diversions and could vary greatly between locations. San Joaquin River pollution would no longer be intercepted by the south Delta pumps, effectively increasing the amount of selenium, nutrients, and other pollutants that come into the Delta from that watershed (WQ 6). The effect of sea level rise on water quality at Hood has not been adequately evaluated.

Isolated Facility (western route). There is no significant difference in water quality outcomes between the eastern route and western route isolated facility options. The only difference might be in the opportunity for water delivery or pump-ins at key points along the route, but these possible variations have not been described.

Delta Corridors Project. This option could improve export water quality by moving Sacramento River water across the Delta with less mixing with San Joaquin River water. The Delta Corridors proposal estimates that water quality will be similar to Sacramento River water quality at Freeport. The project proponents estimate an annual salt reduction of 25 percent (WQ 2). They correctly point out that the bromide benefits of using more Sacramento River water are even greater than those estimated for salts. The proposal, however, does not factor sea level rise or other climate change effects into its water quality improvement estimates.

Other water quality issues, such as Stockton ship channel dissolved oxygen and salinity problems for south Delta agricultural supply, are dealt with by strategic pumping and barrier operations to increase circulation. Delta Corridors effectively increases the proportion of high quality Sacramento River water in export supplies and increases the fraction of lower quality San Joaquin River water remaining in the Delta. Estimates done for BDCP, whose modified through-Delta option is very similar to Delta Corridors, indicate that export salinities could be about half that of baseline conditions (WQ 27). Neither the Delta Corridors proposal nor the BDCP options evaluation considered the effect of sea level rise on salinity intrusion.

Dual Conveyance. Dual conveyance has the potential to capture the greatest amount of good quality Delta inflow for export. The BDCP evaluated a dual conveyance option that is a combination of a Delta Corridors approach and an isolated facility (WQ 27). The BDCP evaluation indicates export salinity improvement greater than the improvement predicted for a Delta Corridors approach but less than what could be achieved with an isolated facility.

A dual conveyance approach that uses current through-Delta conveyance and an isolated facility could have potential export water quality benefits and in-Delta water quality impacts intermediate in value between the two options. Some additional water quality benefit could be derived from increased operational flexibility, but this depends on operating criteria. As with the current export facilities, operations are controlled by water supply, water quality, endangered species protection requirements, and other constraints.

Of the various alternatives reviewed, dual conveyance and an isolated facility (eastern or western route) have the greatest potential for improved export water quality and the greatest potential for negative in-Delta water quality impacts. Operation of new diversion facilities will be critical to water quality outcomes.

Also critical to future Delta water quality will be the reduction of pollutant loads coming from the Delta watershed. Advanced wastewater treatment is becoming the de facto standard for inland surface water dischargers in California. This and other best management practices should become the standard for all dischargers. Relying on dilution and attenuation can no longer serve as a substitute for applying the best available technology to wastewater, agricultural drainage, and stormwater discharges.

TABLE WQ-1. SCENARIO COMPARISON

Conveyance Scenario	Water Uses		
	Export (Drinking and Agriculture)	**In-Delta Agriculture**	**Environmental**
Through-Delta	Salinity and bromide gradually increase due to sea level rise, salt build up, and increased consumptive use. Modifications could provide moderate improvements to export water quality.	Salinity gradually increases due to sea level rise, salt build up and increased consumptive use.	Improvement for some constituents. Urban impacts increase.
Isolated Facility (eastern or western route)	Export water quality greatly improved for salinity and bromide, more modest improvement for organic carbon.	Moderate increase in salinity due to increased diversion of high-quality inflow upstream, followed by a gradual increase due to sea level rise.	Moderate increase in concentrations of pollutants present in San Joaquin River inflow, increase in residence time may contribute to excess local algae and aquatic plant growth.
Delta Corridors Project	Export water quality initially nearly as good as an isolated facility, but vulnerable to degradation due to sea level rise.	Salinity west of the Middle River corridor will be much higher, salinity east of the corridor will be similar to current conditions.	Moderate increase in concentrations of pollutants present in San Joaquin River inflow west of Middle River, increase in residence time may contribute to excess local algae and aquatic plant growth.
Dual Conveyance	Export water quality improvement intermediate between through-Delta and an isolated facility, highly dependent on operating criteria.	Moderate increase in salinity due to increased diversion of high-quality inflow upstream, followed by a gradual increase due to sea level rise.	Moderate increase in concentrations of pollutants present in San Joaquin River inflow, increase in residence time may contribute to excess local algae and aquatic plant growth.

Projected Schedule, Costs and Funding

This section reviews available information about schedules and costs of various conveyance options.

Estimating project costs is not an exact science. Cost estimates generally improve as project information progresses from initial concepts through detailed design. Even after a contractor determines the initial cost to construct a facility based on a set of design drawings and specifications, changed conditions during construction can lead to costly change orders.

All cost estimates for Delta conveyance options contained in existing references are conceptual at best. Any conceptual level estimate will necessarily change as project definitions are refined during future studies, the permit process, design, and construction. The actual cost for any conveyance option will ultimately depend on the features chosen, the engineering, the actual labor and material costs at the time of construction, competitive market conditions contractors face when bidding on construction work, construction schedules, changed conditions during construction, permitting conditions, and other variables.

Participants at the 2007 CALFED Science Program Workshops on Delta conveyance infrastructure agreed that any alternative to through-Delta conveyance will take decades to construct (ENG 36, 37). Therefore, even the best cost estimates made today will be significantly low considering a decade or two of cost escalation will occur before construction is complete.

Key Findings and Data Gaps

None of the Delta conveyance options go beyond the conceptual stage. Without designs it is difficult to make good cost estimates. Various estimates are based on different facility size, different assumptions, and were calculated at different times. Since available references provide cost and schedule estimates based on different assumptions and timeframes, they are not comparable across the options. Often the references provide only an estimate of construction costs and seldom provide estimates of operation and maintenance costs for the facilities.

The following is a summary of relevant cost and schedule information found in different references for the Delta conveyance options.

Existing Through-Delta Conveyance. Even though the existing through-Delta conveyance is already in place, it is not without cost. There are ongoing and unpredictable expenditures to keep the conveyance serviceable. DWR provides grants between $6 million to $8 million annually to local levee maintenance districts through its Delta Levees Maintenance Subventions Program to assist in local levee repair and maintenance. (ENG 38). Local reclamation districts spend more than these amounts on their levees. Levee failures cost much more to repair. For example, the repair and recovery from the 2004 Jones Tract levee break cost nearly $100 million (ENG 39).

Modified Through-Delta Conveyance. The following are cost estimates for potential increments of modified through-Delta conveyance. Since they are considered to provide incremental or different benefits, they are not directly comparable and are listed below as concepts.

- **Pre-event Strategy** – In 2007, Metropolitan Water District (MWD) estimated that $330 million to $485 million over three years of construction would be required to build levee and river flow barriers to block salt water from entering the south Delta in a major emergency (ENG 27).
- **Post-event Strategy** – In 2007, MWD estimated that $50 million would be required to pre-position material to more quickly respond to an emergency when it occurs (ENG 27). They estimated that total costs (in 2007 dollars) could increase to $200 million depending on the scale of an actual emergency.
- **Franks Tract Project** – Cost estimates for the Franks Tract Project in 2005 dollars range from $295 million to $325 million (ENG 9). A 2007 value engineering study estimated that a pilot project to test the full scale Franks Tract Project before the additional funding is committed could be constructed for $43 million to $52 million (ENG 40).
- **Delta Cross Channel Reoperation** – Since this is an operational alternative rather than a structural alternative, reports did not identify any construction costs of the project (ENG 9).
- **CALFED Modified Through-Delta** – In 1996, CALFED estimated the cost of the modified through-Delta conveyance as $1.3 to $1.8 billion (ENG 41). The June 2007 value engineering study estimated the cost of only the diversion from the Sacramento River to the central Delta at $577 million (ENG 42). However, CALFED has determined that its preferred program alternative that included this diversion will not meet the CALFED program objectives (ENG 2).
- **Upgrading Delta Levees –** DRMS Phase 2 (ENG 30) estimated costs (in 2007 dollars) for upgrading levees at:

- $1.6 billion to $1.9 billion for levee upgrades to Public Law 84-99 standards
- $ 8.8 billion for 500 miles of levees upgraded to urban levee standards
- $4.4 billion for seismically repairable levees in the western Delta and $3.9 billion for seismically repairable levees in the south Delta

These estimates are based on preliminary concepts. A final DRMS Phase 2 report is planned for August 2008.

- **Armored Pathway Through-Delta Conveyance** – DRMS Phase 2 (ENG 30) estimated costs in 2007 dollars for a range of armored pathway sizes. Their estimate included habitat restoration as part of the pathway for three facility sizes:
  - $ 3.7 billion for a 5,000 cfs facility
  - $ 4.6 billion for a 10,000 cfs facility
  - $ 5.5 billion for a 15,000 cfs facility

  These estimates are based on preliminary concepts. A final DRMS Phase 2 report is planned for August 2008.

Delta Corridors Project. The simplest version of a Delta Corridors project could cost as little as $500 million to construct (in 2007 dollars) if it were constructed as an interim or temporary experimental facility (ENG 13). This amount, however, is in addition to whatever a through-Delta alternative would cost, so the final cost of a Delta Corridors could be much higher than $500 million.

Isolated Conveyance Facility (eastern route). DRMS Phase 2 (ENG 30) estimated the costs (in 2007 dollars) for three isolated facility sizes:

- $ 2.9 billion for a 5,000 cfs facility
- $ 3.8 billion for a 10,000 cfs facility
- $ 4.9 billion for a 15,000 cfs facility

These estimates are based on preliminary concepts. A final DRMS Phase 2 report is planned for August 2008.

Each of these facilities features an incised cross section for the first portion of the alignment and a cut and fill cross section for the last portion of the alignment (ENG 30). The Washington Group prepared an independent estimate (in 2007 dollars) for a fully incised isolated facility with a cost range of $ 3.4 billion to $3.9 billion (ENG 33), about $1 billion less than estimated by DRMS. This is a good example of the variability in cost estimates that can be expected at the conceptual stage of facility development. Cost estimates become more accurate as a concept moves through feasibility study, preliminary design, and detailed design.

Several references (ENG 43, 44, 45, and 46) provide historical perspective of planning for the Peripheral Canal in the 1960s and 1970s. These documents include diversion capacities in the 21,800 cfs to 26,800 cfs range. The estimated construction cost for a 21,800 cfs canal in 1966 was $196 million.

Isolated Conveyance Facility (western route). When CALFED performed its evaluation of a western isolated conveyance facility in 1997 (ENG 16), it found that the cost was over twice as high as costs for the eastern isolated conveyance facility (ENG 47). While no written documentation exists, recent consideration of a western isolated conveyance facility by the state water contractors concluded that a western isolated conveyance facility could cost about twice what was determined for the eastern isolated facility by The Washington Group in 2007 (ENG 48).

Dual Conveyance. The cost of a dual conveyance system depends on the features and sizes of modified through-Delta conveyance and features and sizes of isolated conveyance. If a dual conveyance system is configured for maximum flexibility so water can be moved for export at times least damaging to the environment, it could be among the most expensive conveyance options (ENG 14).

An example of how dual conveyance could be configured is included in the BDCP, Option 3 (ENG 14). The option uses a variation of the Delta Corridors Project concept to move in-Delta flows, but also provides the opportunity to divert San Joaquin River flows when environmental conditions allow. The BDCP report does not select a size for an isolated conveyance facility; does not specify the level of levee improvements; and does not include other improvements, such as fish screens or moving other water intakes. BDCP does provide a broad range for potential costs, and estimates that dual conveyance could cost between $2.8 billion and $8.7 billion, with a mid-range cost of about $5.4 billion.

Attachment A: Annotated Bibliographies

ENG: Annotated Bibliography for Water Supply Reliability; Seismic and Flood Durability; and Project Schedule, Cost, and Funding sections

ENG 1 **California Department of Water Resources, Bay-Delta Office. 2007 Draft State Water Project Delivery Reliability Report. Draft. Sacramento: State of California. 2007.**
The report presents Department of Water Resources' current information regarding the annual water delivery reliability of the State Water Project for existing (2007) and future levels (2027) of development in the water source areas. The report compares its results with estimates DWR made in the 2005 version of the report. The two biggest changes since the 2005 report are Delta pumping restrictions and consideration of climate change. The report shows continued decline in delivery reliability under the current method of moving water through the Delta and with the effects of climate change. Since future climate conditions are uncertain, the report includes estimates for four climate change scenarios. The report acknowledges the Delta Vision process as one activity that may affect future delivery reliability.
http://baydeltaoffice.water.ca.gov/swpreliability/SWPRel07_draft.pdf

ENG 2 **CALFED Bay-Delta Program. CALFED End of Stage 1 Report. Sacramento: State of California. November 2007.**
After seven years of CALFED Program implementation, CALFED staff concluded that there is sufficient justification to consider alternatives to the existing through-Delta conveyance approach. The report provides evidence why the existing preferred program alternative with a through-Delta conveyance cannot achieve the four objectives for levee system integrity, ecosystem restoration, water supply reliability, and water quality.
http://www.calwater.ca.gov/content/Library/EndofStage/Draft_EOStage_1_11-8-07.pdf

ENG 3 **California Department of Water Resources, Bay-Delta Office. The State Water Project Delivery Reliability Report, 2005. Sacramento: State of California. April 2006.**
The report presents DWR's current information regarding the annual water delivery reliability of the SWP for existing (2005) and future levels (2025) of development in the water source areas, assuming historical patterns of precipitation. The report compares its results with estimates DWR made in the 2002 version of the report that resulted in small reductions in average delivery reliability and substantial reductions in dry period delivery reliability.
http://baydeltaoffice.water.ca.gov/swpreliability/SWPRel05_final.pdf

ENG 4 **California Department of Water Resources. The State Water Project Delivery Reliability Report, 2002. Sacramento: State of California. 2002.**
The report provides information on the ability of the SWP to deliver water under existing (2002) and future levels (2021) of development, assuming historical patterns of precipitation. The SWP delivers water under long-term contracts to 29 public water agencies throughout the State. They, in turn, either deliver water to water wholesalers or retailers or deliver it directly to agricultural and urban water users. One purpose of the report is to provide local agencies with information useful in conducting analyses mandated by legislation authored by Senator Sheila Kuehl (SB 221) and Senator Jim Costa (SB 610). These laws require water retailers to demonstrate the sufficiency of their water supplies for certain proposed subdivisions and development projects subject to the California Environmental Quality Act. The report does not analyze how specific local water agencies integrate SWP water into their water supply equation. The report compares its results with estimates DWR made in the 2002 version of the report.
http://baydeltaoffice.water.ca.gov/swpreliability/SWPReliability02_final.pdf

ENG 5 **CALFED Bay-Delta Program. Storage Program Plan, Year 8. Sacramento: State of California. June 2007.**
This Storage Program Plan identifies the CALFED Program activities that are scheduled to be completed during Year 8, which includes State Fiscal Year (FY) 2007-2008 (July 1, 2007 to June 30, 2008) and Federal FY 2008 (October 1, 2007 to September 30, 2008). The Plan covers both surface storage and groundwater storage. The Plan also describes the accomplishments made during the previous year.
http://www.calwater.ca.gov/content/Documents/library/ProgramPlans/2007/YR8_Storage_ProgramPlan.pdf

ENG 6 **California Department of Water Resources. Surface Storage Investigations Web Portal**.
The web portal provides information on each of the five surface storage investigations initiated as a result of the CALFED Record of Decision. Summary information and report on the Shasta Lake Water Resources Investigations, North-of-the-Delta Offstream Storage Investigations, In-Delta Storage Program, Los Vaqueros Reservoir Expansion, an d Upper San Joaquin River Basin Storage Investigation are available on the site.
http://www.storage.water.ca.gov/

ENG 7 **CALFED Bay-Delta Program. Final Programmatic Environmental Impact Statement/Environmental Impact Report. Sacramento: State of California. June 2000.**
While there are numerous supporting documents to the EIS/EIR, Chapter 5 and Attachment A of the EIR/EIS provide a summary of relevant information on water supply differences between the CALFED alternatives. Storage and conveyance facilities vary among the analyses for the alternatives. Since the CALFED operation studies assumed a capacity of the Banks Pumping Plant of 10,300 cfs, the water supply results should only be used for a general comparison among CALFED alternatives.
http://www.calwater.ca.gov/calfed/library/library_archive_EIS.html

ENG 8 **United States District Court, Eastern District of California. Findings of Fact and Conclusions of Law Re Interim Remedies Re: Delta Smelt ESA Remand and Reconsultation. December 2007.**
On Dec. 14, 2007, Judge Wanger issued an interim order directing potential pumping limits and other actions to protect the delta smelt until the new BO is completed. Judge Wanger directed the Fish and Wildlife Service to complete the new BO by Sept. 15, 2008.
http://www.fws.gov/sacramento/es/documents/OCAP_Court_Finding_of_Fact_12-14-07.pdf

