RI14 Public Hearing Transcript

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MEETING OF THE DELTA STEWARDSHIP COUNCIL

HELD AT THE DSC OFFICE

980 NINTH STREET, SUITE 1500

SACRAMENTO, CALIFORNIA 95814

FRIDAY, JANUARY 11, 2013

1:00 P.M.

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REPORTED BY: JILLIAN M. BASSETT, CSR No. 13619

No comments

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I N D E X

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PAGE

PUBLIC COMMENTS BY:

No comments

- n/a -

BE IT REMEMBERED, that on Friday, January 11, 2013, commencing at the hour of 1:00 p.m., at the Offices of Delta Stewardship Council, 980 Ninth Street, Suite 1500, Sacramento, California before me, JILLIAN M. BASSETT, a Certified Shorthand Reporter in and for the county of Sacramento, state of California, was present and recorded verbatim the following proceedings:

PUBLIC COMMENTS:

BURT WILSON

PUBLIC WATER NEWS SERVICE

MR. ISENBERG: Mr. Wilson, by the way, did something very helpful, ladies and gentlemen, when he filled out the form. He put on the form the part of the hearing today that he wishes to talk about, specified it as the Delta Plan. That's very important. We're hearing testimony on three related documents. RI14-1

And Mr. Wilson, thank you for doing that.

MR. WILSON: I've been coming to these meetings since the Delta Vision Committee. So I've learned something.

MR. ISENBERG: Yes, you have. This is five years

Response to comment RI14-1

This is a comment on the project, not on the EIR.

of work on your part.

MR. WILSON: And having done that, I want to say, I appreciate the input of everybody. Chris got up to speed pretty fast, too. And I want to thank you all for your contributions.

I have a few things. First, about the coequal goals. Coequal doesn't mean build years apart. Coequal -- the dictionary definition is: Equal with another or each other in rank, ability and extent.

So since the bond for the Water Habitat Restoration is not going to be voted on until 2014 in November, I would say that that is when any work on the tunnels should begin. If they are even going to pass. RI14-1 Because then that makes everything coequal.

If the tunnel starts sooner -- and I know Jerry wants to get stuff done, and get the tunnel on. And I'll come back to that. But I think you may -- you're the ones that wrote the coequal goals, so --

MR. ISENBERG: No, Mr. Wilson, the legislature put in statute the coequal goals.

MR. WILSON: Okay. All right.

Now, in financing methods in the Delta Plan you have two general obligation bonds and revenue bonds. My understanding with Jerry Meryl is that the five brothers; the state and federal Water Contractors' Association are

No comments

- n/a -

going to be the principal beneficiaries and put up the money by revenue bonds for the tunnel. That is my understanding.

Revenue bonds, of course, do not require voter approval. And I think anything of the measure of a $14-billion twin tunnels tearing up the Delta is something that should go before the People. Revenue bonds, the reason they don't require voter approval as it says here because they are secured by a dedicated revenue stream, such as water sales.

Now, are you going to tell me that MWD and Westlands Water District and all the others who are in the five brothers are going to make enough money off of this to finance $14-billion of the twin tunnels? I don't think so. But I'm going to come back to that. RI14-1

As far as the Delta Plan, chapter 1, line 16 says: "Today the Delta is many things to many people. And is universally regarding crisis, because people have not yet been able to find balance in the tradeoffs among competing demands for the Delta's resources."

That sentence means nothing. The reason it's in crisis is because the Department of Water Resources increased the diversions to the Metropolitan Water District from 2000 to 2006 to make up for the MWD's loss of Colorado River water. I've given you a chart on this

No comments

- n/a -

before. And that's -- and all the pumps making reverse -- rivers run in reverse at that time, and everything else that happens when you pump water, has put the Delta in crisis. And I would like to see that change.

The Delta is in crisis because of extra DWR diversions to the MWD from 2000 to 2006.

Now, under the Delta problem, line 13, water experts --

MR. ISENBERG: Which page? Same page?

MR. WILSON: No, it's under the next division called, "The Delta problem."

MR. ISENBERG: Yes, page 16.

MR. WILSON: Okay. Line 13.

RI14-1

"These regulatory and court-ordered restrictions on state and federal pumping in 14 combination with the 2000, 2009 drought significantly reduced exported water to the SWP and the CVP contractors."

It doesn't say that the court ordered the restrictions because the diversions okayed by the DWR to the MWD killed all the fish. And it was for this reason that Judge Wanger put in the court order to stop the diversions. Because it was literally ruining the Delta. It was killing all the fish. And that was the reason. And I would like to see that -- I would like to see a little transparency here on what really happened.

No comments

- n/a -

Now, Governments and the Delta Reform Act of 2009, line 30 --

MR. ISENBERG: Members, on the clean copy of the Delta Plan, that's page 18 starting at line 28.

Mr. Wilson, you may be using the red-line version. But that's the section you're talking about.

MR. WILSON: Okay. The legislature established the policy of the state is to reduce reliance on the Delta in meeting future water supply needs through a statewide strategy of investing in improved regional supplies, conservation, and water use efficiencies.

Now, I want to talk about that for a minute. Because my whole problem with this is transparency. That doesn't mean clouding over an issue with a bunch of words that don't mean much. To me it means telling the truth. RI14-1

And as far as this goes, I was at a BDCP meeting a while ago, and Jerry Meryl announced, "We're not going to take any new water from the Delta." And I jumped up and said, "Well, then let's scrap the tunnels. You know? Why are you going to have the tunnels if you're not going to take new water from the Delta?"

Well, I was like everybody else. In fact, there were three protest groups today slamming Governor Brown for the tunnels in the Delta is going to take more water and stuff like that. Would you believe that I have seen

No comments

- n/a -

the light, and I don't believe that more water is going to be taken from the Delta?

MR. ISENBERG: Please note it is 1:59 p.m. on the 11th day of January 2013.

Madam Secretary, note Mr. Wilson's comment on this.

MR. WILSON: Now, let me tell you what I think is going to happen. I happened to watch a PPIC meeting by Ellen Hannick on water marketing. The reason for it was the transfer and exchange of water for compensation. And here we're talking about water sales.

Curt Aiken said -- and I quote -- "The twin tunnels will make it easier to affect water exchanges from northern to southern water markets. Ground water substitution and the need for infrastructure."

RT14-1

Mr. Hersh, Steve Hersh told the story one time that two-thirds of the water banked in Northern California went out to the ocean and there was no way to get it to the MWD because it went past -- it just went down the Sacramento River and went out because the Delta couldn't handle it to get it to the pumps. Mr. -- he said, "The infrastructure is there. Its environmental regulation is to hold up water supplies."

Well, all the sudden a bigger light when on. They're not going to take new water for the Delta. The

No comments

- n/a -

tunnels are actually there to facilitate water transfers from Northern California reservoir through the Delta to the five water districts who are going to control all of this. And this is surplus water. And they're going to sell the surplus water to the oil companies for fracking around Kern County and so forth.

Now, here's a map. And I will give it to you. You've probably seen this before. See the green is where the oil is and the red is where the natural gas is.

MR. ISENBERG: I can't remember. Is that a U.S. Geologic survey?

MR. WILSON: Geothermal.

MR. ISENBERG: I want to make sure for our record that we know what document you're referring to, Mr. Wilson. RT14-1

Do you know the source of the document? An agency? A firm?

Could you give it to us later or shoot us an e-mail, if you would? And if you have a chance of sending copies, we can enter the copies into the record.

MR. WILSON: I'm going to leave these here with you.

MR. ISENBERG: Oh, okay. Thank you.

MR. WILSON: Look at the natural gas deposits under the Delta here. Now, in Greeley, Colorado currently

No comments

- n/a -

this is occurring. The water agencies are selling waters to the farmers for -- and this comes from the Colorado newspaper. Are selling water to the farmers for $30 an acre foot. They're selling water to the oil companies for $3,300 an acre foot.

Now, think of all our water transfers from all of the storage banks and the reservoirs in Northern California that's going to be shipped through the tunnels so Westlands Water District and everybody can sell it at inflated prices to the oil companies for fracking.

Now, I've been having a go with occidental petroleum. Because they want to drill 154 new shale wells this year down there. I wrote their PR Department and said, "Where are you going to get the water for this?" They wrote me back, "We do not discuss company operations."

So they stiffed me on that. But trust me, what we're setting up here is a way for surplus water from the north to be sent through the Delta to the water agencies who have no conscience about selling it for as much as surplus water for as much as they can get to the oil companies.

The oil companies are -- right now, they had a -- Bureau of Land Management had an auction the other day; 18,000 acres went in ten minutes. If this

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No comments

- n/a -

continues -- and see, the debate isn't whether fracking is safe or not. And it's not safe. The debate is this state is going to be overrun with natural gas wells and oil wells. Because once you confiscate land in the Delta, you have a lease on that through the mineral rights, and you can get your mineral rights there. This is all being done for the oil companies.

And this is -- if I may go further?

This is part of a national energy plan that began in Dick Cheney's office two weeks after the inauguration in 2000. He invited all the oil company executives to private meetings over a number of months. None of the information on that meeting -- those meetings ever leaked out. It was stiffed. Nobody ever got a hold of it. The only thing that leaked out was that the meetings were about national energy policy.

RI14-1

Now, here is what that policy is. And California and the Delta figure in that. And if you don't know this, you should know this.

When Obama, in his victory speech, said, "And we're going to achieve energy independence," and everybody screamed and yelled. And I'm sure half the people there meant solar and alternative energies. But no, you think the oil companies are going to allow that?

Here's the thing; California is the key to the

No comments

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whole national energy policy. The natural gas and the oil deposits here. Not only California, but North Dakota which borders Canada, which the two have one of the biggest shale deposits ever existing right there. The keystone -- they want the keystone pipeline to go from North Dakota down to Texas where all the LNG terminals are. Right now LNG is cheap. You're going to see soon trucks running on LNG. It's so cheap that in foreign countries it's selling for three times the price here.

So we're going to export LNG to Europe. At the same time, we're going to export more coal to Europe and end the coal burning here. Because the greenhouse gases and things like that. Because coal is cheaper than natural gas in Europe. From California, we're going to export oil and national gas to China. And we import 8-million barrels a day right now. We produce six-and-a-half million barrels today. It's proposed that by the year 2020, we will double our production here. And California is going to be a big -- play a big role in that. That's thirteen barrels a day.

Where is it going to go? It's going to go to China to pay down the debt we owe to China. That's the whole big picture of the energy policy of the United States. And I tell them, it's going to turn California into a vast industrial wasteland. And the two tunnels are

RI14-1

No comments

- n/a -

the key to that. To letting the five water agencies -- no wonder they're going to pay for the tunnels. They're going to reap millions and millions and millions of dollars the way the water agencies in Colorado are doing now.

Not only that, cities are selling surplus water. They're driving tank trucks up to fire hydrants in Colorado and filling them with water for fracking. All of this for fracking.

So I wanted to bring that to your attention today. Because if we're not going to take more water out of the Delta, and we're going to build tunnels, what are we building the tunnels for? To transfer water from Northern California to the water agencies below the Delta. This is not a deal that won't be -- I believe they will probably be administered by the Department of Water Resources, right?

RI14-1

MR. ISENBERG: I don't know.

MR. WILSON: But water flows upward to money. Where the money is, the control is. It takes the control out of the state and turns it over to private enterprise, just like we've given the current water bank to Stewart Resnick down in Bakersfield now.

So these are all -- these are the real things that you are dealing with today. And I just wanted to

No comments

- n/a -

bring them to your attention. Because I don't think the Delta Plan -- the Delta Plan gives people the wrong idea of what's really happening with the tunnels and the plan. RI14-1

Thank you.

MR. ISENBERG: Thank you very much.

No comments

- n/a -

WILLIAM H. EDGAR

PRESIDENT CENTRAL VALLEY FLOOD PROTECTION BOARD.

MR. ISENBERG: Mr. Edgar?

Members, for those of you who have not met him yet, Mr. Edgar is the current chair of Central Valley Flood Protection Board and former city manager of Sacramento and well known in this region. And a previous member of the old Reclamation Board, which was the entity that preceded the Flood Protection Board.

Mr. Edgar?

MR. EDGAR: Thank you, Chair Isenberg, Members of the Delta Stewardship Council.

My name is Bill Edgar. As Phil indicated, I am the president --

MR. ISENBERG: You've got to have the mic right in front of your -- yup. Even if you can't read your notes.

MR. EDGAR: I have with me this afternoon Tim Ramirez, who is also recently appointed and confirmed member of the board.

MR. ISENBERG: This is the high energy younger member of the board?

MR. EDGAR: Yes. Yes. Yeah. And our Chief Engineer Lynn Moreno is also here.

RI14-2

Response to comment RI14-2

This is a comment on the project, not on the EIR.

Mr. Isenberg, we'll be speaking on the regulations portion of this public meeting.

As an introduction, I don't think it's any secret to anyone that most of the appointments of the Flood Board have been done less than a year ago. And quite frankly, we've been drinking from a fire hose since that time. We were thrown into a very difficult and contentious plan-adoption process. And after six months of pretty hard work and a lot of support locally and regionally, we were able to have the plan adopted in June. Which is an on-time plan adoption. And we also now have a certified environmental document.

And I believe of all the plans we're talking about; the Water Plan, the Delta Plan, the BDCP, the Flood Plan, and so on, this is the only adopted plan with a certified environmental document that we have. RI14-2

In addition to the Plan Adoption Process, we were kind of thrown a curve ball by the Corps of Engineers. And I don't know whether you read that in the paper or not. But after a series of inspections of all the levees -- we estimate, by the way, that there are probably 95 percent of all the levees in our system that does not meet the Corps' standards. Therefore, they have started a process whereby they are incrementally removing reaches of the levees from the PL-8499 program. Which is, as you

No comments

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probably know, the program which gives federal money to local agencies to rebuild levees after floods.

So this is a pretty big deal for us. Particularly, the local LMAs who are concerned about that.

Anyway, we've been worried about that. We've been fighting with them and going back and forth and talking about fixing levees; what we'd do about illegal encroachments; encroachments that are illegal that have, in fact, been permitted. Which is an interesting concept. And a number of other issues.

And the so-called U.S. Corps of Engineers Variance Process, which is called a SWIF, Systemwide Improvement Framework that the Department of Water Resources hates because it kind of diverts us from the implementation of plan. RI14-2

But anyway, the Corps of Engineers is dealing with that. We understand now that the Corps is requiring a SWIF on almost every permit that you seek from the Corps, even though it's not statutorily permitted or required or anything else.

For example, the 408 Process, which is the federal process for reviewing flood improvements. For example, Safe Ca in the Natomas area has done that, Sabuf Ca (phonetic) is working on a 408 Process.

And the 104 Process, which is the reimbursement

No comments

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process that we spend money first and get Corps' money later, they are requiring that a SWIF be included in that process. Which is a new and emerging requirement.

Mr. Isenberg, the bottom line is that our Board has not focussed on the issue of coordinating our Flood Plan implementation efforts with all the other plans that are going on.

I mean, we received a staff, and now that our plan has been adopted, our big issue now is, how does this plan fit into all these other plans? And do they work? And what are we meaning?

Well, we are right now implementing a very robust process of regional planning. The Flood Plan called for nine regional planing efforts in nine regions. We're down to six areas now. Some have been consolidated and went back and forth. We now have six planning areas throughout the system in which the plan is going to be implemented.

RI14-2

Bottom line is they are preparing the plans, regional plans. The Department of Water Resources will be in fact influencing those regional plans by commenting on system -- the need for systemwide improvements and Fitzroy (phonetic). Which is an organization that is run by the Department of Water Resource. I think it stands for Flood Safe Environmental Stewardship -- something or other -- Office. But whatever that is, they are going to

No comments

- n/a -

be coming out with their environmental goals and objectives and of course they also have to be involved in the planning.

Now, all of this said, as we move towards designing of projects and implementation planning and toward construction, we are going to have to figure out how these plans -- how these implementations, who gets what permit from what and how these all work with all these other plans that are going on. And to be honest, I don't have a clue how that's going to happen.

Gary Bardini in Department of Water Resources has a vision for how this is all going to work. But you've got me on how it's all going to work. And it may work. And he's tried to explain it to me, and I don't understand it. But he's good at it. So he can do that. RI14-2

We had a presentation at our board meeting this morning given by the department on how the Water Management Plan is going to integrate all of these different plans that are going on. And we were told this morning that nobody's statutory authority, nobody's current area of responsibilities and jurisdictions are going to change. We are going to work together, is what we were told. Well, that's funny. And that's what we want to do.

But getting back to the subject at hand, which is

No comments

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the Delta Stewardship Council's proposed regulations, we had, for the board -- the new board, we had our presentation given by the staff yesterday. It raised some concerns about regarding the regulations, namely inconsistencies. This was in the staff report. And I don't know whether this is true or not, we haven't had time to really look at it. But raises a lot of concerns regarding the regulations, inconsistencies between boards, Central Valley Flood Protection, Title 23 Regulations, and those proposed by the Stewardship Council staff. Overlapping responsibilities and the need for a jurisdictional authority between board and council, and inconsistencies with existing state laws and regulations, and the need for definitional clarity was raised.

RI14-2

So after some discussion at the board meeting yesterday, and I believe Tim Ramirez can correct me if I'm wrong, that the Board did not believe that the legal council had the appropriate time to analyze our staff comments, nor has the Board had an opportunity to properly consider the issues raised.

DWR's legal council was at the meeting and expressed some concerns about these kinds of issues. And they will be submitting comments to you by your deadline, and probably be making appearance at your public meeting on the 24th is what we're told.

No comments

- n/a -

So now some of the Board members and staff have asked that I ask you for a continuance or postponement of the deadline for comments. I'm not going to do that. Because I don't think you'll grant it, No. 1. And No. 2, I'm not sure you should. When our friend Melinda Terry asked us whether we would grant an extension for the Flood Plan decision, we said no. And the reason we said no is because we were up against the statutory deadline and a lot of pressure to get it adopted and so on. And I'm sure that's what the situation is. So I'm not going to ask for an extension.

But we are going to ask for the ability -- and I think your staff has already offered that ability to work with the Board and try to: No. 1, work out these alleged inconsistencies or issues that have been identified by some of the attorneys.

And to that end, we are going to submit kind of a general letter by your deadline outlining some of the issues that we see on the regulations. We will establish a Board Committee to accompany our staff so that the Board is more up to speed on these issues. And we'll try to get them resolved in more of a face-to-face discussion and meetings, rather than everybody lawyering up and -- you know -- slugging it out. Because I don't think that's going to help anybody.

RI14-2

No comments

- n/a -

So that's what we're proposing to do, and we'll then hopefully followup with a more detailed letter and so on.

And we'd request your -- that you consider the comments and suggestions, and you work with us to see if we can make these things work out.

And frankly, you're going to get a lot of comments on these kinds of issues. "Well, wait a minute, the Flood Board says -- the Title 23 Flood Boards says this, and yours says this." You're going to get a lot of that I'm sure from DWR, and a little bit from us. But quite frankly, we're not as far along as they are. They've been working on this for some time.

On existing authorities of overlap of responsibilities and all of that is going to come before you. And those issues really need to be worked out and resolved, I think, on face-to-face examples.

But I'm less interested in that as I am process. How is all this going to work? For example, we have authority over permitting encroachments on levees, project levees defined by the system. That's what we do. We also enforce encroachments. Not doing a great job with that, but that's what we're supposed to be doing.

And so the question is, how -- if somebody comes in, makes a permit application to us to do some

RI14-2

No comments

- n/a -

improvements, minor improvements, major improvements, whatever they are, to the levees. Or in the case of we found one encroachment in Cash Creek where a person actually dug into the levee and put in a wine cellar.

MR. ISENBERG: Probably pretty cool.

MR. EDGAR: We've got to do a better in enforcing those kinds of things.

But the fact of the matter is, people don't get it. I mean, these are our first lines of public safety. You don't put wine cellars in the levees, and you don't put swimming pools in the levees. We -- just anecdotally, we took a look at a little pocket here. And what's the --

MR. ISENBERG: Not far from what Mr. Edgar, himself, lives.

MR. EDGAR: I know. But what's the universe of the problem? We don't even know. We don't know what the encroachment problem is. We don't have a database, we don't have a map. I mean, we just don't know. And that's going to take a lot of work to figure out. But anecdotally, in six miles of the pocket area, just an example, there were 23 swimming pools. Many of which were encroaching into the clearance area. Some of which were actually embedded into the levees.

Now, I guess if you keep the swimming pool filled, it would be okay. But you know how that works.

RI14-2

No comments

- n/a -

So anyway, there's a lot of problems here. And I'm interested in somebody coming in, asking us for a permit, or we're required to enforce an encroachment in the Delta. How does that work exactly? Somebody submits a permit to us, we review it and we -- I guess we would send it on to you to make a finding of compliance with the Delta Plan, and then --

MR. ISENBERG: Mr. Edgar, I'd like to renew a suggestion we made long before you and Mr. Ramirez were appointed to the Board.

One of your other current Board members, Mr. Valine and staff had come over and visited and we had mentioned that we had already entered into memorandums of agreement with the Bay Delta Conservation Commission and what is now called the Department of Fish and Wildlife of the State of California, essentially setting up a process of review and contact and evaluation. And we kind of generally made that offer both to the Board, but also to other state agencies and even local agencies.

RI14-2

I think there is a lot to be said for that approach for your consideration.

MR. EDGAR: Yeah. You have offered that, as I understand it from the staff. We have taken a look at that. It has to be a lot more specific as to describing the process. The title twenty -- you know me. I'm a city

No comments

- n/a -

manager. I need to know how things are going to work, Phil. I mean, this stuff of policy and planning is fine. But tell me how it's going to work. Somebody comes in for an application, you go through the process -- which people hate, by the way. They think it's too long. They think it's onerous. And we're proposing that we charge for it. I've never heard of a system where you get free -- where you never collect a fee for a permit. We never did that at the city for heaven's sake. You come in and you pay for it.

MR. ISENBERG: Never?

MR. EDGAR: Never. Well, we shouldn't, anyway. It's a time process and they hate the whole thing. I think the memorandum agreement has to be done. We were told this morning that's kind of where everybody is going. They need to get together on these. They have to begin to manage horizontally, not vertically. That's exactly what we need to do.

But still, this process, to me, is going to add time. And which will drive everybody crazy. So we need to do something to fix that.

MR. ISENBERG: Even before the new members of the Board were appointed, I never thought there were fundamental barriers between council's activity, the new legislation that created us and gave us our duties, and

RI14-2

No comments

- n/a -

the Flood Board. It just seems to me that they're compatible. You do, however, have a geographical range of activity up and down the Central Valley that is outside our statutory directed area. And conversely, we have territory that's not within the Flood Board's kind of thing. The heritage of government setting up multiple agencies to do similar kinds of things. So I'm confident that we can resolve some issues.

And we've benefitted from the letters that have actually cranked out of the Flood Board in 2011 and 2012 on the plan, the environmental impact report and so on.

MR. EDGAR: Yeah. As I said, I think those problems can be worked out, Phil. I'm interested in process. The Title 23, specific -- is very specific. And I know Chris has looked at those -- both Chrises -- and always looked at Title 23. Very specific as to what's required and so on. And we'll have to get in that kind of detail to deal with this, I believe. And we need to do that.

RI14-2

MR. ISENBERG: Mr. Notolli?

MR. NOTOLLI: Just in light of Bill's outline and certainly having a little of background from this council's work, but also on other realms. I think that I want to say I appreciate Bill being here on behalf of the Board and his work and leadership in this arena. I think

No comments

- n/a -

he's talked to some of the challenges that his Board and colleagues and certainly the entity that he is responsible for have and was according with. But I think understanding the implications of plans and policies is very important, particularly at the project level.

I guess I have a local government perspective with not only what the intended consequence is and the intended outcome. But also when I hear Bill chose his words, and he picked them pretty carefully, but "inconsistency," "overlap," "lack of clarity," those things aren't without the ability to be resolved. But I think it takes work and understanding. But I think in the institutional framework in which a lot of people work, for the party who is the permittee, that is where it really meets -- the rubber meets the road. And when maybe they don't want to be before you begin with, but they have to by virtue of getting permit and doing things properly. Then you add time to that and cost to that. And then if there wasn't cost before, now I'm paying you to frustrate me more and delay me more.

RI14-2

All built into that mentality, yet you want people to do the right thing and want agencies to enforce their requirements properly and fairly. So I guess I would say to your request, it seems to me to be one that's reasonable. And I know that Phil weighed in and certainly

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No comments

- n/a -

the understanding we have from what you portrayed today, there needs to be work done certainly at the respective staff level. But as we go forward and consider these regulations, it's important to know the implications and what it means to folks at the ground level of those, whether it be agencies, and certainly a lot of cases individuals, some organizations that are going to be seeking permits from your body and obviously from time to time come before this council for review of consistency and/or other certifications.

So I concur. I think it's in everybody's best interest to do that sooner than later, Bill. So I think what you've offered today is important so hopefully Chris and our staff will latch onto that quickly.

RI14-2

MR. ISENBERG: Ms. Gray? Don't touch it.

MS. GRAY: I want to thank you for coming this afternoon.

You know, I think one of the things that are very important -- and I've heard basically the same anxieties that a lot of folks have about the plan is that they're still not sure, in fact, how things will work. And I think you make that point very well today.

And I know there's an Implementation Committee that will be part of the process once the plan is approved, but perhaps there's a need to have a workshop

No comments

- n/a -

that will clearly state -- figure out what the process is, what role we play, what role your Board plays or any other agency as it looks at different parts of the plan.

So perhaps that's something that council can consider as we move on. Because it's a great accomplishment to approve a plan and focus a big part of the process. But people don't really understand how things work. Then it's not always clear that people are supportive or really will move forward in a positive way.

So I think that's a very important element of it. So I think at some point council needs to consider something like that as part of moving on after the plan is completed.

MR. EDGAR: We'd certainly be happy to participate in something like that, Ms. Gray.

Thank you.

MR. ISENBERG: Thank you, sir.

RI4-2

No comments

- n/a -

BOB WRIGHT

ENVIRONMENTAL WATER CAUCUS

MR. ISENBERG: The next speaker is Mr. Wright. And after Mr. Wright is Mr. Gaudiner.

Mr. Wright?

Members, Mr. Wright is representing the Environmental Water Caucus, Friends of The River and Restore the Delta, right?

MR. WRIGHT: Yes, Mr. Chairman.

MR. ISENBERG: Thank you, sir.

MR. WRIGHT: Good afternoon, Mr. Chairman and council members. My comments go to the recirculated draft environmental document, the Delta Plan and the regulations of approaching this in part from a legal perspective. It's necessary to consider all of the documents that are out there, because of course the environmental impact reports, what they address is the project, and the project in this case is your plan and your regulations.

And I've got a number of points to make. And the first one -- one thing that really jumped out at us is the double whammy of at this time calling for new conveyance upstream from the Delta. And we all know from what's going on with the BDCP, the Delta tunnels, that's a major new conveyance. They're talking about twin tunnels with a

RI14-3

Response to comment RI14-3

The proposed BDCP is a reasonably foreseeable future project that is not part of the Delta Plan. It is being evaluated by the Department of Water Resources as the CEQA lead agency. The cumulative impacts of the proposed Delta Plan, in combination with the impact of the proposed BDCP, are described in EIR Sections 22 and 23. Please refer to Master Response 1.

capacity of diverting 15,000 cubic feet per second out of the Sacramento River in the Clarksburg vicinity and taking it around to the Tracy pumping plants.

They have said that -- they claim they've scaled it down by calling for three intakes instead of five, so the intakes would be capable of diverting 9,000 cubic feet per second. The tunnels are 35 miles long. They're going to cost billions of dollars. Obviously you would only build tunnels at that capacity if that was the water you eventually intended to take. And it would be very easy to add two more intakes down the road. And we submit that, with all due respect, that's what must be considered under SEQUA, our environmental laws. RI14-3

The thing that jumps out, is in your own plan, at page 80, there is some candor there. And it says that as a result of climate change we can see sea level rise as much as 55 inches by 2100. And it says that that will result in high salinity levels in the Delta interior, which will impair water quality for agriculture and municipal uses and change habitat for fish species.

So what just jumps out as being absolutely astonishing is recognizing that. We all know the Delta already has a problem with salinity intrusion from the bay. The plan has statements in it where it recognizes and candidly does admit that a lot of that is due, of

No comments

- n/a -

course, to the already extensive diversions of water from the Sacramento River and from the Delta.

In light of that, to add massive new conveyance, improved conveyance, optimizing diversions in the wet years, it just looks like creating a massive double whammy. Kind of a two-front war for the Delta facing a surge of salinity intrusion from the Bay. And at the same time taking out the fresh water upstream from the Delta. RI14-3

Now, if you went instead with the alternative that the Environmental Water Caucus is called for, which you've numbered as Alternative 2, to maintain through Delta conveyance in continue pumping from the South Delta. At least the fresh water that the exporters take remains in the Delta. It's there to be used, to help fight pollution, help fight salinity intrusion, help protect agriculture, commerce, and endangered fish species before it's taken. And what that also does is it keeps everybody on the same page. And that the exporters like the Delta itself do have some interest in trying to win the war against salinity intrusion in the Delta, because they also are presently taking from the south end of the Delta.

If this new conveyance that your plan is in regulations encourage and recommend. If that comes about, then the sky is the limit. The exporters will be taking water upstream from the Delta and not be affected by the RI14-4

Response to comment RI14-4

The range of alternatives analyzed in the EIR is a reasonable range of alternatives based on thorough consideration of public input and the requirements of CEQA. The Delta Plan does not include a Delta conveyance facility of the type described in the comment, and thus the EIR neither analyzes the impacts of such a facility nor considers alternatives to one. Regarding the relationship of BDCP and the Delta Plan, please see Master Response 1. Regarding the development and selection of the range of alternatives considered in the EIR, please refer to Master Response 3.

RI14-4

salinity intrusion, and the Delta would be left to face this on its own.

RI14-5

And as I said, you have to kind of look at all of your documents together. In your recirculated draft EIR in section 3, at page 3, it does make this generalized admission. That operations of new water supply facilities, such as pipelines, tunnels, canals, water intakes or diversions may create long-term changes in local mixtures of source waters within water bodies.

In my book, in my experience, that might pass muster under SEQUA as an initial statement. What you start out the process -- initial study, what are the issues that we need to address in our EIR? That is far too general. It doesn't mean anything. It doesn't tell us anything about the extent of the changes, the severity of the impacts. It just doesn't pass muster in an EIR. An initial study maybe, but not in an EIR.

RI14-6

I'd like to turn to the next subject a little bit related in your recirculated environmental document in section 2 of page 24. There's some very vague information on funding and mitigation. And what we think the situation is, as these massive diversions of fresh water upstream from the Delta, of course, they were threatened turning the Delta -- which is already in danger -- into a polluted and salty wasteland. But the exporters wouldn't

Response to comment RI14-5

Please see the response to comment RI14-3. The Delta Plan EIR is a program-level EIR and the level of detail is adequate for the program EIR approach, as described in Master Response 2.

Response to comment RI14-6

Please see the response to comment RI14-3 and Master Response 1. Future lead agencies will have the obligation under CEQA to mitigate the significant impacts of projects regardless of bond measures or any other circumstances. Please see Master Response 4. The EIR is not intended to, and could not, provide take authorization under the federal Endangered Species Act for the Delta Plan, or for any project encouraged by the Delta Plan. The Delta Plan's significant adverse impacts related to biological resources, including special-status species, are discussed in Section 4 of the EIR. The cumulative impacts of the proposed Delta Plan, in combination with the impact of the proposed BDCP, are described in DEIR and RDEIR Sections 22 and 23.

be paying to fight that problem or attempt to mitigate it. That would be stuck on the taxpayers and the business and agricultural and fishing interest in the Delta itself.

We think that's wrong. And we think if you're going to encourage this kind of diversion of water upstream from the Delta, then the exporter should be taking the water and benefitting from it. The only right and just thing to do would be to have them pay for everything caused by what they've taken.

Now, that's kind of a policy view, but there's also a legal issue there under the Endangered Species Act. The 9th Circuit recently came out with a decision in Center for Biological Diversity versus United States Bureau of Land Management. It's called the Ruby Pipeline Case. We're citing it in our written comments. I'll be happy to furnish citations orally if you want me to.

MR. ISENBERG: It'll come in the written version.

MR. WRIGHT: It'll be in the written version.

They've made it really clear, there's no discretion under the Endangered Species Act to authorize a project that would jeopardize survival of listed fish or adversely modify critical habitat. And also mitigation measures, they must be there, they must be real and assured. And what I said earlier about the exporters trying to shift the cost of attempting to deal with a

RI14-6

No comments

- n/a -

massive destruction, these massive diversions were caused in the Delta, is that bond measures have already been pulled from the ballot twice; 2010, 2012. So there's obviously no certainty that the people, the taxpayers are going to pass bond measures to pay for this.

So we believe you have a real legal problem under the Federal Endangered Species Act and the decisions under that, if you don't require absolute, as part of the project, they mitigate, they pay for everything.

RI14-6

The next subject I'd like to turn to is your plan. And it sounds -- I can see the appeal to it. It calls for optimizing diversions in wet years, and as mentioned in your plan on page 72 and also page 11. But a different part of your plan on page 84 recognizes the adverse impacts in result of reducing the flushing of San Francisco Bay by Delta outflows.

And I've got a document that I'm going to give after I've spoken to Angela of your staff to put in the record. It's a technical memorandum 2010 by the Contra Costa County Water District where they did studies showing the historical flushing of the Delta where fresh water is no longer occurring. This lack of flushing can also allow waste from urban and agricultural development upstream and within the Delta to accumulate. And contaminates and toxins have been identified as factors in the decline of

RI14-7

Response to comment RI14-7

Policy ER P1 has been recategorized as Recommendation ER R1 and has been amended. It states that the SWRCB should adopt updated flow objectives for the Delta by 2014 and flow objectives for high-priority tributaries by 2018. Under ER P1, after the flow objectives are revised, they will be used to determine consistency with the Delta Plan. As described on page 2A-39, Lines 38 through 40, of the Draft Program EIR and Master Response 5, it is anticipated that implementation of updated water quality and flow objectives by the State Water Resources Control Board (SWRCB) could increase Delta outflow, reduce current reverse flow conditions in the south Delta, increase flows in restored Delta floodplains, and result in a more "natural flow regime" in the Delta. The potentially significant water resources impacts of the Final Draft Delta Plan–including those related to water quality—are analyzed in Section 3 of the RDPEIR. Water resources mitigation measures are indentified in RDPEIR subsection 3.4.3.6. Section 4 of the EIR analyzes impacts on biological resources.

the Delta ecosystem.

What that means for you and what's required in your environmental documents instead of just coming up -- "Well, we have this idea we're going to optimize and increase diversions in the wet years." That has to be analyzed, or there has to be environmental analysis of the extent, the severity, and adverse environmental consequences from further reducing the already reduced necessary flushing of the Delta and the Bay. And we've looked, we've scrutinized. We haven't seen a peep about that anywhere in your environmental document.

RI14-7

The next subject I'd like to spend a moment on is just the backwards description of the project purpose and conflict with the Water Code. Your recirculated environmental impact report claims that the revised project will lead to reduced reliance on Delta exports. That's in the executive summary at page 2.

Your plan at page 72 admits that the Delta Reform Act established a new policy in the Water Code of reducing reliance on the Delta and in meeting California's water supply needs. So we can understand why the claim is made. But when you look at the undisputed facts, when you talk about creating massive new conveyance and intake structures that are projected to cost around $14-billion, that isn't reducing reliance on

RI14-8

Response to comment RI14-8

This is a comment on the project, not on the EIR. Please see the response to comment RI14-3 and Master Response 1. As stated in the Revised Draft PEIR at page ES-4, the Project's objectives are: "Furthering achievement of the coequal goals and the eight 'inherent' objectives, in a manner that (1) furthers the statewide policy to reduce reliance on the Delta in meeting the state's future water supply needs through regional self-reliance, (2) is consistent with specific statutory content requirements for the Delta Plan, (3) is implementable in a comprehensive, concurrent, and interrelated fashion, and (4) is accomplished as rapidly as realistically possible without jeopardizing ultimate success." These objectives reflect the priorities and goals that the Legislature set for the Delta Plan and the Delta Stewardship Council in the Delta Reform Act, including the coequal goals (Public Resources Code § 29702(a), the objectives inherent in those goals (Water Code § 85020), and the statewide policy to reduce reliance on the delta (Water Code § 85021). Policy WR P1 in the Delta Plan implements the State policy to reduce reliance on the Delta and improve regional self reliance.

the Delta. That's increasing it. That's a huge expensive Public Work's Project. And what we call upon you to do is either, well, drop the call for new conveyance, improve conveyance, anything other than maintaining existing through-Delta conveyance. Or require your EIR consultants and repairs to candidly set forth that this would not reduce reliance on the Delta. The truth is this would increase reliance on the Delta.

And that's what we call upon you to do. Is either drop it -- that's our first choice. But if you don't drop it, require candor and serve the people and all of the folks involved in this and interested in it with a really candid admission. Because that's the kind of thing that nobody is really going to buy that. It's just kind of like if I was to claim right now that it's nighttime outside. Well, it's not. It's daytime. Anybody can say that, but it doesn't make it so. RI14-8

And in fact in your recirculated environmental document in section 24 at pages 13 and 14, there that sets out that when you use resources, you make a large commitment of resources, that makes removal or nonuse therefore unlikely and generally commits future generations to similar uses.

So in other words, if you build it, it's going to be used. And that's going to be increasing reliance on

No comments

- n/a -

the Delta, not reducing.

I appreciate your attention and listening. So I'm going to speed things up and skip over a point. I'll make that in writing. I have until Monday to do that. It's much appreciated.

RI14-8

And this one, your recirculated environmental document makes some very general admissions of significant adverse and unavoidable impacts of the revised project, including its call for improved or new conveyance. In section 24 at page 10 there's just this general line that says, "Water -- significant and unavoidable impacts of the revised project would include water resources, violate any water quality standards, or waste discharge requirements, or substantially degrade water quality."

Again, it's admitting the obvious. It is true. It's so general, it's absolutely meaningless. And you also include on the same page, page 10 of section 24, the statement: "The significant and unavoidable environmental impact would include biological resources, including substantial adverse effects on sensitive natural communities, including special-status species, substantial adverse effects on fish or wildlife habitat."

That's true. Again, it's so general, to be meaningless. And what I and all of the organizations I'm here representing are saying to you for the first time

RI14-9

Response to comment RI14-9

Please refer to Master Response 2. As described in Section 2B of the Draft Program EIR, the Delta Stewardship Council does not propose or contemplate directly authorizing any physical activities, including but not limited to construction or operation of infrastructure. Rather, through the Delta Plan, the Delta Stewardship Council seeks to influence the actions, activities, and/or projects of other agencies, the details of which would be under the jurisdiction and authority of the agencies that will propose them in the future and conduct future environmental review. To the extent known, projects that may be encouraged by the Delta Plan are named in the EIR. In addition, types of projects that may be encouraged by the Delta Plan are identified. Accordingly, in the absence of specific proposed physical projects, this EIR makes a good faith effort to disclose the potentially significant environmental effects of the types of projects that may be encouraged by the Delta Plan and to identify program-level mitigation measures. Impacts on each of the potentially affected resources areas are analyzed at a program level in Sections 3 through 21 of this EIR.

this afternoon is, your draft EIR and your recirculated draft EIR under the law are so fundamentally and basically inadequate and non-conclusory in nature, that meaningful public review and comment has simply been precluded. And that under SEQUA guideline section 15088.5(a)4, it is necessary that you prepare, in order to comply with law, a new draft EIR and recirculate that for public review.

Just think about it. What does that tell anybody that -- "Well, our revised project we've chosen will violate water quality standards and substantially degrade water quality." Okay. What standards? By what pollutants? To what degree? How severe will it be?

There's a huge difference between a person catching a cold and, unfortunately, having a terminal illness. It's like day and night. Your environmental documents that your consultants have prepared, they don't give a clue. Again, maybe it would pass muster as an initial study starting the SEQUA process; not pass muster as an EIR ending the SEQUA process.

RI14-9

This next point is really very, very important. And that's the absence of information and analysis supplied by your environmental documents. And, again, there's a case site in the written comments. The name of the case is Vineyard Area Citizens for Responsible Growth versus the City of Rancho Cordova. It's a 2007

RI14-10

Response to comment RI14-10

Please see Master Response 1. As described in Section 23 of the Recirculated Draft Program EIR, if completed and approved by the California Department of Fish and Wildlife, the BDCP must be considered by the Delta Stewardship Council and included in the Delta Plan as required by the Delta Reform Act (Water Code section 85320 et seq.). DWR is the California Environmental Quality Act (CEQA) lead agency for the BDCP. Policy ER P1 has been recategorized as Recommendation ER R1 and has been amended. It states that the SWRCB should adopt updated flow objectives for the Delta by 2014 and flow objectives for high-priority tributaries by 2018. Under ER P1, after the flow objectives are revised, they will be used to determine consistency with the Delta Plan. Please see Section 2 of this FEIR for the complete text of the policies and recommendations. CEQA does not require a cost-benefit analysis. CEQA Guidelines §§ 15064(e), 15131; see also Master Response 2.

California Supreme Court Case. It's SEQUA case dealing with water supply issues that frankly paled in significance -- that was for a development project -- to the water supply issues here. And the California Supreme Court made it clear that the EIR must provide facts that allow the reader to evaluate the pros and cons of supplying the needed amount of water, must analyze the environmental impacts of utilizing the particular resources of long-term water supply, and that the key is that an EIR that neglects to explain the likely sources of water and analyzer impacts, but leaves long-term water supply considerations to later stages of the project, does not share the purpose of sounding an environmental alarm bell before the project has taken on overwhelming bureaucratic and financial momentum.

And that's absolutely what we're concerned about here. Delta Plan calls for new and improved conveyance. Then the BDC process, they finish Delta tunnels. And, oh by the way, this is consistent with the Delta Plan, because the Delta Plan called for new and improved conveyance. And that's what we're doing.

What I'm saying to you, Mr. Chairman and council members, is that you're in a historic position. I would submit to you that the State Water Resources should be going first to do its analysis under the Public Trust

RI14-10

No comments

- n/a -

Doctrine, Cost Benefit Analysis, determine water availability. Get all that worked out before you enact the Delta Plan or DWR comes up with a BDCP. But you apparently are first in line at least right now. And what I would submit to you is that in order to comply with the law, you have to insist that that kind of work and analysis all be done before you call for new conveyance. Either by having the work done yourself. And you may not have the resources to do that. And everybody thinks that's for the State Water Resources Control Board. Insist then that they do it before you call for new or improved conveyance.

RI14-10

There's something else that is hugely important on this. Your draft EIR -- and by the way, section 23, dealing with BDCP was incorporated by reference by the recirculated draft EIR. And since it's incorporated by reference, I'm going to comment on that. And at pages 3 and 4, they actually did a good job of saying what had to happen under SEQUA. They said, "The BDCP must comply with SEQUA including a comprehensive review and analysis of a reasonable range of flow criteria, rates and diversion, other operational criteria, requirements and flows necessary for recovering the Delta ecosystem and restoring fisheries under a reasonable range of hydrologic conditions, identify the remaining water available for

RI14-11

Response to comment RI14-11

Please see the response to comments RI14-3 and RI14-10, as well as Master Response 1. As described in Section 23 of the Recirculated Draft Program EIR, if completed and approved by the California Department of Fish and Wildlife, the BDCP must be considered by the Delta Stewardship Council and included in the Delta Plan as required by the Delta Reform Act (Water Code section 85320 et seq.). DWR is the California Environmental Quality Act (CEQA) lead agency for the BDCP. The Delta Reform Act potentially gives the Council three distinct but connected roles related to Delta water conveyance: contingent authority to approve proposed conveyance improvements, authority to generally recommend conveyance options in the Delta Plan, and authority to provide comments to other agencies during the BDCP process. Conveyance options are currently being studied in detail by the agencies and interested parties preparing the BDCP and the related EIR/EIS. If a government agency, such as DWR, proposes to implement the BDCP preferred conveyance project, the BDCP preferred conveyance project would be consistent with the Delta Plan regardless of whether the Delta Plan had previously endorsed a different conveyance option. Accordingly, the Council's regulatory authority over conveyance is contingent upon a different conveyance project being proposed and becoming a covered action prior to BDCP's incorporation into the Delta Plan. It is highly unlikely that a non-BDCP conveyance project would be proposed as a covered action to come before the Council prior to BDCP completion. For this reason, the Delta Plan does not include any regulatory policies regarding Delta conveyance. The Delta Plan includes recommendations to DWR should the BDCP process not be completed by December 31, 2014, for the Council to consider approaches to develop and complete the ecosystem and conveyance planning process without BDCP. If the Council then decides to amend the Delta Plan to include regulatory policies regarding Delta conveyance, the Council would do so only after extensive analysis of the conveyance options and associated detailed environmental review. The environmental setting (baseline) for the analysis in this EIR consists of the existing conditions at the time of the publication of the Notice of Preparation of this EIR in December 2010, which is the normal CEQA environmental baseline pursuant to CEQA Guidelines section 15125(a). As discussed in Master Response 3 and section 25 of the Recirculated Draft PEIR, Alternative 2 is not environmental superior to the Revised Project (the Final Draft Delta Plan), because it would bring about more uncertainty regarding water supply and more conversion of agricultural land to non-agricultural uses than the Revised Project.

export and other beneficial uses, consider a reasonable range of Delta conveyance alternatives including through Delta."

The potential effects of climate change, including what I mentioned earlier that sea level rise up to 55 inches and possible changes in precipitation and run off patterns and so forth.

Your draft EIR was correct on that, on what was necessary. What stands is an undisputed fact that you have to -- well, you're going to do what you're going to do. But I would suggest to you, you need your consultants and attorneys to make sure it's done is to recognize an undisputed fact that simply did not happen. What had happened was, in your draft EIR at page 3, they had anticipated that a public draft of the BDCP and related EIR/EIS would be released by mid-2012. Simply didn't happen. And Deputy Director Jerry Meryl just said at the last public meeting in December that even the nonpublic draft is not going to come out until February and the public draft is not going to come out until the spring of 2013.

What I'm telling you is that by proceeding now to adopt the Delta Plan and regulations calling for new conveyance, since that work that they thought was going to be done didn't get done, the process kind of would stand

RI14-11

No comments

- n/a -

indicted and convicted by your own draft EIR. And that's a pretty serious problem.

Again, our point is that some public agency has to do this work under SEQUA, the Public Trust Doctrine, before new conveyance is called for. That's the most important part of the whole decision making process. Whether or not to build or not to build. To build or not to build new conveyance. That's huge, and that's what has simply been absolutely overlooked; just treated as a given, an ipse dixit or an assumption.

And that jumps into my next point; not now, not ever. Back in May of 2011 the National Academy of Science, when it was reviewing the draft BDCP plan said that choosing the alternative project before evaluating alternative ways to reach your preferred outcome, would be post-talk rationalization. In other words, putting the cart before the horse. Scientific reasons for not considering alternative actions are not presented in the plan. That's still true today. Scientific reasons have not been considered and evaluated for not considering alternatives grounded on not building and developing new conveyance.

RI14-11

There's another problem with your recirculated draft EIR, is between your last environmental document and the recirculated one, the federal and state fishery

No comments

- n/a -

agencies came out last year with the red-flag warnings. We've scrutinized the recirculated environmental impact report. Didn't see a clue about that. Didn't see a clue about the National Academy of Science's determination that scientific reasons for not considering alternatives have not been considered.

What I would say to you -- and again, I do appreciate it, and I'm wrapping up. Two or three more points.

I'm trying to help here because we know we face a stacked deck with the BDCP. The exporters want the water, they're in control of the process. Our hope is -- we got hope in two places. One is the State Water Resources Control Board with board members, and the other is your council with different members on it. And substantial evidence includes things like facts, reasonable assumptions predicated on facts, expert opinion supported by facts, argument, speculation and narrative doesn't muster under SEQUA guideline section 15384.

And I submit to you that everything that's been done so far in calling for new conveyance, calling for adopting the revised project alternative, and fails to address and analyze the admitted significant adverse impacts on water quality and endangered species in the Delta is simply that; argument, speculation, narrative and

RI14-11

No comments

- n/a -

doesn't pass muster.

Same is true for your recirculated environmental document in section 25 of page 17, says an alternative, too, is submitted by the Environmental Water Caucus is slightly inferior to the revised project. Because it would sharply reduce exports from the Delta, potentially creating a supply shortfall. Stating potentially, again, there has to be a narrative in speculation. We say, again, it's on a number of points that it's necessary to prepare a new draft EIR and recirculate. Because the draft and recirculated document out there so far has simply been too inadequate to furnish a form public review.

RI14-11

On a different subject, you have an absence of an accurate stable --

MR. ISENBERG: I'm going to have to give you no more than five minutes and hopefully less than that.

MR. WRIGHT: I appreciate it. And that's fine.

On the project description there are very vague things in your environmental documents in section 2 at page 5 talking about surface water projects, conveyance facilities. In section 2 of page 26 you say that the revised project would not have direct impacts or directly result in construction, but could, however, result in implication of actions or development of projects.

RI14-12

Response to comment RI14-12

Please see the response to comment RI14-3 and Master Response 1.

But since your draft document was out, Deputy Director Meryl said what this project is in June of last summer. The two tunnels, 35 miles long, 50,000 cubic feet per second. The Governor confirmed that at his special press conference in late July 2012. And I would say to you that SEQUA informational purpose is not satisfied by simply stating information on the details provided in the future. And, again, that's in that Vineyard Area Citizens case.

RI14-12

Last couple quick points. We heard talk about economics and cost. Your recirculated EIR should have disclosed and discussed the university of pacific cost benefit study. That came out in July showing that the cost of the Delta tunnels would be two-and-a-half times higher than the benefits. So the project doesn't make economic or financial sense. Because in terms of the public preparing alternatives, that is relevant information to know that in addition to all of the environmental reasons to not go forward, the project also is a bad deal when you look at cost benefit analysis. And I'm going to give that to Angela as well.

RI14-13

A final point is simply there's been a failure to evaluate upstream impacts. Your Delta Plan recognizes changes in storage and flows for fish at pages 80 and 91. This project new conveyance would have enormous impacts

RI14-14

Response to comment RI14-13

The BDCP is a separate project, for which the Department of Water Resources is the lead agency. It is not a part of the Delta Plan and was therefore addressed in Sections 22 and 23 of the EIR, as further explained in Master Response 1. Furthermore, CEQA does not require a cost-benefit analysis. See Master Response 2.

Response to comment RI14-14

The proposed BDCP is a reasonably foreseeable future project that is not part of the Delta Plan. It is being evaluated by the Department of Water Resources as the CEQA lead agency. The cumulative impacts of the proposed Delta Plan, in combination with the impact of the proposed BDCP, are described in EIR Sections 22 and 23. Please refer to Master Response 1. Please refer to Master Response 5 regarding upstream impacts of the Delta Plan, including on fisheries.

requiring changes in reservoir operations upstream, affecting minimum flows, storage so forth for fish presentation purposes.

I would simply wrap up and conclude by saying that the first step in this whole deal is whether to call for new conveyance. That's a huge deal. That's on your plate. What we do is we object to approval of the plan and regulations in so far as they call for new conveyance, optimizing diversions, improve conveyance, and say that it's necessary to do the work, do the analysis before calling for that.

RI14-14

We do think that calling for new conveyance would start the journey that we believe would strike the last nail into a coffin for the Delta. That's why we're fighting so hard in trying to get that from happening.

Thank you. I'll leave my contact information to your staff and submit the exhibits to Angela. And the written comments of the Environmental Water Caucus, you'll receive those on Monday.

MR. ISENBERG: Thank you very much.

No comments

- n/a -

CHARLES GAUDINER

DELTA VISION FOUNDATION

MR. ISENBERG: Mr. Guadiner, and after Mr. Gaudiner, Ms. Mannion.

Mr. Gaudiner?

MR. GAUDINER: Good afternoon, Chair Isenberg and council members. Thank you very much for the opportunity to comment. I will really try and be brief here.

Charles Guadiner from Delta Vision Foundation. As you know, the Delta Vision Foundation was formed to monitor and report on the progress of state agencies, federal agencies and others in implementing the principles, actions, strategies, and goals identifying Delta Vision's strategic plan. The Delta Plan is the key component of the implementation of that strategic plan. I'm going to focus my comments on the Delta Plan, not on the EIR or regulations.

Like Mr. Edgar, we are not interested in interrupting your process. We are trying to be constructive and help ensure the Delta Plan is a successful document and process for implementing the Delta Vision Strategic Plan.

In looking at the final draft Delta Plan we really stepped back to look to see how effective is that

RI14-15

Response to comment RI14-15

This is a comment on the project, not on the EIR.

as a policy and plan document for achieving the goals and implementing Delta Vision Strategic Plan. And does that affectively describe this wicked problem in the Delta and the challenges and conflicts associated with that? And I think in that area it does a very good job. I actually still -- every time I read it I learn something new about the problems in the Delta or how current management works. So I think it's very affective at that. And it's relatively concise, which is hard to do.

The second question really doesn't set the state on a path to success. That is fundamentally different from prior plans. We've been around this loop several times of developing plans and trying to implement them and going back and developing more plans. So let me provide some overall comments and I'll drill down briefly.

RI14-15

I think, as I mentioned, I think it's very effective at describing the problem, the history of the conditions, current management and the challenges. I think it does a decent job of identifying strategies that are needed in each resource area to address the problems. However, I think there's more work that can be done to describe a fundamentally different management strategy that would lead to more effective implementation. And I think that specifically in some areas related to performance management, the linkages and integration and

No comments

- n/a -

near-term actions.

So we look at those areas specifically; linkages in integration, performance management. We also looked at and compared the strategies and actions in the Delta Vision Strategic Plan with a set of policies and recommendations and other actions of the Delta Plan. And I'll touch on a couple of things there. And we're also looking at funding and financing, which we'll submit some written comments on.

In terms of near-term actions, overall our sense continues to be that the Delta Plan does not communicate yet a sense of urgency. I know that council feels a sense of urgency, and I know the staff does and stakeholder as well. There's a level of frustration about implementation. And I think this is an area where some relatively minor improvements in the Delta Plan could communicate that sense of urgency and really start to advance things.

RI14-15

We looked at the 91 policies recommendations and council actions that are in the Delta Plan, and looked to see what type of action they directed. Notably that of those 91, 52 of them are about additional plans and studies, administration and governs or monitoring. They're not about actually doing and changing things. They're about more studying and more monitoring.

No comments

- n/a -

Only nine of the policies and recommendations are about physical or operational changes in the Delta. That's ten percent. And so I think that, from a broad perspective, sends a message that we need to look more at what are some of the near-term things that we can do to change conditions up there.

There are 21 that are about developing or implementing new recommendations. As far as I can tell there are no recommendations about pilot projects that are underway or should be initiated. So that would be an area where the Delta Plan can highlight some near-term things that either are already underway to address these problems or could be very shortly.

I didn't see any recommendations or discussions about existing regulations where those could be enforced more affectively. And so I think that's another area that would communicate some urgency, some action in the near term.

The other observation about the policies and recommendations is only a third of them have actual deadlines associated with them. I can certainly understand the policies wouldn't have a deadline. But there are 71 recommendations that only about a third of them have specific deadlines. So that, too, would create more of a sense of urgency if we're putting things on

RI14-15

No comments

- n/a -

timelines.

There's a good initial effort to identify the 13 priority actions. Two are listed in chapter 1. I think there can be more emphasis on, "What does that mean? What does it mean to be a priority in action?" And I don't think it takes a lot to add a few things to the Delta Plan.

By the linkages, I think the Delta Plan continues to improve in communicating the linkages and integration that are really needed to solve these problems. Clearly every -- the document in whole and each chapter acknowledges and describes the two coequal goals and how they're relevant to that subject area. And I think that's really been a big improvement. But I think that an area where we need to focus, and I'll touch on this in a couple different ways, is the objectives of the plan. That the top level, I think the plan needs a more specific or even measurable set of objectives of how do we achieve the coequal goals and protecting and preserving the Delta as place.

Those discussions are of the objectives are either broadly designed as vision statements or they're put in sidebars. And I think more specific objectives would -- and defining those objectives in an integrated-length way -- and I'll give you one example,

RI14-15

No comments

- n/a -

and then we'll submit some more. But the concept of diverting more water wet years is less than dry years. That is an integrated objective that achieves both water supply or liability, and ecosystem restoration. So those kinds of objectives at the top level would help align all of the different interests that will pick at different parts of the plan on a common purpose.

Let me talk about performance management. Because it is a big focus of our effort across this whole Delta issue, and a substantial portion of our comments.

I think this is an area where some minor changes to the Delta Plan could set the Delta Plan in a new direction. And I think performance management is maybe the only tool that hasn't been tried effectively. We tried legal approaches, we've tried executive fiat. We've tried collaborative process. What we haven't really implemented is a true performance management approach that has the kind of objectivity, transparency and reporting that will hold everybody accountable for results.

RI14-15

So I think this is an area that appears to be more of an afterthought in the Delta Plan. And I think there's a few specific areas that I think could really improve. The adaptive management section I think is a good start. But when I talk about performance management, I mean more broadly than adaptive management. That it is

No comments

- n/a -

applying to organizational performances as well as environmental performance.

So I mentioned the need for top level objectives I would say throughout. And your adaptive management approach acknowledges that clear measurable objectives are a fundamental part of implementing adaptive management, and I would totally agree. And you provide some examples in the adaptive management sidebars. But the Delta Plan itself doesn't have those kind of clear measurable objectives at the top level or in each chapter.

So we have vision statements, we have some policies and recommendations and strategies. But we don't really define what are we trying to achieve in each issue area and how are we going to measure our progress to it. RI14-15

So therefore the performance measures aren't tied to anything specific and measurable. So they also appear as an afterthought. We actually did a side-by-side comparison of the performance measures identified in the Delta Vision Strategic Plan as those in the Delta Plan. And it's pretty easy to see that I think you would have been better off bringing those over from the Delta Vision Strategic Plan and putting them in other examples. Because they're very clear and very succinct. They're tied to specific goals and strategies. And the current performance measures -- some of them aren't even

No comments

- n/a -

measurable in any logical way.

For example, when we're talking in chapter 7 about reducing risk, the performance measure is no lives lost. Which we can only measure after the word catastrophe. So it's impossible to measure progress towards that goal. That doesn't measure progress or accomplishment until after the fact.

The last thing I would say about performance measures is that it's an area where I think there is an inadequate commitment by the council to action in this area. There is a -- I think it's a council action in Appendix C to do a report on performance measures. But I think a more concerted commitment as to how you will develop, implement, and track and report on the performance measures will really help the plan. And I really do think all of these things can be addressed quite simply and wouldn't disrupt your environmental review process or your regulatory process. But it would communicate more clearly that there's a sense of urgency and a sense of accountability in how we implement solutions.

And lastly, let me touch on the long-term implementation. A couple of iterations of the Delta Plan, we've compared the Delta Plan with the Delta Vision Strategic Plan. And I would be remised if I didn't

RI14-15

No comments

- n/a -

highlight a couple of things that I think are still missing in the Delta Plan. Although they may be a little harder to fix on the timeframe you're on.

First, there appear to be no policies or recommendations relating reducing fish losses. Either by improving fish migration cards or reducing in trainman losses or other actions. There is one recommendation related to perdition. Sort of indirectly related to perdition. But I think this is an area -- and maybe the strategy is deferring to BDCP -- they're going to fix the fish problems, but I don't think that's the appropriate strategy with the Delta Plan. I think there could be more attention and focus on even their term with the pilot studies and programs or various things that could more specifically address fish losses.

And then second, I think the area of water quality and salinity management is another one where the policies and recommendations -- actually, there are no policies on the recommendations. If the recommendations focus on regulatory action, which is certainly an important part of the mix of action of state or regional boards is certainly important. But there have, until very recently, been a number of studies or investigations of either operational or physical changes in the Delta that could improve salinity management, barriers, I think

RI14-15

No comments

- n/a -

there's a whole host of things we can be looking at in that area. And those physical operations just don't appear in the note plan.

So with that I will conclude and send you more detailed comments on Monday.

MS. ISENBERG: Thank you very much.

RI14-15

No comments

- n/a -

KATHY MANNION

RCRC

MR. ISENBERG: Ms. Mannion is up next. And Friends of Clear Lake, I think it's Cebelean, but I cannot read the printing. And we'll clarify that later.

Ms. Mannion?

MS. MANNION: Thank you, members of the council.

Kathy Mannion, representing RCRC 32 World Counties. I'm going to be commenting today on all three documents, but I will be brief. You do have our written comments. And I understood you did not want me to repeat the comments. But what I would like to do is at least verbally go over what is contained in our comments.

MR. ISENBERG: Sure.

MS. MANNION: We did, in looking at the documents, in looking at the timeframe and the timeline, decide to limit our comments to select issues of interest where we have recommended changes.

Our first comment dealt on page Roman Numeral 15. This first set of comments is regarding the final draft Delta Plan. The Delta Plan policies and recommendations WRP-1, which is reduced reliance on the Delta and improved self-reliance. What we've done is provide language that would clarify the intent of WRP-1 by indicating that

RI14-16

Response to comment RI14-16

This is a comment on the project, not on the EIR.

you're referring to urban and agricultural water suppliers who propose to undertake a current action. And we believe that clarification is needed so not to confuse a reader as to the scope of the council's authority.

Our second comment was on page Roman Numeral 18. Again, Delta policies and recommendations WRP-1 update Delta flow in that we indicated to the council that we believe the language is confusing in that it includes ERP-1, which is a regulatory policy. And the council's recommendation that the State Water Board take certain actions by specified stakes. We indicate that we believe ERP-1 should be limited to that which is within the authority of the council and that would be that the council would utilize the existing flow objective to determine consistency with the Delta Plan, until such time as the Water Board may revise the flow objectives. RI14-16

And then I make some comments also regarding the regulatory policy, but I'll leave that for my last comments.

On page 59 lines 13 through 17 dealing with covered actions, consistency appeals, chapter 2 of the Delta Plan. This is in regards to the appeals. We believe that given that the council is charged with making the determination of consistency, allowing a member of the council or a staff member to file an appeal raises a

No comments

- n/a -

variety of questions. And we would recommend that the plan, in order to maintain the objectivity of the plan, should instead specifically state that the members of the council and the staff may not file an appeal in regards to the certification of the consistency. You can see the issue there.

Then on page 108, lines 15 to 20, WRP-1, reduced reliance on the Delta and improve regional self-reliance, chapter 3, and more reliable water supply for California, we again refer you to our recommended changes for language --

MR. ISENBERG: This is the language you're going to be stating in writing?

MS. MANNION: Currently you have that. That's why I don't want to repeat the exact language in the interest of time.

And then we also commented on page 155, 156, lines 37 through 10, ERP-1. Again, update the Delta flow objectives. Chapter 4, protect, restore and enhance the Delta ecosystem. Again, referring you to our previous comments in the same comment letter regarding the inclusion of what our recommendations in ERP-1. So you have that document.

RI14-16

Next to the recirculated draft Delta Plan, PEIR. First would just comment that we did submit extensive

RI14-17

Response to comment RI14-17

Please refer to the response to the speaker's comment letter, ROR017.

comments previously. And many of those comments, in fact, just about all of them would still apply. But, again, our comments are very focussed.

On page 3-2, lines 29 through 37, underwater resources, we are proposing some language that would clarify in the discussion in regards to the areas upstream of the Delta and proposing a change in the language which would clarify, we believe, what should be intended there.

And our language that we've submitted, it really conforms to other verbiage in the document. And we feel it would eliminate potential confusion, and on the part of the reader as to the scope of the council's authority.

On page 3-7 and 3-8, lines 27 through 4, dealing with water resources. We are recommending that various statements contained in those lines, lines 27 through 4, as to the assumed outcome of the State Water Board's decision relating to the Delta Plan, that those be deleted.

RI14-17

Essentially, for example -- and I've given several examples. There's a statement that these water quality changes would benefit native species that evolved with a natural flow regime, that the objectives would seek to emulate. In other words, you're assuming as to what the final decision by the Water Board is going to be. So we're suggesting also that you might alternatively use the

No comments

- n/a -

terms "if" and "could." As the use of those terms would conform with language found in other sections of the DEIR.

And recognizing that the DEIR has multiple authors. You have different verbiage here and there. And we did find that the use of the term "apply" can be found in various sections of the document. And in other sections of the document there's the use of the word "encourage." We feel that the word "encourage" provides greater clarity and consistency. And we would ask that you look through the various sections and biological resources, Delta flood risk --

MR. ISENBERG: So you're suggesting using the word "encourage" as opposed to "apply"?

MS. MANNION: Yes. And it's usually associated with the discussion of the water supply that would have conformity in the document, and we feel would be clearer and add clarity.

RI14-17

And then on page 4-11, line 2 dealing with biological resources. Again, there is an assumption as to the end result of the Water Board's updating of the Bay Delta Plan. And at a minimum we would recommend that "would" would be replaced -- would be replaced by "could." So that there's not this assumption.

RI14-18

Then as to the notice of proposed rule making we have indicated in our previous letters concern in regards

RI14-19

Response to comment RI14-18

The EIR includes reasonable assumptions about future outcomes throughout its analysis. As described in Master Response 2, CEQA provides for such assumptions (Public Resources Code §§ 21080, 21080.2; CEQA Guidelines §§ 15144 [preparing an EIR requires some degree of forecasting], 15126.2(a) [direct and indirect significant effects of the project must be clearly identified and described]). Accordingly, the referenced use of "would" is appropriate.

Response to comment RI14-19

This is a comment on the project, not on the EIR.

to the lack of clarity in the Delta Plan, and that that could have been flow over to the regulations. And I believe that we have seen that as a result of the Delta Plan language itself. And the crux of the problem we've identified is the co-mingling of the Delta Plan regulatory policy with Delta Plan recommendations. In the proposed regulations. And we've provided several examples.

The first example is the co-mingling that can be found in the definition of achieving the coequal goals of providing a more reliable water supply in California. And then just as an example, we find the definition of WRP-1, which is a regulatory policy, and WRR-1 and WRR-4, both of which are contained in the Delta Plan as recommendations.

RI14-19

Another example is section 5005, which is to reduce reliance on the Delta through approved regional water self-reliance. We've looked at that, we're recommending that sections 505 A and B of the proposed regulations be deleted. We found that 505 C, D and E and section 505-2 are germane from within the scope of the council's regulatory authority. So we propose the changes there.

Our last example is in 5007, update Delta flow objectives. Section 5007 A and B are recommendations contained in the Delta Plan. We therefore feel that

No comments

- n/a -

they're inappropriately included in the regulations and we're proposing that they should be deleted. And we've also provided revised language to section 5007 C. And that, again, provides some clarity as to the authority of the Water Board and what point in time the Stewardship Council would utilize the flow objectives.

And so that's our comments.

MS. ISENBERG: Thank you, Ms. Mannion. And thank you for putting a lot of the stuff in writing in advance in other documents. It's the only way we can be sure of trying to keep track of the points you're making. We appreciate it.

Thank you.

RI14-19

No comments

- n/a -

JOHN CEBELEAN

FRIENDS OF CLEAR LAKE, INC.

MR. ISENBERG: Doctor, come up here and spell the name so I can write it out and on our reporter transcript we can make sure to get your name correctly.

MR. CEBELEAN: Thank you very much. Don't worry about it.

MR. ISENBERG: No, I gotta worry about it. I noticed your NASA name on your coat.

MR. CEBELEAN: Yes, my name is John Cebelean or Dr. Cebelean.

MR. ISENBERG: How about spelling it for me.

MR. CEBELEAN: C-E-B-E-L-E-A-N. Simple.

MR. ISENBERG: Okay. Got it.

MR. CEBELEAN: We're ready?

MR. ISENBERG: Yes, sir.

MR. CEBELEAN: I'll try not to give you a headache. There were too many behind me that I got tired of. I'm from Mila (phonetic) County from the most beautiful lake in the world. You, for whatever reason, you do not know the seriousness that Clear Lake is producing to Delta. And I wonder why. I was at your inauguration, and the first meeting after I had a chance to address to you, and I did. I believe I left a serious

RI14-20

Response to comment RI14-20

Comment noted.

warning at the time that there we have a serious problem that extends not only one place, but for many places, and gets all together into one nest. And that's the Delta.

How in the world, I wonder -- and this is a question that you will be able to provide -- have the drinking supply water, uncontaminated the public without to remediate the problem that is causing the problem to the Delta. Unless you know who is causing the problem to solve the problem, what is the accomplishment? This is what I question.

Why are you not aware that Clear Lake alone sells you for nothing, one metric ton of mercury a year, plus arsonic, Biotone, Valium, putting in plenty of bacteria and plenty of agent orange. Using our water for mediate the aquatic plans in the water we drink, we consume. Why nobody pays any attention to this? This is what I'm going to assist. I am providing you with sufficient written material. Take a look. Seriously, Clear Lake provides 60 percent of the mercury to the Delta. Then you have additional one, item line 10, but other heavy metal toxins than mercury. But you do have an mine which is totally unexplored. If the agents went into it and put a ten foot fence around, but it is leaking into the Delta also. I'll provide you this written material.

MR. ISENBERG: We will post them on the web. Do

RI14-20

No comments

- n/a -

you think they're capably scanned and reproduced easily? If they're maps or diagrams it's sometimes hard for us to reproduce a paper quality.

MR. CEBELEAN: Yes, you will be able. You are dealing with the most researched lake ever since 1947 up to the present time. UC Davis just finished 116 years of research on. The headache is still there. So I can provide you with any detailed information you would like.

MR. ISENBERG: If you could leave us a copy.

MR. CEBELEAN: Yes. I have two articles that I published and describes everything you want to know. The problem is in my articles.

MR. ISENBERG: Okay. At the end of your testimony --

MR. CEBELEAN: And I have a card here with all information for you to get in touch with me.

MR. ISENBERG: Okay. And the young lady back there with blond hair will take that packet of material and see that it's posted.

MR. CEBELEAN: Well, I hope she'll post it properly. So, I better hit the road because I have an additional three hours to go back. But it has been all warranted. Thank you very much.

MR. ISENBERG: Pleasure to see you. Thank you, Doctor.

RI14-20

No comments

- n/a -

LINDA DORN

SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT

MR. ISENBERG: Okay. The next speaker is Linda Dorn, and Doug Wallice is the last person.

MS. DORN: Good afternoon, Chair Isenberg and Council Member Notolli. The brief in my comments, they will be both on the EIR recirculated, the EIR, and the Delta Plan. But we're submitting detailed written comments. And I wish I could say they were to you already. I'd have a better weekend.

MR. ISENBERG: The fact that you are doing it and have had comments before it, makes our job measurably better by having stuff to compare to the written comments and focus them on. So thank you for doing that.

MS. DORN: So I'll be brief. Actually my comments are two requests. And the first request has to do with financing the Delta Plan. And the second request has to do with development of the Delta Science Plan. The second one is probably more related to the Delta Plan, but there's a relationship to be circulated to the IR. And in going through both the Delta Plan and the EIR, it became very apparent to me how important this area of agency will be. Specifically in developing a finance plan.

And the interagency implementation committee will

RI14-21

Response to comment RI14-21

This is a comment on the project, not on the EIR.

be stated in federal agencies and will look at developing work routes specifically to finance client development. So our request is on actually behalf of the Waste Water Agencies throughout the state to participate on any work group that is foreign through the interagency committee for developing a finance plan. And if there was an ability to have associations represented on that committee, we would recommend the statewide association for various associations to be a part of it.

Also I think that because the discussion of funding options for the finance plan has had a focus on other stressor fees, that waste water discharges have been discussed in that frame. And we have a very good understanding of fees and structuring of them and how you work with Prop 218. So the knowledge that we have as an industry could be helpful on this committee. It's not just to cause trouble.

RI14-21

The second request is to also participate. And that is in the development of the Delta Science Plan. Now, I know that there has been a lot of discussion and that Peter Goodwin had been directed with some flame put to his feet on coming up with an outline in moving forward quickly on this. I'm not sure that's the best approach. A good Delta Science Plan could take some time. And particularly the more folks and stakeholders that you

RI14-22

Response to comment RI14-22

This is a comment on the project, not on the EIR.

would involve in it would make you take more time, but you would end up with better plan in the end.

We've been speaking with Peter Goodwin, so it's not like this request is coming out of the blue. I also participated in the Delta Science Conference.

MR. ISENBERG: Where they have the luncheons town home meetings?

MS. DORN: Yes. We participated in that and filled out the form. So I'm making sure the request is made here in relationship to the Delta claim and EIR.

We also made presentation at the State Water Board's flow meeting that happened this past fall where we focused on the importance of integrated science to coordination and collaboration. And that's another reason why we're requested to participate in the Delta Science Plan.

RI14-22

We're also currently participating as a stakeholder on the steering committee for developing a Delta Regional Monitoring Program in relationship to water quality, but could be more. So I think that's another good reason for having a Sacramento Regional County participate in the development of Delta Science Plan.

And that's really all I have for comments to request.

MR. ISENBERG: Thank you very much.

No comments

- n/a -

Mr. Wallice? I saw you somewhere. Where are you?

MR. NICKEL: He had to leave.

MR. ISENBERG: Okay. Mr. Nickel, are you going to present his testimony?

Well, let's, Members, for the record, let's note that Mr. Doug Wallice, representing the East Bay Municipal Utility District based in Oakland had wanted to testify on the rule making -- and I can't read his handwriting. It's either rule making exchange or rule making garbage or something. I just can't read what he put. And I put on the form that he had to leave and is not able to testify.

Mr. Nickel, as punishment for raising your hand on the issue, will you please call him and urge him to submit any written comments to explain what he wanted to say here in time for our deadline? I would appreciate that.

Any other blue forms?

Okay. Ladies and gentlemen, thank you very much for coming. As you know, this meeting was suggested by Supervisor Notolli. And I think it was a wise suggestion to give another opportunity to some who do not plan on submitting written comments but also wanted to say other things or early things. And this has been useful to our staff.

RI14-23

Response to comment RI14-23

Comment noted.

And just a reminder on next council meeting, which is the 24th of January and it's in West Sacramento, is my recollection, in regular location at the Radisson Hotel -- Ramada Inn in West Sacramento, we'll be conducting a hearing focused on rule-making portion.

There will be other council business, of course. But there will be a special hearing with a court reporter, and that portion will be directed to the rule-making hearing.

Let's see, our general council was working in the back.

Mr. Stephens, what does a hand raised, waiving back and forth mean? We're okay?

MR. STEPHENS: I think we're doing good.

MR. ISENBERG: In the absence of other people submitting forms to speak to the council, ladies and gentlemen, thank you very much. The meeting is adjourned. We appreciate your time.

(Whereupon the meeting was adjourned at 3:37 p.m.)

RI14-23

No comments

- n/a -

REPORTER'S CERTIFICATE

STATE OF CALIFORNIA)
) ss
COUNTY OF SACRAMENTO)

I, JILLIAN M. BASSETT, a Certified Shorthand Reporter, licensed by the state of California and empowered to administer oaths and affirmations pursuant to Section 2093 (b) of the Code of Civil Procedure, do hereby certify:

The said proceedings were recorded stenographically by me and were thereafter transcribed under my direction via computer-assisted transcription;

That the foregoing transcript is a true record of the proceedings which then and there took place;

That I am a disinterested person to said action.

IN WITNESS WHEREOF, I have subscribed my name on January 28, 2013.

____
JILLIAN M. BASSETT
Certified Shorthand Reporter No. 13619

No comments

- n/a -

Delta Flow Criteria Informational Proceeding

Before the

State Water Resources Control Board

Scheduled to Commence
March 22, 2010

Exhibit CCWD-6

Historical Fresh Water and Salinity Conditions
in the Western Sacramento-San Joaquin Delta and Suisun Bay

Technical Memorandum WR10-001
Contra Costa Water District
Water Resources Department
February 2010

Submitted on behalf of

Contra Costa Water District
P.O. Box H2O
Concord, CA 94524

No comments

- n/a -

Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay

A summary of historical reviews, reports, analyses and measurements

Water Resources Department

Contra Costa Water District

Concord, California

February 2010

Technical Memorandum WR10-001

Exhibit CCWD-6

No comments

- n/a -

Acknowledgements

CCWD would like to thank the City of Antioch for their contribution towards funding a technical review of CCWD's draft report "Trends in Hydrology and Salinity in Suisun Bay and the Western Delta" (June 2007); their review substantially improved the work and led to the final report "Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay". CCWD is grateful to the many reviewers including Richard Denton, Matthew Emrick, Gopi Goteti, Phil Harrington, E. John List, Susan Paulsen, David Pene, Mat Rogers, and Peter Vorster. We also thank the following for sharing their data and analyses: Roger Byrne, Chris Enright, Spreck Rosekrans, and Scott Starratt, and we thank Ann Spaulding for her contributions.

No comments

- n/a -

Foreword - Establishing the Historical Baseline

The watershed of the Sacramento–San Joaquin Delta (Delta) provides drinking water to more than 23 million Californians as well as irrigation water for millions of acres of agriculture in the Central Valley. The Delta itself is a complex estuarine ecosystem, with populations of many native species now in serious decline. The Delta estuary as we know it began to form about 6,000 years ago, following the end of the last ice age. Because the estuary is connected to the Pacific Ocean through San Francisco Bay, seawater intrusion causes the salinity of Suisun Bay and the Delta to vary depending on hydrological conditions. This seawater intrusion into the Delta affects estuarine species as well as drinking water and irrigation water supplies.

Successful restoration of the Delta ecosystem requires an understanding of the conditions under which native species evolved. Contra Costa Water District's report on "Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay" presents a detailed review of more than 100 years of studies, monitoring data, scientific reports, and modeling analyses that establish an historical record of the salinity conditions in the Western Delta and Suisun Bay.

No comments

- n/a -

No comments

- n/a -

Executive Summary

The historical record and published studies consistently show the Delta is now managed at a salinity level much higher than would have occurred under natural conditions. Human activities, including channelization of the Delta, elimination of tidal marsh, and water diversions, have resulted in increased salinity levels in the Delta during the past 150 years.