ENG 9 **California Department of Water Resources. Delta Conveyance Improvement Studies Summary Report: Franks Tract, Through-Delta facility, and Delta Cross Channel Reoperation Projects. Prepared by EDAW and AECOM. Sacramento: State of California. December 7, 2007.**
The summary report presents key findings for studies prepared by DWR in cooperation with Reclamation to evaluate Franks Tract, the through-Delta facility, a nd Delta Cross Channel reoperations.
http://www.baydeltaoffice.water.ca.gov/ndelta/frankstract/documents/Delta_Conveyance_Summary_Report_121007.pdf

ENG 10 **California Department of Water Resources and U.S. Bureau of Reclamation. South Delta Improvements Program, Environmental Impact Statement/Environmental Impact Report, Draft. Sacramento: State of California. October 2005**.
The draft document presents several alternatives for gates and barriers in the south Delta channels to improve agricultural water quality and fish protection. An operational component considers raising the permitted diversion limit of the SWP Clifton Court Forebay from 6,680 cfs to 8,500 cfs which would provide direct water supply reliability benefits.
http://baydeltaoffice.water.ca.gov/sdb/sdip/documents/draft_eis_eir/vol-1/vol-1-eir.html

ENG 11 **California Department of Water Resources and U.S. Bureau of Reclamation. South Delta Improvements Program, Environmental Impact Statement/Environmental Impact Report, Final. Sacramento: State of California. December 2006**
The finial EIS/EIR incorporates comments on the draft EIS/EIR. While the document still includes consideration of raising the SWP permitted diversion limit from 6,688 cfs to 8,500 cfs, the project proponents no longer support that as an option. The project would include gates and barriers in the south Delta channels to improve agricultural water quality and fish protection. http://baydeltaoffice.water.ca.gov/sdb/sdip/documents/final_eis_eir/vol-1/vol-1-feir.html

ENG 12 **Brown, R. Delta Corridors Project: Proposal to Reconnect the San Joaquin River to the Estuary. Prepared in response to Delta Vision Task Force request for external visions for the Delta. Sacramento. July 26, 2007.**
The proposal would separate flow of the San Joaquin River from the water supply corridor from the Sacramento River using Delta channels that are strategically separated with flow control structures. The San Joaquin portion of the system would be aimed at restoring natural functions of the estuary. The water supply corridor would be less vulnerable to a major Delta emergency than the existing through-Delta conveyance. The proposal is prepared at the conceptual level of detail without benefit of feasibility study or preliminary design.
http://www.deltavision.ca.gov/docs/externalvisions/EV4_Delta_Corridors.pdf

ENG 13 **Brown, R. Personal communication regarding the Delta Corridors Proposal. February 2008.**
Discussions with Russ Brown indicated that, although detailed studies have not been conducted, he believed that his Delta Corridors proposal could be constructed for as little as $500 million. There is some value in constructing many of the facilities as inexpensively as possible with sheet piling or other temporary techniques so the concept that essentially isolates the conveyance water similar to a peripheral canal can be tested including its influence on ecosystem conditions. If it doesn't work, it could be easily removed and the cost would be relatively small compared with building a full isolated facility. If it does provide improved conditions as expected, it could serve as an interim facility for many years even if a peripheral canal was considered as a long term solution. In this case, it could provide valuable operational information to aid design of the peripheral canal. He thought that a better estimate of the water supply reliability was in the 150 TAF to 250 TAF range.

ENG 14 **Science Applications International Corporation . Conservation Strategy Options Evaluation Report. Prepared for the Bay-Delta Conservation Plan Steering Committee. Sacramento: The Resources Agency. September 17, 2007.**
The report presents initial evaluation of four potential conservation strategy options that include different conveyance facilities in the Delta.
http://resources.ca.gov/bdcp/options_evaluations.html

ENG 15 **Science Applications International Corporation. The Bay Delta Conservation Plan: Points of Agreement for Continuing into the Planning Process. Prepared for the Bay-Delta Conservation Plan Steering Committee. Sacramento: The Resources Agency. November 16, 2007**
This paper describes the agreements reached by the Steering Committee to date on the basic approaches to several important topics for the plan, including potential improvements to the water conveyance system, and strategies for in- Delta habitat restoration and enhancement. The Steering Committee agrees that the most promising approach for achieving the BDCP conservation and water supply goals involves a conveyance system with new points of diversion. http://www.resources.ca.gov/bdcp/docs/BDCP-Points_of_Agreement_Final.pdf

ENG 16 **CALFED Storage and Conveyance Refinement Team. Facility Descriptions and Cost Estimate for a Western Delta Isolated Conveyance Facility. Sacramento: State of California. June 30, 1997.**
This document summarizes an analysis of the environmental considerations and cost estimate for a western Delta isolated conveyance facility. This alternative considered use of the Sacramento Deep Water Ship Channel for the first leg of the conveyance, with various combinations of pipe, tunnel, and open channel to move water to Clifton Court

Forebay. The estimated alternative cost in 1996 dollars for a 5,000 cfs facility is about $2.1 billion to $2.6 billion.

ENG 17 **Swan, P. An Alternative Vision for the Sacramento-San Joaquin Delta. Prepared in response to Delta Vision Blue Ribbon Task Force request for external visions for the Delta. Sacramento. July 20, 2007.** The proposed vision includes a conveyance along the western side of the Delta. The vision is designed to significantly reduce the risks of loss due to subsidence, rising sea levels, flooding, and seismic activity. The proposed isolated conveyance uses the Sacramento Ship Channel as the main stem of the conveyance, tunnels to transport water across the Sacramento River and western portion of the Delta. http://deltavision.ca.gov/docs/externalvisions/EV3_An_Alternative_Vision_for_the_Delta.pdf

ENG 18 **California Department of Water Resources. Delta Risk Management Strategy (DRMS) Phase 1, Risk Analysis Report, Draft. Prepared by URS Corp. and Jack R. Benjamin & Associates. Sacramento: State of California. June 2007.**
The report presents preliminary details of analysis of risks associated with failure of Delta levees from seismic, flood, and "sunny-day" events. Phase 1 of the Delta Risk Management Strategy assess the performance of the levees and the potential economic, environmental and public health and safety impacts of levee failures to the Delta region itself, and California as a whole. The report is scheduled to be revised and finalized by June 2008.
http://www.drms.water.ca.gov/Phase1Information/

ENG 19 **California Department of Water Resources. Draft Summary Report Phase 1: Risk Analysis Delta Risk Management Strategy (DRMS). Prepared by URS Corporation and Jack R. Benjamin & Associates. Sacramento: State of California. June 2007.**
The report presents a summary preliminary results of risks associated with failure of Delta levees from seismic, flood, and "sunny-day" events. More detailed information is contained in the Risk Analysis Report by the same authors. Phase 1 of the Delta Risk Management Strategy assess the performance of the levees and the potential economic, environmental and public health and safety impacts of levee failures to the Delta region itself, and California as a whole. The report is scheduled for revision by June 2008.

ENG 20 **Houston, W. N. and J.M. Duncan. Probability of Failure of Levees in the Sacramento-San Joaquin Delta, California. Final Report. 1978.**
The report is one of the earliest ones that highlights the potential for failure of Delta levees from earthquakes.

ENG 21 **California Department of Water Resources, Central District. Seismicity Hazards in the Sacramento-San Joaquin Delta. Sacramento: State of California. 1982.**
The report is one of the earliest ones that highlights the potential for failure of Delta levees from earthquakes.

ENG 22 **CALFED Bay-Delta Program, Levees and Channels Technical Team, Seismic Vulnerability Subteam. Seismic Vulnerability of Sacramento-San Joaquin Delta Levees (Torres Report). Sacramento: State of California. 2000.**
The report provides an assessment of the vulnerability of Delta levees to damage from earthquakes. An earthquake with a 100-year recurrence interval is predicted to cause 3 to 10 levee failures in the Delta.

ENG 23 **CALFED Bay-Delta Program and the California Department of Water Resources. Preliminary Seismic Risk Analysis Associated with Levee Failures in the Sacramento – San Joaquin Delta. Prepared by Jack R. Benjamin & Associates. Sacramento: State of California. June 2005.**
The report presents results of a preliminary risk analysis to estimate the effects of seismically initiated levee failures on Delta water quality and export and economic consequences to the state. The estimated economic impact to the state for a 50 levee breach scenario was approximately $10 billion and for 100 breaches the impact was estimated to be about $32 billion. http://www.drms.water.ca.gov/docs/Delta_Seismic_Risk_Report.pdf

ENG 24 CALFED Science Program Independent Review Panel. Review of the Delta Risk Management Strategy Report, Phase 1. August 2007.
The review panel made many comments on the draft DRMS Phase 1 Report. Subsequent meetings and discussion with the study team resolved many of these as the study team provided clarifications.
http://www.drms.water.ca.gov/docs/ISB_DRMS_IRP_report_082407.pdf

ENG 25 Salah-Mars, S. Personal communication regarding Delta Risk Management Strategy, Phase 1 report revisions. February 28, 2008.
Said indicated that the DRMS team is in the process of revising the Phase 1 Risk Analysis Report and expect to have a final in June 2008. They expect only small differences, maybe in the neighborhood of plus or minus 5 percent from results shown in the draft report (June 2007). They are also revising the Phase 2 results and expect to have a final in August 2008. He stressed that the costs in the draft report are not directly comparable among the scenarios. For example, the isolated facility cost does not include any environmental mitigation, but the armored pathway through-Delta conveyance does include habitat restoration costs. The Washington Group estimates for a 15,000 cfs isolated facility at $3.754 billion in August 2007 dollars are lower than the costs developed by DRMS. Said agreed that the Washington Group numbers are low and will be raised [note: the Washington Group is now owned by URS Corporation].

ENG 26 Isenberg, P., M. Florian, R.M. Frank, T. McKernan , S. Wright McPeak, W. K. Reilly, R. Seed. Our Vision for the California Delta. Sacramento: State of California. January 2008.
This document lists the 12 integrated and linked recommendations to resolve problems in the California Delta by the Delta Blue Ribbon Task Force.
http://www.deltavision.ca.gov/BlueRibbonTaskForce/FinalVision/Delta_Vision_Final.pdf

ENG 27 Metropolitan Water District of Southern California, Board of Directors, Water Planning and Stewardship Committee. Board Action, Approve Delta Levees Emergency Preparedness and Response Plan. Los Angeles: MWD Board of Directors. April 10, 2007.
The MWD Board letter approves a plan that would respond after a major emergency in the Delta to restore the flow of freshwater to resume export pumping rather than spending large amounts of money to advance construction of levee improvements to advert the emergency.
http://edmsidm.mwdh2o.com/idmweb/cache/MWD%20EDMS/003678914-1.pdf

ENG 28 Mount, J. Memorandum from Independent Science Board. Sea Level Rise and Delta Planning. Sacramento: State of California. September 6, 2007.
The Science Board reviewed a number of estimates for sea level rise and made recommendations for planning purposes. The mid range rise this century is 28 inches to 39 inches. The full range of variability is 20 inches to 55 inches.
http://www.science.calwater.ca.gov/pdf/isb/meeting_082807/ISB_response_to_Is_sea_level_090707

ENG 29. California Department of Water Resources. Enhanced Delta Emergency Response 2007-08 Summary. Sacramento: State of California. November 2007.
The document summarizes the activities DWR is taking to prepare an Emergency Operations Plan for the Delta and to stockpile equipment and material to more quickly respond to an emergency in the Delta that threatens or results in flooding.

ENG 30. California Department of Water Resources. Delta Risk Management Strategy (DRMS); Phase 2, Building Block and Scenario "Flash Cards", Preliminary. Prepared by URS Corp. and Jack R. Benjamin & Associates. Sacramento: State of California. October 25, 2007.
This preliminary document presents several potential improvements in the Delta. They are intended to be building blocks that could ultimately be combined to form a complete solution for the ecosystem, water supply, infrastructure, etc. These preliminary results are expected to be finalized in August 2008.
http://www.deltavision.ca.gov/BlueRibbonTaskForce/August2007/BlueRibbonMeetingMaterials.shtml

ENG 31 Public Policy Institute of California. Research Brief, Dealing with the Delta: Envisioning Futures, Finding Solutions. San Francisco, Public Policy Institute of California. February 2007.
The Research Brief provides a summary of the longer report, "Envisioning Futures for the Sacramento-San Joaquin Delta. http://www.ppic.org/content/pubs/rb/RB_207JLRB.pdf

ENG 32 Lund, J., E. Hanak, W. Fleenor, R. Howitt, J. Mount, and P. B. Moyle. Envisioning Futures for the Sacramento-San Joaquin Delta. San Francisco: Public Policy Institute of California. 2007.
The report explores and compares potential long-term solutions to the Delta's problems. To explore a variety of possible solutions, the authors considered nine different alternatives for their effectiveness for water supply, environmental effects, and economic costs and identified several that deserve additional consideration.
http://www.ppic.org/main/publication.asp?i=671

ENG 33 Washington Group International. Isolated Facility, Incised Canal Bay-Delta System, Estimate of Construction Costs. Prepared for the State Water Contractors. August 2006.
Cost estimates in 2006 dollars were made for several alignments for a 15,000 cfs isolated facility. The estimates ranged from $3.3 billion to $3.7 billion for an unlined canal. The estimates do not appear to include environmental mitigation costs. The one sheet cost summary, Table 2, was revised by Washington Group in to 2007 dollars in August 2007 to $3.4 billion to $3.9 billion.

ENG 34 Zuckerman, T. M. In-Delta Group Delta Vision Document, A Water Plan for the 21st Century: Regional Self-Sufficiency Scenario. Prepared in response to Delta Vision Blue Ribbon Task Force request for external visions for the Delta. July 23, 2007.
The scenario supports less reliance on the Delta as a water supply by promoting self-sufficiency for the regions receiving water from the Delta. It criticizes the peripheral canal concept and supports continued use of Delta channels. The scenario states that proposals that improve the passage of water through the Delta like the Delta Corridors proposal bear more promise than a peripheral canal.
http://www.deltavision.ca.gov/docs/externalvisions/EV2_A_Water_Plan_for_the_21st_Century.pdf

ENG 35 CALFED Water Management Planning Branch. Isolated Facility, Conceptual Analysis of Incised Canal Configuration. Sacramento: State of California. September 1999.
The report presents the results of an engineering evaluation for an incised (cut into the ground) isolated conveyance facility from the Sacramento River along the eastern Delta to Clifton Court Forebay. The study team estimated a cost for a 10,000 cfs unlined canal of $1.9 billion (in 1998 dollars) and an annual cost of $140 million.

ENG 36 CALFED Science Program. Science Issues Related to Delta Conveyance Options for California Water Supply, CALFED Science Program Synthesis. Sacramento: State of California. 2007.
The workshop focused on through-Delta options as the conveyance mechanism for moving Sacramento River water to the export pumps.
http://www.science.calwater.ca.gov/events/workshops/workshop_index.html#2007

ENG 37 CALFED Science Program. Workshop Summary for August 22, 2007. CALFED Science Program Workshop Summary, Science Issues Relating to Delta Conveyance Infrastructure: An Isolated Facility. Sacramento: State of California. 2007.
The workshop focused on the Isolated Facility as the conveyance mechanism for moving Sacramento River water to the export pumps. Specialists agreed that the current through-Delta system is not working. However, they also found that every conveyance option has benefits, risks, and uncertainties – an Isolated Facility offers no "silver bullet" or non-impact way for solving all Delta ecological and water supply problems.
http://www.science.calwater.ca.gov/events/workshops/workshop_index.html#2007

ENG 38 Harder, L. F., Jr. Testimony Concerning: H.R. 6014, A Bill to Authorize the Secretary of the Interior, Acting Through the Bureau of Reclamation, to Improve California's Sacramento- San Joaquin Delta and Water Supply. Presented to U.S. House of Representatives, Committee on Natural Resources, Subcommittee on Water and Power. Sacramento: State of California. September 2006.
The testimony provides a broad perspective on the Delta levee programs. The paper provides a history of state subventions funding to the local levee maintaining districts.
http://www.publicaffairs.water.ca.gov/newsreleases/2006/0906-testimony.doc

ENG 39 County of San Joaquin. Office of Emergency Services. Jones Tract Flooding Update. Stockton: County of San Joaquin. June 7, 2004.
The brief provides damage estimates, including the cost of emergency efforts for Trapper Slough and the break, are being prepared fro the Jones Tract failure. These estimates also include damage to crops, homes, structures, and roads and the cost of providing a variety of emergency services. These include estimates of public agencies losses in addition to the direct costs of flooding. http://207.104.50.39/oes/disasters/jones04/news.6_07.pdf

ENG 40 Strategic Value Solutions, Inc. Final Value Engineering Study Report for Franks Tract Pilot Project. Prepared for the California Department of Water Resources. Sacramento: State of California. June 2007.
A team of engineers and scientists performed a value engineering study of the Franks Tract Pilot project to see what changes could be made the project to improve its performance and/or reduce its cost. A pilot project is one that is constructed to test the likely effects of a full scale before a commitment is made to build the full scale project. The team's review resulted in raising the cost of one alternatives from $30 million to $52 million and a second alternative from $20 million to $43 million. The team also suggested that the most economical solution to reducing saltwater intrusion into the Delta would be to increase the hydraulic capacity of the Delta Cross Channel.
http://baydeltaoffice.water.ca.gov/ndelta/frankstract/documents/Franks%20Tract%20Final%20VE%20Report.pdf

ENG 41 CALFED Storage and Conveyance Refinement Team. Facility Descriptions and Updated Cost Estimates for an Improved Through-Delta Conveyance Facility. Sacramento: State of California. October 1997.
This document summarizes an analysis of the environmental considerations and cost estimate for the CALFED modified through-Delta conveyance facility. A diversion from the Sacramento near Hood and channel, gating, and screening modifications in the south Delta are the main physical changes in the alternative. The estimated alternative cost in 1996 dollars is about $1.3 billion to $1.8 billion.