Eighty years ago, Thomas H. Means wrote ("*Salt Water Problem, San Francisco Bay and Delta of Sacramento and San Joaquin Rivers*," April 1928, pp 9-10):

> "Under natural conditions, Carquinez Straits marked, approximately, the boundary between salt and fresh water in the upper San Francisco Bay and delta region of the two tributary rivers—the Sacramento and San Joaquin. Ordinarily salt water was present below the straits and fresh water was present above. Native vegetation in the tide marshes was predominately of salt water types around San Pablo Bay and of fresh water types around Suisun Bay....
>
> The definite statement that salt water under natural conditions did not penetrate higher upstream than the mouth of the river, except in the driest years and then only for a few days at a time, is warranted....
>
> At present [1928] salt water reaches Antioch every year, in two-thirds of the years running further [sic] upstream. It is to be expected that it will continue to do so in the future, even in the years of greatest runoff. In other words, the penetration of salt water has become a permanent phenomenon in the lower river region.
>
> The cause of this change in salt water condition is due almost entirely to the works of man."

In 1928, Thomas Means had limited data over a short historical period from which to draw these conclusions. Nonetheless, his conclusions remain accurate and have been confirmed by numerous subsequent studies, including paleosalinity records that reveal salinity conditions in the western Delta as far back as 2,500 years ago. The paleosalinity studies indicate that the last 100 years are among the most saline of periods in the past 2,500 years. Paleoclimatology and paleosalinity studies indicate that the prior 1,500 years (going back to about 4,000 years ago) were even wetter and less saline in San Francisco Bay and the Delta. The recent increase in salinity began after the Delta freshwater marshes had been drained, after the Delta was channelized and after large-scale upstream diversions of water, largely for agricultural purposes, had significantly reduced flows from the tributaries into the Delta. It has continued, even after the construction of reservoirs that have been used in part to manage salinity intrusion.

No comments

- n/a -

Increased Salinity Intrusion into the Delta

Studies and salinity measurements confirm that despite salinity management efforts, Delta salinity is now at or above the highest salinity levels found in the past 2,500 to 4,000 years. Under equivalent hydrological conditions, the boundary between salt and fresh water is now 3 to 15 miles farther into the Delta than it would have been without the increased diversions of fresh water that have taken place in the past 150 years.

Reservoir operations artificially manage salinity intrusion to conditions that are saltier than had been experienced prior to the early 1900's. While these managed conditions are certainly fresher than would occur in today's altered system if operated without any salinity management, they are still saltier than what the Delta experienced under similar hydrological conditions in the past. While the Delta is being managed to a somewhat acceptable saline condition to meet many beneficial uses, it is still managed at a more saline condition than would have occurred prior to the anthropogenic changes of the past 150 years.

For example, the 1928-1934 drought was one of the driest periods in the past 1,000 years (Meko *et al.*, 2001a), and occurred after tidal marshes within the Delta had been reclaimed and water diversions began removing substantial amounts of fresh water from the Bay-Delta system. Nonetheless, the Delta freshened during the winter in those drought years. This winter freshening of the Delta has not occurred during recent droughts. While salinity intrusion into the Delta was previously only seen in the driest years, significant salinity intrusion now occurs in nearly every year – exceptions are only found in the wettest conditions.

Changed Variation in Salinity

The variability of fresh and saline conditions in the Delta has considerably changed because of upstream and in-Delta water diversions and water exports (Enright and Culberson, 2009). This change in variability results largely from the lack of fresh conditions in Suisun Bay and the western Delta, especially in the winter and spring. Restoring a variable salinity regime that more closely approximates conditions prior to the early 1900's would require much higher flows and much fresher conditions than current management practices provide, with larger outflows in the fall in most years and much larger outflows in the late winter and spring in all years.

Key Conclusions

The major conclusions of this study are:

1. Salinity intrusion during the last 100 years has been among the highest levels over the past 2,500 years. The Delta has been predominantly a freshwater tidal marsh for the last 2,500 years.
2. Human activities during the last 150 years, including channelization of the Delta, elimination of tidal marsh, construction of deep ship channels, and diversion of water, have resulted in the increased salinity levels in the Delta.

No comments

- n/a -

3. Conditions in the Delta during the early 1900's were much fresher than current conditions for hydrologically similar periods. Salinity typically intrudes 3 to 15 miles farther into the Delta today.
4. The historical record and published studies uniformly demonstrate and conclude the Delta is now managed at a salinity level that is much higher than would have occurred under pre-1900 conditions. Operation of new reservoirs and water diversion facilities for salinity management reduces salinity intrusion somewhat, but the levels still exceed pre-1900 salinities.
5. Seasonal and inter-annual variation in salinity has also been changed; however, this change is largely the result of reduced freshwater flows into the Delta. At any given location in the western Delta and Suisun Bay, the percentage of time during the year when fresh water is present has been greatly reduced or, in some cases, largely eliminated.

Background

Flows and water quality in the Sacramento-San Joaquin Delta (Delta) are strongly influenced by freshwater inflow from the rivers, by the tides in San Francisco Bay and by salinity from Bay waters. Prior to human influence, the historical distribution of salinity in the Delta was controlled primarily by the seasonal and inter-annual distribution of precipitation, the geomorphology of the Bay and Delta, daily tides, the spring-neap[1] tidal cycle, and the mean sea level at Golden Gate. Extended wet and dry periods are both evident in the historical record. Since about 1860, a number of morphological changes to the Delta landscape and operational changes of reservoirs and water diversions have affected flows and the distribution of salinity within the Delta.

Between 1860 and 1920, there was significant modification of the Delta by humans:
(i) marsh land was reclaimed,
(ii) hydraulic mining caused extensive deposition and then erosion of sediment, and,
(iii) Delta channels were widened, interconnected and deepened.

Large-scale reservoir construction began in about 1920 and continued through the 1970's, changing the timing and magnitude of flows to the Delta. Large volumes of water began to be diverted for agricultural use upstream of and within the Delta in the same time period. In more recent times, California's Delta water resources have been extensively managed to meet the water supply needs of the State's municipal, industrial, and agricultural water users, with attempts made to also provide flow and water quality conditions to meet fishery needs.

Proposals for significant additional alteration of the Delta and of flows within the Delta are currently being developed as part of the Bay-Delta Conservation Plan process[2]. To

[1] During a spring tide, the gravitational forces from the sun and moon are largely the same direction and the high-low tidal range is greatest. During a neap tide, the gravitational forces sun and moon are largely not aligned and the tidal range is the lowest. The spring-neap tidal cycle, from strong spring tides through weak neap tides and back to spring tides, in San Francisco Bay has a period of about 14 days.
[2] www.baydeltaconservationplan.com

No comments

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understand the effect of those proposals, it is important to accurately establish historical conditions. For example, for ecological restoration to be successful, it is necessary to establish and understand the conditions to which native species have previously adapted and survived in order to predict their response to future changes in climate or water management. This report uses available data and modeling to examine the consequences of structural changes in the Delta (channelization, channel dredging), increased diversions of water upstream of the Delta, reservoir operations, climate and sea level effects, and other factors on Delta salinity.

Objective

The objective of this report is to answer two major questions regarding the historical extent of fresh water and salinity in the western Delta and Suisun Bay:

I. What was the extent of fresh water and what were the salinity conditions prior to large-scale reservoir operations and water diversions (i.e., prior to early 1900's) and prior to structural changes in the Delta (i.e., prior to the 1860's)?

II. What are the effects of large-scale water management practices (reservoir operations and diversions) on salinity conditions in the western Delta and Suisun Bay?

Approach

Available data were used to characterize historical and present-day fresh water extent and salinity intrusion into the Delta. The data examined in this report include paleohistorical records (over geologic time scales) of river flow and salinity (Section 2), instrumental observations of hydrology and salinity (Section 3), and literature reports on the extent of fresh water in the Delta (Section 4). Additional details and supplemental information are presented in the Appendices to this report.

No comments

- n/a -

Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay

No comments

- n/a -

No comments

- n/a -

Tables

Figures

No comments

- n/a -

No comments

- n/a -

Acronyms

C&H	California and Hawaiian Sugar Refining Corporation
CCWD	Contra Costa Water District
CDEC	California Data Exchange Center
Cl	Chloride concentration
CVP	Central Valley Project
DPW	Department of Public Works
DSM2	Delta Simulation Model 2
DWR	California Department of Water Resources
DWSC	Deep water ship channel
EC	Electrical conductivity
ENSO	El Niño/Southern Oscillation
ESA	Endangered Species Act
IEP	Interagency Ecological Program
M&I	Municipal and Indutrial
NDO	Net Delta Outflow
PDO	Pacific Decadal Oscillation
PPIC	Public Policy Institute of California
SWRCB	State Water Resource Control Board
SRI	Sacramento River Index
STORET	Storage and Retrieval
SWP	State Water Project
TBI	The Bay Institute
TDS	Total Dissolved Solids

Units

AF	Acre-feet
MAF	Million acre-feet
TAF	Thousand acre-ft
µS/cm	MicroSiemens per centimeter, a measure of EC
cfs	Cubic feet per second
mg/L	Milligrams per liter
ppm	Parts per million
ppt	Parts per thousand

No comments

- n/a -

No comments

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1. Introduction

1.1. Background

The Sacramento-San Joaquin River Delta (Delta) is fed by fresh water from the Sacramento River and the San Joaquin River basins (Figure 1-1). The Delta is connected to the San Francisco Bay through Suisun and San Pablo Bays, and the movement of water back and forth between the Delta and the Bay results in mixing between saline water from the Pacific Ocean and fresh water from the rivers flowing into the Delta. The extent to which salty ocean water intrudes into the Delta is a function of natural processes such as ocean tides and precipitation and runoff from the upstream watersheds. It has also been greatly influenced by anthropogenic activities (e.g. construction of artificial river channels, removal of tidal marsh, removal of floodplain connections to channels, deepening of channels for navigation purposes, reservoir storage and release operations, and water diversions).

Proposals for significant additional alteration of Delta channels and marshland, of flows within the Delta, and of reoperation of upstream reservoirs are currently being developed as part of the Bay-Delta Conservation Plan, which builds upon earlier work by the Delta Vision Blue Ribbon Task Force[3], and others (e.g., see Lund *et al.*, 2007). To understand the context and effect of those proposals, it is important to accurately understand the historical conditions previously experienced by Delta species.

An analysis of the salinity trends and variability in northern San Francisco Bay since the 1920's and the factors controlling those salinity trends has recently been published (Enright and Culberson, 2009), with a focus on a comparison of pre-1968 salinity and flows with post-1968 conditions. This report includes analysis and review of reports, data and information from the period prior to Enright and Culberson's analysis, and includes the review of salinity trends using paleohistorical data.

Historically, reproduction of most species in the Bay-Delta (biotic production phase) occurred during the high-flow periods (winter and spring) and biotic reduction occurred in the low-flow periods (summer and fall) (Baxter *et al.*, 2008). Multi-year wet periods most likely resulted in population increases, whereas drought periods likely resulted in reduced reproduction and increased predation. The recent report on Pelagic Organism Decline (POD, Baxter *et al.*, 2008) indicated that reduced flow variability under the current water management conditions may have exacerbated the effects of predation on the population abundance of pelagic fish species in the Bay-Delta estuary. Native species of the Bay-Delta system adapted to the historical salinity conditions that occurred prior to large-scale water management practices and physical changes in the Delta. The historical salinity conditions in the Delta provide insight into the response of fish species to proposed ecosystem restoration actions, and the response of species to future changes in climate or water management.

[3] Delta Vision Blue Ribbon Task Force was appointed by California Governor Arnold Schwarzenegger in February 2007 and adopted the Delta Vision Strategic Plan in October 2008.

No comments

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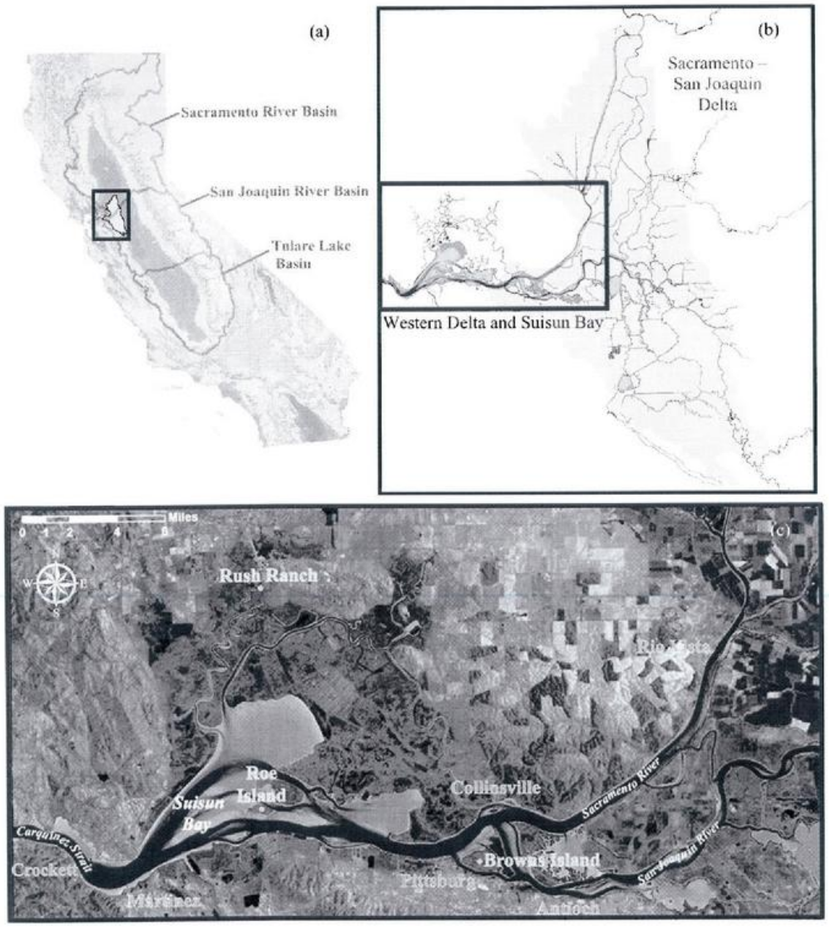

Figure 1-1 – Map

(a) Topographical map of California, with outlines of the Sacramento River, San Joaquin River, and Tulare Lake basins; purple rectangle indicates the extent of the inset in panel (b). (b) Sacramento – San Joaquin Delta and Suisun Bay region; green rectangle indicates the extent of the Western Delta and Suisun Bay enlarged in panel (c). (c) Extent of salinity evaluations considered within this study, including names of locations referenced throughout this report.

No comments

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The salinity concentrations in San Francisco Bay and the Delta are the result of tides that move seawater into the system and are controlled in large part by the amount of fresh water passing through the system (Denton, 1993; Uncles and Peterson, 1996; Knowles *et al.*, 1998). The salinity distribution is driven by the motion of the tides, which convey ocean water into the system on the flood tide and draw a mixture of ocean and river water back out again on the ebb tide. These tides act on natural diurnal (repeating twice per day) and spring-neap (repeating every 14 days) cycles driven by the gravitational forces of the sun and moon (Oltmann and Simpson, 1997; Burau *et al.*, 1999).

Other factors affecting Bay-Delta salinity (discussed in Appendix A) may be smaller but are not insignificant. When comparing historical salinity conditions in the Bay-Delta watershed, it is often helpful to compare periods with similar hydrological conditions so that the changes due to other factors can be discerned. This will reveal if there is an anomalous change in salinity, even if the specific cause of that change in salinity is not known.

Major anthropogenic modifications to the Delta that affect salinity intrusion began with the European settlement of the region and can be classified into two categories: physical modifications of the landscape (e.g., removal of tidal marsh, separation of natural floodplains from valley rivers, construction of permanent artificial river channels, and land-use changes) and water management activities (e.g. diversion of water for direct agriculture, municipal, or industrial use, and reservoir storage and release operations).

As shown in Figure 1-2, tidal marsh acreage in the Delta decreased significantly from nearly 346,000 acres in the 1870's to less than 25,000 acres in the 1920's and has since continued to decrease. Even after hydraulic mining for gold was banned in California in 1884, large quantities of mining debris continued to be carried by runoff into the Delta, where it was deposited as sediment, filling channels in the Delta and Suisun Bay. Between 1887 and 1920, Suisun Bay became an erosional environment and continued to lose sediment through 1990. Enright and Culberson (2009) discuss the effects of the changes in Suisun Bay bathymetry on salinity intrusion. Major dredging projects on the main Delta channels to create the Stockton and Sacramento Deep Water Ship Channels (DWSC) have also changed how flows and, therefore, salinity are distributed throughout the Delta.

Each of these factors has changed the salinity regime: loss of tidal marsh lands has allowed increased tidal energy deeper into the Delta, increasing tidal flows and salinity dispersion (Enright and Culberson, 2009), net erosion and increasing depth within Suisun Bay likely increased dispersive transport of salt up the estuary (Enright and Culberson, 2009), and deeper channels allow increased salinity intrusion due to increased baroclinic circulation and increased tidal flow and dispersion..

However, these physical modifications generally have had less effect on salinity intrusion in the Delta than the major water management activities that have resulted in large-scale diversion of water for reservoir storage and agricultural, domestic, and industrial water use (Nichols *et al*, 1986; Knowles, 2002). As will be seen in data presented in this document, early diversions before large-scale storage projects resulted in greatly increased salinity intrusion, especially in the summer irrigation season, peaking in September. Later, reservoir operations reduced salinity intrusion in the summer and fall, but increased it in the winter and

No comments

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spring, up until the mid-1980's. Subsequent water operations have resulted in increased salinity intrusion year round.

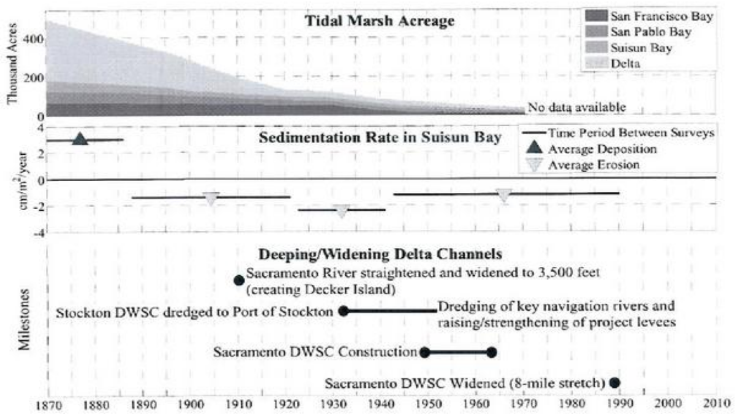

Figure 1-2 – Chronology of anthropogenic modifications to the Bay-Delta landscape

Bay-Delta landscape has undergone significant changes since the mid-1800's. Tidal marsh acreage (top panel) has been significantly reduced (data from Atwater, et al., 1979). Suisun Bay received a pulse of sediment from hydraulic mining in the late 1800's (middle panel), but lost sediment from 1887 to 1990 (data from Cappiella et al., 1999). Numerous efforts to widen and deepen the main channels within the Delta have occurred throughout the 20th Century (bottom panel).

The largest reservoir of the federal Central Valley Project (CVP), Lake Shasta, was completed in 1945, and the largest reservoir of the State Water Project (SWP), Lake Oroville, was completed in 1968. Total upstream reservoir storage capacity increased from 1 MAF in 1920 to more than 30 MAF by 1979. The CVP began exporting water from the southern Delta through Jones Pumping Plant (formerly known as the Tracy Pumping Plant) in 1951, and the SWP began exports through Banks Pumping Plant in 1968. By 1990, the combined export of water from the southern Delta through the Banks and Jones Pumping Plants was about 6 MAF per year.

Figure 1-3 shows that the greatest increase in upstream reservoir storage occurred from the 1920's through the 1960's. Prior to the construction of major water management reservoirs, irrigated acreage grew to about 4 MAF. The construction of the reservoirs allowed irrigated acreage to increase to about 9 MAF. Since 1951, when the first south Delta export facility was completed, annual diversions from the Delta have increased to a maximum of about 8 MAF; total annual diversions from the system are estimated at up to 15 MAF.

No comments

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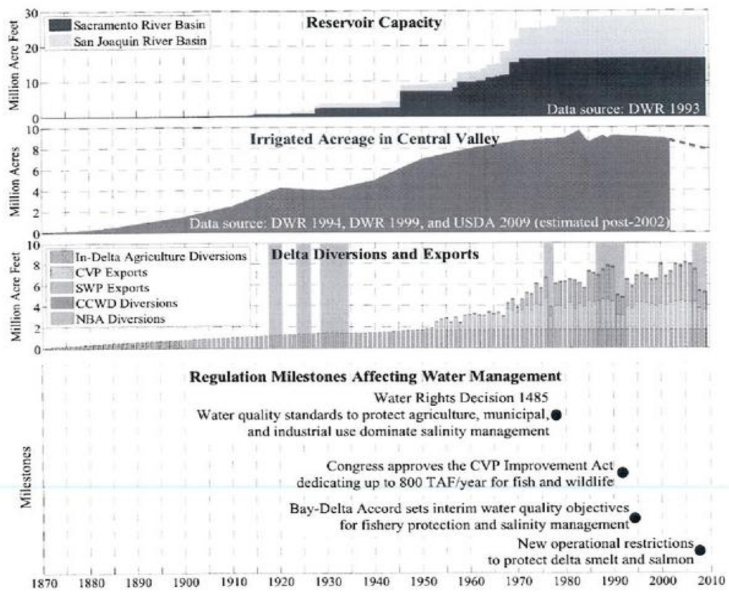

Figure 1-3 – Chronology of anthropogenic activities that affect water management

Reservoirs (top panel) and irrigated crops in the Central Valley (second panel) alter the timing and magnitude of water flow to reach the Delta. Diversions and exports within the Delta (third panel) further reduce the amount of water to flow through the Delta to Suisun Bay. Regulations (bottom panel) require modifications to water management activities to meet specific flow and water quality objectives.

Figure 1-3 also presents the timeline for recent regulatory milestones that have affected Delta water quality. Salinity management was dominated by water quality standards to protect Delta agriculture and municipal and industrial (M&I) uses in the 1978 Water Quality Control Plan and State Water Resources Control Board (SWRCB) Decision 1485. The Bay-Delta Accord of 1994 and subsequent SWRCB Water Rights Decision 1641 made fishery protection the dominant factor for salinity management with new estuarine habitat or "X2 Standards"[4] from February through June, with minimum outflows for the remainder of the

[4] X2 is the distance, in kilometers from the Golden Gate, to the location of the 2 part per thousand salinity line. A larger X2 means salinity has intruded farther into the Delta.

No comments

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year. The relationship between X2 and estuarine habitat is discussed in detail in Jassby *et al.* (1995).

These regulations apply throughout the year and have modified how the large-scale water management reservoirs and export facilities are operated. For instance, delta smelt was listed as a threatened species under the federal Endangered Species Act in 1993, and Sacramento River winter-run salmon was listed as endangered in 1994. The subsequent biological opinions, 1994 Bay-Delta Accord, and the adoption of a new water quality control plan by the State Water Resources Control Board in 1995, required increased reservoir releases in some months for temperature control in the Sacramento River below Shasta and for salinity control in Suisun Bay. They also applied additional limits on pumping at the export facilities in the south Delta.

Changes in water diversions and reservoir operations have altered the magnitude and timing of river flows to the Delta, and anthropogenic modifications to the Delta landscape have altered the interaction of fresh water from the rivers with salt water from the ocean, thus changing patterns of salinity intrusion into the Delta.

1.2. Comparing Historical Conditions

Flow and salinity conditions prior to human interference varied according to seasonal and annual hydrological conditions, short-term and long-term drought cycles and other natural changes, so "natural" conditions include variability that must be considered in any analysis. Hydroclimatic variability is described by "unimpaired" runoff, which represents the natural water production of a river basin, unaltered by water diversions, reservoir storage and operation, and export of water to or import of water from other basins.

As discussed above, large-scale water management operations during the last 100 years superimposed on the anthropogenic modifications to the Delta landscape have significantly changed Delta conditions. It is possible to remove the effect that water management operations have had on flows and generate a corresponding set of unimpaired flows. However, it is not possible, without complex assumptions and modeling, to also remove the additional effect of the land use, channel and tidal marsh modifications to the Delta.

The historical conditions presented in this report have been determined from records in paleoclimatic fossils and measured directly with various scientific instruments. The paleoclimatic data start well before human influence, but continue through the 20th Century when anthropogenic modifications became significant.

Because of the natural hydroclimatic variability, no past historical period may fully represent "natural" conditions. Therefore, this report summarizes the available historical salinity information with reference to the time period of the observations, and then compares each period to the salinity regime during present day periods with similar upstream unimpaired hydrology. Where there are significant changes in salinity, despite similar upstream unimpaired hydrology, other factors such as landscape modifications and water management operations must be contributing factors.

No comments

- n/a -

1.3. Objective

The objective of this report is to answer two major questions regarding the historical extent of fresh water and salinity in the western Delta and Suisun Bay:

I. What was the extent of fresh water and what were the salinity conditions prior to large-scale reservoir operations and water diversions (i.e., prior to early 1900's) and prior to structural changes in the Delta (i.e., prior to the 1860's)?

II. What are the effects of large-scale water management practices (reservoir operations and diversions) on salinity conditions in the western Delta and Suisun Bay?

1.4. Report Structure

The remainder of this report is organized as follows:

Section 2: Paleoclimatic Evidence of the Last 10,000 Years

Estimated river flow data and salinity records for the past several thousand years have been obtained from paleoclimatic records, such as tree rings and sediment cores. These records capture the hydroclimatic variations over decadal and centennial time scales and are useful tools in understanding the freshwater flow and salinity regimes before modern instrumentation.

Section 3: Instrumental Observations of the Last 140 Years

Long-term precipitation and river runoff records from the 1870's to the present provide context for the salinity observations. Climatic variability of precipitation and runoff in the upper watershed has a significant influence on salinity intrusion, with greater salinity during dry periods and lower salinity during wet periods. If, for example, the salinity is greater or less than what would be expected based on the natural climatic variability, as measured by unimpaired runoff, other factors must be influencing salinity intrusion.

Reservoir operations, diversions and consumptive use (collectively termed "water management") alter the amount of runoff from the upper watershed that actually flows out of the Delta. Observations and common computer models are used to assess the effects of this water management on Net Delta Outflow (the net quantity of water flowing from the Delta to the Suisun Bay) and on salinity in the western Delta and Suisun Bay. Observations include measurements of salinity indicators by the California & Hawaiian Sugar Refining Corporation (C&H) from the early 1900's and long-term monitoring data from the Interagency Ecological Program (IEP). Modeling tools include the DAYFLOW program from IEP, the DSM2 model from the California Department of Water Resources, the X2[5]

[5] X2 is defined as the distance from the Golden Gate to the 2 part-per-thousand isohaline (equivalent to a salinity of 2 grams of salt per kilogram of water), measured along the axis of the San Francisco Estuary. X2 is often used as an indicator of freshwater availability and fish habitat conditions in the Delta (Jassby *et al.*, 1995; Monismith, 1998).

No comments

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equation (Kimmerer and Monismith, 1992) and Contra Costa Water District's salinity outflow model (also referred to as the G-model) (Denton, 1993; Denton and Sullivan, 1993).

Section 4: Qualitative Observations of Historical Freshwater Flow and Salinity Conditions

Qualitative observations on salinity conditions in the western Delta and Suisun Bay from an early water rights lawsuit and from various literature reports are discussed to provide a perspective of the salinity conditions prevailing in the late 1800's and early 1900's. The 1920 lawsuit filed by the Town of Antioch against upstream irrigation districts alleged that the upstream water diversions were causing increased salinity intrusion at Antioch (Town of Antioch v. Williams Irrigation District, 1922). Briefings and testimony from the legal proceedings are indicative of the salinity conditions prevailing in the early 1900's, as are literature reports of conditions in the western Delta and Suisun Bay. These reports contain both qualitative observations and anecdotal information regarding historical salinity conditions. Because the proceedings were adversarial in nature, this report focuses on the testimony of the upstream interests, who were trying to demonstrate the extent of salinity intrusion in the Delta prior to their diverting water. Note that the Supreme Court did not base its final decision on the evidence of whether or not Antioch had continuous access to fresh water. The Court's decision was based on the State policy to irrigate as much land as possible for agriculture; the Court did not pass judgment on the accuracy of the testimony of either side.

Section 5: Conclusions

This section synthesizes the findings from Sections 2 through 4 and presents the overall conclusions regarding trends in the historical Delta salinity.

No comments

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2. Paleoclimatic Evidence of the Last 10,000 Years

Paleoclimatic evidence from the watershed of San Francisco Bay (Bay) and Sacramento-San Joaquin Delta (Delta), obtained from proxy information such as tree rings and sediment deposits, provides a history of conditions before modern direct instrumental observations. Evidence of major regional climatic events that represent long-term wet period and drought cycles will be discussed, followed by discussions of Delta watershed runoff and Delta salinity, as measured by flow and electrical conductivity instrumentation.

2.1. *Major Regional Climatic Events*

The modern Bay-Delta is relatively young in terms of geologic timescales. The estuary started forming around 8,000 to 10,000 years ago (Atwater *et al.* 1979), when rapid sea level rise allowed the ocean to enter the Golden Gate. At this time, there was no Bay or Delta, but simply river valleys. Rapid sea level rise continued, such that approximately 6,000 years ago, the outline of San Francisco Bay, including San Pablo Bay and Suisun Bay, resembled the modern extent. At about the same time, sea level rise slowed to a more moderate pace, allowing tidal marshes to begin to form.

Malamud-Roam *et al.* (2007) review paleoclimate studies in the Bay-Delta watershed, summarizing evidence of climate variability through the development of the present day Bay-Delta system (Table 2-1).

Table 2-1 – Climate during the evolution of the Bay-Delta estuary

Overview of precipitation, temperature, and sea level conditions during the last 10,000 years based on data from Malamud-Roam et al. (2007) and Meko et al. (2001). Time periods are given in terms of number of years ago (represented as age, a; or ka for 1,000 year ago) and the Common Era (BCE/CE) calendar system. The shading indicates relatively dry periods.

Approximate Time Period	*Prevailing Climate and Geomorphology*
10 ka to 8 ka 8000 BCE to 6000 BCE	▪ Rapid sea level rise ▪ Ocean enters Golden Gate ▪ San Francisco Bay is just a river valley ▪ Cooler than 20th Century, but becoming warmer and drier
6 ka to 5 ka 4000 BCE to 3000 BCE	▪ Sea level rise slows to more moderate pace ▪ Outline of San Francisco Bay resembles modern extent ▪ Tidal marsh begins to form in the Delta ▪ Temperature reaches a maximum of the last 10,000 years ▪ Relatively dry conditions ▪ Central Valley floodplain system began to develop

No comments

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Approximate Time Period	*Prevailing Climate and Geomorphology*
4 ka to 2 ka 2000 BCE to 1 CE	▪ Cooling trend with increased precipitation ▪ Large flood occurred ~ 3,600 years ago (1600 BCE)

2 ka to 0.6 ka
1 CE to 1400 CE
	▪ Trend to more arid, dry conditions
	▪ Severe droughts:
	  ▪ 1,100 to 850 years ago (900 CE to 1150 CE)
	  ▪ 800 to 650 years ago (1200 CE to 1350 CE)

0.6 ka to 0.2 ka 1400 CE to 1800 CE	▪ Relatively cool and wet conditions ▪ Numerous episodes of extreme flooding ▪ Includes "Little Ice Age" (1400 CE to 1700 CE)

90 a to 50 a
1910 CE to 1950 CE
	▪ Dry period in the Sacramento River Basin.
	  ▪ Longest dry period in the last 420 years (34 years centered on the 1930's)
	  ▪ Driest 20-year period in the last 370 years (1917 CE to 1936 CE)

A number of scientific studies have used paleo-reconstruction techniques to obtain long-term (decadal, centennial and millennial time scale) records of river flow (e.g., Earle, 1993; Meko *et al.*, 2001) and salinity of the Bay and Delta (e.g., Ingram and DePaolo, 1993; Wells and Goman, 1995; Ingram *et al.*, 1996; May, 1999; Byrne *et al.*, 2001; Goman and Wells, 2000; Starratt, 2001; Malamud-Roam and Ingram, 2004; Malamud-Roam *et al.*, 2006; Malamud-Roam *et al.*, 2007; and Goman *et al.*, 2008). The reconstructions described in the following sections focus on the 2,000 years before present. As indicated in Table 2-1, this period was relatively dry with two extreme regional droughts, followed by relatively cool and wet conditions during the "Little Ice Age," then by a return of dry conditions at the early part of the 20th Century.

2.2. Reconstructed Unimpaired Sacramento River Flow

Meko *et al.* (2001a,b) used tree-ring chronologies in statistical regression models to reconstruct time series of annual unimpaired Sacramento River flow[6] for approximately the past 1,100 years (for the period 869 CE – 1977 CE). As discussed in Section 1.2, unimpaired flow is an estimate of the flow that would occur in the basin without the effects of water management activities.

The 1,100-year record shows strong variability between individual water years (Figure 2-1), with annual flow ranging from approximately 8% of average to 265% of average, where average is defined here for practical purposes as the average observed unimpaired flow from

[6] Meko *et al.* (2001a) used the annual unimpaired flow record for the Sacramento River provided by the Department of Water Resources, which is the sum of the following: flow of the Sacramento River at Bend Bridge, inflow of the Feather River to Lake Oroville, flow of the Yuba River at Smartville, and the flow of the American River to Folsom Lake. This definition is consistent with the definition typically used in hydro-climatic studies of this region (e.g., http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST)

No comments

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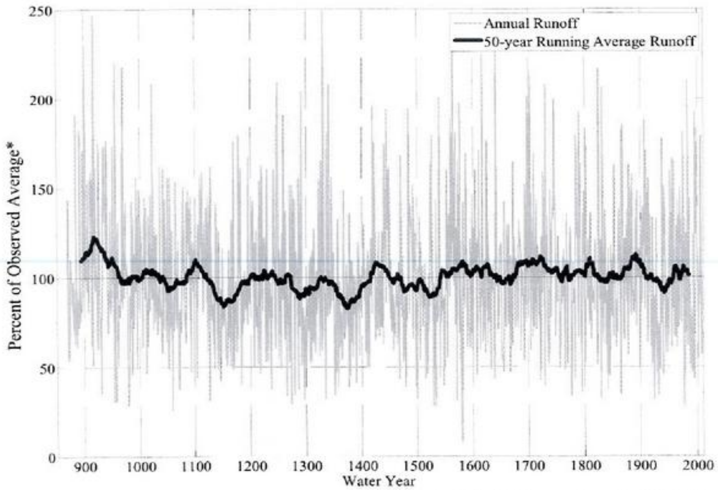
1906 to 2009 of 18 million acre-feet per year (MAF/yr). The reconstructed record shows alternating periods of wet and dry conditions and is consistent with historical droughts (such as the drought in the Mono Lake region of California in the medieval period, around 1150 CE) reported by other paleoclimate studies (Malamud-Roam *et al.*, 2006).

As indicated by the shading in Figure 2-1, the driest long-term drought in the Sacramento River basin in the last 1,100 years occurred from approximately 1130 CE to 1415 CE when the 50-year average flow was seldom above normal for nearly 300 years. Following this drought, conditions were relatively wet (from approximately 1550 CE to 1900 CE). The timing of these droughts and wet periods will be compared to paleosalinity records in the following section.



* Average of 1906-2009 Observed Runoff is 18 MAF/yr.

Figure 2-1 – Reconstructed annual unimpaired Sacramento River flow 869 CE to 2009 CE

Annual reconstructed unimpaired Sacramento River flow (grey line) as a percentage of the average annual observed runoff from 1906 to 2009 shows strong variability between years. The 50-year running average (thick black line) illustrates there were extended periods of above-normal and below-normal runoff conditions. The orange shading highlights an extended dry period in the reconstructed unimpaired Sacramento River data when the 50-year average flow is seldom above normal for nearly 300 years. Data for 869 CE to 1905 CE were reconstructed by Meko et al. (2001b); data for 1906 CE to 2009 CE are observed records from the California DWR (2009).

No comments

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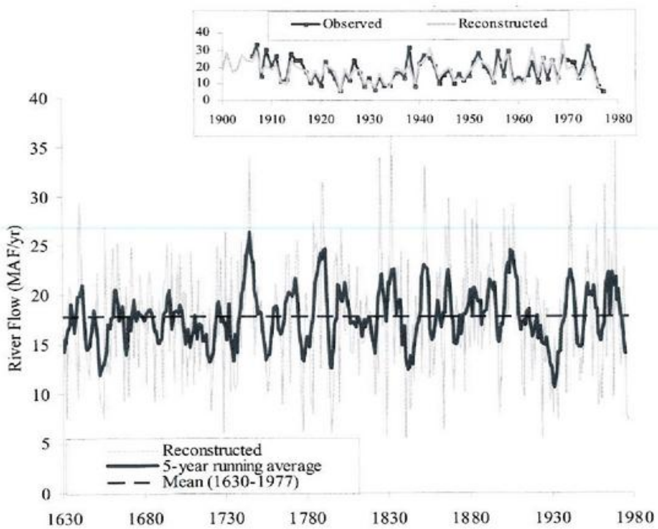
Meko *et al.* (2001a) indicated that for their 1,100-year reconstructed period, the 1630-1977 data are more reliable than the earlier time period, because of better availability of tree-ring information and superior regression model statistics. Figure 2-2 shows the reconstructed time series of annual unimpaired Sacramento River flow from 1630 to 1977 from Meko *et al.* (2001b). The inset in Figure 2-2 shows there is a good match between the reconstructed flows (grey line) and the observed annual flows (red line) during the period of overlap between the reconstructed and observed records (from 1906 to 1977).

Multi-decadal periods of alternating wet and dry conditions are pervasive throughout the reconstructed record. The wet conditions of the late 1800's and early 1900's, which were followed by severe dry conditions in the 1920's and 1930's, are consistent both with observed precipitation and estimated Sacramento River runoff for these time periods (see Section 3) and with literature reports of historical conditions (see Section 4).



No comments

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Figure 2-2 – Reconstructed annual unimpaired Sacramento River flow from 1630-1977.
Annual reconstructed unimpaired Sacramento River flow (grey line in main panel and inset) for the 1630 to 1977 time period was identified by Meko et al. (2001a) as the most accurate period of reconstruction. Inset panel illustrates the comparison between observed (red) and reconstructed (grey) unimpaired flows during the overlap period. The mean of the reconstructed unimpaired flow for 1630-1977 is 17.7 MAF/yr (dashed horizontal line in main panel). The 5-year centered running average (thick solid blue line in main panel) illustrates the decadal trends.