ENG 42 Strategic Value Solutions, Inc. Final Value Planning Study Report for Through-Delta Facility. Prepared for the California Department of Water Resources. Sacramento: State of California. June 2007.
A team of engineers and scientists performed a value engineering study of the through-Delta facility (with diversion near Hood) to see what changes could be made to improve its performance and/or reduce its cost. The team estimated a cost (in 2007 dollars) of about $577 million for a 4,000 cfs diversion facility from the Sacramento River to the central Delta. The team also looked at expanding the capacity of the Delta Cross Channel at significantly lower cost.
http://baydeltaoffice.water.ca.gov/ndelta/TDF/documents/Through%20Delta%20Facility%20Final%20VE%20Report.pdf

ENG 43 U.S. Department of the Interior and U.S. Bureau of Reclamation, Peripheral Canal Unit. A Report on the Feasibility of Water Transfer in the Sacramento – San Joaquin Delta. April 1966.
This report presents the results of a feasibility study for a canal with a 21,800 cfs diversion capacity from the Sacramento River. The estimated construction costs of the unlined canal was $195,902,000. The report justifies the construction of the canal, at least partially, for environmental reasons:

"The Bureau of Reclamation and the State of California, through their respective Central Valley Project and State Water Project, are planning to divert up to 7,458,000 acre-feet of water annually by 2020 from the southwestern part of the Delta. The current diversion rate is about 1,500,000 acre-feet annually. This five-fold increase in diversion would have a tremendous effect on the Delta environment. […] Increased pumped diversions in the southwestern part of the Delta would draw a tremendous amount of fish and their eggs to and through the pumping plants. To relieve this pumping effect, the point of diversion would have to be moved to a less inhabited area."

ENG 44 U.S. Department of the Interior and U.S. Bureau of Reclamation, Peripheral Canal Unit. A Report on the Feasibility of Water Transfer in the Sacramento – San Joaquin Delta. September 1968.
This report presents the results of a feasibility study for a canal with a 26,800 cfs diversion capacity from the Sacramento River. The estimated construction cost of the unlined canal was $208,922,000.

ENG 45 California Department of Water Resources. Draft Environmental Impact Report, Peripheral Canal Project. Sacramento: State of California. August 1974.
This report presents the state's environmental document on the peripheral canal. The report notes that the peripheral canal was officially adopted as a feature of the SWP in 1966. The plan is for a canal with 23,300 cfs diversion capacity with an estimated construction cost of $285,580,000. One concept of this plan was to release water from the canal at 12 point to distribute water from the canal to Delta channels to maintain water quality within prescribed criteria and to improve the Delta aquatic environment and the resources and economies it supports. The report estimated that construction would start in 1975 and the canal would be operational by 1980. The report notes that:

"Expansion of the CVP and the advent of the State Water Project (SWP) have increased these diversions to a current level (1973) of 3.5 million acre-feet annually. By 2020, this is projected to increase to about 8 million acre-feet annually. … Even at current diversion rates, the Delta is subjected to altered flow patterns and water quality problems in some areas. Without intelligent water management, the situation will deteriorate as export diversions increase."

ENG 46 U. S. Department of Interior and U.S. Bureau of Reclamation. Peripheral Canal Environmental Statement, Draft. October 1977.
This report presents the federal environmental document on the peripheral canal. The report is for a canal with a 23,300 cfs diversion capacity. The report estimates that the canal will be in operation by 1986. The report notes that the decision to proceed with construction would require a commitment of approximately $650 million for financing all features of the project. This appears to be total financing cost and not construction cost. The report states:

"Effects of present cross-Delta water transfer operations on the anadromous fishery of the Delta, Sacramento and San Joaquin rivers can then be eliminated."

ENG 47 CALFED Storage and Conveyance Refinement Team. 1997. Facility Descriptions and Updated Cost Estimates for an Isolated Conveyance Facility. Sacramento: State of California. October 1997.
This document summarizes an analysis of the environmental considerations and cost estimate for an eastern Delta isolated conveyance facility. The evaluation included estimates for 5,000 cfs, 10,000 cfs, and 15,000 cfs unlined canals. The estimated alternative cost in 1996 dollars for a 5,000 cfs facility is about $0.8 billion to $1.0 billion. The estimated cost in 1996 dollars for a 10,000 cfs facility is about $1.0 billion to $1.2 billion. The estimated costs for a $15,000 cfs facility is about $1.2 to $1.5 billion.

ENG 48 Majors, D. Personal communication regarding on the western isolated facility. 2008.
Discussed preliminary, unpublished estimates that Washington Group had prepared for the western isolated facility concept. They did not use the Sacramento Ship Channel for conveyance because of concerns about Delta smelt. The cost estimate assumed a conveyance that paralleled the ship channel. The preliminary estimates indicated that the western facility would likely cost twice that of an eastern alignment.

EHR: Annotated Bibliography for Ecosystem Health and Resilience Section

EHR 1 **Arthur, J.F., M.D. Ball, and S.Y. Baughman. "Summary of Federal and State Water Project Environmental Impacts in the San Francisco Bay-Delta Estuary, California."** ***In San Francisco Bay: The Ecosystem*****, edited by J.T. Hollibaugh, 445-495. San Francisco: American Association for the Advancement of Science, Pacific Division. 1996.**
This very useful paper provides a brief summary of early and post Federal and State water project development and summarizes major changes in the physical, chemical, and biological constituents that have occurred as the result of direct water transfer through the Delta (fresh-brackish water portion of the San Francisco Bay-Delta Estuary). Transfer of increasing amounts of Sacramento River water across the Delta channels to the Federal and State water project export pumps in the South Delta over the last 45 years has resulted in several major environmental impacts. A positive impact of water project operations has been the increase in fresh water in many Delta channels during the summer and fall. This increase in fresh water comes from water released from reservoirs to reduce salinity intrusion into the Delta and protect water quality. Most of the negative project-related impacts result from transferring large quantities of water across the Delta in existing channels. The ever-increasing demand for project export water has resulted in net flow reversals during most months of the year in the central and southern Delta. Flow reversal has resulted in: the recycling of large quantities of salt from the San Joaquin Valley back into the valley; scouring of Delta channels; increases in trihalomethane (THM) precursors from Delta sources in export water designated for municipal use; flushing of Delta aquatic habitat resulting from decreased residence times; and entrainment of plankton and various life stages of fish in the project intakes. Other non-project impacts are mentioned. Potential short- and long-term structural and operational management solutions are also discussed.

EHR 2 **Baker, P., and J.E. Morhardt. 2001. "Survival of Chinook Salmon Smolts in the Sacramento-San Joaquin Delta and Pacific Ocean."** ***In Contributions to the Biology of Central Valley Salmonids: Fish Bulletin 179, Vol. 2*****, edited by R.L. Brown, 163-182. Sacramento: California Department of Fish and Game. 2001.**
This paper summarizes current knowledge about the effects of river flow and water export on the survival of San Joaquin River Basin Chinook salmon smolts migrating through the Sacramento-San Joaquin Delta. As will become clear, there are serious deficiencies in our understanding of the needs of smolts as they pass through this region, but there is a general agreement that mortality can be high and can probably be reduced by management actions. The potential for success of the various alternatives remains speculative; something needs to be done, but it remains unclear what will work best. For example, smolt survival is usually better at very high (flood) flows than at very low flows, but there is little solid information about the potential for improved survival in the range that might be managed regularly. Researchers have not really begun the search for optimal flows for smolt survival; analyses to date offer, at best, only the qualitative guidance that "higher" flows are "better" for salmon, without any indication of just how much better survival can be or should be. Similarly, although there is reason to believe that strategically placed barriers should improve smolt survival, by keeping smolts well away from the Delta export pumps; however, experiments to date have not been able to demonstrate or refute the effectiveness of such barriers directly.

EHR 3 **Bennett, W. "Critical Assessment of the Delta Smelt Population in the San Francisco Estuary, California."** ***In San Francisco Estuary and Watershed Science*** **3(2): Article 1. September 2005.**
Delta smelt has an unusual life history strategy relative to many fishes. Some aspects of its biology are similar to other coastal fishes, particularly salmonids. Smelts in the genus, *Hypomesus*, occur throughout the Pacific Rim, have variable life history strategies, and are able to adapt rapidly to local environments. By comparison, delta smelt has a tiny geographic range being confined to a thin margin of low salinity habitat in the estuary. It primarily lives

one year, has relatively low fecundity, and pelagic larvae; life history attributes that are unusual when compared with many fishes worldwide. A small proportion of delta smelt lives two years. These individuals are relatively highly fecund but are so few in number that their reproductive contribution only may be of benefit to the population after years of extremely poor spawning success and survival. Provisioning of reproductive effort by these older fish may reflect a bet-hedging tactic to insure population persistence.

Overall, the population persists by maximizing growth, survival, and reproductive success on an annual basis despite an array of limiting factors that can occur at specific times and locations. Variability in spawning success and larval survival is induced by climate and other environmental and anthropogenic factors that operate between winter and mid-summer. However, spawning microhabitats with egg deposition have not been discovered. Spawning success appears to be timed to lunar periods within a water temperature range of about 15 to 20°C. Longer spawning seasons in cooler years can produce more cohorts and on average higher numbers of adult delta smelt. Cohorts spaced in time have different probabilities of encountering various sources of mortality, including entrainment in freshwater export operations, pulses of toxic pesticides, food shortages and predation by exotic species. Density dependence may provide an upper limit on the numbers of juvenile delta smelt surviving to the adult stage. This may occur during late summer in years when juvenile abundance is high relative to habitat carrying capacity. Factors defining the carrying capacity for juvenile delta smelt are unknown, but may include a shrinking volume of physically suitable habitat combined with a high density of competing planktivorous fishes during late summer and fall.

There is little information on losses of larval delta smelt (<20 mm fork length, FL) to the export facilities. Use of a population model suggests that water export operations can impact the abundance of post-larval (about 20 mm FL) delta smelt, but these effects may not reflect on adult abundance due to other processes operating in the intervening period. Effects from changes to the estuarine food web by exotic species and toxic chemicals occur but measuring their influence on population abundance is difficult. http://repositories.cdlib.org/jmie/sfews/vol3/iss2/art1/

EHR 4 **Bennett, W.A., and P.B. Moyle. "Where have all the fish gone? Interactive factors producing fish declines in the Sacramento-San Joaquin Estuary."** ***In San Francisco Bay: The Ecosystem*****, edited by J.T. Hollibaugh, 519-542. San Francisco: American Association for the Advancement of Science, Pacific Division. 1996.**

This paper reviews evidence for factors contributing to the declining abundance of fishes in the context of a conceptual model that emphasizes the interactive nature of six main pathways by which alteration of freshwater outflow to the estuary affects the survival of larval and juvenile fishes (recruitment success). Although the paper does not focus extensively on conveyance, one of the pathways it discusses is the influence of freshwater outflow on fish transport and entrainment. Other specific pathways include the influence of freshwater outflow on (2) retention in and/or advection from preferred habitats, (3) the success and effects of invading species, (4) primary production and food web dynamics, (5) dilution and/or flushing of toxic compounds, and (6) the quantity and quality of shallow-water spawning/rearing habitat. The collective evidence suggests that within and among years recruitment success may be regulated by several pathways acting in concert or synergistically, indicating the futility of promoting single-factor explanations for fish declines. Clearly, ameliorating the effects of various factors (e.g., reducing entrainment, toxic runoff, and improving shallow-water habitat) will improve conditions for fish. However, recovery of many depressed populations may be precluded by the continuously changing composition of the estuarine food web by exotic species. The current lack of life history information on several of the more severely affected species and the need to prevent extinctions suggests that the most pragmatic and promising solution is to ensure adequate outflow to the estuary.

EHR 5 Brown, L.R. "Will tidal wetland restoration enhance populations of native fishes?" ***In Issues in San Francisco Estuary Tidal Wetlands Restoration. San Francisco Estuary and Watershed Science*** **1(1): Article 2. 2003.**

Restoration of tidal wetlands might enhance populations of native fishes in the San Francisco Estuary of California. In this paper the author: (1) reviewed the currently available information regarding the importance of tidal wetlands to native fishes in the San Francisco Estuary, (2) constructed conceptual models on the basis of available information, (3) identified key areas of scientific uncertainty, and (4) identified methods to improve conceptual models and reduce uncertainty. There are few quantitative data to suggest that restoration of tidal wetlands will substantially increase populations of native fishes. On a qualitative basis, there is some support for the idea that tidal wetland restoration will increase populations of some native fishes; however, the species deriving the most benefit from restoration might not be of great management concern at present. Invasion of the San Francisco Estuary by alien plants and animals appears to be a major factor in obscuring the expected link between tidal wetlands and native fishes. Large-scale adaptive management experiments (>100 hectares) appear to be the best available option for determining whether tidal wetlands will provide significant benefit to native fishes. Even if these experiments are unsuccessful at increasing native fish populations, the restored wetlands should benefit native birds, plants, and other organisms.

EHR 6 Dege, M., and L. Brown. "Effect of Outflow on Spring and Summertime Distribution and Abundance of Larval and Juvenile Fishes in the Upper San Francisco Estuary." American Fisheries Society Symposium 39:49-66. 2004.

Researchers analyzed data on spring and summertime larval and juvenile fish distribution and abundance in the upper San Francisco Estuary (SFE), California between 1995 and 2001. The upper SFE includes the tidal freshwater areas of the Sacramento–San Joaquin Delta downstream to the euryhaline environment of San Pablo Bay. The sampling period included years with a variety of outflow conditions. Fifty taxa were collected using a larval tow net. Two common native species, delta smelt *Hypomesus transpacificus* and longfin smelt *Spirinchus thaleichthys*, and four common alien taxa, striped bass *Morone saxatilis*, threadfin shad *Dorosoma petenense*, gobies of the genus *Tridentiger*, and yellowfin goby *Acanthogobius flavimanus*, were selected for detailed analysis. Outflow conditions had a strong influence on the geographic distribution of most of the species, but distribution with respect to the 2 psu isohaline (X2) was not affected. The distribution patterns of delta smelt, longfin smelt, and striped bass were consistent with larvae moving from upstream freshwater spawning areas to downstream estuarine rearing areas. There were no obvious relationships of outflow with annual abundance indices. The results support the idea of using X2 as an organizing principle in understanding the ecology of larval fishes in the upper SFE. Additional years of sampling will likely lead to additional insights into the early life history of upper SFE fishes.

EHR 7 Feyrer, F. "Ecological Segregation of Native and Alien Larval Fish Assemblages in the Southern Sacramento–San Joaquin Delta." American Fisheries Society Symposium 39:67–79. 2004.

Feyrer sampled fish larvae at multiple fixed sites from late winter to early summer over 6 years (1990–1995) in the southern Sacramento–San Joaquin Delta. He collected a total of 394,797 fish larvae representing 15 species or taxonomic groups. The abundance of native and non-native species differentially clustered along environmental gradients of water temperature and river flow. Each native species (prickly sculpin, splittail, delta smelt, longfin smelt, and Sacramento sucker) and one non-native species (bigscale logperch) were associated with the early season conditions of cool water temperature and high river flow. Non-native species (especially shimofuri goby, threadfin shad, and ictalurid catfishes) were associated with late season conditions of relatively warm water temperature and low river flow. Accordingly, native species dominated the assemblage February–March, while non-native species dominated May–July. However, peak seasonal abundance of alien species was typically five times greater than that of native species. Seasonal succession of assemblage structure was persistent among years and was highly correlated with water temperature, a likely result of the differential spawning requirements of adult fishes. Interannually, the assemblage remained consistent over the study period despite considerable variability in delta inflow.