Meko *et al.* (2001a) identified the severe drought periods in the reconstructed Sacramento River flow record (1630-1977) by computing the lowest *n*-year moving average. For instance, to determine the most severe 6-year drought, Meko *et al.* calculated the moving average using a 6-year window for the entire data set and then identified the lowest 6-year average. Meko *et al.* found that the period from the early 1920's to late 1930's experienced the lowest 6-year, 10-year, 20-year, and 50-year averages (or droughts), both in the reconstructed and observed records. The observed droughts in Table 2-2 have been updated through present (1906-2009) using the same analysis; this update did not change the drought time periods identified by Meko *et al.* The reconstructed record of unimpaired Sacramento River flow shows the period from early 1920's to late 1930's experienced some of the worst drought conditions since 1630. Additional data are presented in Appendix B.

Table 2-2 – Periods of drought from the reconstructed and observed records of unimpaired Sacramento River flow
Severe drought periods in the reconstructed Sacramento River flow record (1630-1977) were determined by Meko et al. (2001a) by computing the lowest n-year moving average of the reconstructed annual unimpaired Sacramento River flow. The same method was used to determine the most severe droughts of the observed record (1906-2009).

	Period of lowest *n*-Year moving average Sacramento River flow					
	1-Year	3-Year	6-Year	10-Year	20-Year	50-Year
Reconstruction (1630-1977)	1924	1775 to 1778	1929 to 1934	1924 to 1933	1917 to 1936	1912 to 1961
Observations (1906-2009)	1977	1990 to 1992	1929 to 1934	1924 to 1933	1918 to 1937	1917 to 1966

Conclusions

Reconstruction of unimpaired Sacramento River flow indicates:

- Annual precipitation is highly variable. Even during long dry periods, individual years can be very wet.
- The Sacramento River basin experienced a multi-century dry period from about 1100 C.E. to 1400 C.E.
- The drought period in the 1920's and 1930's represents some of the worst drought conditions in the last 400 years.

No comments

- n/a -

2.3. Reconstructed Salinity in the Bay-Delta Estuary

Tree Ring Data

The interaction between saline ocean water from the Pacific Ocean and fresh water from the rivers flowing into the Delta determines the ambient salinity conditions in the Delta and the Bay. Estimates of historical precipitation derived from tree ring data can therefore be used to estimate the corresponding salinity conditions in the Delta.

Stahle *et al.* (2001) used tree ring chronologies from blue oak trees located in the drainage basin to San Francisco Bay to reconstruct salinity at the mouth of San Francisco Bay. Recognizing that a number of factors influence salinity other than precipitation (estimated from tree rings), the authors chose a time period prior to substantial water development when the salinity data were fairly constant in mean and variance. During the calibration period (1922-1952), annual tree ring growth correlates well with average salinity near the Golden Gate Bridge (r^2=0.81). Using this transfer function, Stahle *et al.* (2001) reconstructed annual average January to July salinity for all years 1604 to 1997.

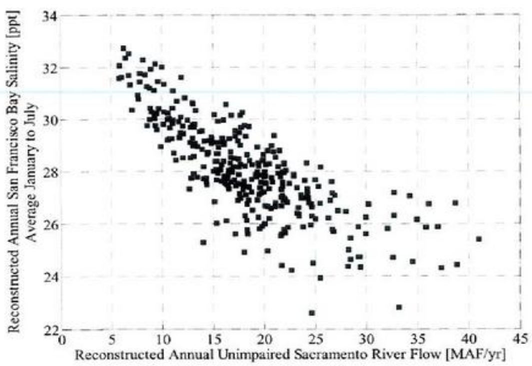

Figure 2-3 – Reconstructed salinity near the mouth of San Francisco Bay compares well with reconstructed unimpaired Sacramento River flow in the upper watershed

For each year from 1630 to 1952, the annual unimpaired Sacramento River flow (from Meko et al., 2001b) is plotted against the annual average salinity at Fort Point (from Stahle et al., 2001).

As shown in Figure 2-3, the salinity reconstruction by Stahle *et al.* (2001) compares well with the unimpaired flow reconstruction by Meko *et al.* (2001b). The data follow the expected inverse exponential relationship between flow and salinity. Over the period from

No comments

- n/a -

1630 to 1952, reconstructed salinity increases as reconstructed unimpaired Sacramento River flow decreases. The agreement is strongest in dry years. The increased scatter in wet years may reflect the limitations in the tree ring methods.

Stahle *et al.* (2001) identified an increasing divergence of observed salinity relative to predicted (reconstructed) salinity after 1952 (Figure 2-4) and suggested that the majority of differences are due to increased water diversions. During the calibration period (1922-1952), the observed salinity is typically within +/- 5% of the reconstructed salinity. However, from 1953-1994, the data show an increasing trend for observed salinity to be greater than predicted, exceeding reconstructed salinity by over 15% in 1978, 1979, 1991, and 1993. Since 1969, observed salinity has exceeded reconstructed salinity in all years except the extremely wet years of 1982 and 1983.

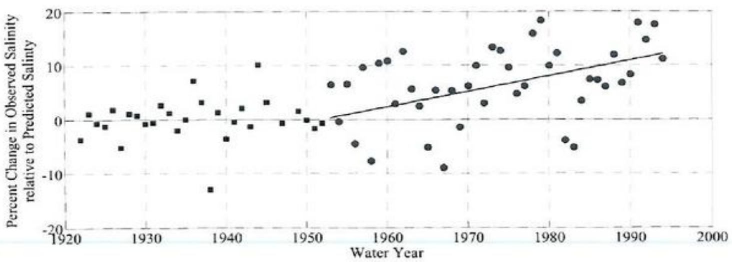

Figure 2-4 – Percent change in observed salinity relative to predicted (reconstructed) salinity for the period 1922 to 1994

The reconstructed salinity record by Stahle et al. (2001) overlaps with the observed salinity record from 1922 to 1994. During this period, the percent change of observed salinity relative to predicted salinity is determined as (observed salinity – reconstructed salinity) divided by reconstructed salinity, with positive values indicating when observed salinity exceeded the reconstructed salinity prediction. The calibration period is indicated with black squares, with the period outside the calibration window indicated by red circles. The straight red line is the linear trend in the post-calibration period, indicating observed salinity is increasingly diverging from predicted (reconstructed) salinity.

These data suggest that since the 1950's, water management operations have increased salinity, with an escalating effect over the period of record. In addition, it is worth noting that significant anthropogenic modifications to the landscape and water usage had already occurred prior to the 1922-1953 calibration period (see Figure 1-2 and Figure 1-3). Although this study is unable to evaluate the effect of anthropogenic modifications prior to 1953, the following section examines salinity prior to human interference at multiple sites in the Bay-Delta.

Tree ring reconstructions such as Meko *et al.* (2001a) and Stahle *et al.* (2001) have the advantage of providing high temporal resolution (i.e. annual) over approximately the last 1,000 years. However, a possible disadvantage of this method is the age of trees, limiting

No comments

- n/a -

high accuracy estimates to approximately the last 400 years. A second possible disadvantage of using tree ring reconstructions for paleosalinity is the remote location of the trees relative to the estuary. Paleosalinity estimates from tree rings in the upper basin necessarily assume that the precipitation patterns archived in the tree rings are representative of the quantity of water that reaches the estuary. However, as observed by Stahle *et al.*, anthropogenic water management affects the amount of water that flows through the estuary.

Sediment Core and Fossil Data

Because of uncertainties in estimates of precipitation and salinity derived from tree ring data, other paleosalinity methods that rely on local fossils to determine local salinity have also been explored. Organic deposits accumulated in the sediments contain signatures of the ambient conditions that can be used to infer the variations in salinity over geologic time scales. Although reconstructions from sediment cores have a coarser temporal resolution than tree rings, the variations in climate and landscape responses to change are better defined geographically because the evidence of localized climate change is preserved as a time series *in situ*, at the site of interest.

The San Francisco Bay-Delta has been the focus of several paleoclimatic reconstructions from sediment cores. Changes in wetland plant and algae communities are the dominant response in the Bay and Delta to climate change and associated fluctuations in temperature and precipitation. Proxies of plant and algae response to environmental conditions are preserved in the sediment cores and determined by:

- quantification and taxonomic identification of
    - (i) diatom frustules (Byrne *et al.*, 2001; Starratt, 2001; Starratt, 2004),
    - (ii) plant seeds and roots (Goman *et al.*, 2008),
    - (iii) plant pollen (May, 1999; Byrne *et al.*, 2001; Malamud-Roam and Ingram, 2004), and,
- measurement of peat carbon isotope ratios (Byrne *et al.*, 2001; Malamud-Roam and Ingram, 2004).

Results from plant pollen identification for three sites in the western Delta and Suisun Bay and Marsh are summarized below in Figure 2-5. The data indicate that Browns Island tidal marsh, near the confluence of the Sacramento and San Joaquin Rivers in the western Delta (Figure 2-5) was predominately a freshwater system for 2,500 years, even during century-long droughts. This condition prevailed until the early 1900's. The shading in Figure 2-5 corresponds to the nearly 300-year dry period identified in the reconstructions of annual unimpaired Sacramento River flow (Figure 2-1). Although salinity intrusion occurred during this period in Suisun Bay at Roe Island, and during earlier long drought periods, salinity did not affect the western Delta to the same degree. This suggests a change in spatial salinity gradient characteristics, and is possibly due to the effect on salinity intrusion of the vast tidal marshes that existed in the Delta until the early 20th Century.

No comments

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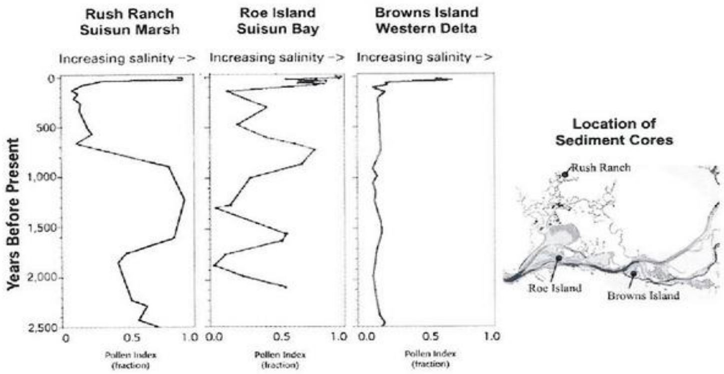

Figure 2-5 – Paleosalinity evidence derived from pollen data

Salinity variability over the last 2,500 years at Rush Ranch in Suisun Marsh (left panel), Roe Island in Suisun Bay (center panel), and Browns Island in the Western Delta (right panel). Data are reproduced from Malamud-Roam and Ingram (2004). Orange shading across each panel corresponds to the nearly 300-year dry period identified in the annual unimpaired Sacramento River flow reconstruction (see Section 2.2) Locations of each of the sediment cores are illustrated in the map on the right.

Malamud-Roam *et al.* (2006) attributed the differences between sites to a combination of methodological issues (such as sampling frequency and core chronology) and site-specific ecological differences (such as site elevation, location relative to channel and sedimentation rates over time). However, all of the paleosalinity reconstructions based on pollen, diatoms and carbon isotopes are in general agreement and suggest that salinity increased abruptly about 100 years ago, reaching or exceeding salinity levels at any other time in the 2,500 years of reconstructed records.

This increase in salinity may correspond to the reduction in unimpaired Sacramento River flow evidenced in the tree ring reconstructions by Meko *et al.* (2001a), which determined that the 1920's and 1930's experienced the worst droughts in the last 400 years. However, the droughts in the 1920's and 1930's do not appear to be as severe as the droughts between 1100 CE to 1400 CE (600 to 900 years ago), as categorized by unimpaired Sacramento River flow. Yet salinity in Suisun Bay and the western Delta appears to meet or exceed the level of the medieval droughts, indicating factors besides natural precipitation and runoff patterns have affected salinity in the last 100 years.

No comments

- n/a -

Conclusions

Reconstructions of salinity in the Bay and Delta indicate:

- Precipitation in the drainage basin for San Francisco Bay (as recorded in tree rings) is a good indicator of salinity near the mouth of the Bay for the period 1922-1953; however, since 1953, increased water diversions have increased observed salinity above the level predicted from precipitation estimates.
- The Delta was a predominately freshwater system for 2,500 years, until the early 1900's, even during century-long droughts.
- The multi-century dry period identified in unimpaired Sacramento River flow reconstruction is evident in Suisun Bay sediments but not in Delta sediments, indicating that salinity did not intrude as far into the Delta during past droughts as it has during the last 100 years.
- The evidence from most sites suggests that current salinity levels are as saline as, or more saline than, previous historical conditions.

No comments

- n/a -

3. Instrumental Observations of the Last 140 Years

Field measurements of rain and snow have far greater accuracy and resolution than the paleoclimate records of precipitation; similarly, field measurements of salinity have far greater accuracy and resolution than the paleosalinity records from sediment cores. These instrumental observations will be used to analyze in more detail the salinity increase identified in the paleoclimate records approximately 100 years ago and determine if the increase in salinity has persisted.

The first sub-section presents observations of precipitation and unimpaired runoff in the upper basin, indicating the natural climatic variability and amount of fresh water available within the Bay-Delta watershed. The second sub-section examines Net Delta Outflow (NDO), which is the amount of water flowing through the Delta into Suisun Bay, directly affecting the level of salinity intrusion into the Delta. NDO is analyzed under both unimpaired (without water diversions and reservoir storage and releases) and historical (actual) conditions; comparison between unimpaired and actual conditions reveals the effect of water management practices. The third sub-section presents field measurements and model-based estimates of salinity at various locations within the Delta and Suisun Bay.

3.1. *Precipitation and Unimpaired Flow in the Upper Basin*

Precipitation in the Bay-Delta watershed indicates the amount of water available within the system, which could ultimately reach the Bay and affect salinity conditions. However, since precipitation falls as both rain and snow, the timing of runoff to the river channels is often lagged a few months due to snow melt conditions. For this reason, estimates of unimpaired flow (runoff) are generally used to characterize hydrological variability. Unimpaired runoff represents the natural water production of a river basin, unaltered by water diversions, reservoir storage and operation, and export of water to or import of water from other basins.

Figure 3-1 illustrates the total annual precipitation at Quincy[7] in the northeastern Sierra, the total annual unimpaired Sacramento River flow[8] and total unimpaired San Joaquin River flow[9]. Figure 3-2 shows the locations of the eight precipitation stations in northern California used to compute the Sacramento eight-station precipitation index (left panel) and the measurement locations of eight flow gages used to calculate the Sacramento and San Joaquin unimpaired flow data (right panel). Additional information on the annual unimpaired flows is provided in Appendix C.

As discussed in Section 2.2, the total annual unimpaired Sacramento River flow exhibits strong variability between years, both in the reconstructed and observed data. Figure 3-1

[7] Precipitation data are from Menne *et al.* (2009)

[8] "Unimpaired Sacramento River flow" is defined as the sum of the "full natural flows" from the Sacramento River at Bend Bridge, Feather River inflow to Lake Oroville, Yuba River at Smartville, and the American River inflow to Folsom Lake. (http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST)

[9] "Unimpaired San Joaquin River flow" is defined as the sum of the full natural flows from the Stanislaus River inflow to New Melones Lake, Tuolumne River inflow to New Don Pedro Reservoir, Merced River inflow to Lake McClure, and San Joaquin River inflow to Millerton Lake (http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST)

No comments

- n/a -

indicates that the trends revealed in the total annual unimpaired Sacramento River flow (middle panel) are also evident in the total annual precipitation at Quincy (top panel) and the total annual unimpaired San Joaquin River flow (bottom panel). Alternating periods of wet and dry conditions are evident in both river basins. These data indicate there were wetter than normal conditions in the late 1800's and early 1900's, followed by severe dry conditions in the 1920's and 1930's. These were then followed by generally wetter conditions until the mid-1970's.

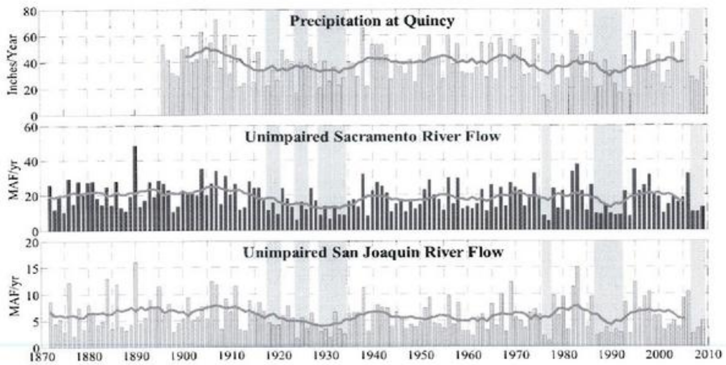

Figure 3-1 – Total annual precipitation and unimpaired flow in the upper Sacramento and San Joaquin River basins (1872-2009)

Total annual precipitation at Quincy in the northeastern Sierra (top panel), total annual unimpaired Sacramento River flow (middle panel), and total annual unimpaired San Joaquin River flow (bottom panel). Bar color on each panel indicates the regional location of the measurements, reflected in the remaining figures of this section (Figure 3-2, Figure 3-3 , and Figure 3-4). Grey line within each panel is the 10-year moving average for each parameter.

No comments

- n/a -

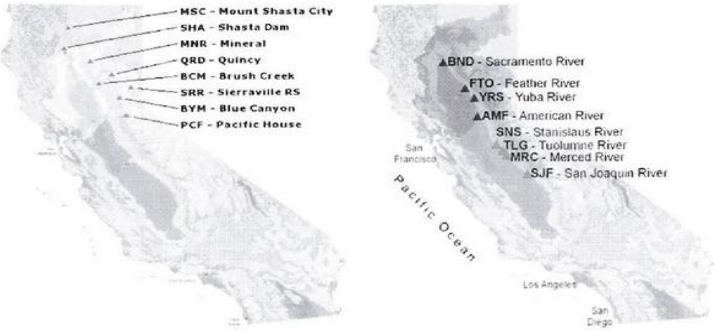

Figure 3-2 – Locations of Precipitation and Runoff Measurements
Location of stations used in the determination of the 8-station precipitation index for northern California (left map), including the location of Quincy (QRD), and the unimpaired Sacramento River flow (red stations, right map) and unimpaired San Joaquin River flow (orange stations, right map).

Knowles (2000) illustrated that the seasonal timing of runoff can significantly alter salinity intrusion without any change to the total annual runoff. For this reason, it is critical to examine the monthly variability in precipitation and unimpaired runoff. Monthly precipitation and unimpaired flow values are available for a shorter time period (generally 1921 to present) than the total annual values (generally 1870's to present).

The monthly distribution of the Sacramento eight-station precipitation index[10] indicates that most of the precipitation in northern California occurs during November through March (Figure 3-3). The variability between years, represented by the vertical bars and '+' marks, shows the distribution is positively skewed, i.e., excessively high precipitation occurs in relatively few years.

Figure 3-4 presents the monthly distribution of unimpaired flow for both the Sacramento and San Joaquin River basins. River flow lags precipitation by about two months because of storage of some precipitation in the form of snow and subsequent snowmelt in the spring. Most of the unimpaired inflow to the Delta originates from the Sacramento Basin, although the contributions from the two basins are approximately the same during the months of late-spring and early-summer snow melt, when unimpaired runoff from the San Joaquin Basin peaks.

[10] Data from 1921 through 2008, downloaded from http://cdec.water.ca.gov/cgi-progs/precip1/8STATIONHIST

No comments

- n/a -

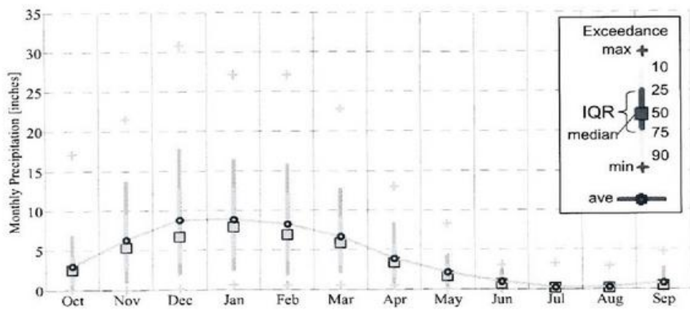

Figure 3-3 – Monthly Distribution of Precipitation in the Sacramento River Basin

Distribution of monthly precipitation for water years 1921 through 2008. Monthly averages are indicated by the blue line with black circles. Monthly median is given by the blue squares, while the interquartile range is indicated by the vertical blue line for each month and the vertical grey line extends to the 10th and 90th percentiles. Maximum and minimum values are indicated by '+' marks.

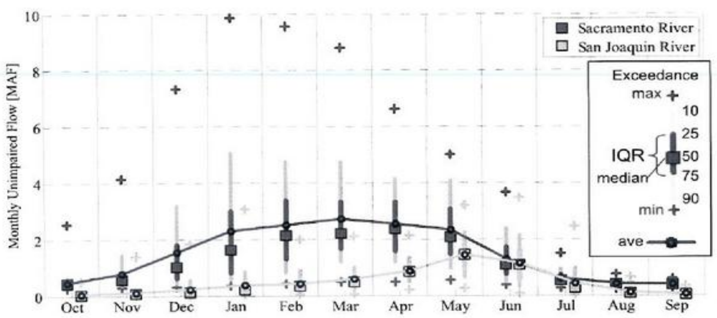

Figure 3-4 – Monthly distribution of unimpaired flow in the Sacramento and San Joaquin River basins

Distribution of monthly unimpaired flows for water years 1921 through 2008. Monthly averages are indicated by the lines with black circles. Monthly median is given by the squares, while the interquartile range is indicated by the vertical line for each month and the vertical grey line extends to the 10th and 90th percentiles. Maximum and minimum values are indicated by '+' marks.

No comments

- n/a -

Conclusions

The long-term observations of precipitation and unimpaired flow indicate:

- Relatively wet conditions occurred in the late 1880's to about 1917 in both the Sacramento and San Joaquin River watersheds prior to large-scale water management operations.
- Unusually dry conditions occurred from about 1918 through the late 1930's; these persistent dry conditions are not representative of the average conditions over the last 130 years.
- Precipitation in Sacramento River watershed peaks between December and March; the unimpaired river flow lags by about 1 to 2 months because of snow melt.

No comments

- n/a -

3.2. Net Delta Outflow

The quantity of water flowing from the Delta into Suisun Bay, defined as Net Delta Outflow (NDO), is the primary factor in determining salinity intrusion in Suisun Bay and the western Delta. Unimpaired NDO is calculated using unimpaired flow in the Sacramento and San Joaquin Rivers (Section 3.1) as well as contributions from other minor tributaries.[11] Unimpaired NDO is the hypothetical Delta outflow that would occur in the absence of any upstream diversion or storage, but with the existing Delta channel and upstream channel configuration.

Because the outflow from the Delta at the wide and deep entrance to Suisun Bay cannot be measured accurately, the parameter of historical (actual) NDO is estimated from a daily mass balance of the measured river inflows to the Delta, measurements of water diversions at major pumping plants in the Delta, and estimates of net within-Delta consumptive use (including Delta precipitation and evaporation).

The effect of anthropogenic water management on NDO is illustrated below by comparing monthly estimates of unimpaired NDO[12] and historical (actual) NDO[13] (Figure 3-5). Since unimpaired flow estimates also assume the existing Central Valley and Delta landscape (reclaimed islands, no natural upstream flood storage, current channel configuration, etc.), this comparison reveals the net effect of water management only. This analysis does not address the change due to physical modification to the landscape or sea level rise.

For the period of joint record, when both unimpaired and historical NDO values are available (water year 1930 through 2003), historical NDO decreased even though unimpaired NDO increased slightly. The long-term (74-year) linear trend in monthly unimpaired NDO (the black dashed line in top panel of Figure 3-5) increased on average 0.49 MAF/month; thus, by 2003, the average annual unimpaired NDO had increased 5.9 MAF/year since 1930. In contrast, the long-term linear trend in monthly historical NDO (the black dashed line in middle panel of Figure 3-5) decreased on average -0.29 MAF/month, totaling a decrease in historical (actual) NDO of -3.5 MAF/year. This corresponds to a net increase in diversion of 9.4 MAF/year of water from the Delta upstream watershed relative to the 1930 level[14].

Increased diversion and export of water have decreased historical NDO (middle panel of Figure 3-5), but this has been partially offset by a natural increase in unimpaired NDO (top panel). The difference between historical and unimpaired NDO (bottom panel) is due to the cumulative effects of upstream diversions, reservoir operations, in-Delta diversions, and

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[11] Unimpaired NDO does not include water imported from the Trinity River system, which is outside the Delta watershed.

[12] Unimpaired NDO data was obtained from Ejeta (2009), which is an updated version of DWR (1987).

[13] Historical NDO data was obtained from the IEP's DAYFLOW program (http://www.iep.ca.gov/dayflow/index.html).

[14] This is consistent with current estimates of approximately 15 MAF/year total diversion from the system, which includes the 4-5 MAF/year diversions established prior to 1930 and approximately 1 MAF/year additional water supply imported from the Trinity River system.

No comments

- n/a -

south-of-Delta exports. During most months, water management practices have historically resulted in historical (actual) NDO that is less than unimpaired conditions, indicated by a negative value for the quantity (historical NDO – unimpaired NDO).

Because the difference between monthly historical and unimpaired NDO has become more negative over time, the periods of excess conditions (when historical NDO exceeds unimpaired NDO) have become very infrequent. The only occurrences are now following the wettest years, primarily due to releases from reservoirs in the fall to make room for winter flood control storage.

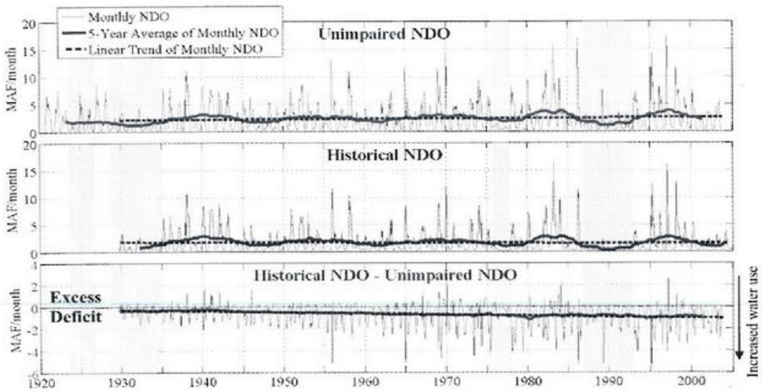

Figure 3-5 – Time series of Monthly Net Delta Outflow under unimpaired conditions and historical (actual) conditions

The thin color line on each panel indicates the monthly NDO, the thick color line indicates a running 5-year average of the monthly NDO, and the dashed black line indicates the linear long-term trend.

The monthly distribution (Figure 3-6) of unimpaired NDO and historical NDO for water years 1930 to 2003 reveals that for all months except September and October (when NDO is low), average unimpaired NDO is greater than average monthly historical NDO. The tendency in the average historical NDO toward greater flow in September and October is influenced strongly by the period prior to about 1975 when reservoir operations resulted in more flow in those months (see Figure 3-7 and related discussion below). On average from 1930-2003, water management practices reduced Delta outflows in the months of November through August (and in all months since about 1975, see Figure 3-7). The greatest reduction in Delta outflow relative to unimpaired conditions occurs in the months of March through June, when spring snow melt is captured in reservoirs and a portion of the river flow is diverted for direct use.

No comments

- n/a -

As also shown in Figure 3-6, water management practices also shift the peak flow periods to earlier in the year. The unimpaired NDO hydrograph peaks in May when snow melt contributes to high river flows, with at least 4.1 MAF in May in 50% of the years (averaging 4.2 MAF in May over all years). The historical NDO peaks in February with at least 2.9 MAF/month in 50% of the years (averaging 3.7 MAF/month over all years). The variability between years, represented by the vertical bars and '+' marks, indicates the distribution is positively skewed, which means a relatively few years have excessively high flows.

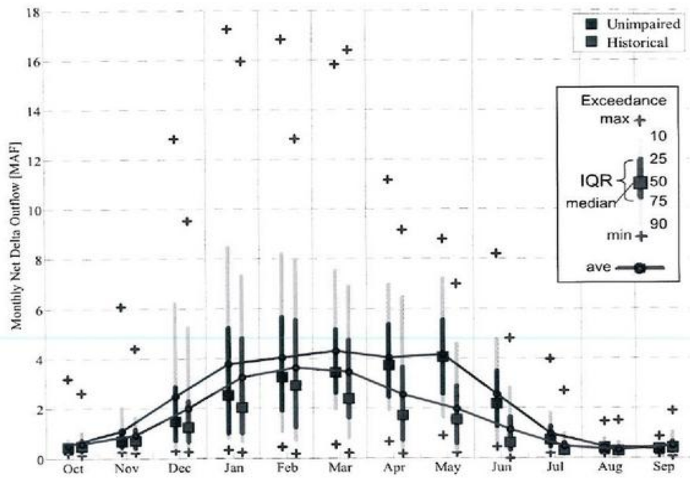

Figure 3-6 – Monthly distribution of Net Delta Outflow

Distribution of monthly NDO for water years 1930 through 2008. Monthly averages are indicated by the lines with black circles. Monthly median is given by the squares, while the interquartile range is indicated by the vertical line for each month and the vertical grey line extends to the 10th and 90th percentiles. Maximum and minimum values are indicated by '+' marks.

Figure 3-7 shows the long-term trends in the difference between historical (actual) monthly NDO and unimpaired monthly NDO. Increased water usage and increased diversion of water to storage has reduced historical NDO relative to unimpaired NDO in most months of the year. In July (and August, not shown in Figure 3-7), the deficit is reduced, likely due to reservoir releases which provide a portion of the water diverted by upstream users prior to reservoir construction. The 1994 Bay-Delta Accord called for higher minimum Delta outflows in July and August to protect Delta fish species, which should also serve to reduce the deficit. However, historical (actual) NDO still remains less than unimpaired NDO.

No comments

- n/a -

In September (and October, not shown in Figure 3-7), historical (actual) NDO exceeded unimpaired NDO from about 1945 to 1975, with an increasing trend in the percent change. Since 1975, the percent change has shown a downward trend with a deficit (historical NDO less than unimpaired NDO) during most years since 1975.

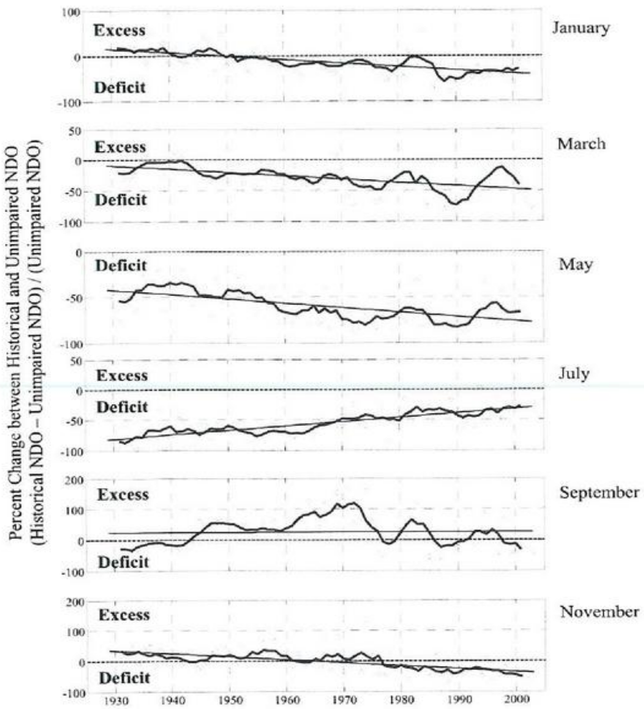

Figure 3-7 – Long-term trends in monthly NDO

Percent change of NDO relative to unimpaired conditions. Circles indicate the percent change for each month of the period of record. The red line indicates a moving 5-year average of the percent change, while the black line indicates the long-term linear trend over the entire period of record.

No comments

- n/a -

Conclusions

Anthropogenic water management practices have altered NDO in the following ways:

- Long-term data demonstrate that the difference between historical (actual) NDO and unimpaired NDO is increasing over time, indicating that water management actions have reduced Delta outflow significantly.
- During most months, water management practices have reduced Delta outflow relative to unimpaired conditions. From the mid-1940's to the mid-1980's, reservoir operations resulted in historical (actual) NDO slightly greater than unimpaired NDO slightly in a number of months, largely in the fall. However, since 1985, reservoir operations have resulted in increased NDO only in the wettest years, and NDO has declined in all other months.
- On average, water management practices have resulted in reduced Delta outflows in all months except September and October. The greatest reduction in Delta outflow relative to unimpaired conditions occurs in the months of March through June, when spring snow melt is captured in reservoirs and some of the remaining river flows are diverted for direct use.

No comments

- n/a -

3.3. Salinity in the Western Delta and Suisun Bay

Observations and model-based estimates can be used to examine historical variations in salinity in the western Delta and Suisun Bay. The observations examined in this section include records from the early 1900's from the California & Hawaiian Sugar Refining Corporation in Crockett (C&H) and long-term monitoring data published online by the Interagency Ecological Program (IEP). Estimates of salinity intrusion were obtained using the Kimmerer-Monismith equation describing X2 (Kimmerer and Monismith, 1992).

Section 3.3.1 addresses the importance of consistency among salinity comparisons. The spatial variability of a specific salinity level is examined in Section 3.3.2 and Section 3.3.3, while the temporal variability of salinity at specific fixed locations is explored in Section 3.3.4 and Section 3.3.5.

3.3.1. Importance of Consistency among Salinity Comparisons

Water salinity in this report is specified either as electrical conductivity (EC) or as a concentration of chloride in water. EC is a measure of the ability of an aqueous solution to carry an electric current and is expressed in units of microSiemens per centimeter (µS/cm)[15]. Chloride concentration is specified in units of milligrams of chloride per liter of water (mg/L). Conversion between EC and chloride concentration can be accomplished using site-specific empirical relationships such as those developed by Kamyar Guivetchi (DWR, 1986).

Previous studies have evaluated the level of salinity in the Bay and Delta, using a variety of salinity units (e.g. EC, chloride concentration, or concentration of total dissolved solids in water) and various salinity parameters (e.g. annual maximum location 1,000 µS/cm EC, monthly average location of 50 mg/L chloride, or daily average EC at a specific location). Therefore, when comparing studies, it is critical to use consistent salinity units, parameters, and timing, including the phase of tide and time of year. These concepts are discussed further in Appendix D.

3.3.2. Distance to Fresh Water from Crockett

The California & Hawaiian Sugar Refining Corporation (C&H) is located in Crockett, near the western boundary of Suisun Bay (see Figure 3-8). C&H either obtained its freshwater supply in Crockett, or, when fresh water was not available at Crockett, from barges that traveled upstream on the Sacramento and San Joaquin Rivers. The barges generally travelled upstream twice a day beginning in 1908 (DPW, 1931). C&H recorded both the distance traveled by its barges to reach fresh water and the quality of the water they obtained. This provides the most detailed quantitative salinity record available prior to the initiation of salinity monitoring by the State of California in 1920. The distance traveled by the C&H barges serves as a surrogate for the prevailing salinity conditions in the western Delta and

[15] The reported EC values are actually specific conductance, i.e., the electrical conductivity of the water solution at a reference temperature of 25° centigrade, as is standard practice.

No comments

- n/a -

Suisun Bay. Operations by C&H required water with less than 50 mg/L chloride concentration.[16] Additional detail on C&H operations and the detailed barge travel data are included in Appendix D.

Figure 3-8 – Map of Suisun Bay and Western Delta with locations of continuous monitoring stations

C&H barges traveled up estuary from Crockett (yellow star). Locations of IEP continuous monitoring stations are shown in red. Scale in miles is indicated in the upper left corner of the map.

[16] In comparison, the 50 mg/L concentration required for C&H operations is one-third the concentration of the industrial water quality standard under current conditions in the Delta.

No comments

- n/a -

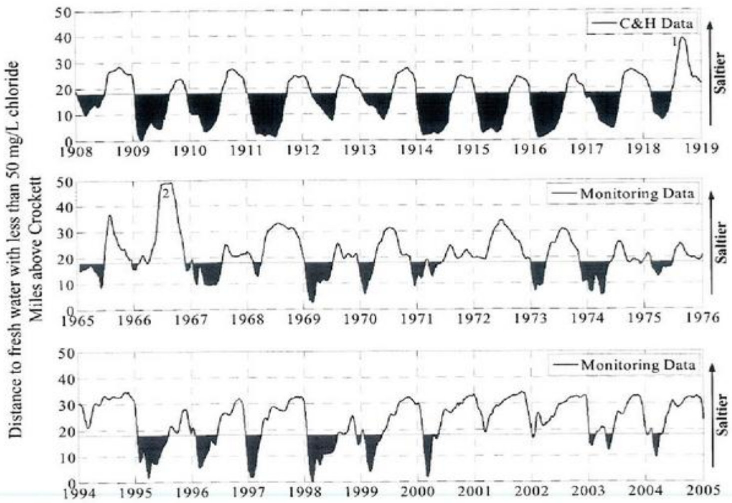

Figure 3-9 – Distance to fresh water from Crockett

"Distance to fresh water" is defined as the distance in miles upstream of Crockett to water with less than 50 mg/L chloride concentration. The horizontal line, at approximately 18 miles, is the distance from Crockett to the Delta. The shading represents the spatial extent and duration of the presence of fresh water within Suisun Bay, downstream of the Delta.

Data notes: (1) During August and September 1918, average water quality obtained by C&H exceeded 110 mg/L chlorides; (2) Salinity during 1966 is likely an overestimate due to relatively sparse spatial coverage of IEP monitoring stations. During 1966, salinity at Emmaton (28 miles from Crockett) exceeded 3,000 μS/cm; the nearest station upstream of Emmaton is near Courtland (58 miles from Crockett) and had a salinity of ~ 300 μS/cm. Location of 350 μS/cm isohaline based on data interpolation between these two stations (which are 30 miles apart) is not likely to be representative of the true location.

Figure 3-9 compares surface[17] salinity data from C&H with estimates derived from a network of continuous surface salinity monitoring stations (Figure 3-8) within Suisun Bay and the western Delta dating back to 1964. The monitoring data are published online by the Interagency Ecological Program (IEP, see http://iep.water.ca.gov/dss). The location of the 350 μS/cm EC isohaline, which approximately coincides with the C&H criterion of 50 mg/L chloride concentration, was estimated from the IEP measurements by linear interpolation between the average daily values at IEP monitoring stations.

[17] Due to the method of collection, C&H water samples are assumed to be from near the water surface.

No comments

- n/a -

As a cautionary note, depending on the source of information, the C&H barges are said to have traveled with the tide, indicating they either took water at high tide (moving up river on the flood and down on the ebb) or at low tide (traveling against the tide, but moving a shorter distance). Thus, the C&H records either represent the daily maximum or daily minimum distance traveled. In contrast, the distances to fresh water calculated from recent monitoring data are based on the average daily values of EC measured at fixed locations. The difference between daily average distance and daily minimum or maximum is approximately 2 to 3 miles. However, since the difference between the data from the early 1900's and the more recent time periods exceed this 2 to 3 mile uncertainty, the conclusions of this section remain unchanged regardless of the specific barge travel timing.

From 1908 through 1918, C&H was able to collect fresh water for a large portion of the year within Suisun Bay, without having to travel all the way from Crockett to the Delta. However, as can be seen in Figure 3-9, that would no longer be possible in many years (e.g., 2001-2004).