EHR 8 Feyrer, F., and M. P. Healey. "Fish Community Structure and Environmental Correlates in the Highly Altered Southern Sacramento-San Joaquin Delta." ***In Environmental Biology of Fishes*****: 66:123-32. 2003.**

This piece characterizes fish communities and their associations with environmental variables, based on samples of 11 sites in the southern Sacramento-San Joaquin Delta from 1992–1999. It does not address issues of conveyance directly; however, it does identify the species that coexisted with different hydrodynamics. In the study, riparian habitats were dominated by rock-reinforced levees, and large water diversion facilities greatly influenced local hydrodynamics and water quality. The researchers captured 33 different taxa, only eight of which were native. None of the native species represented more than 0.5% of the total number of individuals collected. The abundance of native species was consistently low but typically peaked during high outflow periods. Fish communities were predominantly structured along environmental gradients of water temperature and river flow. Native species (tule perch, *Hysterocarpus traski*, & Sacramento sucker, *Catostomusoccidentalis*) were associated with conditions of high river flow and turbidity, while the majority of the non-native species were associated with either warm water temperature or low river flow conditions. The exceptions were the non-native striped bass, *Morone saxatilis*, and white catfish, *Ameiurus catus,* which were positively associated with relatively high river flow. Variation in fish community structure was greater among river locations within years than within river locations among years, thus fish communities at each river location were consistently different each year. Differences in fish communities among river locations were correlated with river flow and turbidity. We predict that the fish communities of this region will remain numerically dominated by non-native species if the environmental conditions we observed persist in the future.

EHR 9 Feyrer, F., B. Herbold, S. Matern, and P. Moyle. "Dietary Shifts in a Stressed Fish Assemblage: Consequences of a Bivalve Invasion in the San Francisco Estuary." ***In Environmental Biology of Fishes*** **67: 277-88. 2003.**

This paper compares dietary patterns within a temperate estuarine fish assemblage – Suisun Marsh – during a period of high mysid shrimp abundance and after a major decline in mysid abundance caused by the invasion of the overbite clam *Potamocorbula amurensis.* Note that this paper does not address issues of conveyance directly, but other pieces have drawn out the link between water exports and reduced phytoplankton (Arthur et al 1996), and the importance of phytoplankton compared with particulate detritus for zooplankton growth (Muller-Solger et al 2002). The reseachers found that prior to the invasion, high dietary overlap, high stomach fullness, and low niche breadth occurred among the fishes in spring when mysid populations were high. Dietary overlaps decreased and niche breadth increased for all species but the endemic splittail *Pogonichthys macrolepidotus* in fall when mysid populations were low. Eight native species exhibited lower overall collective overlaps and fuller stomachs than five non-native species, suggesting more efficient resource partitioning. After mysid abundance declined, only alien striped bass *Morone saxatilis* preyed upon mysids in greater than trace amounts. An alien mysid became an important prey for small striped bass, but striped bass also switched to piscivory at a smaller size than when mysids were abundant. Eight of 13 species exhibited significant declines in abundance during the study period, which were concordant with the original importance of mysids in their diets. Their results suggest that altered lower food web dynamics in the San Francisco Estuary caused by the invasion of the overbite clam changed fish diets and have contributed to declines in fish abundance.

EHR 10 Feyrer, F., M. Nobriga, and T. Sommer. "Multidecadal Trends for Three Declining Fish Species: Habitat Patterns and Mechanisms in the San Francisco Estuary, California, USA." ***In Canadian Journal of Fisheries and Aquatic Sciences*** **64:723-734. 2007.**

Researchers examined a 36-year record of concurrent midwater trawl and water quality sampling conducted during fall to evaluate habitat trends for three declining fish species in the San Francisco Estuary, California, USA: delta smelt (*Hypomesus transpacificus*), striped bass (*Morone saxatilis*), and threadfin shad (*Dorosoma petenense*). Generalized additive modeling revealed that Secchi depth and specific conductance were important predictors of occurrence for delta smelt and striped bass, while specific conductance and water temperature were important for threadfin shad. Habitat suitability derived from model predictions exhibited significant long-term declines for each species; the southeastern and western regions of the estuary exhibited the most dramatic changes. Declines in habitat suitability were associated with anthropogenic modifications to the ecosystem. For delta smelt, an imperiled annual species endemic to the estuary, the combined effects of fall stock abundance and water quality predicted recruit abundance during recent years of chronically low food supply. The results are consistent with existing evidence of a long-term decline in carrying capacity for delta smelt and striped bass and demonstrate the utility of long-term data sets for evaluating relationships between fish and their habitat.

EHR 11 Isenberg, P., M. Florian, R.M. Frank, T. McKernan, S. Wright McPeak, W.K. Reilly, R. Seed. Our Vision for the California Delta. Sacramento: State of California. January 2008.
This document states the Governor's Blue Ribbon Task Force's vision for the Sacramento-San Joaquin Delta. This vision includes 12 integrated and linked recommendations to resolve the issues that are identified.

EHR 12 Jassby, A.D., W.J. Kimmerer, S.G. Monismith, C. Armor, J.E. Cloern, T.M. Powell, J.R. Schubel, and T.J. Vendlinski. "Isohaline Position as a Habitat Indicator for Estuarine Populations." ***In Ecological Applications*** **5(1): 272-289. 1995**
Populations of native and introduced aquatic organisms in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary ("Bay/Delta") have undergone significant declines over the past two decades. Decreased river inflow due to drought and increased freshwater diversion have contributed to the decline of at least some populations. Effective management of the estuary's biological resources requires a sensitive indicator of the response to freshwater inflow that has ecological significance, can be measured accurately and easily, and could be used as a "policy" variable to set standards for managing freshwater inflow. Positioning of the 2% (grams of salt per kilogram of seawater) bottom salinity value along the axis of the estuary was examined for this purpose. The 2% bottom salinity position (denoted by X2) has simple and significant statistical relationships with annual measures of many estuarine resources, including the supply of phytoplankton and phytoplankton-derived detritus from local production and river loading; benthic macroinvertebrates (molluscs); mysids and shrimp; larval fish survival; and the abundance of planktivorous, piscivorous, and bottom-foraging fish. The actual mechanisms are understood for only a few of these populations. X2 also satisfies other recognized requirements for a habitat indicator and probably can be measured with greater accuracy and precision than alternative habitat indicators such as net freshwater inflow into the estuary. The 2%~ value may not have special ecological significance for other estuaries (in the Bay/Delta, it marks the locations of an estuarine turbidity maximum and peaks in the abundance of several estuarine organisms), but the concept of using near-bottom isohaline position as a habitat indicator should be widely applicable. Although X2 is a sensitive index of the estuarine community's response to net freshwater inflow, other hydraulic features of the estuary also determine population abundances and resource levels. In particular, diversion of water for export from or consumption within the estuary can have a direct effect on population abundance independent of its effect on X2. The need to consider diversion, in addition to X2, for managing certain estuarine resources is illustrated using striped bass survival as an example. The striped bass survival data were also used to illustrate a related important point: incorporating additional explanatory variables may decrease the prediction error for a population or process, but it can increase the uncertainty in parameter estimates and management strategies based on these estimates. Even in cases where the uncertainty is currently too large to guide management decisions, an uncertainty analysis can identify the most practical direction for future data acquisition. ***This paper, despite the abstract, does not say a great deal about water exports and conveyance.***

EHR 13 Kimmerer, W.J. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages? Marine Ecology Progress Series 243: 39-55. 2002
Note that while focused on flow, this piece does not say a word about conveyance and how this relates to flow. All ecosystems are influenced by physical forcing. Estuarine ecosystems

respond most strongly on an interannual timescale to variability in freshwater flow. Several mechanisms for positive or negative flow effects on biological populations in estuaries have been proposed; however, positive effects appear to operate mainly through stimulation of primary production with effects propagating up the food web. In the northern San Francisco Estuary, abundance or survival of several common species of fish and shrimp varied positively with flow-in data through 1992. I re-examined these relationships and those of several additional taxa in an analysis of long-term (20 to 40 yr) monitoring data. The spread of the introduced clam *Potamocorbula amurensisin* 1987 provided an opportunity to examine simultaneously the responses of estuarine species to flow and to changes in the food web. I separated variability into a flow response, a step change after 1987 and other sources of variability. Responses of fish and shrimp contrasted with those of lower trophic levels. All but 1 species of nekton responded positively to flow, only 2 had clear declines after 1987, and none of the relationships changed in slope after 1987. In contrast with the higher trophic levels, chlorophyll a (chla) and several species of zooplankton declined markedly after 1987, and had either weak responses to flow or responses that changed after 1987. Thus, the food web appears strongly coupled between benthos and plankton, and weakly coupled between zooplankton and fish, as has been found in other systems. More importantly, the variation with freshwater flow of abundance or survival of organisms in higher trophic levels apparently did not occur through upward trophic transfer, since a similar relationship was lacking in most of the data on lower trophic levels. Rather, this variation may occur through attributes of physical habitat that vary with flow.

EHR 14 Kimmerer WJ. "Open Water Processes of the San Francisco Estuary: from Physical Forcing to Biological Responses." ***In San Francisco Estuary and Watershed Science*** **2(1): Article 2. February 2004**

This paper reviews the current state of knowledge of the open waters of the San Francisco Estuary. This estuary is well known for the extent to which it has been altered through loss of wetlands, changes in hydrography, and the introduction of chemical and biological contaminants. It is also one of the most studied estuaries in the world, with much of the recent research effort aimed at supporting restoration efforts. This review emphasizes the conceptual foundations for our current understanding of estuarine dynamics, particularly those aspects relevant to restoration. Several themes run throughout this paper. First is the critical role physical dynamics play in setting the stage for chemical and biological responses. Physical forcing by the tides and by variation in freshwater input combine to control the movement of the salinity field, and to establish stratification, mixing, and dilution patterns throughout the estuary. The second theme is the importance of time scales in determining the degree of interaction between dynamic processes. Physical effects tend to dominate when they operate at shorter time scales than biological processes; when the two time scales are similar, important interactions can arise between physical and biological variability. The third theme is the key role of introduced species in all estuarine habitats; particularly noteworthy are introduced waterweeds and fishes in the tidal freshwater reaches of the estuary, and introduced clams there and in brackish water. The final theme is the rather heterogeneous set of results from monitoring and research in the estuary.
http://repositories.cdlib.org/jmie/sfews/vol2/iss1/art1/

EHR 15 Lopez, C., J. Cloern, T. Schraga, A. Little, L. Lucas, J. Thompson, and J. Burau. "Ecological values of shallow-water habitats: implications for the restoration of disturbed ecosystems." ***In Ecosystems*** **9:422-440. 2006.**

A presumed value of shallow-habitat enhanced pelagic productivity derives from the principle that in nutrient-rich aquatic systems phytoplankton growth rate is controlled by light availability, which varies inversely with habitat depth. The authors measured a set of biological indicators across the gradient of habitat depth within the Sacramento-San Joaquin River Delta to test the hypothesis that plankton biomass, production, and pelagic energy flow also vary systematically with habitat depth. Results showed that phytoplankton biomass and production were only weakly related to phytoplankton growth rates whereas other processes (transport, consumption) were important controls. Distribution of the invasive clam *Corbicula fluminea* was patchy, and heavily colonized habitats all supported low phytoplankton biomass and production and functioned as food sinks. Surplus primary production in shallow, uncolonized habitats provided potential subsidies to neighboring recipient habitats. Zooplankton in deeper habitats, where grazing exceeded phytoplankton production, were likely supported by significant fluxes of phytoplankton biomass from connected donor habitats. The results provide three important lessons for ecosystem science:

- in the absence of process measurements, derived indices provide valuable information to improve our mechanistic understanding of ecosystem function and to benefit adaptive management strategies;
- the benefits of some ecosystem functions are displaced by water movements, so the value of individual habitat types can only be revealed through a regional perspective that includes connectedness among habitats; and
- invasive species can act as overriding controls of habitat function, adding to the uncertainty of management outcomes.

EHR 16 Lund, J., E. Hanak, W. Fleenor, R. Howitt, J. Mount, and P. B. Moyle. Envisioning Futures for the Sacramento-San Joaquin Delta. San Francisco: Public Policy Institute of California. 2007

After reviewing years of policy studies on the Delta, as well as delving into the most updated ecological information, the authors conclude that the future requires a "vision of a variable Delta, as opposed to the commonly held vision of a static Delta." The strategy of rigorously preserving a freshwater Delta has been risky and expensive. Instead, the authors present a case for a future approach that "yields the best outcomes overall, accompanied by strategies to reasonably compensate those who lose Delta services." Nine alternatives are presented across three objectives—maintaining high levels of fresh water, allowing the Delta to fluctuate between high and low levels of salinity, and moving toward a Delta that provides high levels of fresh water as needed. The authors carry out an initial summary evaluation of all nine alternatives and provide a rationale for their assessment of each one. The report does not endorse any single "best" solution among these alternatives. As the authors note, a closer look at the details will be required before the best strategy can be decided on.

However, they suggest that a hybrid solution, relying on some combination of key elements, may provide the most promising path forward. In this spirit, the report offers a number of new ideas for managing the Delta and presents a set of central themes for ways to think about the future of the region. The most striking of these themes is that business as usual is unsustainable for current stakeholders. The combined effects of continued land subsidence (that is, sinking land elevations), sea level rise, increasing seismic risk, and worsening winter floods make continued reliance on weak Delta levees imprudent and unworkable over the long term. In very strong language, the authors conclude that significant political decisions will be needed to make major changes in the Delta. Incremental, consensus-based solutions are unlikely to prevent a major ecological and economic catastrophe of statewide significance. The report concludes with recommendations for several actions—some related to the use of technical and scientific knowledge and others to the design of governance and finance policies. Most important, the authors identify a number of urgent items for debate and policy action. With a substantial base of empirical evidence and a considered assessment of the options, the report is not alarmist—but it does make a strong case that California's future water supply is in serious jeopardy unless the problems of the Sacramento–San Joaquin Delta are dealt with in a thoughtful and timely fashion.

EHR 17 Moyle, P.B., P.K. Crain, and K. Whitenener. "Patterns in the Use of a Restored California Floodplain by Native and Alien Fishes." *In San Francisco Estuary and Watershed Science* 5(3): Article 1. 2007

This paper does not directly address water exports or conveyance. Fishes were sampled on the restored floodplain of the Cosumnes River in Central California in order to determine patterns of floodplain use. The floodplain was sampled for seven years (1998-2002, 2004-2005) during the winter-spring flooding season. The fishes fell into five groups: (1) floodplain spawners, (2) river spawners, (3) floodplain foragers, (4) floodplain pond fishes, and (5) inadvertent users. Eight of the 18 abundant species were natives, while the rest were aliens. There was a consistent pattern of floodplain use, modified by timing and extent of flooding. The first fishes to appear were floodplain foragers, inadvertent users, and juvenile

Chinook salmon (river spawners). Next were floodplain spawners, principally Sacramento splittail and common carp. At the end of the season, in ponds of residual water, non-native annual fishes, mainly inland silverside and western mosquitofish, became abundant. Adult spawners left when inflow decreased; their juveniles persisted as long as flood pulses kept water levels up and temperatures low. Juvenile splittail and carp quickly grew large enough to dominate floodplain fish samples, along with smaller numbers of juvenile Sacramento sucker and pikeminnow (river spawners). Such juveniles left the floodplain either with pulses or in drainage water. Relatively few fishes that used the floodplain for spawning or rearing became stranded, except late season alien fishes. Most alien fishes had resident populations in adjacent river, sloughs, and ditches and were not dependent on the floodplain for persistence. This indicates that Central Valley floodplains managed to favor native fishes should have the following characteristics:

- extensive early season flooding;
- complete drainage by the end of the flooding season;
- few areas with permanent water;
- a mosaic of physical habitats; and
- regular annual flooding but with high variability in flood regime.

EHR 18 Moyle, P. and T. Light. "Biological Invasions of Fresh Water: Empirical Rules and Assembly Theory." ***In Biological Conservation*** **78:149-161. 1996.**

Using case histories of fish invasions in streams, lakes, and estuaries including the San Francisco Bay-estuary, the authors devise a dozen empirically-derived rules (conceptual model) that seem to govern most aquatic invasions. Also noted is that invading species and systems being invaded interact in idiosyncratic ways that are often hard to predict, largely because of the role of environmental variability in determining the outcomes of invasions. These rules are:

- Most invaders fail to become established;
- Most successful invaders are integrated without major negative effects (e.g. extirpations) on the communities being invaded;
- All aquatic systems are invasible and invasibility is not related to diversity of the resident organisms;
- Major community effects of invasions are most often observed where the number of species is low;
- In systems that have been minimally altered by human activity, fishes most likely to be successful invaders are top predators and omnivore/detritivores;
- Piscivorous invaders are most likely to alter the fish assemblages they invade while omnivore and detritivores are least likely to do so;
- In aquatic systems with intermediate levels of human disturbance, any species with the right physiological and morphological characteristics can become established;
- In the long term, or in relatively undisturbed aquatic systems, success of an invader will depend on a close match between its physiological and life history requirements and the characteristics of the system being invaded;
- Invaders into natural aquatic systems are most likely to become established when native assemblages of organisms have been temporarily disrupted or depleted;
- Long-term success (integration) of an invading species is much more likely in an aquatic system permanently altered by human activity than in a lightly disturbed system;
- The invasibility of a natural aquatic system is related to the interactions among environmental variability, predictability, and severity; and
- Invaders are most likely to extirpate native species in aquatic systems with extremely high or extremely low variability or severity.

EHR 19 Moyle, P.B. and M.P. Marcheti. "Predicting Invasion Success: Freshwater Fishes in California as a Model." ***In BioScience*** **Vol. 56, No. 6. 2007.**

The authors conclude that there is no universal set of characters that can predict which aquatic invasions will succeed or which fishes are likely to become nuisance species. They do indicate though, that there are a number of characters, both of the invader and of the place being invaded, that increase the probability of an invader being successful. A fish species is likely to be a successful invader if:

- it has a history of successful establishment outside its native range;
- it has characters likely to promote success at multiple stages of the invasion process;
- it is introduced into a habitat that more or less matches its native habitat;
- it is introduced into a region with comparatively high fish species richness, including other alien fishes; and
- it is introduced repeatedly, with propagule sizes exceeding 100 individuals.
- They also conclude that there are a wide variety of characteristics, often confined to a particular set of species or environments, that increase (or decrease) the likelihood of successful invasion.

They recommend that introductions of more alien species should be prevented even if we can predict with confidence the potential for a new invader to cause harm, since this may be too high a risk to take.

EHR 20 Muller-Solger, A.B., A.D. Jassby, D.C. Muller-Solger. "Nutritional Quality of Food Resources for Zooplankton (Daphnia) in a Tidal Freshwater System (Sacramento-San Joaquin River Delta)." ***In Limnology and Oceanography*** **47(5): 1468-1476. 2002.**

This paper examines the relative nutritional values of natural phytoplankton and particulate detritus for zooplankton growth in a detritus-rich environment. It does not address issues of conveyance directly or indirectly, although does provide evidence of the role of phytoplankton in regulating zooplankton growth. For the work, seston was collected seasonally from four different habitat types in a tidal freshwater system and fed to juvenile *Daphnia magna* under controlled culture conditions by use of a flow-through design. Seston particulate organic carbon (POC) and chlorophyll *a* contents ranged from 330 to 3,800 mg L21 POC and 1.4 to 45 mg L21 Chl *a.* A partial residual analysis revealed that detrital carbon concentrations were only weakly related to *Daphnia* growth, whereas Chl *a* proved to be highly predictive of *Daphnia* growth rates across all investigated habitat types. Overall, habitat type had a strong effect on growth rates, whereas season of seston collection did not, but differences among habitats could be attributed to differing Chl *a* concentrations. The results from this study imply that, even in systems with overwhelming amounts of detrital carbon from a variety of sources, nutritional factors associated with phytoplankton can be dominant in regulating zooplankton growth.

EHR 21 Myrick, C. A., and J. J. Cech, Jr. <u>Temperature effects on Chinook Salmon and Steelhead: a Review Focusing on California's Central Valley Populations.</u> Bay-Delta Modeling Forum Technical Publication 01-1. 59 pp. 2001.

This report is a review of the effects of water temperature on Chinook salmon and steelhead, with particular emphasis on populations in the Central Valley of California. The authors summarize the known information in: thermal tolerance at the different salmonid life-stages; thermal preference, effects on growth; effects on smotification; effects on disease; effects on predation; and effects on hooking mortality. They also suggest areas of needed research. They summarize this work by stating that

- optimal temperature ranges for Central Valley chinook salmon and steelhead vary depending on life stage;
- eggs and alevins are extremely stenothermal, requiring temperatures between 4 and 12°C for the highest survival rates;
- juveniles are more stenothermal, requiring temperatures between 15 and 19°C for maximum growth under optimal conditions;
- in order to complete the parr-smolt transformation, cooler temperatures (10 – 17°C for chinook salmon; 6 – 10°C for steelhead) are needed to maximize saltwater survival.

- Cooler temperatures also reduce the risk of predation and disease, both of which are enhanced at higher temperatures.

Based on this literature review, it is not possible to recommend a single, fixed temperature criterion. They do state that the changes made to Central Valley rivers have had, and will continue to have far-reaching effects on Chinook salmon and steelhead populations. Ideally, river temperatures should be managed so that they follow the pre-regulation thermal regime. Because this is unlikely, they strongly recommend that resource managers evaluate the changing temperature needs of juvenile Chinook salmon and steelhead and take advantage of modern reservoir design to maintain instream temperatures within those ranges. Finally, more research on the effects of temperature on Central Valley Chinook salmon and steelhead physiology, behavior, and survival is clearly needed.

EHR 22 Newman, K.B., and J. Rice. "Modeling the Survival of Chinook Salmon Smolts Outmigrating through the Lower Sacramento River System." ***In Journal of the American Statistical Assoc.*** **00(00) (sic.): 1-11. 2002.**

To study the factors associated with the freshwater mortality of outmigrating chinook salmon, releases of tagged juvenile salmon were made at multiple locations in the Sacramento River each spring between the years 1979 and 1995. A midwater trawl located downstream of the release sites caught salmon soon after release and, 1 to 4 years later, samples taken from the catches of marine fisheries recovered other tagged fish. An extended quasi-likelihood model was fit to both the freshwater and the marine recoveries. A ridge parameter was included to stabilize the parameter estimates and to improve predictive ability. Overdispersion was due, at least in part, to heterogeneity in the trawl's capture efficiency, as well as to the complex aggregation of marine recoveries. Different dispersion parameters were used for the river and ocean recoveries because of the additional sources of variation experienced by ocean recoveries relative to river recoveries. Interpretation of estimated coefficients was delicate, given the correlation between some of the covariates, the biases introduced by the ridge parameter, and possible confounding factors. With these caveats in mind, we found the most influential covariate to be the temperature of the water into which the fish were released, with increasing temperatures having a negative association with recoveries. Three covariates were of particular interest to the biologists and water managers: water flow, position of a water diversion gate (open or closed) separating the mainstem from the central delta, and relative fraction of water exported for irrigation and urban consumption. The effects of flow were slightly positive but were confounded by salinity levels. The effect of the water diversion gate being open was to lower apparent survival for fish released above the gate, but apparent survival increased for fish released in the central delta into which the water was diverted. There was evidence that increasing the export-to-inflow ratio lowered survival, but the effect was slight and not statistically significant. Although this is their key finding, the authors do provide a small amount of further discussion of the influence of water exports.

EHR 23 Nobriga, M. L. and F. Feyrer. "Shallow-Water Piscivore-Prey Dynamics in California's Sacramento-San Joaquin Delta." ***San Francisco Estuary and Watershed Science*** **5(2): Article 4. May 2007.**

The authors investigated whether predation is the primary mechanism that leads to low native fish abundance in macropyhyte dominated shallow-water habitats in the Sacramento-San Joaquin Delta. They found that striped bass, largemouth bass, and Sacramento pikeminnow are three of the major predators of juvenile and small adult fishes in the Delta, especially in the nearshore habitats. The study also presented information about predator-prey dynamics involving these fishes, and provided insight into the relative importance of piscivory on native fishes. They authors addressed the following questions:

- What are the spatial and temporal distributions of age-1 and older striped bass, largemouth bass, and Sacramento pikeminnow?
- What prey are eaten by these predators?
- What is the relative importance of predator size versus seasonal prey availability on incidence of piscivory for these predators?

- What is the likely per capita impact of each piscivore on prey fishes, particularly native fishes?
- These results have management implications for native fishes and the design of shallow water restoration projects. Their work did show that these predatory fishes frequently occur in Delta shallow water habitats. All three had diverse diets comprised of numerous invertebrate and fish taxa. There were noticeable seasonal shifts in prey fish for each of the three fishes. In general, most native fish were consumed during spring (March-May) and the highest prey species richness occurred during summer (June-August). Largemouth bass likely have the highest per capita impact on nearshore fishes, including native fishes. Largemouth bass preyed on a greater diversity of native fishes than the other two species and consumed native fishes farther into the season (July versus May). The study indicated that the incidence of piscivory was predominantly a function of size for largemouth bass and Sacramento pikeminnow. Largemouth bass became predominantly piscivorous at smaller sizes than Sacramento pikeminnow; about 115 mm versus about 190 mm respectively. In contrast, incidence of piscivory was predominantly a function of season for striped bass. Striped bass were typically most piscivorous during summer and fall regardless of size. They conclude that shallow water predators are widespread in the Delta and generally respond in a density-dependent manner to seasonal changes in prey availability.

EHR 24 Nobriga, M. L., F. Feyrer, R. Baxter, and M. Chotkowski. "Fish community ecology in an altered river delta: spatial patterns in species composition, life history, strategies and biomass." *In Estuaries* 28:776-785. 2005.

Researchers sampled nearshore fishes in the Sacramento-San Joaquin Delta during 2001 and 2003 with beach seines and gill nets. Analysis of sampling data showed that habitat variables had more influence on fish assemblages than temporal variables. Results from both gear types indicated fish assemblages varied between Sacramento and San Joaquin River sampling sites. Results from gill net sampling were less pronounced than those from beach seine sampling. The Sacramento and San Joaquin river sites differed most notably in terms of water clarity and abundance of submerged aquatic vegetation (SAV), suggesting a link between these habitat characteristics and fish relative abundance. Among-site differences in the relative abundance of periodic and equilibrium strategist species (e.g., tule perch) suggested a gradient in the importance of abiotic versus biotic community structuring mechanisms. Fish biomass varied among years, but was generally higher in SAV-dominated habitats than the turbid, open habitats in which we found highest abundances of striped bass and special-status native fishes such as delta smelt, Chinook salmon, and splittail. The low abundance of special-status fishes in the comparatively productive SAV-dominated habitats suggests these species would benefit more from large-scale restoration actions that result in abiotic variability that mirrors natural river-estuary habitat than from actions that emphasize site-specific productivity.

EHR 25 Orr, M., S. Crooks and P. B. Williams. "Will Restored Tidal Marshes Be Sustainable?" Issues in San Francisco Estuary Tidal Wetlands Restoration. Larry R. Brown, editor. *In: San Francisco Estuary and Watershed Science* 1(1): Article 5. October 2003.

The authors asses whether or not restored marshes in the San Francisco Estuary are expected to be sustainable in light of future landscape scale geomorphic processes given typical restored marsh conditions using a review of the literature, appraisal of monitoring data for restored marshes, and application of vertical accretion modeling of organic and inorganic sedimentation. The results from using their vertical accretion model suggests that salt marshes in San Pablo Bay will be sustainable for moderate relative sea level rise (3 to 5 mm yr-1) and average sediment supply (c. 100 mg L-1). Accelerated relative sea level rise (above 6 mm yr-1) and/or reduced sediment supply (50 mg L-1) will cause lowering of the marsh surface relative to the tide range and may cause shifts from high to low marsh vegetation by the year 2100. Widespread conversion of marsh to mudflat – "ecological drowning" - is not expected within this time frame. Marshes restored at lower elevations necessary to aid the natural development of channel systems (c. 0.5 m below mean higher high water) are predicted to accrete to high marsh elevations by the year 2100 for moderate relative sea level rise and sediment supply conditions. Existing rates of sediment accretion in restored fresh water tidal marshes of the Delta of greater than 9 mm yr-1 and slightly lower drowning elevations suggest that these marshes will be resilient against relatively high rates of sea level rise. Because of higher rates of organic production, fresh water marshes are expected to be less sensitive to reduced sediment availability than salt marshes. The ultimate long-term threat to the sustainability of tidal marshes is the interruption of coastal rollover-the process by which landward marsh expansion in response to sea level rise compensates for shoreline erosion. Bay front development now prevents most landward marsh expansion, while shoreline erosion is expected to accelerate as sea level rises.

EHR 26 Sobczak, W. V., J. E. Cloern, A. D. Jassby, B. E. Cole, T. S. Schiraga and A. Arnsberg. "Detritus Fuels Ecosystem Metabolism but not Metazoan Food: Webs in San Francisco Estuary's Freshwater Delta." ***In Estuaries*** **28(1): 124–137. February 2005.**

This study of the Sacramento-San Joaquin River Delta supported the emerging principle that allochthonous detritus supports a large component of riverine and estuarine ecosystem metabolism. It did not find evidence for detrital pathways significantly contributing to pelagic food webs supporting higher trophic levels. The authors also found that only a small fraction of the organic matter is bioavailable, even over the course of 21-day bioassays. This finding suggests that the vast majority of the organic matter delivered to the Delta is transported conservatively to the San Francisco Bay and coastal marine waters. The ultimate fate of this organic matter is unknown.

The Delta ecosystem was routinely heterotrophic, respiring more organic matter than it produces within the system. This finding indicates that the Delta functions as a sink for organic matter as it moves to coastal waters. A corollary to this finding is that the Delta ecosystem functions as a net source of CO2 to the atmosphere. The authors found that Dissolved Organic Carbon was usually several times Particulate Organic Carbon. This finding is ecologically significant because different categories of organic carbon enter food webs at different trophic levels and it indicates the Delta, a net heterotrophic ecosystem, is microbially coupled to dissolved allochthonous organic matter.

The authors also found that although the northern San Francisco Bay and associated Delta is a highly-turbid, light-limited ecosystem with low primary productivity relative to other estuaries, phytoplankton biomass was a strong predictor of bioavailable Particulate Organic Carbon and is likely the major food resource for the Delta's pelagic metazoans. Delta habitats functioned differently in terms of potential transfer of organic matter to higher trophic levels. Deep River habitats in the Sacramento River and central Delta, which represent 50% of the Delta's spatial coverage, provide the lowest potential trophic transfers among Delta habitats. Tidal-marsh sloughs routinely support the largest potential zooplankton biomass. Several shallow water habitats throughout the Delta sporadically supported modest algal blooms and these habitats appear to be critical for supplying bioavailable food resources to zooplankton. Since growth and survival rates of juvenile salmon are higher in the shallow floodplain than adjacent deep river channel, these differences in phytoplankton may propagate to higher trophic levels.

This study provides a framework for using organic matter dynamics to aid restoration actions that are geared at modifying the supply of bioavailable organic matter to higher trophic levels. Effective restoration of aquatic ecosystems requires knowledge of disparities in the amounts, bioavailability, and food web importance of organic matter delivered from adjacent terrestrial watersheds compared to organic matter produced among diverse habitats within aquatic ecosystems. Bioavailability of organic matter is an essential and powerful measure of aquatic ecosystem response to restoration actions aimed at creating habitats within aquatic ecosystems or manipulating land-use features in connected.

EHR 27 Sommer, T. R., W.C. Harrell, A. Mueller-Solger, B. Tom and W. Kimmerer. "Effects of Flow Variation on Channel and Floodplain Biota and Habitats of the Sacramento River, California, USA." ***In Aquatic Conserv: Mar. Freshw. Ecosyst.*** **14: 247-261. 2004**

The authors developed and evaluated a model that examines the effect of variation in flow on the responses of two trophic levels in the Sacramento River and its seasonal floodplain in the Yolo Bypass. The simulations showed more hydrologic variability in the floodplain than in the river, with greater total surface and shallow area, longer hydraulic residence times and lower water velocities for the floodplain. They also reported higher Chlorophyll a levels in the floodplain than in the river and that these levels were negatively correlated with flow. Copepods and cladoceran (zooplankton) densities were similar in the river and its floodplain, and were mostly negatively associated with flow. Diptera densities and terrestrial invertebrates were found in higher densities in the floodplain and were positively associated with flow. Overall, the results provide evidence of the value of floodplains and the connectivity of floodplains to rivers in the production at lower trophic levels and at relatively rapid time scales.

EHR 28 Sommer, T. R., W. C. Harrell, and M. L. Nobriga. "Habitat Use and Stranding Risk of Juvenile Chinook Salmon on a Seasonal Floodplain." In North American Journal of Fisheries Management 25:1493–1504. 2005
The authors studied the Yolo Bypass, a floodplain of the Sacramento River to help determine weather use of seasonal floodplains by juvenile Chinook salmon is a net ''source'' or a net ''sink'' for salmonid production. They found that juvenile salmon were present in the Yolo Bypass during winter to spring and that fish were in all regions and substrates of the floodplain. Experimental releases of tagged hatchery salmon suggest that the fish reared on the floodplain for extended periods. Floodplain rearing and associated growth are also supported by the significantly larger size of wild salmon at the floodplain outlet than at the inlet during each of the study years. Several lines of evidence suggest that although the majority of young salmon successfully emigrated from the floodplain, areas with engineered water control structures had comparatively high rates of stranding. Adult ocean recoveries of tagged hatchery fish indicate that seasonal floodplains support survival at least comparable with that of adjacent perennial river channels. These results of this study indicate that floodplains appear to be a viable rearing habitat for Chinook salmon, making floodplain restoration an important tool for enhancing salmon production.