Figure 3-10 shows the monthly distribution of distance traveled by C&H barges during water years 1908 through 1917, and the equivalent distance from determined from observed data for water years 1966 through 1975 (top panel) and water years 1995 through 2004 (bottom panel). These two latter periods have similar hydrologic characteristics to the period of the C&H data.[18] The monthly distribution for each dataset illustrates the seasonal fluctuations of the salt field as well as the variability between years for each month.

During the early 1900's, the median distance traveled by C&H barges to procure fresh water was less than 8 miles in the spring (March-June) and about 25 miles (between Collinsville and Emmaton) in the fall (September-October). In contrast, due to water management conditions from 1995 to 2005, the equivalent distances would be 13 to 23 miles in the spring and up to 30 miles in the fall. It is worth noting that from 1966 to 1977, the distance to fresh water in the fall and early winter months (September through January) was generally less than the equivalent distance in the early 1900's, indicating that large-scale water management operations circa 1970 tended to reduce salinity in the fall and early winter. However, this trend has reversed in the more recent water management period (1995-2005), with salinity intrusion significantly increased over levels in the early 1900's during all months.

Figure 3-10 also shows that the range of the average annual distance from Crockett to fresh water from 1995 to 2005 was approximately 15 miles (from about 13 to 30 miles), while the range during the early 1900's was approximately 20 miles (from 6 to 25 miles). This analysis indicates that large-scale water management activities limit the fluctuating nature of the salt field by preventing fresh water from reaching as far downstream as it did in the early 1900's.

Finally, Figure 3-10 indicates that salinity intrusion in the Delta occurred later in the year (beginning in July) in the early 1900's than under more recent time period conditions (beginning in March).

[18] This similarity in hydrological characteristics between the periods was established by approximately matching the distribution of annual Sacramento River flow during these periods (see Appendix E).

No comments

- n/a -

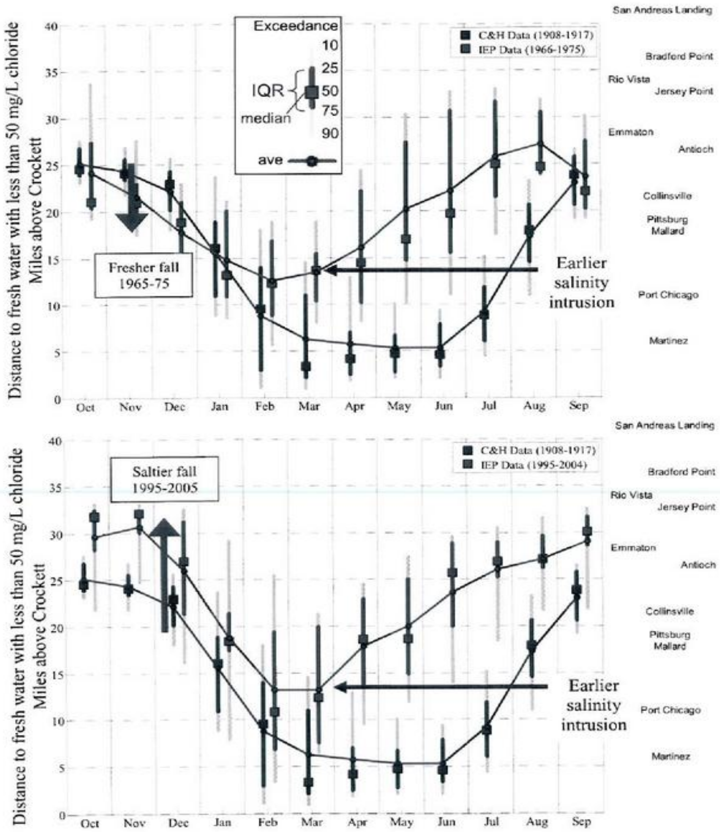

Figure 3-10 – Monthly distribution of distance to fresh water from Crockett

No comments

- n/a -

These comparisons (and other relevant comparisons in Appendix D) show that, on average, C&H barges would have had to travel up to 19 miles farther to procure fresh water under recent large-scale water management conditions than in the early 1900's. These comparisons also indicate that fresh water was present for significantly longer time periods, and over a larger area of the western Delta, in the early 1900's than during similar hydrological periods under current water management conditions. Abrupt changes in salinity just prior to 1920 caused C&H to abandon the Sacramento and San Joaquin Rivers and switch to a water supply contract with Marin County beginning in 1920 (Appendix D).

The distance to fresh water during individual wet years and during individual dry years is presented in Appendix D. The data in Appendix D also show that salinity has been generally higher in recent times than in the early 1900's and that water management has restricted the range in salinity experienced during a water year. The periods when fresh water is present at given locations have been reduced, or, in some cases, eliminated.

Conclusions

The records of the distance traveled upstream from Crockett by C&H barges to procure fresh water and estimates of this distance under large-scale water management conditions (reservoir operations and water diversions) show that:

- Fresh water was present farther downstream and persisted for longer periods of time in the western Delta in the early 1900's than under recent time periods with similar hydrologic conditions;
- Water management practices result in greater salinity intrusion in the western Delta for most months of the year; and,
- Salinity intrusion begins earlier in the year, extends farther upstream, and persists for a longer period each year.

No comments

- n/a -

3.3.3. X2 Variability

An often-used indicator of fresh water availability and fish habitat conditions in the Delta is a metric called X2. X2 is defined as the distance from the Golden Gate to the 2 part-per-thousand isohaline (equivalent to a salinity of 2 grams of salt per kilogram of water), measured near the channel bed along the axis of the San Francisco Estuary. Higher values of X2 indicate greater salinity intrusion. Monthly values of X2 are estimated in this report using the monthly regression equation from Kimmerer and Monismith (1992):

$$\text{Monthly} \quad X2(t) = 122.2 + 0.3278 * X2(t-1) - 17.65 * \log_{10}(NDO(t))$$

The K-M equation expresses X2 (in units of kilometers) in terms of Net Delta Outflow (NDO, see Section 3.2) during the current month and the X2 value from the previous month. The monthly K-M equation was based on a statistical regression of X2 values (interpolated from EC measurements at fixed locations) and estimates of NDO from IEP's DAYFLOW computer program. Hence, the K-M equation is only valid for the existing Delta channel configuration and existing sea level conditions.

The K-M equation can be used to transform unimpaired and historical NDO data into the corresponding X2 values for unimpaired (without reservoir operations or water diversions) and historical (with historical water management) conditions, respectively.

The seasonal and annual variations of X2 are dependent on the corresponding variations of NDO under both historical and unimpaired flow conditions (Figure 3-11). X2 under historical flow conditions is shifted landward relative to unimpaired conditions by approximately 5 km. During the 1930's, historical NDO was often negative, sometimes averaging approximately -3,000 cfs for several months. This was due to relatively low runoff and significant upstream water diversions. Unfortunately, the K-M equation, which includes the logarithm (base 10) of NDO, is unable to account for negative values of NDO. In the case of historical flow conditions, this results in high variability of X2 in the 1930's. The values of X2 under historical flow conditions during 1930's in Figure 3-11 are likely underestimated.

Figure 3-12 compares X2 under unimpaired and historical conditions for the period from 1945-2003, following initiation of the Central Valley Project (i.e., after the completion of the Shasta Reservoir of the CVP). Figure 3-12 shows that, compared to unimpaired conditions, X2 under historical conditions was higher by about 10 km during April-July and by about 5 km during the rest of the year.

Salinity intrusion under historical water management conditions is, therefore, greater (higher X2) than the intrusion that would occur under unimpaired conditions. Moreover, the switch from declining X2 values during fall and winter months to increasing X2 values (increasing salinity intrusion) occurs in March under historical water management conditions and in June under unimpaired conditions. Thus, recent water management practices have resulted in a saltier Delta with earlier occurrence of salinity intrusion in the year.

No comments

- n/a -

Although current water management practices operate to provide salinity control, both the extent and duration of salinity intrusion are greater under current water management practices than under historical conditions. Likewise, current water management practices have changed the overall annual range in salinity (i.e., the difference between the highest and lowest salinity values during the year).

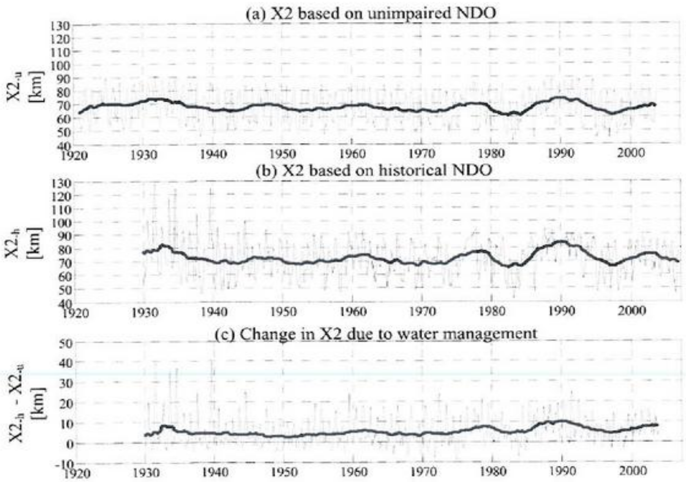

Figure 3-11 – Location of X2 under unimpaired and historical conditions
X2 has a strong seasonal and decadal variability under both unimpaired (top panel) and historical (middle panel) flow conditions reflecting the strong seasonal and decadal variability of NDO. The difference between historical and unimpaired conditions (bottom panel) illustrates the net effect of water management activities.

No comments

- n/a -

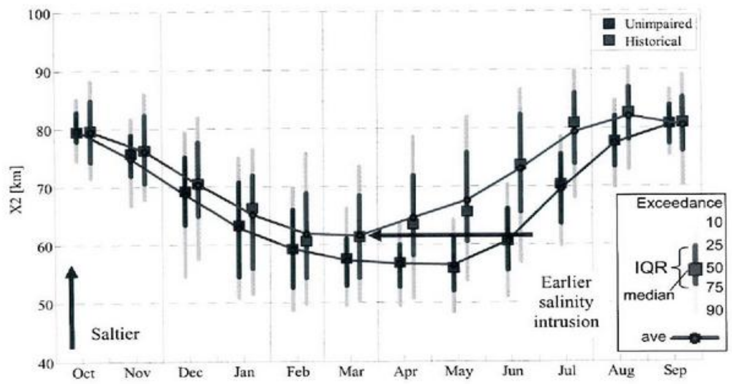

Figure 3-12 – Monthly distribution of X2 from 1945 through 2003

Figure 3-13 presents a comparison of unimpaired X2 and historical X2 during the 10 driest and the 10 wettest years of the CVP period (1945-2006).[19] During dry years (top panel), X2 is substantially greater under historical water management conditions than under unimpaired conditions (i.e., without water management); these effects are less dramatic but still occur during the wet years (bottom panel). Additionally, the annual range in salinity variability is significantly reduced under dry conditions (from approximately 22 km with unimpaired flows to 14 km with historical flows), but not wet conditions. The result of water management practices is a saltier Delta during both wet and dry years, with the greatest amount of salinity intrusion and reduced seasonal variability occurring in dry years.

Conclusions

The analysis of X2 (a measure of salinity intrusion in the Delta) shows that:

- Water management practices (reservoir operations and water diversions) result in a saltier Delta, with earlier salinity intrusion in the year.
- Water management practices result in a saltier Delta during both wet and dry years, but the effect is more pronounced in the dry years when the seasonal variability of salinity is also significantly reduced.

[19] Determination of the ten wettest and driest years is based on the total annual unimpaired Net Delta Outflow. The ten wettest years are 1952, 1956, 1958, 1969, 1974, 1982, 1983, 1986, 1995, and 1998. The ten driest years are 1947, 1976, 1977, 1987, 1988, 1990, 1991, 1992, 1994, and 2001.

No comments

- n/a -

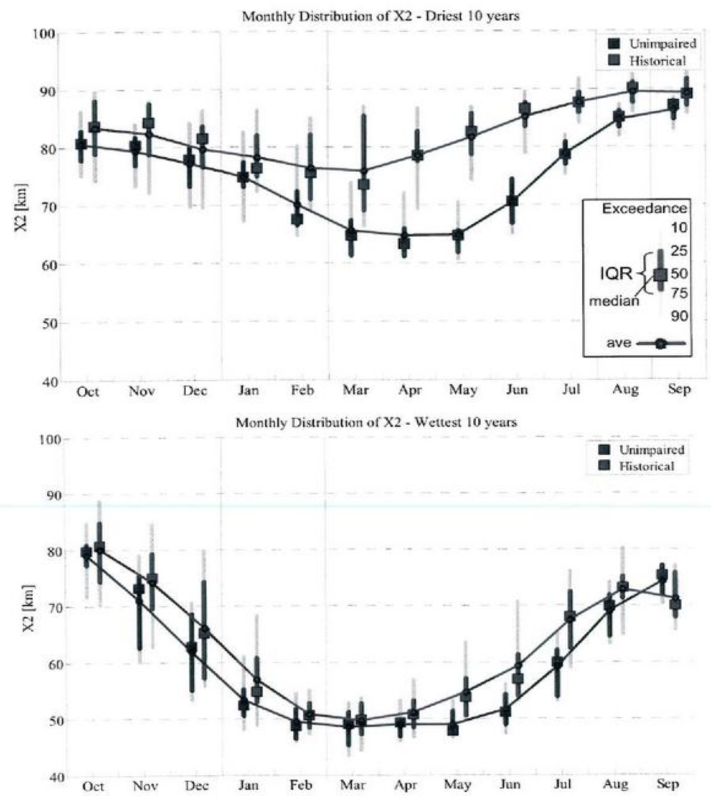

Figure 3-13 – Monthly X2 variability during wet and dry years (1945-2003)

Determination of the ten wettest and driest years is based on the total annual unimpaired Net Delta Outflow. The ten wettest years are 1952, 1956, 1958, 1969, 1974, 1982, 1983, 1986, 1995, and 1998. The ten driest years are 1947, 1976, 1977, 1987, 1988, 1990, 1991, 1992, 1994, and 2001.

No comments

- n/a -

No comments

- n/a -

3.3.4. Salinity at Collinsville

Collinsville, near the confluence of the Sacramento and San Joaquin Rivers, was one of the first long-term sampling locations implemented by the State of California. The Suisun Marsh Branch[20] of the DWR estimated monthly average salinity at Collinsville for the period 1920-2002, using a combination of 4-day TDS (total dissolved solids) grab samples from 1920-1971 and EC measurements from 1966-2002. Data from the overlap period of 5 years between the TDS grab samples and EC measurements were used in a statistical regression model, and the monthly averaged 4-day TDS samples were converted to monthly average EC (Enright, 2004). The result of this regression analysis was a time series of monthly EC values at Collinsville for the period of 1920-2002.

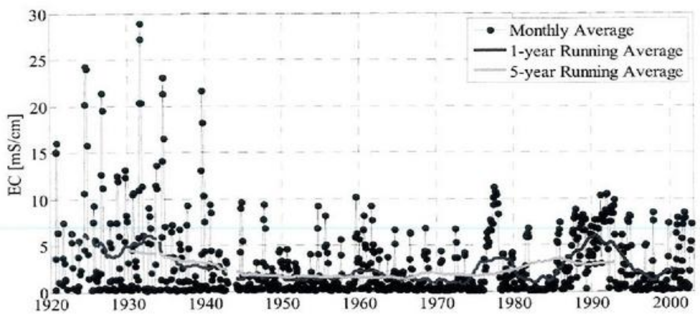

Figure 3-14 – Observed salinity at Collinsville
Monthly average salinity at Collinsville (black dots and black line), with the 12-month running average (red line) and 5-year running average (blue line).

Figure 3-14 shows the monthly average salinity at Collinsville for the period of 1920-2002, and Figure 3-15 shows the long-term trends in monthly salinity at Collinsville. Although the maximum values of salinity in the 1920's and 1930's far exceed subsequent salinity measurements at Collinsville, during the winters and springs of the 1920's and 1930's, the water at Collinsville freshened considerably. During the dry periods of 1920's and 1930's, monthly average salinity was below 350 μS/cm EC (approximately 50 mg/L chloride) for at least one month in every year. The one exception is 1924 which is inconclusive because no data were available from November through March. Monthly average EC data are missing for a portion of the winters and springs prior to 1926, and data for 1943 are missing entirely.

[20] Data provided by Chris Enright (DWR), personal communication, 2007.

No comments

- n/a -

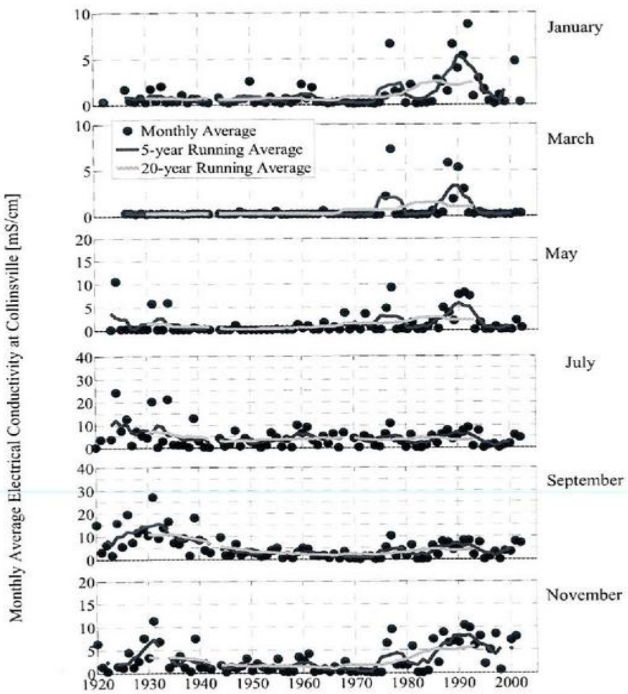

Figure 3-15 – Year-to-year trends in monthly-average salinity at Collinsville, 1920-2002
Monthly average salinity at Collinsville (black dots), with the 12-month running average (red line) and 5-year running average (blue line) for individual months.

Relatively fresh winters and springs during the 1920's are consistent with observations by C&H during that time period. However, monthly EC at Collinsville during the recent droughts (1976-1977 and 1987-1993) was always greater than 350 μS/cm EC, except for one month in both 1989 and 1992. These monthly observations of EC at Collinsville indicate that during the recent dry periods (1976-1977 and 1987-1993), EC at Collinsville was higher than that during similar dry periods in the 1920's and 1930's.

Enright and Culberson (2009) analyzed the trend in salinity variability at Collinsville from 1920-2006. They found increasing salinity variability in eleven of twelve months and

No comments

- n/a -

attributed it to water operations. In seven months (January-May, September-October) the increasing trend was significant ($p<0.05$).

Even in the six-year drought from 1928 to 1934, the Delta still freshened every winter (Figure 3-16). However, as shown in Figure 3-16, the Delta has not freshened during more recent droughts (1976-1977, 1987-1994, and 2007-2009). This indicates that the historical "flushing" of the Delta with fresh water is no longer occurring. This lack of flushing can also allow waste from urban and agricultural developments upstream of and within the Delta to accumulate. Contaminants and toxics have been identified as factors in the decline of the Delta ecosystem (Baxter *et al.* 2007). The data indicate the effect of managing to the X2 standard (implemented in 1995), as the salinity levels attained in the most recent drought are not as high as the 1976-77 and 1987-1992 droughts.

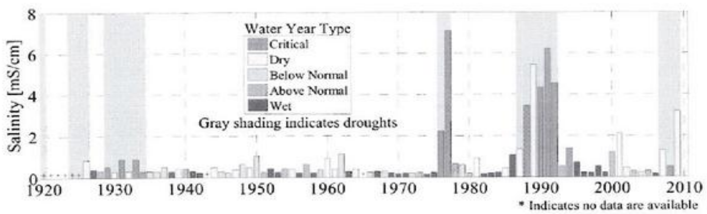

Figure 3-16 – Average Winter salinity at Collinsville

Annual average salinity during the winter (January through March) for water years 1927 to 2009. Bars are colored by water year type as defined by the Sacramento 40-30-30 index. Grey shading indicates multi-year droughts that include at least one critical water year.

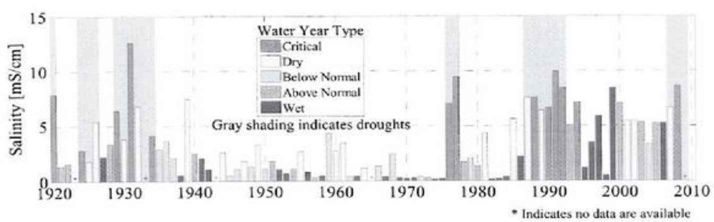

Figure 3-17 – Average Fall salinity at Collinsville

Annual average salinity during the fall months (October through December) for water years 1920 to 2009. Bars are colored by water year type as defined by the Sacramento 40-30-30 index. Grey shading indicates multi-year droughts that include at least one critical water year.

No comments

- n/a -

Figure 3-17 presents the variation in average fall salinity at Collinsville from 1920 to 2008 (October-December). Fall salinity is now high almost every year, while in the past, fall salinity was only high in dry and critical years. High salinity in the fall has been identified as a factor in the decline of the Delta ecosystem. Baxter *et al.* (2008) noted that "fall salinity has been relatively high during the POD years, with X2 positioned further [sic] upstream, despite moderate to high outflow conditions during the previous winter and spring of most years."

Conclusions

- In the 1920's and 1930's, the Delta freshened annually, even during droughts. In recent droughts, the Delta does not always freshen during the winter.
- Prior to 1976, fall salinity was high only in relatively dry years. Recently, fall salinity is high almost every year.

3.3.5. Salinity at Mallard Slough

A 1967 agreement between the Contra Costa Water District (CCWD) and the State of California requires the State to reimburse CCWD for the decrease in availability of usable river water, defined as water with less than 100 mg/L chlorides, at the Mallard Slough intake (CCWD, 1967). The 1967 agreement, and similar agreements between the State and other Delta water users, recognized the State Water Project (SWP) would increase salinity at Mallard Slough. The agreement defined a baseline of 142 days of usable water per year, based on the average number of days of usable water at the Mallard Slough intake from 1926-1967. Since 1967, the average number of days of usable water[21] (for the period 1967-2005) has declined to 122, indicating a 20-day (14%) reduction in the number of days of high quality water at Mallard Slough since the completion of the SWP.

[21] The data are from the USBR-CVO record of EC at Pittsburg, approximately 2 km upstream of Mallard Slough from 1967-2005. Since this station is located upstream of Mallard Slough, the number of days of usable water at Mallard Slough since the SWP was built may be overestimated.

No comments

- n/a -

4. Qualitative Observations of Historical Freshwater Flow and Salinity Conditions

In this section, qualitative observations of salinity conditions in the western Delta and Suisun Bay from the lawsuit filed by the Town of Antioch in 1920 and from various literature reports are discussed to provide a perspective of the salinity conditions prevailing in the late 1800's and early 1900's. Qualitative observations from early explorers and settlers are discussed in Appendix E.

4.1. Town of Antioch Injunction on Upstream Diverters

In 1920, the Town of Antioch filed a lawsuit (hereinafter referred to as the "Antioch Case") against upstream irrigation districts, alleging that upstream water diversions were causing increased salinity intrusion at Antioch. An overview of the Antioch Case is provided in Appendix E. The court decision, legal briefings, and petitions provide qualitative salinity observations from a number of witnesses. Although testimony in the Antioch Case is generally anecdotal, not quantitative, it provides a perspective of the salinity conditions prevailing in the early 1900's. Because the proceedings were adversarial in nature, this report focuses on the testimony of the upstream interests, who were trying to demonstrate that salinity intrusion was common near Antioch prior to their diverting water (prior to 1920). Consequently, the testimony may be biased in support of this "more saline" argument.

The upstream interests in the Antioch Case provided information on the operation of pumping plants along the San Joaquin River at Antioch for domestic water supply and the quality of water obtained from the pumping plants, summarized in Table 4-1.

Table 4-1 – Testimony regarding pumping plant operations and water quality in the 1920 Antioch Case

Time period of observation	Relevant information from the testimony
1866-1878	Mr. Dodge ran a pumping/delivery operation at Antioch ▪ Dodge pumped water into a small earthen reservoir at Antioch and then hauled the water to residents in a wagon. ▪ Cary Howard testified that while he was living in Antioch (1867-1876), the water became brackish one or two years in the fall, when they had to drive into the country to get water. This likely occurred during the drought of 1870-71.
1878-1880	Mr. Dahnken bought and operated the Dodge operation ▪ Dahnken testified that the water became brackish at high tide every year in the late summer, and remained brackish at high tide until it rained "in the mountains."

No comments

- n/a -

Time period of observation	Relevant information from the testimony
1880-1903	Belshaw Company provided water ▪ Dahnken testified that Belshaw Company pumped only at low tide.
1903-1920	Municipal Plant ▪ William E. Meek (resident since 1910) testified the water is brackish at high tide every year, for some months in the year. ▪ James P. Taylor testified that for at least the last 5 years, insufficient storage required the plant to pump nearly 24 hours per day, regardless of tidal phase. ▪ Dr. J. W. DeWitt testified that during October of most years between 1897 and 1918, the water was too brackish to drink. Even when the city only pumped at low tide, the water was occasionally so brackish that it would be harmful to irrigate the lawns.

This testimony suggests that, in the late 1800's, water at Antioch was known to be brackish at high tide during certain time periods, but Antioch was apparently able to pump fresh water at low tide year-round. A possible exception was the fall season during a few dry years. Water at Antioch was apparently fresh at low tide until at least around 1915. At that time, due to increased demand and inadequate storage, the pumping plants started pumping continuously, regardless of tidal stage. The window of time each year when Antioch is able to pump fresh water from the river has been substantially reduced in the last 125 years.

As shown in Appendix A, DWR (1960) estimated that water with a chloride concentration of 350 mg/L or less would be available about 85% of the time if there were no water management effects. DWR (1960) estimated that chloride concentrations at Antioch would be less than 350 mg/L about 80% of the time in 1900 and about 60% of the time by 1940. DWR also projected further deterioration of water quality by 1960 and beyond but did not include the effects of reservoir releases for salinity control.

Observations of salinity at Antioch during recent years indicate that salinity is strongly dependent on ocean tides, and the diurnal range in salinity can be as much as the seasonal and annual ranges in salinity. This is discussed in more detail in Appendices D and E. For instance, salinity at high tide can be more than five times the salinity at low tide (Figures D-1, D-2, and D-3), and the salinity during the course of a single day may vary up to 6,000 µS/cm EC (Figure D-1). Average daily salinity at low tide during the period of 1983-2002 exceeded 1,000 µS/cm[22] EC for about four and a half months of the year (Figure D-3). During the driest 5 years between 1983 and 2002, salinity at low tide was always greater than 1,000 µS/cm EC (i.e., no fresh water was available at any time of day) for about eight months of the year. Fresh water is currently available at Antioch far less frequently than prior to the 1920's.

[22] The current water quality criterion for municipal and industrial use is 250 mg/L, equivalent to about 1,000 µS/cm EC.

No comments

- n/a -

Available data and observations indicate that, prior to about 1918, fresh water was available at least at low tide during almost the entire year, in all but a few dry years. Around 1918, an abrupt change to higher salinity occurred. Although a prolonged and severe drought also began about this time, salinity conditions at Antioch did not return to pre-drought levels when the drought ended, indicating that water management activities (increased upstream diversions and later storage of water in upstream reservoirs) were the primary causes of this increased salinity.

4.2. Reports on Historical Freshwater Extent

Several literature reports discuss the spatial extent and duration of salinity conditions in the western Delta and Suisun Bay during the late 1800's and early 1900's. Salinity conditions at several key Delta locations are summarized below.

Location: **Western Delta**
Source(s): DPW (1931)
Quotation: "*The dry years of 1917 to 1919, combined with increased upstream irrigation diversions, especially for rice culture in the Sacramento Valley, had already given rise to invasions of salinity into the upper bay and lower delta channels of greater extent and magnitude than had ever been known before.*" (DPW, 1931, pg. 22)
Quotation: "*It is particularly important to note that the period 1917-1929 has been one of unusual dryness and subnormal stream flow and that this condition has been a most important contributing factor to the abnormal extent of saline invasion which has occurred during this same time.*" (DPW, 1931, pg. 66)
Summary: Salinity intrusion into the Delta during the period 1917-1929 was much larger than experienced prior to that time.

Location: **Pittsburg, CA**
Source(s): Tolman and Poland (1935) and DPW (1931)
Quotation: "*From 1880 to 1920, Pittsburg (formerly Black Diamond) obtained all or most of its domestic and municipal water supply from New York Slough offshore.*" (DPW, 1931, pg. 60)
Quotation: "*There was an inexhaustible supply of river water available in the New York Slough* [near Pittsburg at the confluence of the Sacramento and San Joaquin Rivers]*, but in the summer of 1924 this river water showed a startling rise in salinity to 1,400 ppm of chlorine, the first time in many years that it had grown very brackish during the dry summer months.*" (Tolman and Poland, 1935, pg. 27)
Summary: Prior to the 1920's, the water near the City of Pittsburg was sufficiently fresh for the City to obtain all or most of its fresh water directly from the river.

Location: **Antioch, CA**
Source(s): DPW (1931)

No comments

- n/a -

Quotation: *"From early days, Antioch has obtained all or most of its domestic and municipal water supply from the San Joaquin River immediately offshore from the city. This supply also has always been affected to some extent by saline invasion with the water becoming brackish during certain periods in the late summer and early fall months. However, conditions were fairly satisfactory in this respect until 1917, when the increased degree and duration of saline invasion began to result in the water becoming too brackish for domestic use during considerable periods in the summer and fall."* (DPW, 1931, pg. 60)

Summary: Until 1917, the City of Antioch obtained all or most of its freshwater supplies directly from the San Joaquin River. Salinity intrusion has prevented domestic use of water at the Antioch intake in summer and fall after 1917.

Location: **Benicia, CA (Suisun Bay)**

Source(s): Dillon (1980) and Cowell (1963)

Quotation: *"In 1889, an artificial lake was constructed. This reservoir, filled with fresh water from Suisun Bay during the spring runoff of the Sierra snow melt water ..."* (Dillon, 1980, pg. 131)

Quotation: *"...in 1889, construction began on an artificial lake for the* [Benicia] *arsenal which would serve throughout its remaining history as a reservoir, being filled with fresh water pumped from Suisun Bay during spring runoffs of the Sacramento and San Joaquin Rivers which emptied into the bay a short distance north of the installation."* (Cowell, 1963, pg. 31)

Summary: In the late 19th Century, fresh water was available in the Suisun Bay and Carquinez Straits for use by the City of Benicia.

The reported presence of relatively fresh water in the western Delta and the Suisun Bay during the late 1800's and early 1900's is consistent with the relatively fresh conditions observed in the paleoclimate records for this time period (Section 2.3) and the relatively wet conditions observed in the Sacramento River runoff and precipitation records (Section 3.1).

Additional observations between 1775 and 1841 are included in Appendix E. These qualitative observations indicated the presence of "*sweet*" water near the confluence of the Sacramento and San Joaquin Rivers in the vicinity of Collinsville in August 1775 (a period of average or above-average Sacramento River flow), and September 1776 (a period of below-average Sacramento River flow). The presence of "*very clear, fresh, sweet, and good*" water was reported in April 1776 (a dry year). Historical observations from 1796 and August 1841 (dry periods) indicated salinity "*far upstream*" at high tide and the presence of brackish (undrinkable) water in Threemile Slough. Current salinity controls and regulations put brackish water (averaged over 14 days) near Jersey Point and Emmaton, each about 2.5 miles below Threemile Slough, on a regular basis annually.

No comments

- n/a -

5. Conclusions

1. Measurements of ancient plant pollen, carbon isotope and tree ring data show that the Delta was predominately a freshwater marsh for the past 2,500 years, and that the Delta has become far more saline in the past 100 years because of human activity. Salinity intrusion during the last 100 years is comparable to the highest levels over the past 2,500 years.
2. Human activities during the last 150 years, including channelization of the Delta, elimination of tidal marsh, construction of deep water ship channels, and diversions of water, have resulted in increased salinity levels in the Delta. Today, salinity typically intrudes 3 to 15 miles farther into the Delta than it did in the early 20th Century.
3. Before the substantial increase in freshwater diversions in the 1940's, the Delta and Suisun Bay would freshen every winter, even during the extreme drought of the 1930's. However, that pattern has changed. During the most recent droughts (1976-1977, 1987-1994, and 2007-2009), the Delta did not always freshen in winter. Without seasonal freshening, contaminants and toxics can accumulate in the system and young aquatic species do not experience the same fresh conditions in the spring that occurred naturally.
4. While half of the past 25 years have been relatively wet, the fall salinity levels in 21 of those 25 years have resembled dry-year conditions. In terms of salinity, the Delta is now in a state of drought almost every fall because of human activity, including water diversions.
5. Seasonal and inter-annual variation in salinity has also been changed; however, this change is the result of reduced freshwater flows into the Delta. At any given location in the western Delta and Suisun Bay, the percentage of the year when fresh water is present has been greatly reduced or even eliminated.
6. The historical record and published studies show the Delta is far saltier now, even after the construction of reservoirs that have been used in part to meet State Water Resources Control Board water quality requirements in the Delta. Operation of reservoirs and water diversions for salinity management somewhat ameliorates the increased salinity intrusion, but the levels still exceed pre-1900 salinities.

No comments

- n/a -

No comments

- n/a -

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No comments

- n/a -

Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay

A summary of historical reviews, reports, analyses and measurements

Appendices

Water Resources Department

Contra Costa Water District

Concord, California

February 2010

Technical Memorandum WR10-001

Exhibit CCWD-6

No comments

- n/a -

No comments

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Exhibit CCWD-6

Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay

Appendices
February 2010

No comments

- n/a -

Tables

Figures

No comments

- n/a -

No comments

- n/a -

No comments

- n/a -

Appendix A. Factors Influencing Salinity Intrusion

Salinity intrusion in the Delta is the result of the interaction between tidally-driven saline water from the Pacific Ocean and fresh water from rivers flowing into the Delta. Regional climate change (e.g., sea level rise and change in precipitation regime), physical changes to the Central Valley landscape (e.g., creation of artificial channels and land use changes), and water management practices (e.g., reservoir storage, water diversions for agricultural and municipal and industrial use) affect this interaction between the ocean tides and the freshwater flow, in turn affecting salinity intrusion in the Delta (The Bay Institute (TBI), 1998, Department of Public Works (DPW), 1931, Nichols *et al.*, 1986, Conomos, 1979, and Knowles, 2000).

These factors are grouped into three categories (Table A-1) and discussed individually and qualitatively to provide context for observed salinity variability, which is necessarily due to the cumulative impact of all factors.

Table A-1 – Factors Affecting Salinity Intrusion into the Delta

Natural and artificial factors affect the salinity of the Delta. The factors are grouped into three categories: regional climate change, physical changes to the landscape, and water management practices.

Category	Factors affecting salinity intrusion and specific effect on Delta salinity
Regional Climate Change	• Precipitation regime o Long-term reduction of spring (April-July) snowmelt runoff may increase salinity in the spring, summer, and fall. o A shift to more intense winter runoff may not decrease salinity in the winter because outflows are typically already high during winter storms. • Ocean conditions o Added periodic variability to precipitation (via mechanisms such as the El Niño/Southern Oscillation (ENSO) or Pacific Decadal Oscillation (PDO)) • Sea level rise o Expected to increase salinity intrusion (DWR, 2006). Actual salinity response to rising sea level will depend upon actions taken to protect against flooding or overtopping (e.g., new tidal marsh vs. sea walls or dykes).
Physical Changes to the Landscape	• Deepening, widening, and straightening of Delta channels o Generally increase salinity, but response will depend upon location within the Delta (DWR, 2006)

No comments

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Category	Factors affecting salinity intrusion and specific effect on Delta salinity

	• Separation of natural floodplains from valley rivers
	  o Confining peak flows to river channels would reduce salinity during flood events.
	  o Preventing floodplains from draining back into the main channel would increase salinity after floods (late spring and summer).
	
	• Reclamation of Delta islands
	  o Varies (the effect on salinity depends on marsh vegetation, depth, and location), but marshes generally dampen tides, reducing salinity intrusion
	
	• Creation of canals and channel "cuts"
	  o Generally creates more efficient routes for tidal flows to enter the Delta, thereby increasing salinity intrusion relative to native conditions
	
	• Deposition and erosion of sediments in Suisun Bay (Cappiella *et al.*, 1999)
	  o Deposition of mining debris (occurred from 1860's to approximately 1887) reduced salinity in Suisun Bay and the western and central Delta (Enright, 2004, Enright and Culberson, 2009)
	  o Erosion (occurring since 1887) increases salinity in Suisun Bay and the western and central Delta (Enright, 2004, Enright and Culberson, 2009)

Water Management Practices (reservoir operations, water diversions, and exports from the Delta)	• Decreasing Net Delta Outflow (NDO) by increasing upstream and in-Delta diversions as well as exports
	  o Increases salinity
	
	• Increasing upstream storage capacity
	  o Generally increases salinity when reservoirs are filling. Reservoir releases may decrease salinity if they increase outflow. Historically, this occurred when flood control or other releases were required in wetter years. However, as this study shows, this has generally been small and intermittent; salinity measurements indicate it occurred occasionally prior to 1985, and very seldom since. Increased early winter diversion of runoff to storage will maintain or increase high salinities in the winter.

No comments

- n/a -

A.1. *Climatic Variability*

Changes in precipitation regimes and sea levels, brought about by a changing climate, can affect the spatial and temporal salinity conditions in the Delta. Long-term variations in river runoff, precipitation and sea level are discussed below.

A.1.1. Regional Precipitation and Runoff

Precipitation in the Bay-Delta watershed sets the amount of water available within the system which could ultimately reach the Bay and affect salinity conditions. However, since precipitation falls as both rain and snow, runoff to river channels is spread over more months than the precipitation events themselves; any runoff from rain generally reaches the river channels within days of the precipitation event, but runoff resulting from snow is delayed until the spring snowmelt. For this reason, estimates of unimpaired flow (runoff), rather than precipitation, are generally used to characterize hydrological variability. Unimpaired runoff represents the natural water production of a river basin, unaltered by water diversions, reservoir storage and operation, and export of water to or import of water from other basins.

Knowles (2000) determined that variability in freshwater flows accounts for the majority of the Bay's salinity variability. The spatial distribution, seasonal timing, annual magnitude, decadal variability, and long-term trends of unimpaired flow all affect the hydrology and salinity transport in the Delta. Total annual unimpaired flow in the Sacramento and San Joaquin basins from 1872 through 2009 is presented in Section 3.1, with the seasonal distribution provided for 1921 through 2003.

The total annual unimpaired flow of the upper Sacramento Basin for water years 1906 through 2006 exhibits substantial year-to-year variability with a strong decadal oscillation in the 5-year running average (see Figure 3-1). On average, over the last 100 years, the total annual unimpaired Sacramento River flow is increasing by about 0.06% or 11 thousand-acre feet (TAF) each year. However, increased total annual unimpaired flow does not necessarily reduce salinity intrusion. Knowles (2000) illustrated that the seasonal timing of runoff can significantly alter salinity intrusion without any change to the total annual runoff.