EHR 29 Sommer, T. R., M. L. Nobriga, W. C. Harrell, W Batham, and W. Kimmerer."Floodplain Rearing of Juvenile Chinook Salmon: Evidence of Enhanced Growth And Survival." ***In Canadian Journal of Fisheries and Aquatic Sciences*****, 58(2): 325–333. 2001.**
In this study, researchers provided evidence that the Yolo Bypass, the primary floodplain of the lower Sacramento River, provides better rearing and migration habitat for juvenile Chinook salmon (*Oncorhynchus tshawytscha*) than adjacent river channels. During 1998 and 1999, salmon increased in size substantially faster in the seasonally inundated agricultural floodplain than in the river, suggesting better growth rates. Similarly, coded-wire-tagged juveniles released in the floodplain were significantly larger at recapture and had higher apparent growth rates than those concurrently released in the river. Improved growth rates in the floodplain were in part a result of significantly higher prey consumption, reflecting greater availability of drift invertebrates. Bioenergetic modeling suggested that feeding success was greater in the floodplain than in the river, despite increased metabolic costs of rearing in the significantly warmer floodplain. Survival indices for coded-wire-tagged groups were somewhat higher for those released in the floodplain than for those released in the river, but the differences were not statistically significant. Growth, survival, feeding success, and prey availability were higher in 1998 than in 1999, a year in which flow was more moderate, indicating that hydrology affects the quality of floodplain rearing habitat. These findings support the predictions of the flood pulse concept and provide new insight into the importance of the floodplain for salmon.

EHR 30 Sommer, T., B. Suits, M. Mierzwa, and J. Wilde. Evaluation of Residence Time and Entrainment using a Particle Tracking Model for the Sacramento-San Joaquin Delta. Sacramento: Department of Water Resources. 2005
The authors used a coupled hydrodynamic-particle tracking model to assess the recent trends (1990-2004) in residence time and entrainment risk for organisms in the San Francisco Estuary, California. If anything, the model runs suggested that residence time may have increased slightly for the San Joaquin River. However, the Sacramento River runs provided evidence that residence time tended to be longer prior to the Bay-Delta Accord. This effect may have been strongly influenced by hydrology as residence time was typically longer in drier years. Second, the runs supported the hypothesis that operations typically have a stronger effect on inflow from the San Joaquin River than the Sacramento River: residence times tended to be shorter for particles released in the San Joaquin River than the Sacra-

mento River. This was at least partially supported for late-winter through early-spring (March-June), when the model runs suggested that entrainment risk during the past 3-4 years has been somewhat higher than the long-term average. This was inconsistent with the hypothesis that the entrainment of pelagic species has not increased. The model results may partially be related to hydrology as entrainment risk appeared to be somewhat inversely correlated with hydrology for March-May. Moreover, the model suggested that entrainment risk tended to be lower during June-October before 1994, the drier period prior the Bay-Delta Accord.

EHR 31 Bay-Delta Conservation Plan. <u>The Bay Delta Conservation Plan: Points of Agreement for Continuing into the Planning Process</u>. Sacramento: State of California. 2007.

Members of the Steering Committee for the Bay Delta Conservation Planning process are developing a conservation plan for the Bay Delta pursuant to the Endangered Species Act and the Natural Community Conservation Planning. This memorandum describes the agreements reached by the Steering Committee on the basic approaches to several important topics for the plan, including potential improvements to the water conveyance system, and strategies for in-Delta habitat restoration and enhancement. Points of Agreement include:

- The types of habitat restoration and enhancement actions which will be initially evaluated for inclusion in the conservation strategy include:
  - Restoring intertidal habitat to establish vegetated marshes and associated sloughs to increase habitat diversity and complexity, food production and in-Delta productivity, and rearing habitat for covered species.
  - Increasing hydraulic residence time and tidal exchange within the Delta sloughs and channels by changing circulation patterns to increase primary productivity and food web support and improve turbidity conditions for Delta smelt and longfin smelt.
  - Increasing the amount of functional floodplain habitat to increase the quantity and quality of rearing habitat for salmonids and sturgeon and spawning habitat for Sacramento splittail, and generate food resources for pelagic species.
  - Providing adequate water quality and quantity within the Delta at appropriate times to help conserve resident native fishes and improve rearing and migration habitats for salmon moving through the Delta.
- Evaluate and, as appropriate, include in the BDCP other conservation actions designed to help address a number of stressors on covered species other than water conveyance facilities and operations. These stressors include:
  - Exposure to contaminants
  - Non-native species competition and predation
  - Entrainment at non-CVP/SWP intake facilities
  - Harvest
  - Reduced genetic diversity and integrity
  - Effects of climate change
- The most promising approach for achieving the BDCP conservation and water supply goals involves a conveyance system with new points of diversion, the ultimate acceptability of which will turn on important design, operational and institutional arrangements that the Steering Committee will develop and evaluate through the planning process.
- Evaluate the ability of a full range of design and operational scenarios to achieve BDCP conservation and planning objectives over the near and long term, from full reliance on the new facilities to use of the new facilities in conjunction with existing facilities.
- Develop and evaluate operating criteria for water conveyance facilities to achieve applicable near and long-term conservation and water supply goals.
- Will include comprehensive adaptive management and monitoring programs with measurable objectives to address uncertainties regarding the role and importance of

various stressors and the capacity of the conservation strategy to achieve its conservation objectives.

- Will continue to seek independent scientific input to further inform the development of the BDCP.
- Will include an analysis of the costs associated with plan implementation, including one-time and on-going costs. This analysis will be used to determine the level of funding and other resources that will be required to implement the BDCP. The BDCP will identify potential sources of funds for implementation, reflecting the concept of proportionality identified in the Planning Agreement, and will include assurances that adequate funding will be provided to implement the plan over its term.
- Will include a description of the steps and actions necessary to implement the plan, including an implementation approach and schedule for BDCP conservation actions. The plan will further detail a decision-making structure for the elements of the plan, that includes the establishment of an entity or entities to assume responsibility for plan implementation, and will assign specific functions and duties to such an entity or entities.

EHR 32 CALFED Bay-Delta Program. Final Programmatic EIS/EIR Technical Appendix. Ecosystem Restoration Program Plan, Volume 1: Ecological Attributes of the San Francisco Bay-Delta Watershed. Sacramento: State of California. July 2000.

Volume I: Ecological Attributes of the San Francisco Bay-Delta Watershed presents the visions for ecological processes and functions, fish and wildlife habitats, species, and stressors that impair the health of the processes, habitats, and species throughout the watershed. The visions presented in Volume I are the foundation of the ERP and display how the many ecosystem elements relate to one another and establish a basis for actions which are presented in Volume II.

Volume I contains information related to problems, theory, and concepts linked to the Central Valley ecosystem and includes descriptions of important ecological processes and functions, habitats, species, and stressors which impair or otherwise adversely effect the other ecosystem elements. Individually and cumulatively, the visions for the ecosystem elements establish the foundation and scientific basis of the ERP. Volume I also incorporates important elements from the CALFED Multi-Species Conservation Strategy such as standardized species designation, conservation measures for evaluated species, and species goal prescriptions.

Each section follows the same format and begins with introductory information regarding the ecosystem elements. Three introductory tables summarize the strategic objectives, basis for selection as an ecosystem element, and the distribution of ecosystem elements by ecological zone.

EHR 33 CALFED Bay-Delta Program. Final Programmatic EIS/EIR Technical Appendix. Ecosystem Restoration Program Plan, Volume 2: Ecological Management Zone Visions. Sacramento: State of California. July 2000.

Volume II: Ecological Management Zone Visions integrates the landscape ecological concepts for processes, habitats, species, and stressors presented in Volume I: Visions for Ecosystem Elements. Volume II presents the visions for the 14 ecological management zones and their respective ecological management units. Each individual ecological management zone vision contains a brief description of the management zone and units, important ecological functions associated with the zone, important habitats, species which use the habitats, and stressors which impair the functioning or utilization of the processes and habitats. Volume II also contains strategic objectives, targets, programmatic actions, and conservation measures which describe the ERP approach, and which balances and integrates the needs of the CALFED Multi-Species Conservation Strategy in order to improve the ecological health of the zone and its contribution to the health of the Delta. Volume II also presents rationales which clarify, justify, or support the targets and programmatic actions.

Each Ecological Management Zone (Zone) is further divided into component Ecological Management Units (Unit). For example, the East San Joaquin Zone is divided into three Units: Stanislaus River, Tuolumne River, and Merced River. The vision for each Ecological

Management Zone provides introductory information; Zone and Unit descriptions which identify the status of ecological processes, habitats, and species; and describes how stressors adversely affect those ecosystem elements.

EHR 34 CALFED Bay-Delta Program. Final Programmatic EIS/EIR Technical Appendix. Ecosystem Restoration Program Plan, Strategic Plan for Ecosystem Restoration. Sacramento: State of California. July 2000.

Strategic Plan for Ecosystem Restoration is the guidance document for implementing the Ecosystem Restoration Program Plan. It defines an ecosystem-based approach that is comprehensive, flexible, and iterative, designed to respond to changes in the complex, variable Bay-Delta system and changes in the understanding of how this system works. The Strategic Plan:

1. describes an Ecosystem-Based Management Approach for restoring and managing the Bay-Delta ecosystem;
2. describes an Adaptive Management Process that is sufficiently flexible and iterative to respond to changing Bay-Delta conditions and to incorporate new information about ecosystem structure and function;
3. describes the value and application of Conceptual Models in developing restoration actions and defining information needs, with examples of their development and use;
4. presents Decision Rules and criteria to help guide the selection and prioritization of restoration actions;
5. presents CALFED's broad Goals and specific Objectives for ecosystem restoration;
6. presents Twelve Critical Issues that need to be addressed early in the restoration program;
7. describes Opportunities for Restoration to address the twelve critical issues in the first seven years of implementation;
8. describes the approach for selecting actions for the Stage 1 Implementation period, the first 7 years of Program implementation; and
9. describes Institutional and Administrative Considerations necessary to implement adaptive management, to ensure scientific credibility of the restoration program, and to engage the public in the restoration program.

EHR 35 CALFED Bay-Delta Program. Final Programmatic EIS/EIR Technical Appendix. Multi-Species Conservation Strategy. Sacramento: State of California. July 2000.

CALFED has developed a Multi-Species Conservation Strategy (MSCS) to serve as the framework for compliance with the Federal Endangered Species Act (FESA), the California Endangered Species Act (CESA), and the State's Natural Community Conservation Planning Act (NCCPA). The MSCS has identified a subset of species which are federally and State listed, proposed, or candidate species, other species identified by CALFED that may be affected by and for which the CALFED Program and the ERP have responsibility related to (1) recovery of the species, (2) contribute to their recovery, or (3) maintain existing populations.

Specifically, the MSCS:

1. analyzes CALFED's effects on 244 species and 20 communities for FESA, CESA, and NCCPA purposes;
2. identifies species goals ("recovery ", "contribute to recovery", or "maintain") for each of the 244 evaluated species, as well as conservation measures to achieve the goals;
3. identifies goals for each of the 20 Natural Community Conservation Plan communities comprising 18 habitat types and two fish groups, as well as conservation measures to achieve the goals; and
4. provides for the preparation of Action Specific Implementation Plans (ASIPs), which strengthen and simplify CALFED compliance with FESA, CESA, and NCCPA.

The MSCS contains two types of conservation measures:

10. measures to avoid, minimize, and compensate for adverse effects to NCCP communities and evaluated species caused by individual CALFED actions; and

11. measures to enhance NCCP communities and evaluated species that are not directly linked to CALFED's adverse effects.

EHR 36 Reed, D., J. Anderson, E. Fleishman, D. Freyberg, W. Kimmerer, K. Rose, M. Stacey, S. Ustin, and I. Werner. Bay Delta Conservation Plan Independent Science Advisors Report. Sacramento: State of California. 2007.

A group of nine scientists were convened in September 2007 to provide independent advice to the Bay Delta Conservation Plan Steering Committee. These scientists provided advice on the use of science in developing an effective Conservation Plan for the Sacramento-San Joaquin Delta in accordance with California's Natural Community Conservation Planning Act and the Bay Delta Conservation Plan Planning Agreement. The Advisors developed sixteen principles:

- Overarching Principles
    - Changes in the estuarine ecosystem may be irreversible.
    - Future states of the Delta ecosystem depend on both foreseeable changes (e.g., climate change and associated sea-level rise) and unforeseen or rare events (e.g., the consequences of new species invasions).
    - The Delta is part of a larger river-estuarine system that is affected by both rivers and tides. The Delta is also influenced by long-distance connections, extending from the headwaters of the Sacramento and San Joaquin Rivers into the Pacific Ocean.
- Delta Ecosystem Dynamics
    - The Delta is characterized by substantial spatial and temporal variability, including disturbances and extreme events that are fundamental characteristics of ecosystem dynamics. The Delta cannot be managed as a homogeneous system.
    - Species that use the Delta have evolved life history strategies in response to variable environmental processes. Species have limited ability to adapt to rapid changes caused by human activities.
    - Achieving desired ecosystem outcomes will require more than manipulation of Delta flow patterns alone.
    - Habitat should be defined from the perspective of a given species and is not synonymous with vegetation type, land (water) cover type, or land (water) use type.
    - Changes in water quality have important direct and indirect effects throughout the estuarine ecosystem.
    - Land use is a key determinant of the spatial distribution and temporal dynamics of flow and contaminants which, in turn, can affect habitat quality.
    - Changes in one part of the Delta may have far-reaching effects in space and time.
- Conservation Approaches and Analysis
    - Prevention of undesirable ecological responses is more effective than attempting to reverse undesirable responses after they have occurred.
    - Adaptive management is essential to successful conservation.
    - Conservation measures to benefit one species may have negative effects on other species.
    - Data sources, analyses, and models should be documented and transparent so they can be understood and repeated.
    - Ecosystem responses, especially to changes in system configuration, can be predicted using a combination of statistical and process models. Statistical models document status, trends, and relationships between responses and environmental variables, whereas process-based models are useful in understanding system responses and for forecasting responses to new conditions.
    - There are many sources of uncertainty in understanding a complex system and predicting its responses to interventions and change.

EHR 37 **Baxter, R., R. Breuer, L. Brown, M.Chotkowski, F. Feyrer, M. Gingras, B. Herbold, A. Mueller-Solger, M. Nobriga, T. Sommer, and K. Souza. Pelagic Organism Decline Progress Report: 2007 Synthesis of Results. Prepared for the Interagency Ecological Program. Sacramento: State of California. 2008.**

Fish abundance indices calculated by the Interagency Ecological Program (IEP) through 2007 suggest recent marked declines in four pelagic (open water) fishes in the Delta and Suisun Bay. These fishes include delta smelt which is listed under State and federal Endangered Species acts and the longfin smelt, which has been proposed for protection under those acts. Although several species show evidence of long-term declines, the recent low levels were unexpected given the relatively moderate winter-spring flows of the past several years. In response to these changes, the IEP formed a Pelagic Organism Decline ("POD") work team to evaluate the potential causes. The major findings through 2007 were synthesized using two conceptual modeling approaches. A basic conceptual model was developed that included the following major components: 1) previous abundance levels, which describes how continued low abundance of adults leads to juvenile production; 2) habitat, which describes how water quality variables (including contaminants and toxic algal blooms) affect estuarine species; 3) top-down effects, which posits that predation and water project entrainment affect mortality rates; and 4) bottom-up effects, which focuses on food web interactions in Suisun Bay and the west Delta. The second set of conceptual models focused on temporal and species-specific interactions of these stressors. Towards this end, the POD work team developed individual conceptual models for each species that incorporate seasonal and geographic variability in how stressors act upon a species. The team also began to consider how stressors may interact in their effects on each species.

EHR 38 **Healey, M. Delta Vision Context Memorandum: Delta Ecosystem. Iteration 1. Sacramento: State of California. August 2007.**

Sets the ecological context of the Delta for the Governor's Blue Ribbon Task Force. List 12 principles to consider as the Task Force prepares a vision for the Delta and recommended strategies to achieve that vision.

http://deltavision.ca.gov/Context_Memos/Context_Memo_Environment.shtml

EHR 39 **CALFED Science Program. Conveyance Workshop Summaries. Sacramento: State of California 2006.**

These summaries review the key messages from a series of talks given on the science issues relating to (A) an isolated facility and (B) through Delta options.

http://science.calwater.ca.gov

EHR 40 **Sommer, T. R., C. Armor, R. Baxter, R. Breuer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer, M. Gingras, and B. Herbold. "The Collapse of Pelagic Fishes in the Upper San Francisco Estuary."** ***In Fisheries*** **32(6): 270-77. 2007.**

Although the pelagic fish community of the upper San Francisco Estuary historically has shown substantial variability, a recent collapse has captured the attention of resource managers, scientists, legislators, and the general public. The ecological and management consequences of the decline are most serious for delta smelt (*Hypomesus transpacificus*), a threatened species whose narrow range overlaps with large water diversions that supply water to over 25 million people. The decline occurred despite recent moderate hydrology, which typically results in at least modest recruitment, and investments of hundreds of millions of dollars in habitat restoration and environmental water allocations to support native fishes. In response to the pelagic fish collapse, an ambitious multi-agency research team has been working since 2005 to evaluate the causes of the decline, which likely include a combination of factors: stock-recruitment effects, a decline in habitat quality, increased mortality rates, and reduced food availability due to invasive species. This piece is written for a lay audience and has limited discussion of conveyance.

EHR 41 **Nobriga, M. J. Burau, G. Gartrell, L. Hastings, M. Healey, W. Kimmerer, P. Moyle, T. Smith, and J. Thompson. Report on the CALFED Science Program Workshop: Defining a Variable Delta to Promote Estuarine Fish Habitat. Prepared for CALFED Bay-Delta Science Program. Sacramento: State of California. 2007**

This workshop included six technical presentations followed by an audience participation/panel discussion. This workshop was inspired by the Variable Delta Hypothesis (VDH), which was originally outlined in the Public Policy Institute of California report "Envisioning Futures for the Sacramento-San Joaquin Delta" (www.ppic.org). Prior to the workshop, the VDH was informally being simplified into a notion of a Delta system with variable salinity. However, the VDH encompasses more than salinity. It is based on the premise that (1) increasing the variability of estuarine habitat will improve conditions for native estuarine fishes (and the introduced sport fish striped bass), and (2) increased expanses of aquatic habitat with more variability are likely on the way, and we should attempt to manage that variability to achieve positive benefits for native species. The VDH can be stated as increasing the variability (or heterogeneity) of the Delta's geometry, which comprises both regional scale plan forms and local scale channel morphology, will lead to water residence time diversity that will improve habitat conditions for desirable fishes and other organisms. A Delta with more variability in habitat gradients, it is argued, will provide more habitat that is suitable for desired species and less habitat that is suitable for undesirable invasive species like *Corbula amurensis* (overbite clam), *Corbicula fluminea* (Asiatic freshwater clam), and *Egeria densa* (Brazilian waterweed).

There was agreement among the presenters that greater variability in environmental conditions in the Delta might be good for currently desired estuarine fishes like delta smelt and striped bass, and other desirable organisms like waterfowl and invertebrates that are important as fish food. All of the presenters agreed that a focus simply on salinity variability is inappropriate; that habitat variability had to include a broad range of attributes. There was also general agreement that dendritic channel geometry would promote more variability in water residence time, salinity gradients, and other water quality attributes than the current channelized, interconnected geometry of the Delta. However, there was no consensus as to what the necessary environmental gradients and their scales of variability should be.

There are predictions of the VDH that are testable, but several panelists and audience members cautioned that we do not have a level of understanding that would inform a full-scale system-level manipulation in the near-term. Existing simulation models could be used to test the water residence time and salinity responses to different combinations of channel geometry and hydrologic change. Some of this work is underway as part of the Delta Risk Management Strategy, but additional work, including examining salinity responses to specific geometric restoration concepts is needed. Unfortunately, the ecological responses to these changes are much less predictable so field and laboratory testing of predictions is desirable though such research cannot be completed as quickly as hydrodynamic and water quality modeling. It was suggested that the Science Program's Proposal Solicitation Process represents a good opportunity for focused learning about aspects of the VDH. For instance, laboratory and microcosm tests of clam responses to various salinity challenges, or field evaluations of existing dendritic marsh systems in Suisun Marsh or the Cache Slough complex could be undertaken with the goal of developing mathematical models of how these systems develop and respond to variation in habitat attributes.

EHR 42 **Science Applications International Corporation . Conservation Strategy Options Evaluation Report. Prepared for the Bay-Delta Conservation Plan Steering Committee. Sacramento: The Resources Agency. September 17, 2007.**

The report presents initial evaluation of four potential conservation strategy options that include different conveyance facilities in the Delta.
http://resources.ca.gov/bdcp/options_evaluations.html

EHR 43 **Washington Group International. Isolated Facility, Incised Canal Bay-Delta System, Estimate of Construction Costs. Prepared for the State Water Contractors. August 2006.**

Cost estimates in 2006 dollars were made for several alignments for a 15,000 cfs isolated facility. The estimates ranged from $3.3 billion to $3.7 billion for an unlined canal. The estimates do not appear to include environmental mitigation costs. The one sheet cost summary, Table 2, was revised by Washington Group in to 2007 dollars in August 2007 to $3.4 billion to $3.9 billion.

EHR44 **Swan, P.** An Alternative Vision for the Sacramento-San Joaquin Delta**. Prepared in response to Delta Vision Blue Ribbon Task Force request for external visions for the Delta. Sacramento. July 20, 2007.** The proposed vision includes a conveyance along the western side of the Delta. The vision is designed to significantly reduce the risks of loss due to subsidence, rising sea levels, flooding, and seismic activity. The proposed isolated conveyance uses the Sacramento Ship Channel as the main stem of the conveyance, tunnels to transport water across the Sacramento River and western portion of the Delta. http://deltavision.ca.gov/docs/externalvisions/EV3_An_Alternative_Vision_for_the_Delta.pdf

WQ: Annotated Bibliography for the Water Quality Section

WQ 1 **Bergamaschi, B. A., T. Kraus, and R. Fujii. Towards a New Conceptual Model for Drinking Water Concerns in the Sacramento-San Joaquin Delta. White paper presented to the Delta Vision Blue Ribbon Task Force. Sacramento: State of California. May 31, 2007.**
This white paper addresses the some of the causes, concerns and new information regarding dissolved organic carbon (DOC) . CALFED funded several studies that examined DOC both in and upstream of the Delta to assist in managing source water. Recent results from these studies have reshaped scientists' understanding of DOC, indicating that river sources of DOC are more important than previously thought; wetlands, floodplains, peat island drains, and other sources all contribute significant amounts of DOC in the Delta. Together these findings demonstrate the need to include DOC, bromide and other drinking water constituents of concern in planning for flow alterations or land use changes in the Delta.
http://www.deltavision.ca.gov/BlueRibbonTaskForce/May2007/DVBRTF_Item_8_Handout_7_Drinking_Water_Concerns.pdf

WQ 2 **Brown, R. T. Delta Corridors: Proposal to Reconnect the San Joaquin River to the Estuary. Prepared in response to Delta Vision Task Force request for external visions for the Delta. Memorandum report. Sacramento: State of California. March 23, 2007.**
This report describes a plan to separate the San Joaquin River estuary from the water supply corridor to restore natural functions of the river-estuary habitat and eliminate entrainment of San Joaquin River fish. In the proposal, the Delta channels will be divided between Old River and Middle River to provide a water supply corridor on the east and a river-estuary habitat corridor on the west. The report proposes that the separation of the San Joaquin River-estuary habitat from the water supply corridor may allow greater salinity fluctuations in the vicinity of Franks Tract without impacting the export water quality and that such a separation reduces substantially the risk of water supply interruption from levee failure and island flooding events.
http://www.deltavision.ca.gov/docs/externalvisions/EV4_Delta_Corridors.pdf

WQ 3 **CALFED Bay-Delta Program. Final Programmatic Environmental Impact Report/Environmental Impact Statement (PEIS/R). Sacramento: State of California. July 2000.**
This report provided the environmental documentation for the CALFED Bay-Delta Program's 30-year plan to develop its preferred program alternative—one that included a screened facility on the Sacramento River and other North Delta improvements. The Program analyzed four alternatives: the preferred program alternative, an alternative that relied on the 2000 configuration of the Delta channels, an alternative that relied on both North and South Delta improvements, and an alternative that would add a canal connecting the Sacramento River in the North Delta to the State Water Project and Central Valley Project export facilities in the South Delta. These alternatives were analyzed by program elements including water quality and ecosystem restoration.
http://www.calwater.ca.gov/calfed/library/library_archive_EIS.html

WQ 4 **CALFED Bay-Delta Program. Conceptual Model for Salinity in the Central Valley and Sacramento-San Joaquin Delta. Prepared for the Central Valley Drinking Water Policy Workgroup. Sacramento: State of California. July 2007.**
This report examines the state of knowledge about the causes of salinity increase in the system and opportunities to improve the Delta as a source of municipal and agricultural water supply. It begins with background information about salinity, its measurement, and its impacts; after the background information, observed salinity in the Bay-Delta system is presented. The conceptual models section, the core of this report, explains the forces and processes (drivers) that cause the observed salinity patterns. The computational models section introduces some of the tools available to assist with salinity management and planning. The last chapter explores the implications of the conceptual model for monitoring and management of salinity.
http://www.swrcb.ca.gov/rwqcb5/water_issues/drinking_water_policy/salinity_conceptual_model/salinity_conceptual_model_july2007_final.pdf

WQ 5 **CALFED Bay-Delta Program. Ecosystem Restoration Program Plan (ERPP). Vols. 1-3. Technical Appendix to the CALFED Bay-Delta Program's Final PEIS/R. Sacramento: State of California. July 2000.**
This three-volume set includes the Strategic Plan for Ecosystem Restoration; Vol. 1: Ecological Attributes of the San Francisco Bay-Delta Watershed; and Vol. 2: Ecological Management Zone Visions. The Strategic Plan presents broad strategic goals and objectives for achieving ecosystem restoration. Vol. 1 presents the visions for ecological processes and functions, fish and wildlife habitats, species, and reducing stressors that impair the health of the processes, habitats, and species. Vol. 2 presents the visions for 14 ecological management zones and a brief description of important ecological functions, habitats, species and stressors associated with the zone. Vol. 2 includes objectives, targets and programmatic actions. The ERPP central theme is the recognition that truly durable and resilient populations of fish and wildlife inhabiting the Bay and Delta require, above all else, the rehabilitation of ecological processes throughout the Central Valley river and estuary systems and watersheds.
http://www.delta.dfg.ca.gov/erp/reports_docs.asp

WQ 6 **CALFED Bay-Delta Program. Delta Water Quality. Summary Paper About Water Quality in the Delta. Presented to the Delta Vision Blue Ribbon Task Force. Sacramento: State of California. August 2007.**
This overview of some of the most critical Delta water quality issues includes chapters, in the form of fact sheets, on dissolved oxygen, selenium, mercury, pesticides, unknown toxicity, and drinking water. It presents information gathered from interviews with subject matter experts and available documents. Sources and causes, geographic extent, a conceptual model, corrective actions, and next steps are presented for each issue. The importance of Delta flow patterns (hydrodynamics) in Delta water quality is identified. Salinity and nutrients (and their effects) were recognized as important problems, but were beyond the scope of this report.
http://www.deltavision.ca.gov/BlueRibbonTaskForce/August2007/DVBRTF_Item_9_Attachment_2_CALFED_Report_on_Delta_Water_Quality.pdf

WQ 7 **CALFED Bay-Delta Program. CALFED Water Quality Program Stage 1 Final Assessment. Sacramento: State of California. October 2007.**
The CALFED Water Quality Program (WQP) Stage 1 Final Assessment has multiple purposes: it provides a drinking water quality context for the End of Stage 1 Delta conveyance decision; it integrates and synthesizes the scientific information of Delta drinking water quality from the source to the tap; it uses this synthesis to measure Stage 1 progress and identify water quality actions for Stage 2; and, it attempts to move the Water Quality Program to a performance-based program. This report presents new analysis along with the synthesis of several recent and related studies.
http://www.calwater.ca.gov/content/Documents/Draft_Final.pdf

WQ 8 **CALFED Bay-Delta Program. Water Quality Program Plan. Technical Appendix to the CALFED Bay-Delta Program's Final PEIS/R. Sacramento: State of California. July 2000.**
This report describes both long-term programmatic actions as well as certain, more specific actions that may be carried out over the 30-year term of the CALFED Water Quality Program. The programmatic actions in a long-term program of this scope are described generally and without detailed site-specific information. The Water Quality Program plan is structured around a water quality problem and approaches to solve that problem in a region-by-region description. Among the water quality problems addressed in this plan are: low dissolved oxygen, drinking water contaminants, mercury, pesticides, salinity, selenium, sedimentation, and toxicity of unknown origin.
http://www.calwater.ca.gov/content/Documents/library/306.pdf

WQ 9 **CALFED Bay-Delta Program. Delta Regional Ecosystem Restoration Implementation Plan Conceptual Models. Collected works, various authors. Sacramento: State of California. In progress, various dates.**
The latest versions of the conceptual models were presented to the Bay-Delta Conservation Plan Steering Committee in January 2008. A draft hydrodynamics conceptual model has been developed, perhaps the most important for water quality. Some of the ideas in the current draft hydrodynamics conceptual model were introduced in Wim Kimmerer's article, "Open Water Processes of the San Francisco Estuary: From Physical Forcing to Biological Responses" (Water Quality reference number 22 in this bibliography) and in a more simplified form in the CALFED Water Quality Program salinity conceptual model.

WQ 10 **California Department of Water Resources. Methodology for Flow and Salinity in the Sacramento-San Joaquin Delta and Suisun Marsh. Annual report series: 1979-2007. Sacramento: State of California. December 2006.**
This series of annual reports document the progress of the department in developing and enhancing computer models and documents the latest findings of studies conducted as part of the program. For this assessment, one chapter was used –Chapter 3—in one of many studies in this annual progress report to the State Water Resources Control Board, prepared in accordance with Water Rights Decision 1485 and 1641.

Ch. 3, "Developing a Residence Time Index to Study Changes in 1990-2004 Delta Circulation Patterns," presents long-term trends in historical Sacramento-San Joaquin Delta circulation patterns. These patterns were studied by developing indexes of residence time for the two major sources of inflow to the Delta. Hydraulic residence time is an important factor affecting a number of estuarine processes. By releasing particles at the major estuary inflows and tracking them until they are no longer in Delta channels, it is possible to calculate the length of time and path those particles took through the Delta.

WQ 11 **California Department of Water Resources. California State Water Project Watershed Sanitary Survey, 2006 Update. Sacramento: State of California. 2007.**
The sanitary survey gives a drinking water quality perspective of the Delta. It describes water quality issues impacting municipal users of Delta water, the sources of problem constituents, the timing of drinking water quality problems, and proposes actions to address these problems. The sanitary survey is a regulatory requirement but also serves as a work plan for corrective actions. The 2006 survey includes extensive water quality and flow data compilation and analysis as well as an analysis of the Jones Tract levee failure from a water quality perspective.

WQ 12 **California Department of Water Resources. Factors Affecting the Composition and Salinity of Exports from the South Sacramento-San Joaquin Delta. Sacramento: State of California. 2004.**
This report identifies factors affecting the composition and salinity of exports from the south Sacramento-San Joaquin Delta. Composition is defined here as sources of salt, such as rivers and seawater. Specific objectives are to (1) identify factors determining the export of cross-Delta flows versus the San Joaquin River – the two immediate sources of water flowing to the State Water Project (SWP) and Central Valley Project (CVP) export sites in the south Delta; and (2) identify long-term salinity trends in SWP exports and factors affecting them.

WQ 13 **California Department of Water Resources. Municipal Water Quality Investigations (MWQI) Real Time Data and Forecasting (RTDF) Weekly Reports. Sacramento: State of California. Various dates.** These weekly reports provide real time and near real time water quality information from sensors on the San Joaquin River at Vernalis, the Sacramento River at Freeport and Hood, at the export pumps and other State Water Project and Central Valley Project locations. These reports are part of the Real Time Data and Forecasting (RTDF) project. The goal of these weekly reports is to bring real time, near real time, and forecasted water quality data to source water managers, treatment plant operators, scientists, and other stakeholders.
http://www.wq.water.ca.gov/mwqi/RTDF/RTDF_weekly.cfm

WQ 14 **California Department of Water Resources. Municipal Water Quality Investigations (MWQI) Annual Reports. Sacramento: State of California. Various dates.**
Since 1982, the Municipal Water Quality Investigations (MWQI) unit has been conducting comprehensive and systematic source water monitoring in the Delta region, and regularly preparing annual or multi-year data summary reports. The MWQI Program monitors the drinking water quality at 10 MWQI sampling sites. The annual report presents the data and findings for major water quality constituents, including organic carbon, bromide, salinity, regulated organic constituents in drinking water, and a few unregulated constituents of current interest. The data is continuously monitored and is accessible online in the Department of Water Resources Water Data Library.
http://www.wq.water.ca.gov/mwqi/mwqi_index.cfm

WQ 15 **California Department of Water Resources. Progress on Incorporating Climate Change into Management of California's Water Resources. Technical Memorandum Report. Sacramento: State of California. July 2006.**
This report presents the progress and future directions on incorporating climate change science into management of California's water resources. It focuses on assessment methodologies and preliminary study results. Chapter 5, Impacts of Climate Change on the Sacramento-San Joaquin Delta focuses on potential impacts of climate change on Delta water quality and water levels. Sea level rise is an aspect of climate change of particular interest for the Delta area, preliminary analyses were conducted to examine the potential salt intrusion for one foot rise in sea level. Models were run to see the affect of sea level rise on chloride concentrations and chloride mass loadings.
http://baydeltaoffice.water.ca.gov/climatechange/reports.cfm

WQ 16 **Central Valley Regional Water Quality Control Board. The Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board Central Valley Region, Fourth Edition. Sacramento: State of California. October 2007.**
This plan establishes a number of water quality standards and policies for water bodies in the Delta and its watersheds. This listing includes an extensive body of work, including several policies and plans included as appendices to the Basin Plan. For example, all Total Maximum Daily Loads (TMDL) documents are included by reference here because TMDLs are promulgated as Basin Plan amendments in California. This includes the Stockton Ship Channel Dissolved Oxygen TMDL, the Delta mercury TMDL, the San Joaquin River salinity TMDL, and others.
http://www.waterboards.ca.gov/centralvalley/water_issues/basin_plans/SacSJR.pdf