Typically, most precipitation in California occurs during winter in the form of snow in the Sierra Nevada. The subsequent melting of this snow, beginning in the spring, feeds the rivers that flow into the Delta. The four months from April through July approximately span the spring season and represent the period of runoff due to snow melt. The long-term trend in spring (April-July) runoff decreased by approximately 1.3 MAF from 1906 to 2006 (Figure A-1). This effect is believed to be caused by climate change; as temperatures warm, more precipitation falls as rain instead of snow, and what snowpack that does accumulate tends to melt earlier in the year. This leads to higher runoff during winter months, but lower runoff in spring or summer, resulting in the potential for greater salinity intrusion. These observed changes in the magnitude and timing of spring runoff of the Sacramento River watershed are consistent with similar changes in spring runoff observed across river watersheds of the

No comments

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western United States (e.g., Dettinger, 2005; Mote *et al.*, 2005; Stewart *et al.*, 2005). Note that, from 1920 to 2006, the long-term trend in spring runoff actually increased slightly (approximately 0.5 MAF).

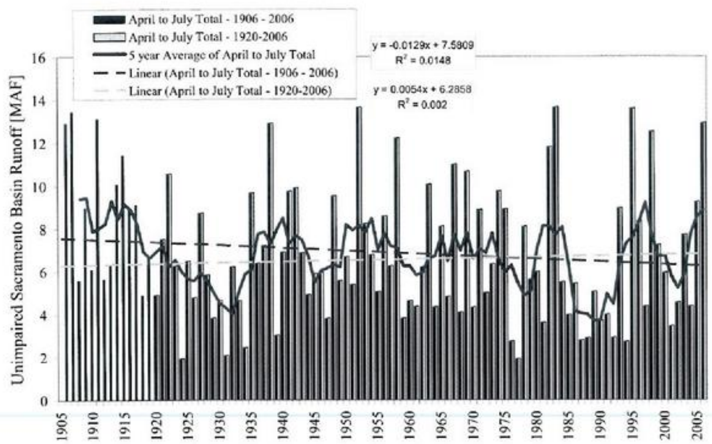

Figure A-1 – Unimpaired runoff from the Sacramento River basins from April to July
Data source: http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST.

Precipitation and runoff are influenced by regional events such as the Little Ice Age (about 1300 to 1850 CE) and the Medieval Warm Period (about 800 to about 1300 CE). During the Little Ice Age, the winter snowline in the Sierra was generally at a lower elevation, and spring and summer nighttime temperatures were significantly lower. This temperature pattern would allow the snowmelt to last further into the summer, providing a more uniform seasonal distribution of runoff such that significantly less salinity intrusion than occurs today would be expected. This expectation is borne out by paleosalinity studies (see Section 2.3).

At shorter time scales, oceanic conditions such as the Pacific Decadal Oscillation (PDO) and El Niño/Southern Oscillation (ENSO) also impact precipitation and runoff patterns. Runoff in the upper watershed is the primary factor that determines freshwater outflow from the Delta. Anthropogenic flow management (upstream diversions, reservoir operations, in-Delta diversions, and south-of-Delta exports) alters the amount and timing of flow from the upper watershed (see Section 2.3). Changes to the physical landscape further alter the amount and timing of flow (see Section 2.2).

No comments

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A.1.2. Sea Level Rise

Sea level fluctuations resulting from the repeated glacial advance and retreat during the Pleistocene epoch (extending from 2 million years ago to 15,000 years ago) resulted in deposition of alternating layers of marine and alluvial sediments in the Delta (TBI, 1998). A warming trend starting about 15,000 years ago ended the last glacial advance and triggered rapid sea-level rise. At the end of this period (known as the "Holocene Transgression") approximately 6,000 years ago, sea level had risen sufficiently to inundate the Delta at high tide (Atwater *et al.*, 1979).

Sea level is estimated to have risen at an average rate of about 5 cm/century during the past 6,000 years and at an average rate of 1-2 cm/century during the past 3,000 years (Cayan *et al.*, 2008). Observations of sea level at the Golden Gate in San Francisco reveal that the mean sea level has risen at an average rate of 2.2 cm/decade (or 0.22 mm/yr) over the past 100 years (Cayan *et al.*, 2008). Future increases in sea level are expected to increase salinity intrusion into the Delta (DWR, 2006); actual salinity response to rising sea level will depend upon actions taken to protect against flooding or levee overtopping (e.g. new tidal marsh would generally reduce salinity intrusion, while construction of sea walls or dykes may further increase salinity).

A.2. Physical Changes to the Delta and Central Valley

Creation of artificial channels, reclamation of marshlands, land use changes and other physical changes to the landscape of the Delta and Central Valley have significantly altered water movement through the Delta and the intrusion of salinity into the Delta. Major physical changes to the Delta and Central Valley landscape have occurred over the last 150 years. As many of these physical changes were made prior to flow and salinity monitoring (which began in the 1920's), only a qualitative discussion is presented below.

A.2.1. Deepening, Widening, and Straightening Channels (early 1900's-present)

The lower Sacramento River was widened to 3,500 feet and straightened (creating Decker Island) around 1910 (Lund *et al.*, 2007). Progressive deepening of shipping channels began in the early 1900's. Original channel depths were less than 10 feet; channels were gradually dredged to depths exceeding 30 feet, and maintenance dredging continues today.

These changes to the river channels have increased salinity intrusion. Deepening the river channels increases the propagation speed of tidal waves, leading to increased salinity intrusion. Similarly, straightening the river channels provides a shorter path for the passage of the tidal waves and increases salinity intrusion. Widening of the river channels increases the tidal prism (the volume of water in the channels), resulting in further salinity intrusion. Larger cross-sections reduce velocities, lowering friction losses and maintaining more tidal energy, which is the driving force for dispersing salinity into the Delta.

No comments

- n/a -

A.2.2. Reclamation of Marshland (1850-1920)

In the Central Valley

The original natural floodplains captured large winter flows, gradually releasing the water back into the river channels throughout the spring and summer, resulting in a more uniform flow into the Delta (reduced peak flow and increased low flow) compared to current conditions. The increased surface area of water stored in these natural floodplains increased total evaporation and groundwater recharge, reducing total annual inflow into the Delta.

Even with less Delta inflow, the difference in the seasonal flow pattern may have limited salinity intrusion. The drainage of floodplains back into rivers during the spring and groundwater seepage back to the rivers in the summer and fall provided a delayed increase in river flows during the low flow period. Raising and strengthening natural levees in the Central Valley effectively disconnected the rivers from their floodplains, removing this natural water storage, increasing the peak flood flows and reducing the low flows. The net effect of these changes in the Central Valley was to reduce salinity during floods, when salinity is typically already low, and increase salinity during the following summers and falls, which is likely to have led to increased maximum annual salinity intrusion.

In the Delta

Reclamation of Delta marshland began around 1850. By 1920, almost all land within the legal Delta[1] had been diked and drained for agriculture (DPW, 1931). Before the levees were armored and the marshes were drained, the channels would have been shallower and longer (more sinuous), which would have slowed propagation of the tides into the Delta, reduced tidal energy and reduced salinity intrusion.

The natural marsh surface would have increased the tidal prism. However, the shallow marsh depth and native vegetation would have slowed the tidal wave progression. The combined effect on salinity intrusion depends on the location and depth of the marsh, the native vegetation distribution, and the dendritic channels that were removed from the tidally active system.

Figure A-2 shows the western, central, and southern portions of the Delta in 1869. For comparison, Figure A-3 shows the same area in 1992, with man-made channels highlighted grey.

A.2.3. Mining debris

Hydraulic mining in the Sierra Nevada began in the 1860's and produced large quantities of debris which traveled down the Sacramento River, through the Delta and into the Bay. Mining debris may have contributed to the extensive flooding reported in 1878 and 1881. Cappiella *et al.* (1999) estimate that, from 1867 to 1887, approximately 115 million cubic meters (Mm3) of sediment were deposited in Suisun Bay. This deposition was due to the inflow of hydraulic mining debris.

[1] The legal Delta is defined in California Water Code Section 12220.

No comments

- n/a -

Figure A-2 - Map of the Delta in 1869

Channels of the western, central, and southern Delta in 1869, prior to extensive reclamation efforts (Gibbes, 1869)

No comments

- n/a -

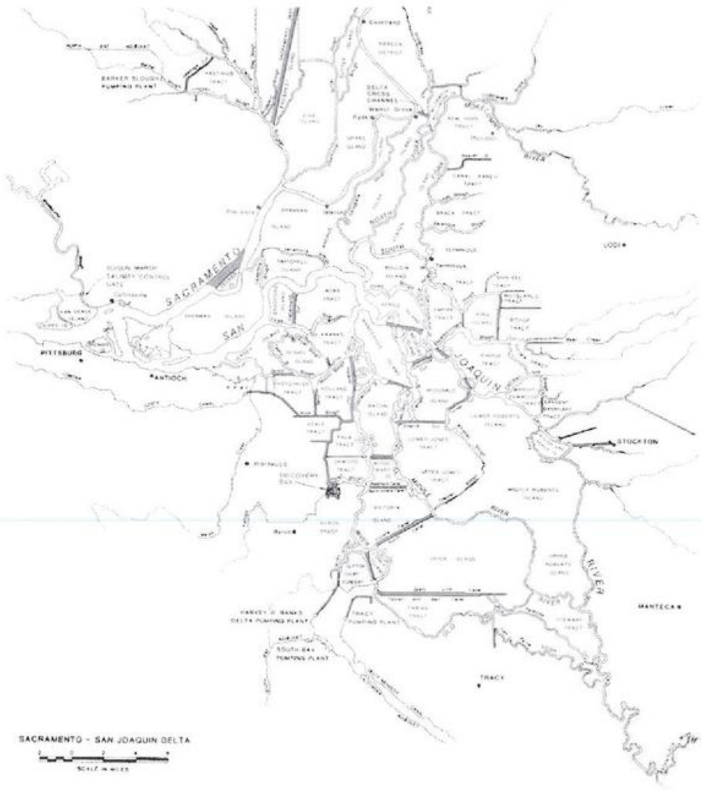

Figure A-3 – Map of the Delta in 1992

Channels of the western, central, and southern Delta from the Delta Atlas (DWR, 1992) Constructed waterways (highlighted in grey) generally create more efficient routes for tidal flows to enter the Delta, thereby increasing salinity intrusion relative to the native tidal marshes.

No comments

- n/a -

Cessation of hydraulic mining around 1884 resulted in erosion of Suisun Bay, which continues to erode even today. From 1887 to 1990, approximately 262 Mm3 of sediment were eroded from Suisun Bay. The net change in volume of sediment during 1867-1887 was 68 Mm3 (net deposition) and during 1887-1990 was -175 Mm3 (net erosion). As a result of these changes, the tidal flat of Suisun Bay increased from about 41 km^2 in 1867 to 52 km^2 in 1887, but decreased to 12 km^2 by 1990 (due to erosion subsequent to the cessation of hydraulic mining). Cappiella *et al.* (1999) attributed the change in the Suisun Bay area from being a largely depositional environment to an erosional environment not only to the hydraulic mining practices of the late 1800's but also to increased upstream water management practices. The Suisun Marsh Branch of the DWR estimated that erosion of Suisun Bay (modeled as a uniform change in depth of 0.75 meters) has increased salinity in Suisun Bay and the western Delta by as much as 20% (Enright, 2004; Enright and Culberson, 2009).

A.3. Water Management Practices

Extensive local, state, and federal projects have been built to move water around the state, altering the natural flow patterns throughout the Delta and in upstream watersheds. For clarity in the discussion that follows, definitions and discussions of actual flow and salinity, unimpaired flow and salinity, and natural flow and salinity, are given below.

Historical (actual) flow and salinity
Historical (or actual) flow and salinity refer to the flow and electrical conductivity, total dissolved solids concentration, or chloride concentration that occurred in the estuary. Historical conditions have been observed, measured, or estimated at various times and locations; they are now measured at monitoring stations throughout the estuary. Historical data are also used to estimate flow and water quality conditions at other locations with the following tools: the DAYFLOW program from IEP, the DSM2 model from the California Department of Water Resources, the X2[2] equation (Kimmerer and Monismith, 1992) and Contra Costa Water District's salinity outflow model (also referred to as the G-model) (Denton, 1993; Denton and Sullivan, 1993). The use of these tools to estimate flow and water quality is necessarily dependent upon the Delta configuration to which they were calibrated. Use of these tools in hypothetical configurations (such as pre-levee conditions, flooding of islands, etc) is subject to un-quantified error.

Unimpaired flow and salinity
Unimpaired flows are hypothetical flows that would have occurred in the absence of upstream diversions and storage, but with the existing Delta and tributary configuration. Unimpaired flows are estimated by the California Department of Water Resources (DWR) for the 24 basins of the Central Valley; the Delta is one of the 24 basins. Additionally, DWR estimates unimpaired in-Delta use and unimpaired net Delta outflow (NDO). Unimpaired NDO estimates can be used to estimate unimpaired water quality using a salinity-outflow relationship such as the X2 or G-model tools discussed above.

[2] X2 is defined as the distance from the Golden Gate to the 2 part-per-thousand isohaline (equivalent to a salinity of 2 grams of salt per kilogram of water), measured along the axis of the San Francisco Estuary. X2 is often used as an indicator of freshwater availability and fish habitat conditions in the Delta (Jassby *et al.*, 1995; Monismith, 1998).

No comments

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Since unimpaired flows assume the existing Delta configuration, the use of these tools should not violate their basic assumptions. However, the results should be taken in context. Water quality based on unimpaired flows compared to water quality based on historical (actual) flows shows how water management activities affect water quality. Water quality based on unimpaired flows cannot be considered natural.

Natural flow and salinity

Natural flow and salinity reflect pre-European settlement conditions, with a virgin landscape in both the Central Valley and the Delta, native vegetation, and no diversions or constructed storage. As discussed above, the natural landscape included natural storage on the floodplains and extensive Delta marsh. Estimation of natural flow requires assumptions regarding the pre-European landscape and vegetation throughout the Central Valley. Estimation of natural salinity requires development of new models to account for pre-European Delta geometry, incorporating the estimates of natural flow. These assumptions induce an unknown level of error. For this reason, no attempt is made in this report to calculate natural flow or the resulting salinity. Instead, paleosalinity studies are examined to provide evidence of salinity in the pre-European era.

Water management practices have continually evolved since the mid-1850's. As discussed in Section 1.1, anthropogenic modification include diversion of water upstream and within the Delta, construction of reservoirs, and system operations to meet regulatory requirements.

The irrigated acreage in the Central Valley has been steadily increasing since 1880 (Figure 1-3), increasing the upstream diversions of water. There were two periods of rapid growth in irrigated acreage: from 1880 to 1920 and from 1940 to 1980. In-Delta diversions (Figure 1-3) began in 1869 with reclamation of Sherman Island; from 1869 to 1930, in-Delta diversions are assumed to have grown in proportion to the area of reclaimed marshland (from Atwater *et al.*, 1979).

Upstream diversions first became an issue with respect to Delta salinity around 1916 with the rapid growth of the rice cultivation industry (Antioch Case, Town of Antioch v. Williams Irrigation District, 1922, 188 Cal. 451; see Appendix E.2). These early "pre-project" diversions for irrigation had particularly large impacts because of the seasonality of water availability and water use. Diversions for agriculture typically start in the spring and continue through the early fall (when river flow is already low). These early irrigation practices, combined with the decrease in spring and summer flow due to the separation of rivers from their natural floodplains, resulted in a significant reduction of the spring and summer river flow, leading to increased salinity intrusion.

Figure A-4 shows the Department of Water Resources' estimates of the effects of upstream diversions and south-of-Delta exports on the salinity in the San Joaquin River at Antioch (DWR, 1960). DWR's 1960 report indicated that water with less than 350 mg/L chlorides would be present at Antioch approximately 88% of the time on average "naturally," and that availability decreased to approximately 62% by 1940 due to upstream diversions. This illustrates that upstream depletions had a significant effect on salinity at Antioch during 1900-1940, prior to the construction of large upstream reservoirs. (For reference, Shasta Dam was completed in 1945.)

No comments

- n/a -

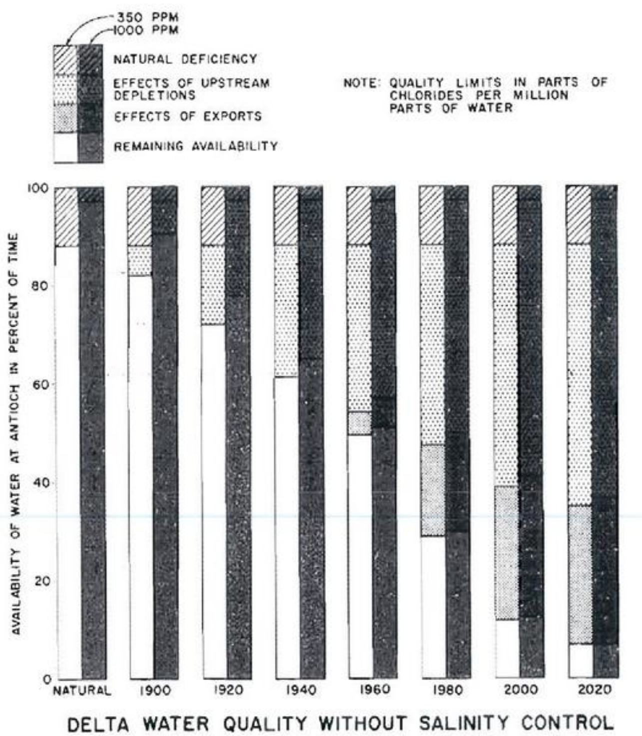

Figure A-4 - Salinity on the San Joaquin River at Antioch (DWR, 1960)

The Department of Water Resources examined the effects of upstream depletions and south-of-Delta exports on salinity in the San Joaquin River at Antioch, estimating the percent of time water that a certain quality of water (with less than 350 mg/L chlorides; or less than 1,000 mg/L chlorides) would be available in the river without reservoir releases to provide salinity control. The estimates for 1960, 1980, 2000, and 2020 assume the reservoirs do not make releases for salinity control and therefore underestimate the actual quality of water during these years.

Figure A-4 also shows estimates of the availability of water in 1960, 1980, 2000, and 2020, without reservoir releases to provide salinity control, demonstrating that upstream depletions and in-Delta exports would have continued to degrade water quality at Antioch.

No comments

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Exports from the south Delta started in 1951 with the completion of the federal Central Valley Project pumping facility near Tracy, California. Exports from the State Water Project Banks Pumping Plant, just to the west of the federal facility, began in 1967. As shown in Figure 1-3, south-of-Delta exports increased rapidly from 1951 through the mid-1970s, and since then the combined exports have averaged more than 4 million acre-feet per year.

Construction of upstream reservoirs also altered natural patterns of flow into the Delta. Figure A-5 and Figure A-6 show the extent and rapid rise of constructed reservoirs in the upstream watersheds of the Delta (DWR, 1993). The location, year of completion and approximate storage capacities (in acre-feet, AF) are shown in Figure A-5. Figure A-6 shows the temporal development of reservoir capacity. Reservoir construction began in 1850. The major reservoirs of the Central Valley Project (CVP) and State Water Project (SWP) are the Shasta (4.5 MAF capacity) and Oroville (3.5 MAF) reservoirs, respectively. These reservoirs capture the flow in the wet season (reducing the flow into the Delta in the wet season) and release water for irrigation and diversions.

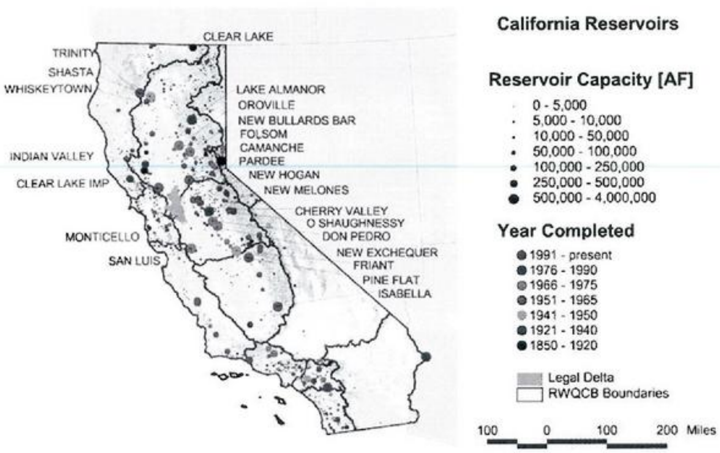

Figure A-5 – Storage reservoirs in California

Location of storage reservoirs within California. Reservoir capacity is indicated by the size of the circle, while the year construction was completed is indicated by color.

No comments

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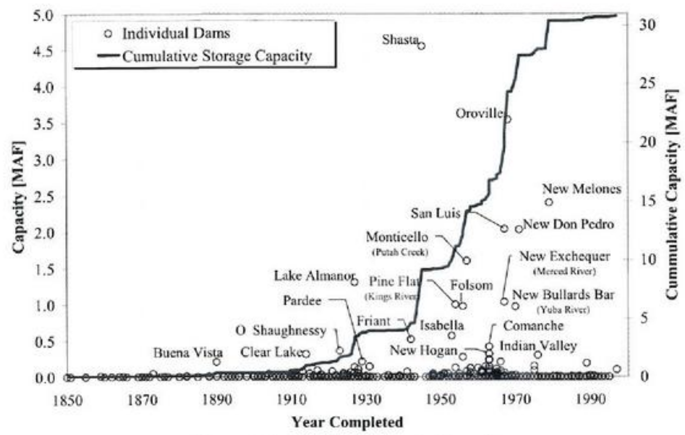

Figure A-6 – Surface Reservoir Capacity

Timeline of reservoir development in California. Individual reservoir capacity is indicated by the blue circles (left axis), while the cumulative capacity is indicated with the red line (right axis).

Water management practices have been altered by regulations that require maintenance of specified flow and salinity conditions at locations in the Bay-Delta region during certain periods of the year. The 1978 Water Quality Control Plan and State Water Resources Control Board (SWRCB) Decision 1485 established water quality standards to manage salinity to protect Delta agriculture and municipal and industrial (M&I) uses. The listing of delta smelt as a threatened species under the Endangered Species Act in 1993, followed by the Bay-Delta Accord in 1994 and the adoption of a new water quality control plan by the State Water Resources Control Board in 1995 changed the amount and timing of reservoir releases and south-of-Delta exports. California's Rice Straw Burning Act was enacted in 1992 to reduce air pollution by phasing out the burning of rice field stubble; by 1999, Sacramento Basin rice farmers were diverting additional water to flood harvested fields to decompose the stubble.

Changes in water diversions and reservoir operations have altered the magnitude and timing of river flows to the Delta, and anthropogenic modifications to the Delta landscape have altered the interaction of fresh water from the rivers with salt water from the ocean, thus changing patterns of salinity intrusion into the Delta.

No comments

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No comments

- n/a -

Appendix B. Paleoclimatic Records of Hydrology and Salinity

This section presents paleoclimate records of hydrology (precipitation and unimpaired runoff) and salinity in the Bay-Delta region, in addition to those presented in Section 2 of the main report.

B.1. Methods of Paleoclimatic Reconstruction

The field of paleoclimatology aims to deduce climatological information from natural "archives" in order to reconstruct past global climate. These archives are created by such Earth processes as the formation of ice sheets, sediments, rocks, and forests. Examples of information sampled from such archives include atmospheric temperatures from ice cores and precipitation cycles from tree rings. When samples are dated, through radiometric or other methods, the data preserved therein become proxy indices, establishing a timeline of major events in the local environment of the sample. Multiple samples collected over larger spatial scales can be cross-dated to create regional climate and landscape process chronologies.

The material sampled for paleoclimatic reconstructions has limitations that decrease the resolution and confidence of data going back in time. Although paleoclimatic reconstructions have a coarser temporal resolution than modern measurements, the variations in climate and landscape responses to change are reliably described "in the first person" because the evidence of localized climate change is preserved as a time series *in situ*, absent of human influence.

The San Francisco Bay-Delta has been the focus of several paleoclimatic reconstructions. Surveys have sampled from Browns Island (Goman and Wells, 2000; May, 1999; Malamud-Roam and Ingram, 2004), Roe Island (May, 1999; Malamud-Roam and Ingram, 2004) Rush Ranch (Starratt, 2001; Byrne *et al.*, 2001; Starratt, 2004), and China Camp and Benicia State Parks (Malamud-Roam and Ingram, 2004).

Sediment cores are the predominate archive used to reconstruct Bay-Delta climate. Changes in wetland plant and algae communities are the dominant response in the Bay-Delta to climate change and associated fluctuations in temperature and precipitation. Proxies of plant and algae response to environmental conditions are preserved in the sediment cores and determined by quantification and taxonomic identification of diatom frustules (Byrne *et al.*, 2001; Starratt, 2001; Starratt, 2004), plant seeds and roots (Goman and Wells, 2000) and plant pollen (May, 1999; Byrne *et al.*, 2001; Malamud-Roam and Ingram, 2004) and measurement of peat carbon isotope ratios (Byrne *et al.*, 2001; Malamud-Roam and Ingram, 2004).

Plant communities in the Delta are characterized by salt tolerance. Salt-tolerant plant communities are dominated by pickleweed (*Salicornia* spp.) while freshwater plant

No comments

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assemblages are dominated by tule (*Scirpus* spp.) and cattail (*Typha* spp.) (Atwater *et al.*, 1979). Plants contribute pollen, seeds, and vegetative tissue in the form of peat to the sediment archive. Plant material deposited to surface sediments are significantly correlated to the surrounding standing vegetation, and thus plant material preserved in sediment cores are considered autochthonous to the type of wetland existent at the time of sediment deposition, allowing reconstruction of the salinity conditions in the Delta over time.

Diatom taxa are classified according to their salinity preference expressed as the Diatom Salinity Index (DSI) (Eq 1) (Starratt, 2004). Starratt (2001) classified salinity preference as freshwater (F; 0-2‰), freshwater and brackish water (FB; 0-30‰), brackish (B; 2-30‰), brackish and marine (BM; 2-35‰), and marine (M; 30-35‰). Samples dominated by marine taxa have a DSI range of 0.00 to 0.30.

$$DSI = \frac{F + FB + 0.5B}{F + FB + B + BM + M} \qquad (1)$$

Carbon-isotope ratios ($^{13}C/^{12}C$) (Eq 2) are measured by spectrometry and the δ notation calculated as

$$\delta^{13}C = \left[\left(\frac{^{13}C/^{12}C_{sample}}{^{13}C/^{12}C_{std}}\right) - 1\right] \times 1000 \qquad (2)$$

The $\delta^{13}C$ value of peat samples is a proxy for the composition of the plant assemblages contributing vegetation to the formation of the peat. Plants utilizing the C_4 mechanism have higher $\delta^{13}C$ values (~-14‰) than those utilizing the C_3 or CAM (~-27‰) (Table B-1). Using the $\delta^{13}C$ proxy can detect the presence of upland bunchgrasses such as *Spartina* and *Distichlis*.

Pollen can be classified to the taxonomic family level. *Chenopodiaceae (*now *Salicornioideae*) is representative of salt-tolerant *Salicornia*. *Cyperaceae* is representative of freshwater species including *Scirpus*. The ratio of *Chenopodiaceae* to the sum of *Chenopodiaceae* and *Cyperaceae* (Eq. 3) is a proxy of the percent relative abundance of salt-tolerant species (May, 1999).

$$\%ST = \frac{Chenopodiaceae}{Chenopodiaceae + Cyperaceae} \qquad (3)$$

To establish chronologies for sediment archives, dates must be established for when material was deposited through the length of the sediment cores. Radiocarbon dating by Accelerator Mass Spectrometry (AMS) determines age by counting the ^{14}C content of plant seeds or carbonate shells calibrated against a northern hemisphere atmospheric carbon calibration curve (Malamud-Roam *et al.*, 2006). Radiocarbon dating is valid to about 40,000 years

No comments

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before present (BP)[3], making it an ideal method for establishing dates through the period of interest for the Bay and Delta. When archived proxies are correlated with the sediment core chronology, a timeline is established reconstructing past climate and landscape response.

Table B-1 – Carbon Isotope Ratios ($\delta^{13}C$) of Plant Species in the San Francisco Estuary
(adapted from Byrne et al. 2001)

Species	Common Name	Photosynthetic Pathway	δ13C (‰)
Distichlis spicata	Saltgrass	C4	-13.5
Spartina foliosa	California cordgrass	C4	-12.7
Cuscuta salina	Salt-marsh dodder	C3	-29.8
Frankenia grandifolia	Alkali heath	C3	-30.2
Grindelia stricta	Gumplant	C3	-26.4
Jaumea carnosa	Marsh jaumea	C3	-27.2
Juncus balticus	Baltic rush	C3	-28.4
Lepidium latifolium	Perennial pepperweed	C3	-26.6
Scirpus californicus	California bulrush	C3	-27.5
Scirpus maritimus	Alkali bulrush	C3	-25.5
Typha latifolia	Cattail	C3	-27.8
Salicornia virginica	Pickleweed	CAM	-27.2

A large number of paleoclimatic reconstructions exist for California and the western U.S., but a complete discussion is beyond the scope of this report. These reconstructions are reviewed by Malamud-Roam *et al.* (2006; 2007) and provide important context to events in the Bay and Delta by recording major non-localized events and larger regional climate shifts. Important examples include: Central Valley oaks, Sierra Nevada giant sequoias, and White Mountain Bristlecone pines used to establish precipitation and temperature from the location of the tree line and tree rings; Mono Lake sediments and submerged tree stump rings for precipitation; and Sacramento and San Joaquin River floodplain deposits for flood events. These studies establish a record of environmental conditions in the Bay and Delta from their formation to the present.

B.2. *Major Regional Climatic Events*

Formation of the Sacramento-San Joaquin Delta

The Holocene epoch began approximately 8000 BCE at the end of Pleistocene glaciations (Malamud-Roam *et al.*, 2007). In the early Holocene, a general warming and drying period in California accompanied high orbitally driven insolation until insolation reached current values at approximately 6000 BCE. In the Sierra Nevada, western slopes were in the early stages of ecological succession following the retreat of glaciers. The modern river floodplain systems were forming in the Central Valley. Parts of the Delta and Bay were river valleys

[3] Before Present (BP) is a time scale, with the year 1950 as the origin, used in many scientific disciplines. Thus, 100 BP refers to the calendar year 1850.

No comments

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prior to approximately 8000 to 6000 BCE, when rapidly rising sea level entered the Golden Gate and formed the early Bay estuary (Atwater *et al.*, 1979). A fringe of tidal marshes retreated from a spreading Bay until approximately 4000 BCE when the rate of submergence slowed to 1 to 2 cm per year, allowing the formation of extensive Delta marshes over the next 2000 years (Atwater *et al.*, 1979). Sedimentation from upstream sources kept up with subsidence from increasing sea-level rise.

2000 – 1 BCE

After 2000 BCE, information from archives indicates climate in the Bay and Delta was cooler with greater freshwater inflows. The Sierra Nevada became more moist and cooler during a period ca. 4000-3500 BP (Malamud-Roam *et al.*, 2006).

1 BCE - Present

The cooler and wetter period ended approximately 1 BCE, replaced by more arid conditions (Malamud-Roam, 2007). Major climatic events, known from other parts of the world, are captured in the regional paleoclimatic reconstructions and help to calibrate or correlate these reconstructions to global events. Unusually dry conditions prevailed during the Medieval Warm Period (approximately 800-1300 CE). Wetter and cooler conditions existed during the Little Ice Age (approximately 1400-1700 CE). These climate variations are reflected in variations in the plant communities.

Droughts

Two extreme droughts occurred in the region from about 900 to 1150 CE and from 1200 to 1350 CE. Low freshwater inflows to the Delta occurred during periods 1230-1150, 1400-1300, 2700-2600, and 3700-3450 B.P.

Flood Events

Periods of increase moisture occurred from 800-730 BP and 650-300 BP. Massive flooding inundated the Central Valley in the winter of 1861 (Malamud-Roam *et al.*, 2006). High periods of inflow occurred during 1180-1100, 2400-2200, 3400-3100, and 5100-3800 BP.

Sampling for paleoclimatic reconstructions captures the modern era, enabling a comparison of current conditions with conditions over the past several thousand years. The erratic nature of precipitation in California observed over the past century have been normal and small compared to natural variations over the past millennia.

Reconstructed River Flow and Precipitation Records

Meko *et al.* (2001a) used tree-ring chronologies in statistical regression models to reconstruct time series of annual unimpaired Sacramento River flow for approximately the past 1,100 years (see Section 2.1). Similarly, Graumlich (1987) used tree ring data from the Pacific Northwest to reconstruct precipitation records for the period of 1675-1975 (Figure B-1). Compared to the average observed precipitation from 1899 to 1975, the reconstructed record has above-average precipitation during the latter half of the nineteenth century (1850-1900) (Figure B-1). These relatively wet conditions during the late 1800's and the severe dry

No comments

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conditions from the 1920's trough the 1930's in the reconstructed precipitation record are consistent with the annual unimpaired Sacramento River flow reconstruction from Meko *et al.* (2001) presented in Section 2.1.

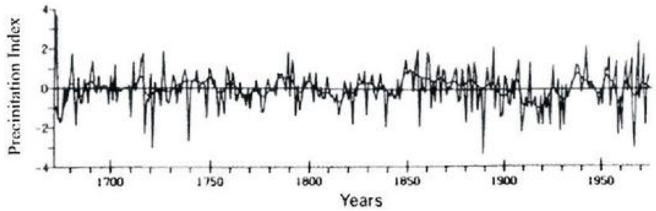

Figure B-1 – Reconstructed annual precipitation, 1675-1975
Data from Graumlich (1987). Precipitation index is presented in units of standard deviation from the 1899-1975 observed mean value.

Estimates of annual precipitation (Graumlich, 1987) and unimpaired runoff (Meko *et al.*, 2001a) from tree ring analysis are used in this study to provide hydrological context, indicating the relative hydrology (e.g. wet or dry) of a specific year and surrounding decade. The reconstructed hydrological data are not used to estimate salinity intrusion for two reasons. First, the seasonal distribution of hydrology is critical in determining salinity variability; two years with the same total annual flow could have significantly different salinity intrusion due to the timing of the flow (Knowles, 2000). Second, since 1850, anthropogenic modifications to the landscape and river flows alter the hydrodynamic response to freshwater flow, somewhat decoupling the unimpaired hydrology from the downstream response (i.e. salinity intrusion).

Malamud-Roam *et al.* (2005) and Goman *et al.* (2008) review paleoclimate as it relates to San Francisco Bay. Generally, they found that paleoclimatic studies showed that a wetter (and fresher) period existed from about 4000 BP to about 2000 BP. In the past 2,000 years, the climate has been cooling and becoming drier, with several extreme periods, including decades-long periods of very wet conditions and century-long periods of drought. As discussed in the next section, the century-long periods of drought are found in paleosalinity records in Suisun Bay and Rush Ranch in Suisun Marsh, but are much less evident in Browns Island, indicating a predominately freshwater marsh throughout the Delta. Citing Meko *et al.* (2001), they note that only one period had a six-year drought more severe than the 1928-1934 period: a seven-year drought ending in 984 CE. They also not the most extreme dry year was in 1580 CE, and state that it was almost certainly drier than 1977. On the whole, however, the last 600 years have been a generally wet period. This is reflected in the salinity records discussed in the next section.

No comments

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B.3. *Reconstructed Salinity in the Bay-Delta*

Starratt (2001) reconstructed historical salinity variability at Rush Ranch, in the northwestern Suisun Marsh, over the last 3,000 years by examining diatoms from sediment cores. The taxa were classified according to their salinity preference: freshwater (< 2‰), freshwater and brackish water (0‰ to 30‰), brackish (2‰ to 30‰), brackish and marine (2‰ to > 30‰), and marine (> 30‰). Based on the composition of the diatom assemblages, Starrat identified centennial-scale salinity cycles (Table B-2).

Table B-2 – Salinity Intervals over the last 3,000 years at Rush Ranch

Salinity intervals determined from the diatom populations in a sediment core in northwestern Suisun Marsh.

Approximate Years	*Type of Interval* [a]
1850 CE – present	[not classified]
1250 CE – 1850 CE	fresh
250 CE – 1250 CE	brackish
500 BCE – 250 CE	fresh
1000 BCE – 500 BCE	brackish

[a] Classification according to Starratt (2001)

These results correspond well to other paleoclimatic reconstructions. The most recent broad-scale freshwater interval roughly corresponds to the Little Ice Age, and the most recent brackish interval corresponds to the Medieval Warm Period.

Starratt notes that the post-1850 interval indicates an increase in the percentage of diatoms that prefer brackish and marine salinities compared to the last freshwater interval, indicating an increase in salinity during the last 150 years, in comparison to the previous 600 years. During the post-1850 period, diatoms that prefer "marine" environments constitute as much as 50% of the total diatom population, a percentage that is at or above that of any other period. During the most recent years, "freshwater" assemblages constitute about 20% of the total population, a percentage that is only about 10% higher than the most recent *brackish* interval from 250 to 1250 CE.

Malamud-Roam *et al.* (2006) compared reconstructed salinity records for the past three thousand years from four locations (three tidal marsh locations and one location in the Bay) in the Bay-Delta region (Figure B-2(a)). Figure B-2(b) shows several periods with higher than average salinity (e.g., 1600-1300 and 1000-800 BP and 1900 CE to present) and several periods with lower than average salinity (e.g., 1300 to 1200 BP and 150 to 100 BP). These paleosalinity records are consistent with each other and with the paleoclimatic records of river flow and salinity presented in Section 2.

No comments

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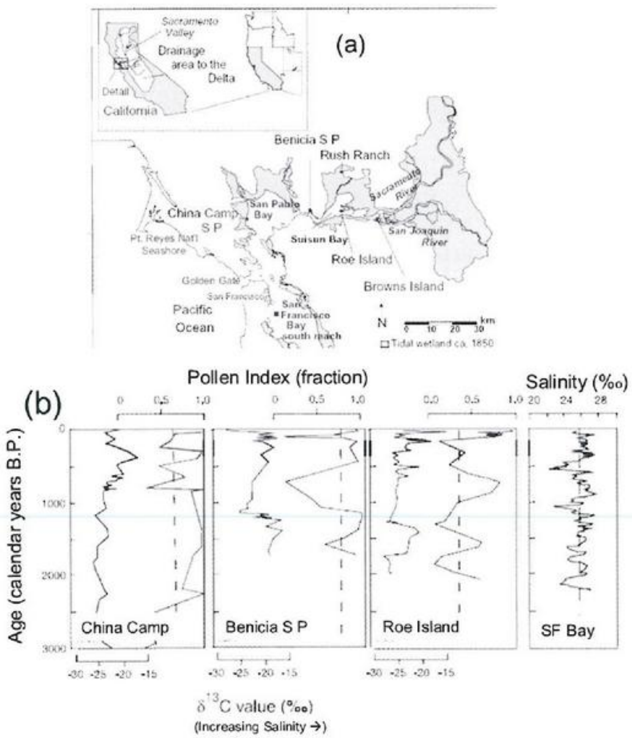

Figure B-2 – Paleosalinity records at selected sites in the San Francisco Estuary

(a) location of the three tidal marsh sites (China Camp, Benicia State Park and Roe Island) and one site in the Estuary (Oyster Point in San Francisco Bay) where sediment cores were obtained.
(b) time series for the pollen index (ranging from 0 to 1, higher values corresponding to higher salinity) and the δ13C values at the tidal marsh sites; salinity at Oyster Point, San Francisco Bay (inferred from δ13O values) is also shown. The broken line shows the estimated mean pollen index prior to European disturbance. (modified from Malamud-Roam and Ingram (2004) and Malamud-Roam et al. (2006))

No comments

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No comments

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Appendix C. Quantitative Hydrological Observations

Long-term records of river runoff are useful in understanding hydroclimatic variations. Section 3.1 discusses the long-term variations of the unimpaired Sacramento River runoff and unimpaired San Joaquin River runoff. The estimates of these variables from early 1900's to the present are available on the internet . Estimates prior to the early 1900's (late 1800's to early 1900's) were obtained from a 1923 California Department of Public Works report (DPW, 1923). Table C-1 through Table C-4 present estimates of Sacramento River runoff and San Joaquin River runoff for the period of 1872-2008, obtained from DPW (1923) and http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST.

The unimpaired Sacramento River runoff is the sum of the flows from the Sacramento River at Bend Bridge, Feather River inflow to Lake Oroville, Yuba River at Smartville, and the American River inflow to Folsom Lake. The unimpaired San Joaquin River runoff is the sum of the flows from the Stanislaus River inflow to New Melones Lake, Tuolumne River inflow to New Don Pedro Reservoir, Merced River inflow to Lake McClure, and San Joaquin River inflow to Millerton Lake.

Table C-1 – Annual unimpaired Sacramento River runoff for 1872-1905
Data source: DPW (1923

Water Year	Sacramento River @ Bend Bridge	Feather River @ Lake Oroville	Yuba River @ Smartville	American River @ Folsom Lake	Sacramento River Runoff
	Acre-feet (AF)				Million acre-feet (MAF)
1872	10,200,000	7,254,000	4,352,000	4,215,600	**26.0**
1873	4,780,000	3,347,000	1,638,400	1,862,200	**11.6**
1874	7,300,000	5,571,000	3,340,800	3,079,800	**19.3**
1875	4,390,000	2,747,000	1,561,600	1,391,600	**10.1**
1876	14,500,000	6,867,000	3,594,000	4,450,900	**29.4**
1877	9,870,000	2,437,000	1,292,800	1,289,200	**14.9**
1878	17,800,000	4,836,000	2,528,000	2,721,700	**27.9**
1879	8,380,000	5,513,000	2,796,800	3,304,900	**20.0**
1880	12,300,000	7,061,000	3,641,600	4,502,100	**27.5**
1881	15,400,000	5,610,000	3,104,000	3,540,300	**27.7**
1882	8,000,000	4,797,000	2,150,400	3,264,000	**18.2**
1883	6,670,000	3,714,000	1,804,800	2,169,200	**14.4**
1884	11,400,000	6,190,000	3,104,000	4,103,000	**24.8**
1885	6,460,000	3,482,000	2,304,000	1,780,400	**14.0**
1886	14,400,000	6,384,000	3,174,400	3,918,900	**27.9**
1887	6,670,000	2,611,000	1,561,600	1,862,200	**12.7**
1888	5,430,000	2,669,000	998,400	1,575,700	**10.7**
1889	10,600,000	5,126,000	1,612,800	1,903,200	**19.2**
1890	22,700,000	12,090,000	6,176,000	7,725,200	**48.7**

No comments

- n/a -

Water Year	Sacramento River @ Bend Bridge	Feather River @ Lake Oroville	Yuba River @ Smartville	American River @ Folsom Lake	Sacramento River Runoff
1891	6,460,000	3,482,000	1,747,200	1,944,100	**13.6**
1892	7,250,000	5,416,000	1,945,600	2,568,200	**17.2**
1893	12,400,000	7,177,000	3,488,000	4,399,800	**27.5**
1894	8,640,000	4,410,000	2,432,000	3,304,900	**18.8**
1895	12,300,000	7,177,000	4,160,000	4,737,400	**28.4**
1896	11,343,200	7,738,000	3,641,600	3,857,500	**26.6**
1897	10,391,400	5,610,000	3,040,000	3,632,400	**22.7**
1898	5,135,800	2,805,000	1,184,000	1,186,900	**10.3**
1899	5,977,400	3,288,000	1,984,000	2,362,600	**13.6**
1900	8,712,500	6,500,000	2,956,800	3,683,500	**21.9**
1901	9,020,900	6,229,000	2,854,400	3,714,200	**21.8**
1902	11,380,600	4,468,000	2,432,000	3,079,800	**21.4**
1903	9,941,800	4,483,500	2,368,000	3,038,900	**19.8**
1904	16,095,800	9,377,000	4,101,800	5,249,000	**34.8**
1905	10,775,200	4,529,200	2,403,500	2,050,000	**19.8**

No comments

- n/a -

Table C-2 – Annual unimpaired Sacramento River runoff for 1906-2009
Data Source: http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST

Water Year	Sacramento River Runoff (MAF)	Water Year	Sacramento River Runoff (MAF)	Water Year	Sacramento River Runoff (MAF)	Water Year	Sacramento River Runoff (MAF)
1906	26.7	1936	17.4	1966	13.0	1996	22.3
1907	33.7	1937	13.3	1967	24.1	1997	25.4
1908	14.8	1938	31.8	1968	13.6	1998	31.4
1909	30.7	1939	8.2	1969	27.0	1999	21.2
1910	20.1	1940	22.4	1970	24.1	2000	18.9
1911	26.4	1941	27.1	1971	22.6	2001	9.8
1912	11.4	1942	25.2	1972	13.4	2002	14.6
1913	12.9	1943	21.1	1973	20.1	2003	19.3
1914	27.8	1944	10.4	1974	32.5	2004	16.0
1915	23.9	1945	15.1	1975	19.2	2005	18.6
1916	24.1	1946	17.6	1976	8.2	2006	32.1
1917	17.3	1947	10.4	1977	5.1	2007	10.3
1918	11.0	1948	15.8	1978	23.9	2008	10.3
1919	15.7	1949	12.0	1979	12.4	2009	12.9
1920	9.2	1950	14.4	1980	22.3		
1921	23.8	1951	23.0	1981	11.1		
1922	18.0	1952	28.6	1982	33.4		
1923	13.2	1953	20.1	1983	37.7		
1924	5.7	1954	17.4	1984	22.4		
1925	16.0	1955	11.0	1985	11.0		
1926	11.8	1956	29.9	1986	25.8		
1927	23.8	1957	14.9	1987	9.3		
1928	16.8	1958	29.7	1988	9.2		
1929	8.4	1959	12.1	1989	14.8		
1930	13.5	1960	13.1	1990	9.3		
1931	6.1	1961	12.0	1991	8.4		
1932	13.1	1962	15.1	1992	8.9		
1933	8.9	1963	23.0	1993	22.2		
1934	8.6	1964	10.9	1994	7.8		
1935	16.6	1965	25.6	1995	34.6		

No comments

- n/a -

Table C-3 – Annual unimpaired San Joaquin River runoff for 1872-1900
Data source: DPW (1923)

Water Year	Stanislaus River @ New Melones Lake	Tuolumne River @ New Don Pedro Reservoir	Merced River @ Lake McClure	San Joaquin River @ Millerton Lake	San Joaquin River Runoff
	units of acre-feet (AF)				units of million acre-feet (MAF)
1872	1,860,000	2,624,000	1,511,000	2,627,000	**8.6**
1873	959,000	1,543,000	769,000	1,122,000	**4.4**
1874	970,000	1,576,000	791,000	1,862,000	**5.2**
1875	482,000	982,000	439,000	887,000	**2.8**
1876	2,930,000	4,059,000	2,384,000	2,862,000	**12.2**
1877	408,900	561,000	220,000	809,000	**2.0**
1878	1,570,000	2,286,000	1,274,000	2,218,000	**7.3**
1879	823,000	1,353,000	659,000	470,000	**3.3**
1880	1,390,000	2,071,000	1,132,000	3,349,000	**7.9**
1881	970,000	1,576,000	791,000	2,740,000	**6.1**
1882	944,000	1,526,000	764,000	1,000,000	**4.2**
1883	1,020,000	1,600,000	813,000	1,392,000	**4.8**
1884	2,250,000	3,152,000	1,840,000	5,732,000	**13.0**
1885	582,000	1,097,000	505,000	1,218,000	**3.4**
1886	2,070,000	2,929,000	1,692,000	5,211,000	**11.9**
1887	619,000	1,139,000	538,000	1,479,000	**3.8**
1888	540,000	1,048,000	478,000	957,000	**3.0**
1889	718,000	1,262,000	599,000	1,574,000	**4.2**
1890	3,580,000	5,099,000	2,955,000	4,349,000	**16.0**
1891	959,000	1,543,000	769,000	1,227,000	**4.5**
1892	1,050,000	1,650,000	846,000	1,931,000	**5.5**
1893	2,150,000	3,036,000	1,758,000	1,914,000	**8.9**
1894	1,860,000	2,624,000	1,511,000	1,331,000	**7.3**
1895	2,700,000	3,795,000	2,236,000	2,786,700	**11.5**
1896	1,380,000	1,588,100	1,110,000	1,985,700	**6.1**
1897	1,920,000	2,437100	1,566,000	2,219,700	**8.1**
1898	498,000	960,500	450,000	922,300	**2.8**
1899	1,030,000	1,334,700	824,000	1,269,500	**4.5**
1900	1,350,000	1,628,100	1,099,000	1,343,000	**5.4**

No comments

- n/a -

Table C-4 – Annual unimpaired San Joaquin River runoff for 1901-2009

Data Source: *http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST*

Water Year	San Joaquin River Runoff (MAF)	Water Year	San Joaquin River Runoff (MAF)	Water Year	San Joaquin River Runoff (MAF)	Water Year	San Joaquin River Runoff (MAF)
1901	9.4	1931	1.7	1961	2.1	1991	3.2
1902	5.1	1932	6.6	1962	5.6	1992	2.6
1903	5.7	1933	3.3	1963	6.2	1993	8.4
1904	7.6	1934	2.3	1964	3.1	1994	2.5
1905	5.3	1935	6.4	1965	8.1	1995	12.3
1906	12.4	1936	6.5	1966	4.0	1996	7.2
1907	11.8	1937	6.5	1967	10.0	1997	9.5
1908	3.3	1938	11.2	1968	2.9	1998	10.4
1909	9.0	1939	2.9	1969	12.3	1999	5.9
1910	6.6	1940	6.6	1970	5.6	2000	5.9
1911	11.5	1941	7.9	1971	4.9	2001	3.2
1912	3.2	1942	7.4	1972	3.6	2002	4.1
1913	3.0	1943	7.3	1973	6.5	2003	4.9
1914	8.7	1944	3.9	1974	7.1	2004	3.8
1915	6.4	1945	6.6	1975	6.2	2005	9.2
1916	8.4	1946	5.7	1976	2.0	2006	10.4
1917	6.7	1947	3.4	1977	1.1	2007	2.5
1918	4.6	1948	4.2	1978	9.7	2008	3.5
1919	4.1	1949	3.8	1979	6.0	2009	5.0
1920	4.1	1950	4.7	1980	9.5		
1921	5.9	1951	7.3	1981	3.2		
1922	7.7	1952	9.3	1982	11.4		
1923	5.5	1953	4.4	1983	15.0		
1924	1.5	1954	4.3	1984	7.1		
1925	5.5	1955	3.5	1985	3.6		
1926	3.5	1956	9.7	1986	9.5		
1927	6.5	1957	4.3	1987	2.1		
1928	4.4	1958	8.4	1988	2.5		
1929	2.8	1959	3.0	1989	3.6		
1930	3.3	1960	3.0	1990	2.5		

No comments

- n/a -

No comments

- n/a -

Appendix D. Instrumental Observations of Salinity

In Section 3, historical variations in the net quantity of water flowing from the Delta to the Suisun Bay (called net Delta outflow or NDO) and salinity in the western Delta were discussed using available observations and a suite of commonly used modeling tools. This section presents additional information on the historical variations of NDO and salinity in the western Delta and Suisun Bay discussed in Section 3.

D.1. Introduction

D.1.1. Salinity Units

Salinity is specified in this report either as electrical conductivity (EC, in units of microSiemens per centimeter, or µS/cm) or as a concentration of chloride in water (in units of milligrams of chloride per liter of water, or mg/L). Conversion between EC and chloride concentration is accomplished using site-specific empirical relationships developed by Kamyar Guivetchi (DWR, 1986). Table D-1 presents a sample of typical EC concentrations and their approximate equivalent chloride concentrations.

Table D-1 – Typical electrical conductivity (EC) and equivalent chloride concentration

Electrical Conductivity (µS/cm)	Chloride (mg/L)
350	50
525	100
1,050	250
1,900	500
2,640	700
3,600	1,000

Qualitative terms such as "fresh" and "brackish" are often used to describe relative salinity. The quantitative thresholds of average chloride concentration that distinguish fresh water from brackish water and the averaging time period vary among studies. For instance, chloride concentrations of 1,000 mg/L, 700 mg/L, and 50 mg/L have been used by different studies (Table D-2).

D.1.2. Temporal and Spatial Variability of Salinity

The main variability in salinity along the length of the Bay-Delta system is due to the gradient from saline Pacific Ocean water (EC of approximately 50,000 µS/cm) to fresh water of the Central Valley rivers (EC of approximately 100 µS/cm). However, the salinity in the Bay-Delta varies both in space and time. It is important to clarify which time scales and measurement locations are being used when comparing and discussing salinity trends.

No comments

- n/a -

Table D-2 – Metrics used to distinguish between "fresh" and "brackish" water

Description	Sample timing or averaging	Salinity Value	
		Chloride (mg/L)	EC (µS/cm)
Isohalines in Delta Atlas (DWR, 1995)	Annual maximum of the daily maximum	1,000 mg/L	3,700 µS/cm
X2 position (Jassby *et al.*, 1995)	Daily average (or a 14-day average)	700 mg/L	2,640 µS/cm
Barge travel by C&H[4]	Monthly average of the daily maximum	50 mg/L	350 µS/cm

Salinity in the western Delta is strongly influenced by tides. The hourly or daily variability of salinity can be much larger than the seasonal or annual variability. For instance, during the fall of 1999 (following a relatively wet year[5]), hourly EC in the San Joaquin River at Antioch varied by about 6,000 µS/cm (from about 3,000 µS/cm to 9,000 µS/cm) while the daily-averaged EC for all of 1999 ranged from about 100 µS/cm to 6,000 µS/cm (Figure D-1).

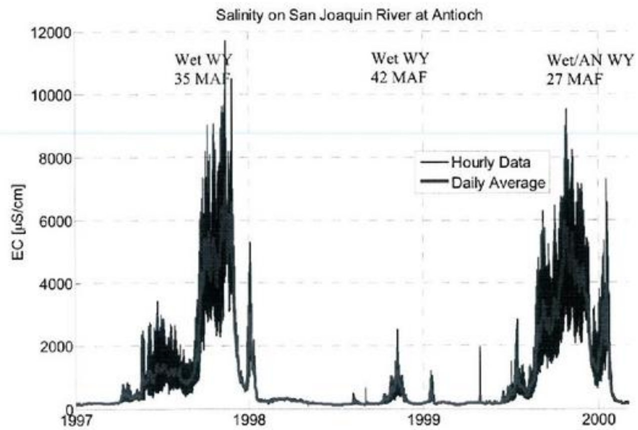


Figure D-1 – Hourly and daily salinity variability in the San Joaquin River at Antioch
Total annual unimpaired Sacramento River flow and water year type is indicated for each water year. Data Source: IEP Data Vaults (http://www.iep.ca.gov/dss/)

[4] The California & Hawaiian Sugar Refining Corporation in Crockett (C&H) obtained its freshwater supply from barges traveling up the Sacramento and San Joaquin Rivers, generally twice a day beginning in 1908 (DPW, 1931).
[5] Water year 1999 was classified as wet using the Sacramento Valley 40-30-30 index and above-normal using the San Joaquin Valley 60-20-20 index; indices are defined in D-1641.

No comments

- n/a -

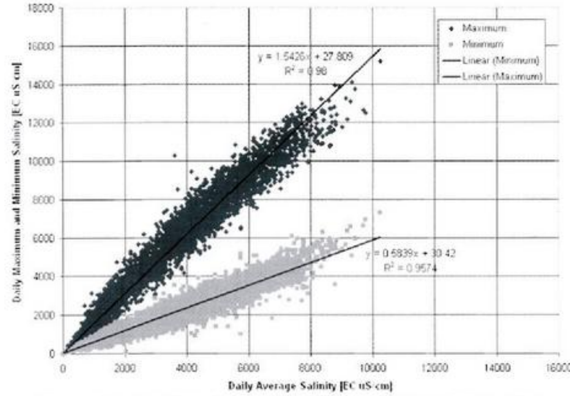


Figure D-2 – Tidal Variability in Salinity at Antioch (1967 to 1992)
Data Source: IEP Data Vaults (http://www.iep.ca.gov/dss/)

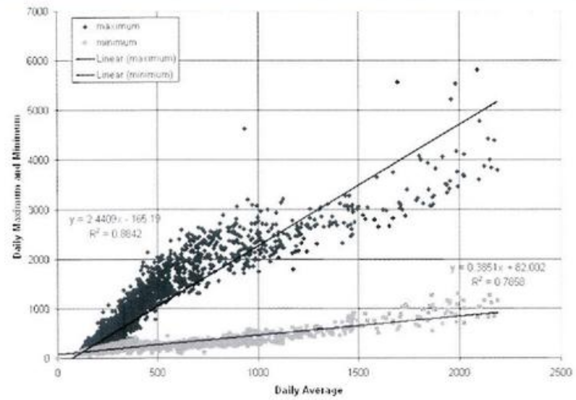


Figure D-3 – Tidal Variability in Salinity at Rio Vista (1967 to 1992)
Data Source: IEP Data Vaults (http://www.iep.ca.gov/dss/)

No comments

- n/a -

The high tide maximum, low tide minimum, and daily-averaged salinity at a given location are very different. As shown in Figure D-2, the daily maximum salinity in the San Joaquin River at Antioch can be double the daily-averaged salinity. Because of the large tidal variability in salinity, any comparisons of salinity observations should be at the same phase of the tide, or at least take into account tidal variability.

Similarly, as shown in Figure D-3, the daily maximum salinity in the Sacramento River at Rio Vista can be 170-400% of the daily average salinity. The daily minimum at Rio Vista may be 10-65% of the daily average.

D.2. Variations in the Spatial Salinity Distribution

Observations examined in this section and Section 3.3 include records from the early 1900's from the California & Hawaiian Sugar Refining Corporation in Crockett (C&H) and the long-term monitoring data from the Interagency Ecological Program (IEP). Estimates of salinity at specific locations of interest were obtained from DWR's DSM2 model and Contra Costa Water District's salinity-outflow model (also known as the G-model) (Denton, 1993). Estimates of salinity intrusion were obtained using the K-M equation (Kimmerer and Monismith, 1992).

D.2.1. Distance to Freshwater from Crockett

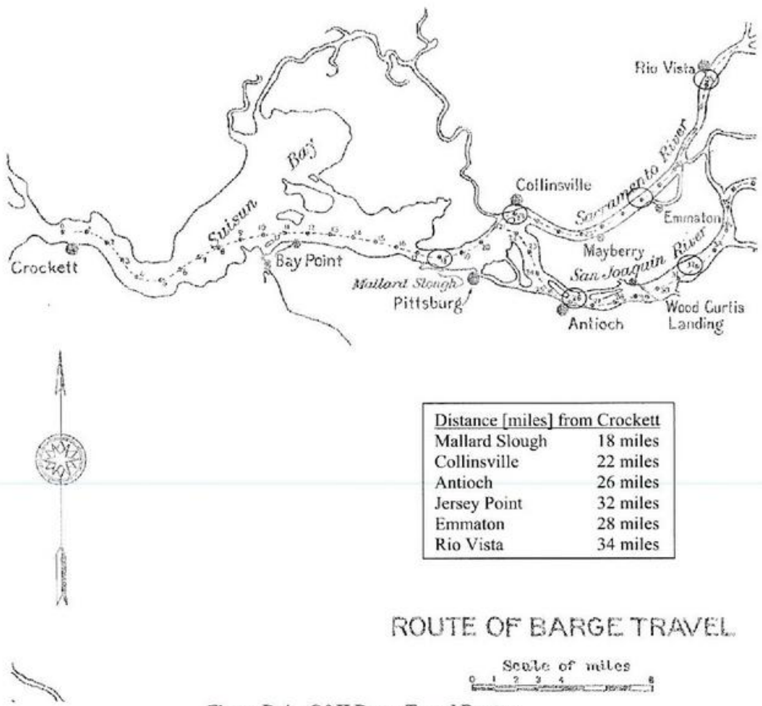
The California & Hawaiian Sugar Refining Corporation in Crockett (C&H) obtained its freshwater supply from barges traveling up the Sacramento and San Joaquin Rivers, generally twice a day beginning in 1905 through 1929 or later (DPW, 1931). The salinity information recorded by C&H is the most detailed salinity record available prior to the intensive salinity monitoring by the State of California, which started in 1920. This section presents a comparison of the salinity observations of C&H with recent monitoring data and modeling results to determine how the managed salinity regime of the late 20th Century compares to the salinity regime of the early 1900's.

Data Sources and Methods

C&H data: C&H operations required water with less than 50 mg/L chloride concentration. According to DPW (1931), the C&H barges typically traveled up the river on flood tide and returned downstream on ebb tide. Since the maximum daily salinity for a given location in the river channel typically occurs about one to two hours after high slack tide, the distance traveled by the C&H barges represents approximately the daily maximum distance to 50 mg/L water from Crockett. The monthly minimum, average, and maximum distance traveled by C&H barges are shown in Figure D-4 and Figure D-5. For the following analysis, monthly averages of the C&H daily maximum distances were extracted from Figure D-5 for the period of 1908-1918 (after 1917, extensive salinity intrusion was reported and agricultural diversions reportedly started affecting flows into the Delta).

No comments

- n/a -



Distance [miles] from Crockett	
Mallard Slough	18 miles
Collinsville	22 miles
Antioch	26 miles
Jersey Point	32 miles
Emmaton	28 miles
Rio Vista	34 miles

Figure D-4 – C&H Barge Travel Routes

Map adapted from DPW (1931). Red circles indicate locations of landmarks, with distance from Crockett listed in the inset box.

No comments

- n/a -

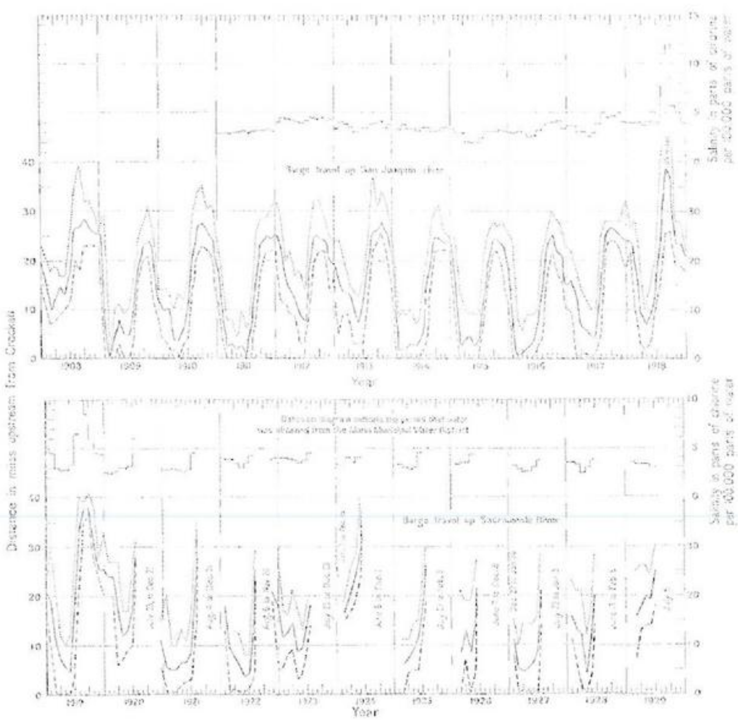


Figure D-5 – C&H Barge Travel and Quality of Water obtained

C&H barge travel up the San Joaquin River (1908 through 1918, top panel) and Sacramento River (1919 through 1929, bottom panel). The lower three lines on each panel (reference to the left axes) indicate the monthly minimum (dashed line), monthly maximum (dotted line), and monthly average (solid line) distance traveled by C&H barges to obtain their fresh water supply. The uppermost solid line on each panel (reference to the right axes) indicates the average monthly salinity of the water obtained by the barges. Figure adapted from DPW (1931)

From 1908 through 1917, C&H was able to obtain water with less than 50 mg/L chlorides within 30 miles of Crockett on average (below Jersey Point on the San Joaquin River). In 1918, the salinity of the water obtained by C&H barges had increased due to a combination of a lack of precipitation and upstream diversions (especially for newly introduced rice cultivation) (DPW, 1931). During August and September 1918, salinity exceeded 60 mg/L chloride, and the C&H barges traveled farther upstream than any time previously recorded.

No comments

- n/a -

In 1919, a wetter year than 1918, salinity was high for an even longer period of time, most likely due to increased upstream diversions for irrigation. Salinity exceeded 60 mg/L chloride during July, August, and September. Beginning in 1920, C&H abandoned the Sacramento and San Joaquin Rivers during the summer and fall seasons, replacing the water supply with a contract from Marin County. However, even during the driest years of the 1920's, C&H obtained water with less than 50 mg/L chloride below the confluence of the Sacramento and San Joaquin Rivers during a portion of every year.

Salinity observations from the Interagency Ecological Program (IEP): Long-term monitoring of electrical conductivity (EC) at multiple stations within the Bay and Delta began around 1964. Publicly-available daily-averaged data were obtained for this analysis from the Interagency Ecological Program (IEP) data vaults (Table D-3).

Table D-3 – Overview of long-term salinity observation records from IEP
(see http://www.iep.ca.gov/dss/)

Location	*Station*	*Source*	*Data*
Selby	RSAC045	USGS-BAY	Historical
Martinez	RSAC054	CDEC	Real-time
Benicia Bridge	RSAC056	USBR-CVO	Historical
Port Chicago	RSAC064	USBR-CVO	Historical
Mallard	RSAC075	CDEC	Real-time
Pittsburg	RSAC077	USBR-CVO	Historical
Collinsville	RSAC081	USBR-CVO	Historical
Emmaton	RSAC092	USBR-CVO	Historical
Rio Vista	RSAC101	USBR-CVO	Historical
		DWR-ESO-D1485C	Historical
Georgiana Slough	RSAC123	DWR-CD-SURFWATER	Historical
Greens Landing	RSAC139	USBR-CVO	Historical
Antioch	RSAN008	USBR-CVO	Historical
Jersey Pont	RSAN018	USBR-CVO	Historical
Bradford Point	RSAN024	USBR-CVO	Historical
San Andreas Landing	RSAN032	USBR-CVO	Historical

Delta Simulation Model (DSM2) Historical Simulation: The DSM2 historical simulation (1989-2006) was used to provide estimates of water quality to complement the limited field data from IEP. Because DSM2 has a very detailed spatial computational network covering the Delta and Suisun Bay, DSM2 can output much more detailed spatial and temporal salinity information than just the water quality at the IEP monitoring stations. DSM2 results include the daily-averaged EC at each model node along the lower Sacramento and San Joaquin Rivers. The location of the 350 μS/cm EC isohaline (corresponding to 50 mg/L chloride) was identified from the DSM2 results and compared with the equivalent C&H and IEP data.

No comments

- n/a -

Analysis time frame: The first decade of C&H barge travel (1908-1917) was a relatively wet period compared to the entire period of record (1906-2006) (Figure D-6). To compare conditions under similar hydrological conditions, specific recent decades (Figure D-6(a)) and select recent years (Figure D-6(b)) were selected that have comparable or slightly wetter hydrology than the C&H years. The periods 1966-1975 and 1995-2004 have similar annual unimpaired Sacramento River flow to the C&H data period (1908-1917) (see Figure D-6(a)). In addition, two wet years (1911 and 1916) and two dry years (1913 and 1918) selected from the C&H time period were compared with two wet years (1969 and 1998) and two dry years (1968 and 2002) from the IEP record.

Limitations of the analysis: The C&H data approximately represent the maximum daily salinity at a given location, whereas recent conditions (IEP or DSM2 data) are represented by the daily-averaged salinity. The estimates of the distance that must be traveled to reach fresh water under current conditions are, therefore, underestimated.

In addition, the C&H barges traveled up the San Joaquin River from 1908 through 1917, yet the equivalent travel distance for C&H barges under current conditions are estimated for the Sacramento River, and not the San Joaquin River. Under present-day conditions, the upstream distance to fresh water on the San Joaquin River is greater than for the Sacramento River, so this approach will also serve to underestimate the actual distance that C&H barges would have to travel under present-day conditions.

No comments

- n/a -

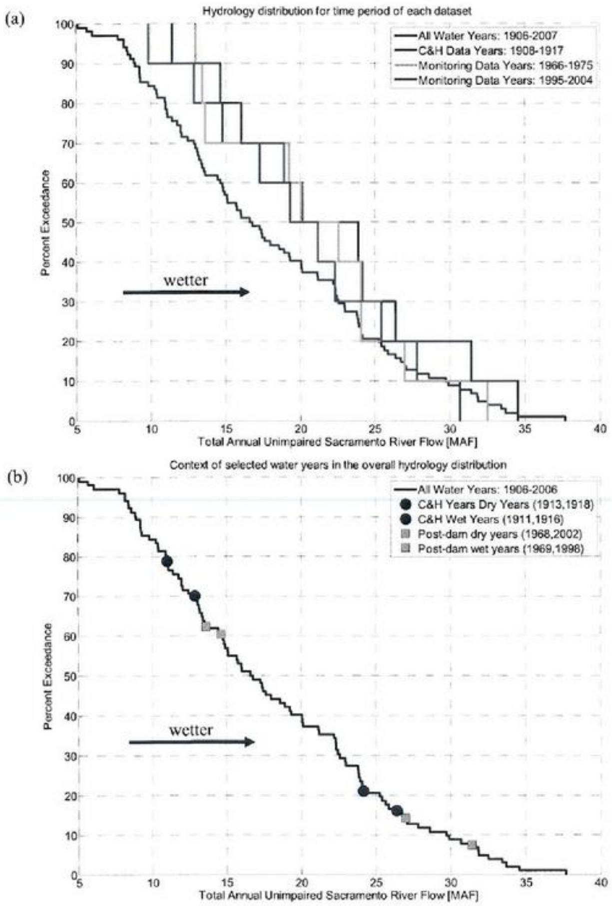


Figure D-6 – Hydrologic Context for Analysis of Distance to Fresh Water

(a) Hydrology distribution for water years 1906 to 2007, and select decades.

(b) Hydrology distribution for water years 1906 to 2007, with select water years shown for context.

No comments

- n/a -

Results and Discussion

Selected Wet Years

As shown in Figure D-7, the salinity patterns during the two selected C&H-era wet years, 1911 and 1916, are similar to each other. During these wet years, the location of 50 mg/L chloride water is west of Martinez for about 4-5 months (late February to early August in 1911 and from early February to late June in 1916). In contrast, during recent wet years 1969 and 1998, water with 50 mg/L chlorides or less was west of Martinez for only about 6 weeks in February and March. This comparison shows that in 1969 and 1998 the western Delta was saltier in the fall and spring than it was in 1911 and 1916, and salinity intrusion occurred much earlier in 1969 and 1998.

If barges were still traveling up the Sacramento River today to find fresh water, they would have to travel farther during the fall, spring, and summer than the C&H barges traveled during similar wet years. In 1916, fresh water retreated upstream about one month earlier than in 1911, possibly influenced by the increasing upstream diversions during 1911-1916 (see Figure 1-3). In recent years with even greater unimpaired runoff, fresh water retreats two to three months earlier than in 1916. Additionally, fresh water reaches Martinez for a much shorter period of time, about less than one month in recent years compared to four and five months during 1916 and 1911, respectively.

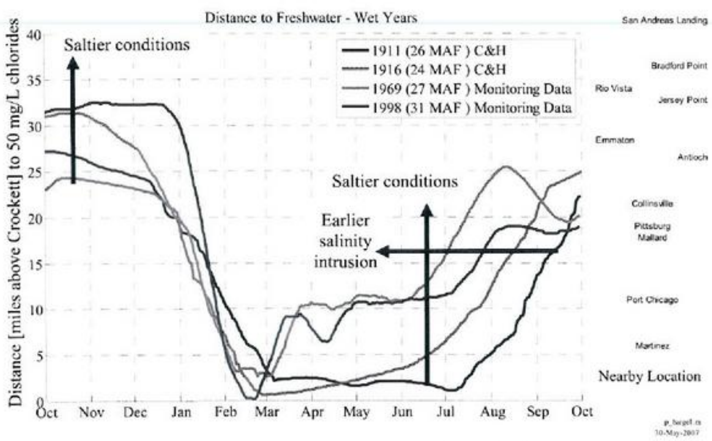


Figure D-7 – Distance to Fresh Water in Select Wet Years

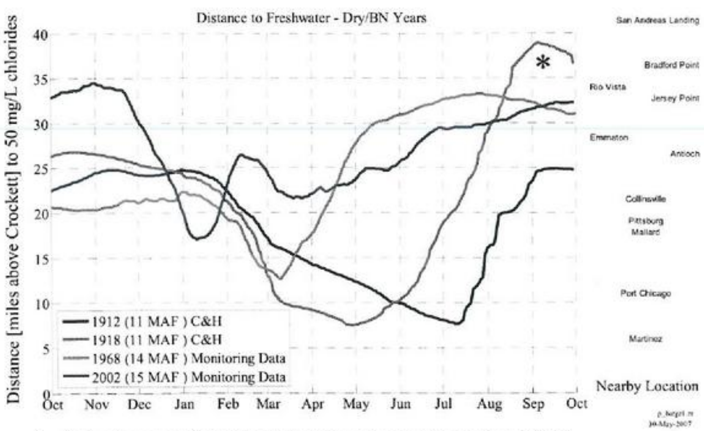
No comments

- n/a -

Selected Dry Years

Figure D-8 shows that the most visible difference between the distance to fresh water in dry years of the early 1900's and more recent dry years is the substantial increase in distance to fresh water, particularly from April through June. This indicates the spring was much fresher during the dry years of the early 1900's, before large upstream reservoirs were built to capture the spring runoff. In dry and below-normal water years under today's conditions, barges would have to travel farther during spring, summer and fall than they traveled in the early 20th Century.

The C&H barge travel distance in the dry years of 1913 and 1918 are quite different, especially the additional 10 miles of distance to fresh water traveled in August and September of 1918. C&H recorded relatively high salinity (greater than 110 mg/L chlorides) above Bradford Point on the San Joaquin in 1918, which is greater than observed salinity on the Sacramento River near Rio Vista in similar water years. This may be partially explained by the development of the rice cultivation industry around 1912 (DPW, 1931) and increased upstream diversions when seasonal river flows were already low.



* During August and September 1918, average water quality obtained by C&H exceeded 110 mg/L chlorides

Figure D-8 – Distance to Fresh water in Select Dry or Below Normal Years

Figure D-9 shows the exceedance probabilities for distance traveled up the Sacramento River for different salinity levels. During 1908-1917, on a monthly-averaged basis, C&H barges had to travel above the confluence of the Sacramento and San Joaquin Rivers (approximately 22 miles above Crockett) about 26% of this time period to reach water with salinity less than

No comments

- n/a -

350 μS/cm EC (about 50 mg/L chlorides). In contrast, from 1995-2006, DSM2 simulations suggest that barges would have to travel above the confluence approximately 56% of the time to reach water with salinity of 350 μS/cm EC.

The location of the 50 mg/L chloride isohaline during 1908-1917 approximately corresponds to the location of X2 (2,640 μS/cm EC, or 700 mg/L chlorides) during 1995-2006 (Figure D-9). This is equivalent to more than a 7-fold increase in salinity from the early 1900's to the present day.

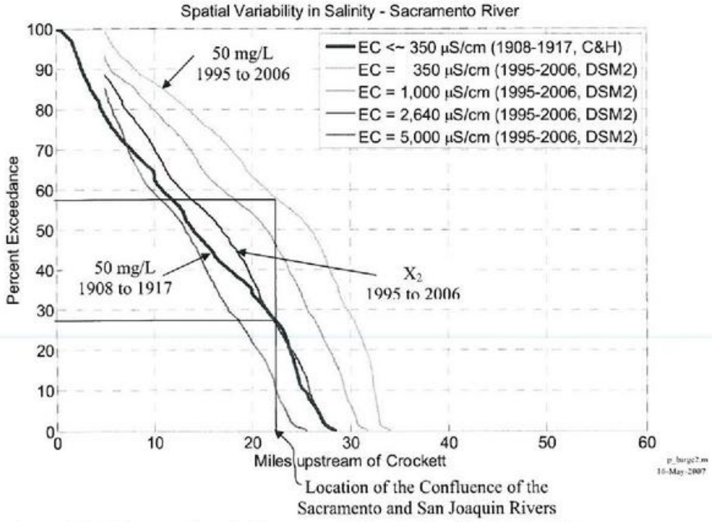


Figure D-9 – Distance along the Sacramento River to Specific Salinity Values

No comments

- n/a -

D.2.2. Maximum Annual Salinity Intrusion Before and After Large-scale Reservoir Construction

Figure D-10 shows maximum salinity intrusion during 1921-1943 (pre-CVP period), prior to the completion of the Shasta Dam of the Central Valley Project in 1945. Salinity intrusion is presented in terms of contours of 1,000 mg/L chlorides. Figure D-11 shows the maximum salinity intrusion during the post-CVP period of 1944-1990. These figures indicate the pre-CVP period experienced greater salinity intrusion than the post-CVP period, with seawater intruding farther into the Delta during 6 of the 24 pre-CVP years (1920, 1924, 1926, 1931, 1934, and 1939) than in any of the 47 years in the post-CVP period (1944-1990).

The extreme salinity intrusion during the pre-CVP period was due, in part, to relatively low runoff during these years. Meko *et al.* (2001a) determined that the period from 1917 through 1936 was the driest 20-year period in the past 400 years; this long-term drought encompassed 16 of the 24 years in the pre-CVP period. In addition, estimates of unimpaired runoff from the Sacramento River (obtained from http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST) indicate that the Sacramento River had 6 critical water years during the 24-year period of 1920-1943, whereas, the Sacramento River had only 4 critical water years during the 47-year period of 1944-1990.

Figure D-12 shows that the peak salinity intrusion during the pre-CVP period occurred between mid-August and mid-September, while peak salinity intrusion during the first portion of the the post-CVP period (1944-1960) occurred between late-July and late-August. Salinity intrusion during the pre-CVP period was not only affected by relatively low runoff, but also by extensive upstream diversions (DPW, 1931).