WQ 17 **Central Valley Regional Water Quality Control Board (Central Valley RWQCB). Salinity in the Central Valley: An Overview. Prepared for State Water Resources Control Board. Sacramento: State of California. May 2006.**
This document is joint effort of the Central Valley RWQCB and the State Water Resources Control Board to document knowledge about the sources and impacts of salts. The accumulating load of salts in Central Valley groundwater is a product of taking water from the Delta, irrigated agriculture, and other in-valley water uses. This work demonstrates the connection between Delta conveyance, Delta water quality, and Central Valley water quality. http://www.swrcb.ca.gov/rwqcb5/water_issues/salinity/init-dev/swrcb-02may06-ovrvw-rpt.pdf

WQ 18 **Domagalski, J. L., P. D. Dileanis, D. L. Knifong, C. M. Munday, J. T. May, B. J. Dawson, et al. Water-Quality Assessment of the Sacramento River Basin, California: Water-Quality, Sediment and Tissue Chemistry, and Biological Data, 1995-1998. Open File Report 2000-391. Sacramento: U.S. Geological Survey. 2000.**
Part of the National Water Quality Assessment Program (NAWQA), this report is a data report with little interpretation. Although there are water quality problems in the Sacramento River basin, they are fewer and tend to be more localized. Habitat modification due to dams and water diversion are identified as major factors affecting aquatic species. Mercury and mine drainage are identified as key issues. Urban runoff is an important source in the Sacramento area and agricultural runoff degrades water quality in some areas. Nutrient and salt concentrations in the Sacramento River are much lower than those in the San Joaquin River.
http://ca.water.usgs.gov/sac_nawqa/waterindex.html

WQ 19 **Dubrovsky, N. M., C. Kratzer, L. R. Brown, J. M. Gronberg, and K. R. Burow. Water Quality in the San Joaquin-Tulare Basins California, 1992-1995. U.S. Geological Survey Circular 1159. Sacramento: U.S. Geological Survey. 1998.**
Part of the National Water Quality Assessment Program (NAWQA), this report summarizes the major findings about water quality in the San Joaquin River and its tributaries by analyzing data from 1992-1995. The analysis was constrained by comparing ambient concentrations of pesticides, nutrients, and other constituents against existing numeric standards, but what emerges is a picture of a region with a broad range of water quality problems affecting drinking water supplies and the ecosystem. Nearly all of these impacts are traceable to agriculture. More recent water quality monitoring indicates that there has been some improvement in pesticide-related aquatic toxicity but that nutrient and salt concentrations have not changed much. A follow-up study is under way.

WQ 20 **California Department of Water Resources. Delta Conveyance Improvement Studies Summary Report (Franks Tract, Through Delta Facility, and Delta Cross Channel Reoperation Projects). Prepared by EDAW. Sacramento: State of California. December 7, 2007.**
This report presents the key findings for the CALFED Bay-Delta Program Stage 1 studies as well as reports prepared by the Department of Water Resources (DWR), in cooperation with the U.S. Bureau of Reclamation (Reclamation), to evaluate Franks Tract, Through Delta Facility, and Delta Cross Channel Reoperation project actions. This report also describes continuing and planned project studies.
http://baydeltaoffice.water.ca.gov/ndelta/frankstract/documents/Delta_Conveyance_Summary_Report_121007.pdf

WQ 21 **Jassby, A. D., and E. Van Niewuwenhuyse. Low dissolved oxygen in an estuarine channel (San Joaquin River, California): mechanisms and models based on long-term time series. In *San Francisco Estuary & Watershed Science*. 3(2): Article 2. 2005.**
In this article, the authors examine underlying mechanisms using long-term water quality data and look at the efficacy of possible solutions using time-series regression models. Model scenarios imply that controlling either river phytoplankton or wastewater ammonium load alone would be insufficient to eliminate the effects of low oxygen (hypoxia). Model scenarios also imply that preventing discharge down Old River with a barrier markedly reduces hypoxia in the Stockton Deep Water Ship Channel.
http://repositories.cdlib.org/jmie/sfews/vol3/iss2/art2/

WQ 22 **Jones and Stokes. Freeport Regional Water Project, Draft Environmental Impact Report / Environmental Impact Statement. Prepared for Freeport Regional Water Authority and the U.S. Bureau of Reclamation. Sacramento: U.S. Department of the Interior, Bureau of Reclamation. July 2003.**
In "Water Quality-Sacramento River and American River Basins," the upper regions of the Sacramento River and American River basins are characterized as generally producing high-quality water suitable for all beneficial uses. Upper watershed source waters generally have excellent mineral and nutrient quality, with low total dissolved solids content. As water flows from the upper watersheds into the Central Valley, water quality typically changes as a result of water diversions and return water. Sources of degradation include waste discharges such as municipal wastewater treatment plant discharges, urban stormwater runoff,

and irrigated agricultural return flows. Natural water quality changes also occur in the valley, such as temperature increases during warmer months, natural erosion, and suspended sediment transport of organic and mineral matter.

"Water Quality-Sacramento-San Joaquin Delta" describes how water quality in the Delta is controlled by complex circulation patterns that are affected by inflows, pumping for Delta agricultural operations and exports, operation of flow control structures, and tidal actions. The SWP and CVP export pumping plants exert a considerable influence on water circulation in the Delta by creating a net flow of water from northern regions of the Delta southward through Old River and Middle River.
http://www.freeportproject.org/nodes/project/draft_eir_eis_v1.php

WQ 23 **Kimmerer, W. "Open Water Processes of the San Francisco Estuary: From Physical Forcing to Biological Responses."** ***In San Francisco Estuary & Watershed Science*****. 2(1): Article 1. February 2004**.
This paper reviews the state of knowledge of the open waters of the San Francisco estuary, including the California Delta. The four themes in the paper are: (1) the critical role physical dynamics play in setting the stage for chemical and biological responses such movement of the salinity field through tides and variations of fresh water flow; (2) the importance of time scales in determining the degree of interaction between dynamic processes, such as phytoplankton blooms; (3) the role of introduced species in all estuarine habitats; and (4) the data sets from research and monitoring tend to focus on the same subjects or regions, thereby limiting the scientific knowledge regarding opportunities for open water restoration and making it difficult to detect ecosystem responses in the context of high natural variability.
http://repositories.cdlib.org/jmie/sfews/vol2/iss1/art1/

WQ 24 **Lund, J., E. Hanak, W. Fleenor, R. Howitt, J. Mount, and P. Moyle. Envisioning Futures for the Sacramento-San Joaquin Delta. San Francisco: Public Policy Institute of California. 2007.**
This report explores and compares long-term Delta solutions. The authors consider a variety of options, constructing nine alternatives for Delta management and evaluating their performance in three key areas: water supply, environmental effects, and economic costs. In addition, the report includes detailed historical, ecological, and economic analysis, drawing lessons from the Delta's past and looking to its future.
http://www.ppic.org/main/publication.asp?i=671

WQ 25 **Monsen, N., J. Cloern, J. Burau. "Effects of Flow Diversions on Water and Habitat Quality: Examples from California's Highly Manipulated Sacramento-San Joaquin Delta."** ***In San Francisco Estuary & Watershed Science*****. 5(3): Article 2. July 2007.**
This article uses selected monitoring data to illustrate how localized water diversions from seasonal barriers, gate operations and export pumps alter water quality across the Sacramento-San Joaquin Delta. The authors used a tidal hydrodynamic model to reveal how these different diversions influence water quality through their alteration of Delta-wide water circulation patterns and flushing time. Each shift in water quality has implications either for habitat quality or municipal drinking water, illustrating the importance of a systems view regarding flow changes and to minimize conflicts between multiple objectives.
http://repositories.edlib.org/jmie/sfews/vol5/iss3/art2.

WQ 26 **San Francisco Bay Regional Water Quality Control Board. San Francisco Bay Basin Water Quality Control Plan (Basin Plan). San Francisco: State of California. December 22, 2006.**
This is the Basin Plan for the San Francisco Bay region. The San Francisco Bay region includes Suisun Bay and Marsh extending upstream to Broad Slough near Pittsburg and a small part of the legal Delta around Chipps Island and Browns Island. It establishes beneficial uses and standards for this region and implements TMDLs. Since the Central Valley (including the Delta) is the single greatest source of freshwater and most pollutants to the bay, TMDLs established for the San Francisco Bay region must be coordinated with basin plans, TMDLs, and associated regulatory programs in the Central Valley region. The San Francisco Bay Basin Plan implements a recently adopted mercury TMDL; a TMDL for selenium is under development. Selenium limits established in the San Francisco Bay region could drive future selenium regulations and control programs in the Central Valley.
http://www.waterboards.ca.gov/sanfranciscobay/basinplan.htm

WQ 27 **Science Applications International Corporation. Conservation Strategy Options Evaluation Report. Prepared for the Bay-Delta Conservation Plan Steering Committee. Sacramento: The Resources Agency. September 17, 2007.**
This document evaluates four conveyance and conservation options to assist the Bay Delta Conservation Plan (BDCP) Steering Committee in developing its final conservation plan. The options are: (1) existing through-Delta conveyance, (2) improved through-Delta conveyance, (3) dual conveyance, and (4) peripheral aqueduct. This report describes how each of the options performs in relation to a wide range of criteria, including the expected water quality changes associated with the four conveyance options. Each of the four options was evaluated against 17 evaluation criteria set by the Steering Committee. In addition to species specific evaluation criteria, the options were evaluated against planning; feasibility, durability and sustainability; and other resource impacts criteria (including water quality).

Hydrologic and system operations, hydrodynamic, and water quality modeling was performed to provide information on Delta flows, CVP/SWP operations and exports, Delta circulation patterns, and water quality effects in a response to the assumptions and criteria applied under each of the Options. The modeling information was used, in part, to assist in the overall evaluation of the Options. The modeling performed for this evaluation report should be considered "screening-level," consistent with the objectives and timeframe of the report.
http://resources.ca.gov/bdcp/options_evaluations.html

WQ 28 **Stakeholder Coordination Group. Preliminary Visions Recommendations Report from the Delta Vision Stakeholder Coordination Group (SCG). Memorandum report to the Delta Vision Blue Ribbon Task Force. Sacramento: State of California. August 21, 2007.**
This report summarizes the SCG's progress in developing visions and related recommendations. The visions described in this report (and appendices) address the nine substantive topics in Executive Order S-17-06: environment, land use, infrastructure and utilities, transportation, water supply and quality, recreation and tourism, flood risk management, state and local economics, and emergency management. The visions also address the potential impacts of natural disasters; impact of residential, commercial and other development on the Delta; the ability of the Delta to continue to exist as a vital environmental resource for California; and the ability of the Delta to continue to supply a statewide supply of water, of high quality, for residents, businesses, and agriculture. The emerging visions described in this report suggest potential sets of management actions and physical changes in the Delta that address all of these vision components.
http://www.deltavision.ca.gov/StakeholderReports/Stakeholder_Coordination_Group_Preliminary_Report.pdf

WQ 29 **State Water Resources Control Board. 2006 CWA Section 303(D) List Of Water Quality Limited Segments Requiring TMDLs. Sacramento: State of California. June 28, 2007.**
There are numerous water body segments within the Delta listed as impaired for various pollutants. These impairments must all be addressed by a TMDL at some point although they are prioritized by date. This list is statewide. The CALFED Program addresses impairments in Region 5 (Central Valley) and Region 2 (San Francisco Bay). Once a TMDL is adopted it is incorporated into the appropriate basin plan.
http://www.swrcb.ca.gov/tmdl/docs/303dlists2006/approved/state_06_303d_reqtmdls.pdf

WQ 30 State Water Resources Control Board. Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Sacramento: State of California. December 13, 2006.
Also known as the "Bay-Delta Plan," this is the regulatory document that establishes water quality standards related to flow and water diversions from the Delta. While salinity (usually expressed as electrical conductivity or EC) and flow are the primary constituents of concern, there are also standards for dissolved oxygen and chloride. The Bay-Delta Plan is the basic regulatory mechanism establishing a freshwater Delta to protect agricultural, fish and wildlife, and municipal and industrial beneficial uses. Permits for operating the SWP and CVP apply the standards established by this plan. It overlaps with, and is complimentary to, the Central Valley Basin Plan.
http://www.waterrights.ca.gov/baydelta/docs/2006_plan_final.pdf

WQ 31 State Water Resources Control Board. Draft Final Staff Report Water Quality Control Plan for Enclosed Bays and Estuaries, Part 1. Sediment Quality. Sacramento: State of California. January 29, 2008.
This new policy, scheduled to be adopted by the SWRCB soon, could have a significant regulatory impact on activities which might contribute to or mobilize pollutants in sediments. The plan will likely require additional chemical and bioassay testing for entities diverting water, dredging channels, or discharging into the Delta and its tributaries. Pollutants that accumulate in sediments are most likely to be affected. These include some pesticides, heavy metals, selenium, PCBs, and other organic compounds that have toxic effects on bottom dwelling or feeding organisms.
http://www.swrcb.ca.gov/bptcp/docs/sediment/staffreport.pdf

WQ 32 State Water Resources Control Board. Revised Water Right Decision 1641 Sacramento: State of California. March 15, 2000.
This regulatory action by the SWRCB implements the standards established in the Bay-Delta Plan. It includes reporting, monitoring, and study requirements for DWR (SWP), USBR (CVP), and others. This is the regulatory action that requires actions such as the Interagency Ecological Program (IEP) monitoring, the USBR recirculation studies, a plan for meeting South Delta salinity standards, development of Delta modeling tools, and other actions related to the state and federal projects. The development documents for this decision and prior Delta water rights decisions are also good sources of information about the linkages between water diversions and water quality in the Delta.
http://www.waterrights.ca.gov/Decisions/D1641revs.pdf

WQ 33 Swan, P. An Alternative Vision for the Sacramento-San Joaquin Delta. Prepared in response to Delta Vision Task Force request for external visions for the Delta. Sacramento: State of California. July 20, 2007.
This document describes a vision designed to use the strongest assets and beneficial attributes of the current Delta system by augmenting and building new "protected" corridors that would to provide sustainable water conveyance, transportation and utility service system. The proposal also has suggestions regarding improved water supply and water quality, land use in the central and western Delta, regional economics, transportation, utilities alignment, agriculture, and environmental restoration.
http://www.deltavision.ca.gov/docs/externalvisions/EV3_An_Alternative_Vision_for_the_Delta.pdf

WQ 34 **Tetra Tech, Inc. Conceptual Model for Organic Carbon in the Central Valley and Sacramento-San Joaquin Delta. Prepared for U.S. Environmental Protection Agency, Region IX and Central Valley Drinking Water Policy Workgroup. Lafayette, CA: Tetra Tech, Inc. April 14, 2006.**
This report presents a conceptual model of organic carbon for the Central Valley and the Sacramento-San Joaquin Delta. The conceptual model was based on previously collected data from a variety of sources and can be used to direct future investigations to improve understanding of organic carbon-related sources, transformations, impacts, and management.
http://www.swrcb.ca.gov/rwqcb5/water_issues/drinking_water_policy/oc_model_final.pdf

WQ 35 **Tetra Tech, Inc. Conceptual Model for Nutrients in the Central Valley and Sacramento-San Joaquin Delta. Prepared for U.S. Environmental Protection Agency, Region IX and Central Valley Drinking Water Policy Workgroup. Lafayette, CA: Tetra Tech, Inc. September 20, 2006.**
This report presents a conceptual model of nutrients for the Central Valley and the Sacramento-San Joaquin Delta. The conceptual model was based on previously collected data from a variety of sources and can be used to direct future investigations to improve understanding of nutrients sources, transport, and impacts.
http://www.swrcb.ca.gov/rwqcb5/water_issues/drinking_water_policy/final_nutrient_report_lowres.pdf

WQ 36 **Tetra Tech, Inc. Conceptual Model for Pathogens and Pathogen Indicators in the Central Valley and the Sacramento-San Joaquin Delta. Prepared for U.S. Environmental Protection Agency, Region IX and Central Valley Drinking Water Policy Workgroup. Lafayette, CA: Tetra Tech, Inc. August 24, 2007.**
This report presents a conceptual model of pathogens and indicators for pathogens in the Central Valley and the Sacramento-San Joaquin Delta. The conceptual model was based on previously collected data from a variety of monitoring programs over the last decade and can be used to direct future investigations to improve understanding of pathogen sources, transport, and impacts to drinking water quality.
http://www.swrcb.ca.gov/rwqcb5/water_issues/drinking_water_policy/pathogen_conceptual_model_aug2007.pdf

WQ 37 **CALFED Bay-Delta Program. Tracking Organic Matter in Delta Drinking Water. In Science Action, News from the CALFED Science Program. Sacramento: State of California. April 2008.**
This brochure summarizes work by the U.S. Geological Service and Department of Water Resources regarding dissolved organic carbon (DOC) and other organic material in the Delta. This includes an overview of the DOC dynamics and sources and a new conceptual model about the sources and fate of DOC in Delta water.