The salinity investigations of the pre-CVP era found that the extreme salinity intrusion was larger than any previous intrusions known to local residents and concluded the intrusion was due, in part, to the extensive upstream diversions. As observed in DPW (1931):

> "Under conditions of natural stream flow before upstream irrigation and storage developments occurred, the extent of saline invasion and the degree of salinity reached was much smaller than during the last ten to fifteen years." (DPW, 1931, page 15)
>
> "Beginning in 1917, there has been an almost unbroken succession of subnormal years of precipitation and stream flow which, in combination with increased irrigation and storage diversions from the upper Sacramento and San Joaquin River systems, has resulted in a degree and extent of saline invasion greater than has occurred ever before as far as known." (DPW, 1931, page 15)
>
> "The abnormal degree and extent of saline invasion into the delta during recent years since 1917 have been due chiefly to: first, subnormal precipitation and run-off with a subnormal amount of stream flow naturally available to the delta, and second, increased upstream diversions

No comments

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for irrigation and storage on the Sacramento and San Joaquin River systems, reducing the inflow naturally available to the delta. It is probable that the degree of salinity in the lower channels of the delta and the extent of saline invasion above the confluence of the Sacramento and San Joaquin rivers have been about doubled by reason of the second factor." (DPW, 1931, page 42)

Conclusions from DPW (1931) and similar investigations have been corroborated by paleosalinty studies (see Section 2.3), which indicate that Browns Island in the western Delta was a freshwater marsh for approximately 2,500 years until salinity intruded in the early 20th Century.

No comments

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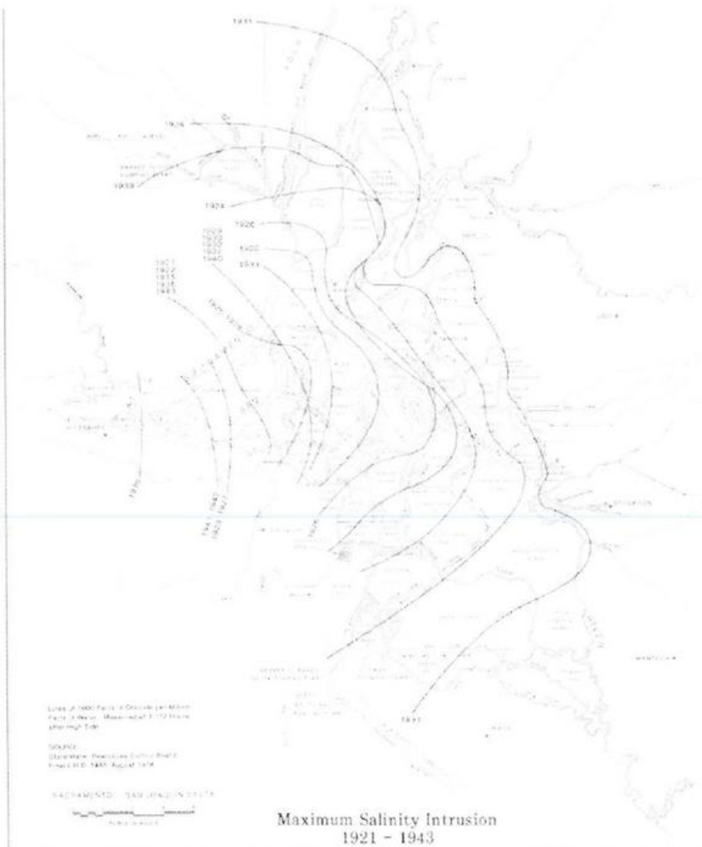

Figure D-10 – Salinity intrusion during pre-CVP period, 1921-1943 (DWR, 1995)

No comments

- n/a -

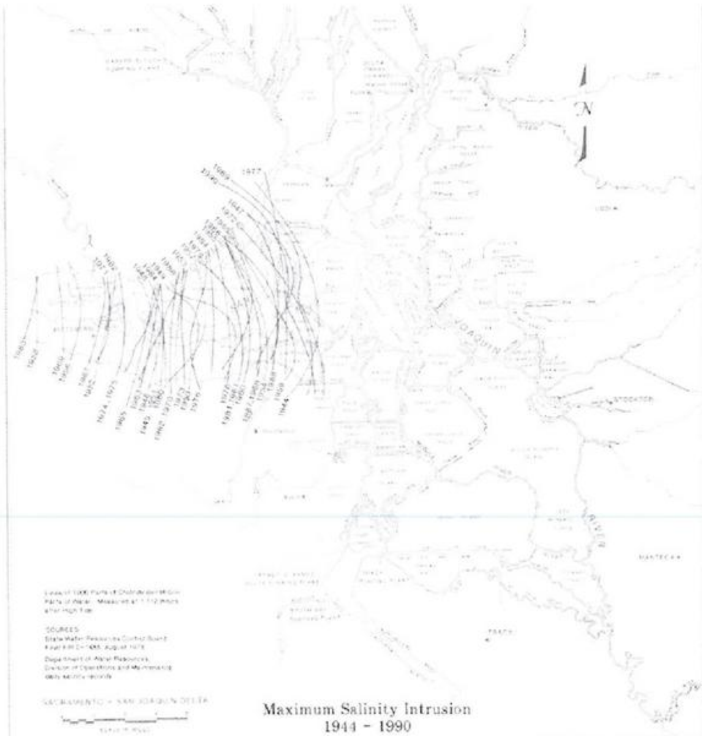

Figure D-11 – Salinity intrusion during post-CVP period, 1944-1990 (DWR, 1995)

No comments

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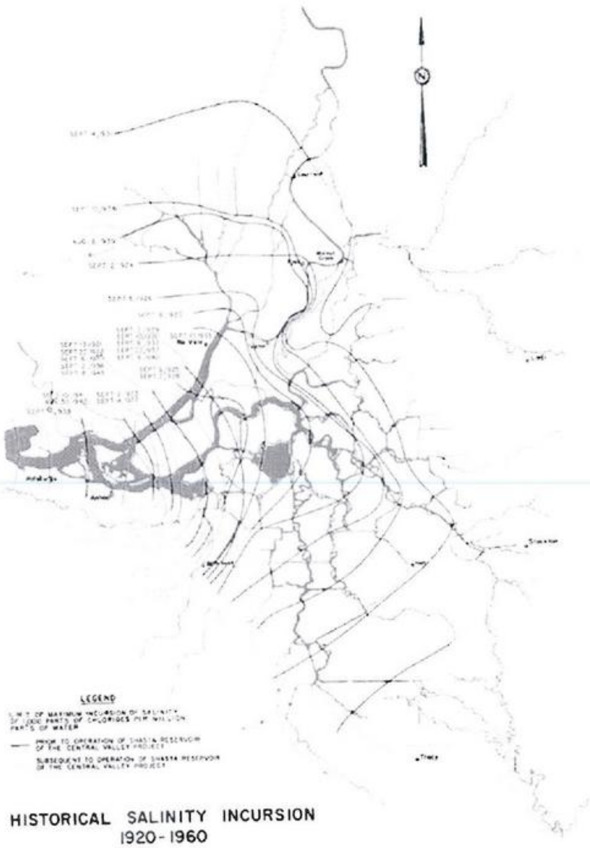

Figure D-12 – Salinity intrusion during 1920-1960 (DWR, 1960)

No comments

- n/a -

Figure D-13 illustrates the maximum annual salinity intrusion for comparable dry years[6]. Water year 1913 experienced the least extent of intrusion, most likely because upstream diversions were significantly less than in later years. Water years 1926 and 1932 were subject to extensive upstream agricultural diversions, while water years 1979 and 2002 had the benefit of the CVP and SWP to provide "salinity control". The CVP and SWP operations now regulate the amount of freshwater flowing through the Delta in order to prevent extreme salinity intrusions such as those observed during the 1920's and 1930's.

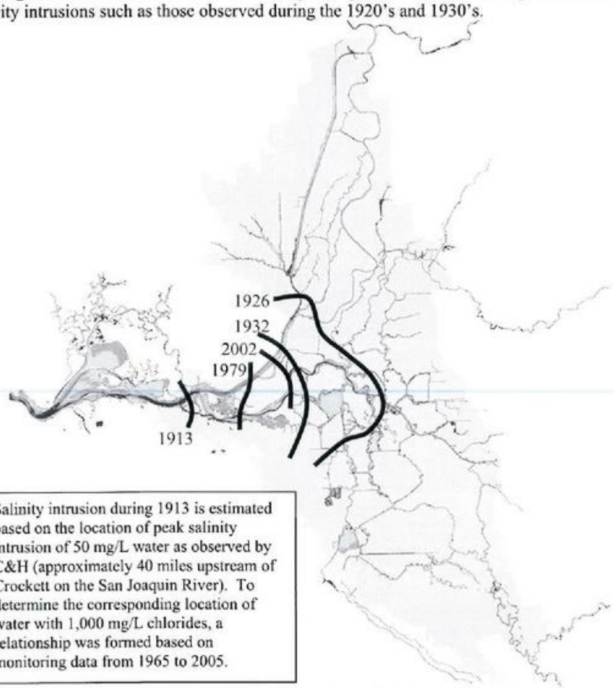

Figure D-13 – Annual Maximum Salinity Intrusion for relatively dry years

Salinity intrusion for relatively dry water years with similar total annual unimpaired runoff, using 1,000 mg/L chloride concentration to distinguish the extent of intrusion.

[6] Hydrological metrics from http://cdec.water.ca.gov/cgi-progs/iodir/wsihist for comparison: total unimpaired Sacramento River and San Joaquin River flow for water years 1913, 1926, 1932, 1979, and 2002 was 15.9 MAF, 15.3 MAF, 19.8 MAF, 18.4 MAF, and 18.7 MAF, respectively; Sacramento River water year type index for water years 1913, 1926, 1932, 1979, and 2002 was 6.24, 5.75, 5.48, 6.67, and 6.35, respectively; and San Joaquin River water year type index for water years 1913, 1979, and 2002 was 2.00, 2.30, 3.41, 3.67, and 2.34, respectively.

No comments

- n/a -

D.3. *Temporal Variability of Salinity in the Western Delta*

D.3.1. Seasonal Salinity at Collinsville

Collinsville, near the confluence of the Sacramento and San Joaquin Rivers, was one of the first long-term sampling locations implemented by the State of California. The Suisun Marsh Branch[7] of the DWR estimated monthly average salinity at Collinsville for the period 1920-2002, using a combination of 4-day TDS (total dissolved solids) grab samples from 1920-1971 and EC measurements from 1966-2002. Data from the overlap period of 5 years between the TDS grab samples and EC measurements were used in a statistical regression model, and the monthly averaged 4-day TDS samples were converted to monthly average EC (Enright, 2004). The result of this regression analysis was a time series of monthly EC values at Collinsville for the period of 1920-2002.

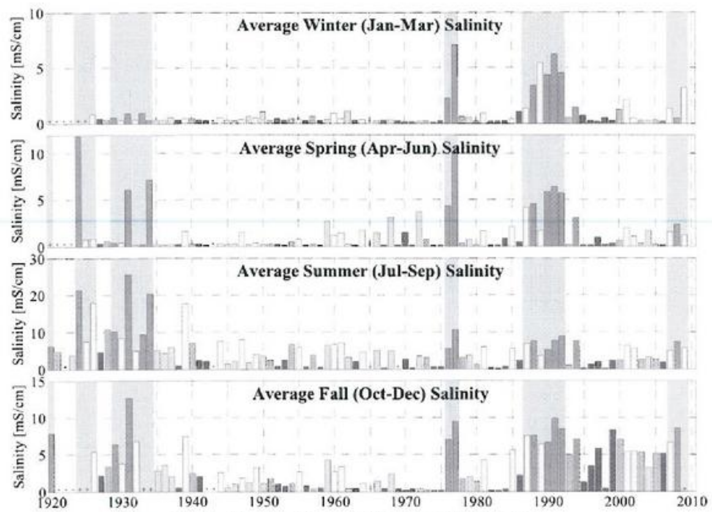

Figure D-14 – Average Seasonal Salinity at Collinsville

[7] Data provided by Chris Enright (DWR), personal communication, 2007.

No comments

- n/a -

D.3.2. Effects of Water Management on Salinity at Collinsville

In order to compare the effects of water management on salinity at Collinsville, an empirical model of salinity transport (Denton (1993), Denton and Sullivan (1993)) was used in the following analyses. Contra Costa Water District's salinity-outflow model (also known as the G-model) estimates salinity in the western Delta as a function of NDO. Estimates of salinity at Collinsville were derived for both actual historical flow (1930-2008) and unimpaired flow (1922-2003) conditions.

Figure D-15 shows the estimated monthly-averaged salinity at Collinsville under unimpaired and actual historical flow conditions. The predicted seasonal and annual variations of EC at Collinsville are dependent on corresponding variations of NDO under both unimpaired and actual flow conditions. Water management practices have a significant effect on the seasonal variability of salinity at Collinsville, particularly during dry years (1930's, 1976-1977 and 1987-1993), when Collinsville experiences a much greater range of monthly-averaged salinity under actual historical conditions than would be the case under unimpaired conditions.

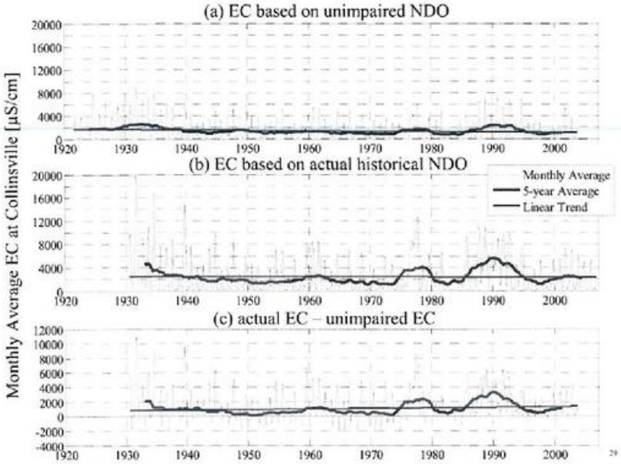

Figure D-15 – Estimates of Collinsville salinity using the G-model for unimpaired and actual historical flow conditions

Historical (actual) NDO during the 1930's was relatively low, sometimes averaging about -3,000 cfs for several months under actual conditions. The low values of NDO result in the high variability of estimated salinity in the 1930's under actual historical conditions.

No comments

- n/a -

The effects of water management on salinity at Collinsville are highlighted in Figure D-16, which shows the estimated salinity under actual historical conditions as a percent change from the unimpaired conditions. The data in Figure D-16 are the change in G-model estimates of salinity at Collinsville for the period of 1956-2003, computed as the difference between actual and unimpaired salinity as a percent change from the unimpaired salinity. Positive values indicate an increase in salinity under actual conditions and negative values indicate a decrease in salinity (freshening).

From April through August, estimated median salinity under actual historical conditions is substantially greater (more than a 100% increase) than median salinity under unimpaired conditions (Figure D-16). For the remainder of the year, there are no substantial differences between the estimates of median salinity under unimpaired and actual conditions. These distributions of estimated salinity indicate that water management practices result in significant increase in salinity throughout the year at Collinsville.

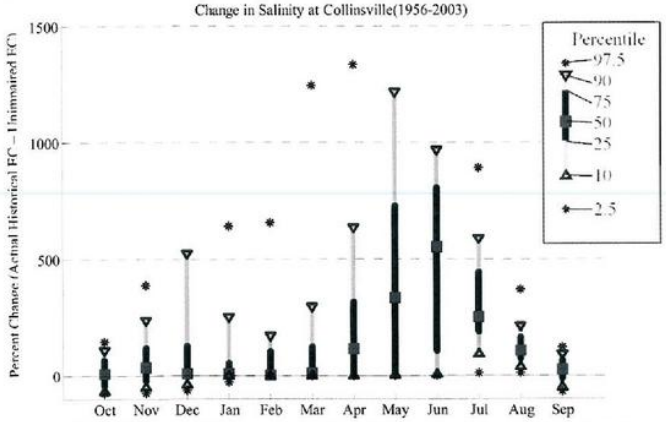

Figure D-16 – Estimated change in salinity at Collinsville under actual historical conditions, as a percent change from unimpaired conditions, 1956-2003

Figure D-17 shows the estimated salinities at Collinsville under actual historical and unimpaired conditions for just the more recent years (1994-2003). Positive values again indicate an increase in salinity under actual conditions and negative values indicate a decrease in salinity. The effects of water management on fall salinity are greater during this recent period 1994-2003 than during the longer period (1956-2003), but the effects during the recent period in the spring and early summer are smaller. This response reflects implementation of the X2 regulatory requirements agreed upon in the 1994 Bay-Delta Accord and regulated by the subsequent 1995 Water Quality Control Plan.

No comments

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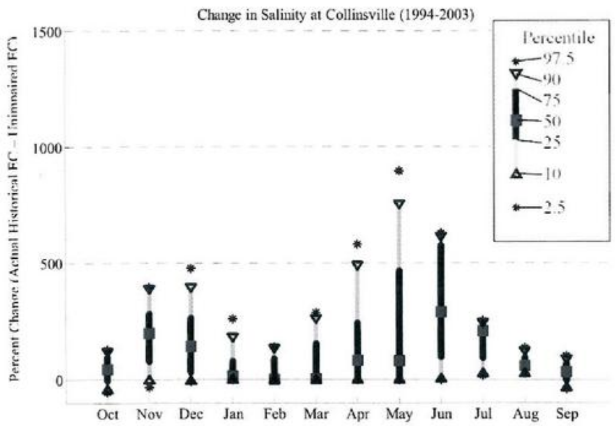

Figure D-17 – Estimated change in salinity at Collinsville under actual historical conditions, as a percent change from unimpaired conditions, 1994-2003

D.3.3. Fall Salinity in the Western Delta

Figure D-18 shows the average fall salinity (October-December) at three stations in Suisun Bay and the western Delta (Chipps Island, Collinsville, and Jersey Point). The fall salinity data categorized according to the pre-Endangered Species Act (ESA) period of 1964-1992 and the post-ESA period (1993-2006)[8]. Figure D-18 illustrates that there has been a noticeable increase in fall salinity since the release of the ESA biological opinions for winter-run salmon and Delta smelt in 1993. These increases occur during normal water years, when total annual runoff ranges from 15 to 30 MAF. During very wet years, there are large Delta outflows and the ESA limits do not affect water operations. Similarly, during very dry years, the biological opinions do not have a large effect on water operations because upstream reservoir storage is low and exports from the south Delta are already small.

[8] In 1993, delta smelt and winter-run salmon were listed under the California ESA, triggering new water management regulations.

No comments

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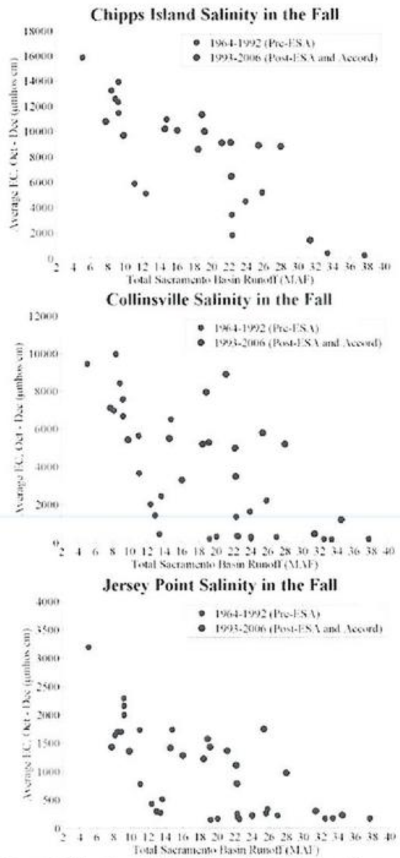

Figure D-18 – Post-ESA salinity in the Suisun Bay and western Delta

Figure D-19 shows the observed salinity at Chipps Island during the fall (October-December) for the period of 1976-1992 (pre-ESA) and 1993-2005 (post-ESA). Fall salinity at Chipps

No comments

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Island during normal years is now comparable to fall salinity during dry and critical years prior to 1994.

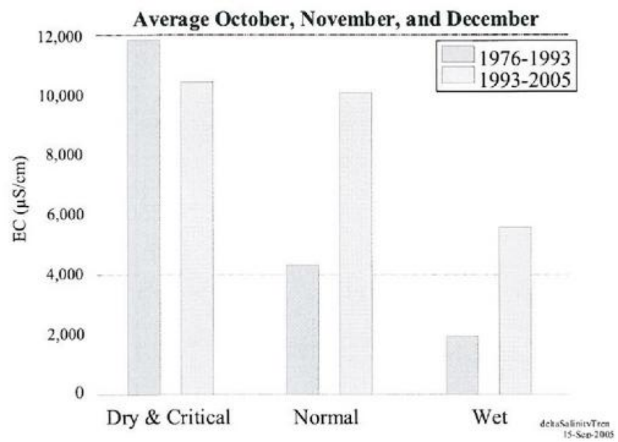

Figure D-19 – Increase in Fall Salinity at Chipps Island

D.4. General conceptual overview of salinity changes

Observed changes in seasonal salinity with time

The salinity regime in the western Delta has changed as the level of development has increased and water project operations have changed due to regulatory requirements. The comparison of three decades with similar hydrology in Figure D-20 presents a conceptual illustration of the changing salinity regime in Suisun Bay and the western Delta.

Monthly-averaged salinity in the spring and summer was substantially greater from 1966 through 1975 than during the early 1900's. However, fall and early winter salinity was lower than the early 1900's. This reduction in salinity in the fall and early winter was likely due in part to CVP and SWP reservoir releases for flood control purposes in the fall, which freshened the Delta. Flood control releases during this period were large because CVP and SWP diversions and exports were not fully developed and upstream reservoirs were often above flood control maximum storage levels in the fall, entering the wet season.

Salinity during 1995 through 2004, however, exceeded the salinities in the early 1900's during all months, for years with similar hydrologic conditions. The dramatic increase in fall

No comments

- n/a -

salinity relative to observed levels from 1966 to 1975 is accompanied by a slight decrease in spring and summer salinity. This is likely due to minimum flow and X2 requirements imposed by the State Water Resources Board in 1995. However, spring and summer salinities remain much greater relative to salinity in the early 1900's.

The range of seasonal variability during 1966-1975 was greatly reduced because the Delta did not get as fresh as it did in the early 1900's. During the last decade, seasonal variability has increased such that the range of salinity observed in the Delta over the course of a year is similar to that in the early 1900's. However, salinity intrusion has moved inland relative to the early 1900's, resulting in saltier conditions in the Suisun Bay and western Delta and a reduction in the period when fresher water is available.

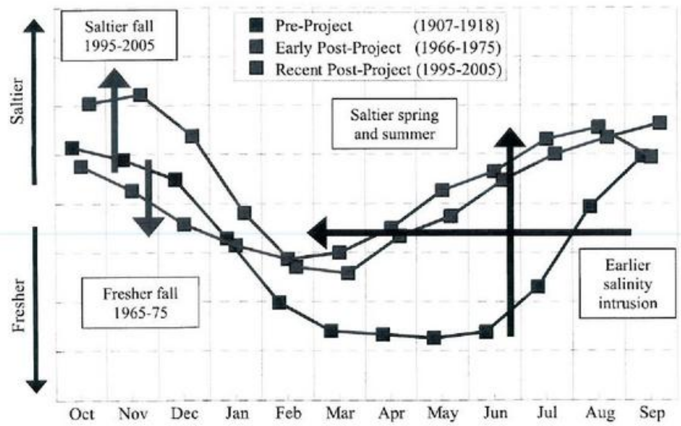

Figure D-20 – Conceptual plot of seasonal variability of salinity in Suisun Bay and the western Delta during different water management eras

The effect of water management for wet and dry years

Water management has the largest effect during dry years when the Delta stays relatively salty throughout the year with limited seasonal variability compared to unimpaired conditions. As shown conceptually in Figure D-21, during wet years the Delta freshens as much as it would under unimpaired conditions, but the Delta does not stay fresh for as long.

No comments

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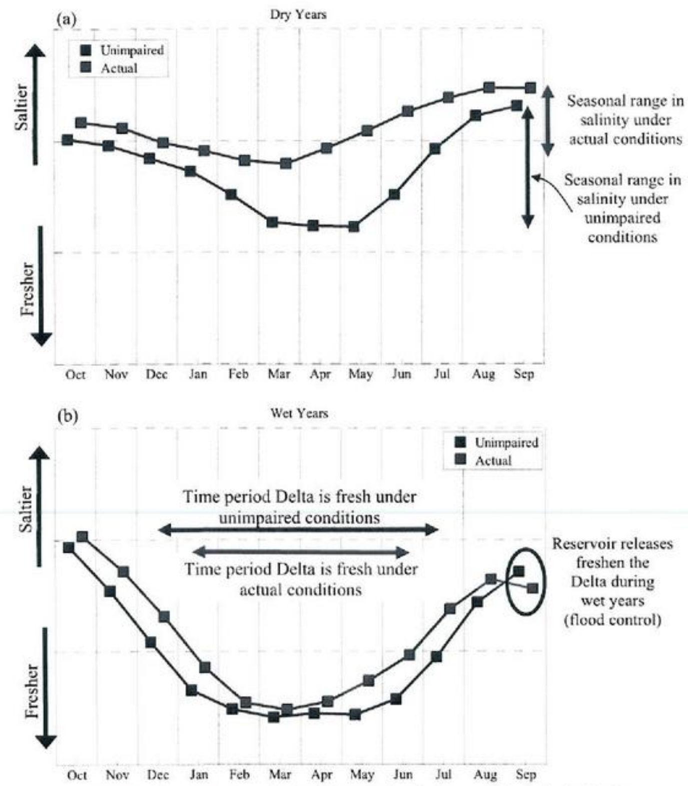

Figure D-21 – Conceptual plot of seasonal salinity variations in the Delta under actual historical conditions compared to unimpaired conditions in (a) dry years and (b) wet years

No comments

- n/a -

Appendix E. Qualitative Salinity Observations

The earliest written accounts of explorers were often concerned with adequate drinking water, and salinity was generally described in qualitative terms, such as "brackish," "fresh," or "sweet." For the purposes of comparing the present-day water quality with the historical conditions, these qualitative observations need to be quantified.

Testimony from Antioch Case (Town of Antioch v. Williams Irrigation District, 188 Cal. 451) indicated early settlers required water with less than 100 mg/L of chloride (approximately 525 μS/cm EC) for municipal use.[9] Similarly, DPW (1931) indicated that a "noticeable" level of salinity was 100 mg/L chloride. The current secondary water quality standard for municipal and industrial use is 250 mg/L chloride (1,000 μS/cm EC) (SWRCB 2006; US EPA 2003). This report assumes a value of 250 mg/L chloride (equivalent to 1000 μS/cm EC) to be the demarcation between "fresh" (or "sweet") water and "brackish" water.

E.1. Observations from Early Explorers

Table E-1 summarizes some reported observations of water quality made by early explorers and settlers. These observations were qualitative and were most likely only a glimpse of the ambient conditions and may not completely represent true historical water quality conditions. Moreover, these observations were from a time period when anthropogenic effects on this region were minimal and this region was close to natural conditions.

Table E-1 also lists the reconstructed Sacramento River annual flow (MAF) from Meko *et al.* (2001b) for the year of observation and for the previous year. For reference, the average Sacramento River flow from Meko *et al.* (2001b) for the period 1860-1977 is 18 MAF/yr.

Table E-1 – Qualitative salinity observations from early explorers

Date	Location	Description	Year / Reconstructed Flow [MAF]	Observer	Reference
1775 August	near the Sacramento-San Joaquin confluence	sweet, the same as in a lake	1774 / 25 1775 / 19	Canizares	Britton, 1987 in Fox, 1987b
1776 April	near Antioch (San Joaquin River)	very clear, fresh, sweet, and good	1775 / 19 1776 / 9	Font	Britton, 1987 in Fox, 1987b
1776 September	near the Sacramento-San Joaquin confluence	sweet	1775 / 19 1776 / 9	Canizares	Britton, 1987 in Fox, 1987b

[9] Supplement to Respondent's Answering Brief, p. 10.

No comments

- n/a -

Date	Location	Description	Year / Reconstructed Flow [MAF]	Observer	Reference
1796	unknown	salinity "far upstream" at high tide	1795 / 6 1796 / 10	Hermengildo Sal	Cook, 1960 in TBI, 1998
1811 October	near the Sacramento-San Joaquin confluence	sweet	1810 / 19 1811 / 23	Abella	Britton, 1987 in Fox, 1987b
1841 August	Three Mile Slough north of Emmaton	brackish (undrinkable)	1840 / 16 1841 / 6	Wilkes	Britton, 1987 in Fox 1987b

E.1.1. Fresh Conditions

Table E-1 indicates that some early explorers observed "sweet" water near the confluence of the Sacramento and San Joaquin Rivers both in relatively wet years (August of 1775 and October of 1811, reconstructed runoff about 19 MAF/yr) and in relatively dry years (September of 1776, reconstructed runoff about 9 MAF/yr). Except as noted, it is unknown whether these observations were made at high tide or low tide.

In order to provide a context for these anecdotal observations, present-day observed monthly salinity (EC) conditions at Collinsville (located near the confluence of Sacramento and San Joaquin Rivers) are plotted against unimpaired annual Sacramento River flow in Figure E-1. The observed data are monthly-averaged salinity (µS/cm) during August-October for the period 1965-2005. The data for the post-ESA years (1994-2005) are shown as shaded circles. Note that the anecdotal observations in Table E-1 are likely "one-time" observations, while those shown in Figure E-1 are average monthly values.

No comments

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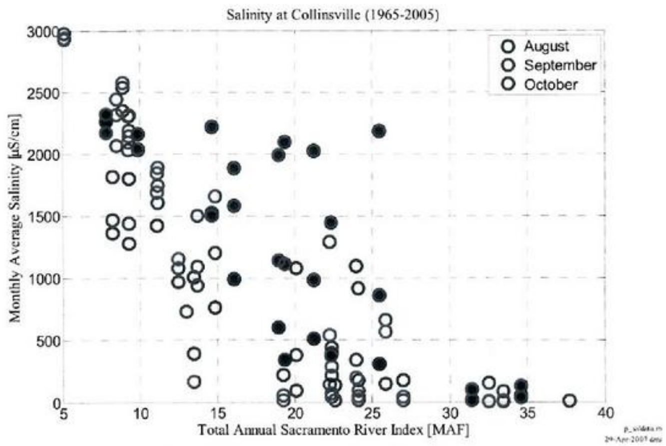

Figure E-1 – Observed salinity at Collinsville, 1965-2005

Under current management conditions, the monthly average salinity at Collinsville from August through October is only less than 1,000 µS/cm EC (the interpretation of the "sweet" threshold for drinking water) when the unimpaired runoff is greater than about 20 to 25 MAF/yr (Figure E-1). This suggests either the "sweet" threshold used in this report is too small, or salinity at Collinsville is higher today than it was in the late 18th and early 19th centuries.

If the definition of the "sweet" threshold is changed to 1,300 µS/cm EC and the post-ESA years (1994-2005) are excluded, then the monthly-averaged salinity at Collinsville during August-October is "fresh" (less than 1,300 µS/cm EC) when runoff is greater than 16 MAF/yr. This corresponds better to the anecdotal observations, discussed above, but suggests a recent increase in salinity at Collinsville during moderately wet years (with runoff between 14 and 26 MAF/yr). In 5 of the 12 post-ESA years (1997, 1999, 2000, 2003 and 2004), the water at Collinsville in October would not be considered "sweet" even under the relaxed criterion of 1,300 µS/cm EC, suggesting that October salinity under present conditions could be greater than it was in 1811.

E.1.2. Brackish Conditions

The qualitative observations of high salinity intrusion in Table E-1 are less specific about location. However, some of these observations have been interpreted by others (Cook, 1960, in TBI, 1998; Fox, 1987b) to indicate intrusion as far upstream as Rio Vista. The drought periods of 1976-1977 and 1987-1992 are similar to these periods when these qualitative

No comments

- n/a -

observations were made. During 1976-1977, daily average salinity at Rio Vista exceeded 1,000 μS/cm for approximately six months of the year. During 1987-1992, salinity at Rio Vista at high tide often exceeded 2,000 μS/cm, particularly during the fall. This is consistent with the anecdotal observations made in 1796 and 1841, which report salt water extending into the western Delta.

Summary: Interpretation of the above observations in the context of the reconstructed Sacramento River flows shows that the Delta is generally saltier than the historical levels for equivalent runoff conditions and does not support the hypothesis that the present-day Delta is managed as a freshwater system in comparison with its historical salinity regime. Moreover, this analysis indicates that salinity in the western Delta has increased during September and October in the recent years (post-1994 period).

E.2. Observations from early settlers in the Western Delta

Observations from early settlers in the western Delta provide a more complete description of salinity in the late 1800's and early 1900's than the observations from early explorers discussed earlier. Assuming the early settlers inhabited a particular region for longer time periods than the early explorers, observations from the early settlers capture the temporal variability better than those from the early explorers.

E.2.1. Town of Antioch Injunction on Upstream Diverters

In 1920, the Town of Antioch filed a lawsuit against upstream irrigation districts alleging that the upstream diversions were causing increased salinity intrusion at Antioch. The court decision, legal briefings, and petitions provide salinity observations from a variety of witnesses. Although anecdotal testimony summarized in these legal briefs is far from scientific evidence, it provides a perspective of the salinity conditions prevailing in the early 1900's. Because the proceedings were adversarial in nature, this report focuses on the testimony of the upstream interests, who were trying to demonstrate that salinity intrusion was common near Antioch prior to their diverting water (prior to 1920). Consequently, the testimony may be biased in support of this "more saline" argument. Nonetheless, these anecdotal testimonies indicate that the western Delta was less salty in the past than it is today. Analyses of some of the testimonies are presented below.

Case History

On July 2, 1920, the Town of Antioch filed suit in the Superior Court of the State of California (hereinafter referred to as the "Antioch Case") against upstream diverters on the Sacramento River and Yuba River. A hearing for a temporary injunction began on July 26, 1920, and lasted approximately three months. On January 7, 1921, Judge A. F. St. Sure granted a temporary injunction, restraining the defendants "from diverting so much water from the said Sacramento River and its tributaries, to non-riparian lands, that the amount of water flowing past the City of Sacramento, in the County of Sacramento, State of California, shall be less than 3500 cubic feet per second" (Town of Antioch v. Williams Irrigation District, Supplement to Appellants' Opening Brief, p. 13).

No comments

- n/a -

The defendants appealed to the Supreme Court of the State of California, which issued its opinion on March 23, 1922. The Supreme Court reversed the lower court and withdrew the injunction, declaring "[i]t is evident from all these considerations that to allow an appropriator of fresh water near the outlet of these two rivers to stop diversions above so as to maintain sufficient volume in the stream to hold the tide water below his place of diversion and secure him fresh water from the stream at that point, under the circumstances existing in this state, would be extremely unreasonable and unjust to the inhabitants of the valleys above and highly detrimental to the public interests besides."

The Supreme Court did not make any comment whatsoever on the evidence of salinity intrusion prior to the upstream diversions in question. The Court indicated that their decision was based on a "policy of our law, which undoubtedly favors in every possible manner the use of the waters of the streams for the purpose of irrigating the lands of the state to render them fertile and productive, and discourages and forbids every kind of unnecessary waste thereof." (Town of Antioch v. Williams Irrigation District (1922) 188 Cal. 451). The Court concluded that allowing 3,500 cubic feet per second (cfs) to "waste" into the Bay to provide less than 1 cfs of adequate quality water for the Town of Antioch would constitute unreasonable use of California's limited supply of water.

The court did not base their decision on historical salinity observations at Antioch, which indicate that Antioch was able to divert freshwater at low tide at all times from 1866 to 1918, except possibly for some fall months during some dry years (Section 3.1).

E.2.2. Salinity at Antioch – then and now

In the present day, the City of Antioch maintains a municipal water intake on the San Joaquin River at Antioch. As a general operating rule, the City of Antioch pumps water from the river when salinity at the intake is less than 1,000 µS/cm EC. Salinity varies substantially with the tide; generally the greatest salinity is observed near high tide and the lowest salinity is observed at low tide. Figure E-2 shows that salinity in the San Joaquin River at Antioch is highly variable and is dependent on tidal conditions and season. Figure E-2 indicates that for water year 2000 (an above-normal water year) the City of Antioch could pump water all day for about four and half months (early February through mid-June) and could pump for a portion of the day at low tide for another three and half months (mid-June through September). For the remaining four months (October-January), water at Antioch's intakes exceeded 1,000 µS/cm EC for the entire day, regardless of tidal phase.

Testimony from multiple witnesses in the Antioch Case indicates that fresh water was always available in the San Joaquin River at Antioch at low tide until just prior to 1920. Antioch's legal position was that fresh water was always available before upstream development. In cross-examination of Antioch's witnesses, the upstream irrigators demonstrated that brackish conditions did occasionally exist at high tide.

No comments

- n/a -

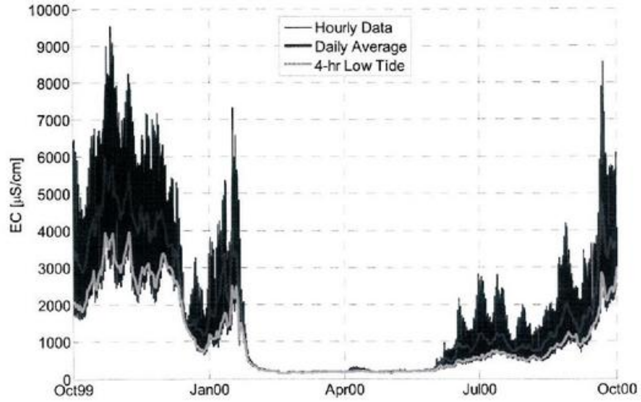

Figure E-2 – Salinity variations in the San Joaquin River at Antioch, water year 2000

Figure E-3 shows the distribution of low tide salinity (salinity during the freshest 4 hours of each day) for the period of May 1, 1983 through September 30, 2002.[10] These data indicate that, on average (in 50% of the water years), low tide salinity exceeds 1,000 µS/cm EC from late-August through December. The data in Figure E-3 provide context for the qualitative observations from the Antioch Case. During the driest 25% of the years (5 out of 20 years), low tide salinity exceeds 1,000 µS/cm EC from June through January, leaving the Antioch intake with no fresh water for eight months of the year.

Under average conditions corresponding to the period 1983-2002, Antioch would have to stop pumping from late August to late December in 10 of the 20 years; i.e., they would have an average of eight months of low-tide pumping per year, compared to the pre-1915 average of twelve months per year (based on the anecdotal information filed by the Appellants (upstream diverters) in the Antioch Case).

[10] Data Source: Interagency Ecological Program, HEC-DSS Time-Series Databases. Station RSAN007. Agency: DWR-ESO-D1485C. Measurement: 1-hour EC. Time Range: May 1, 1983 through September 30, 2002

No comments

- n/a -

No comments

- n/a -

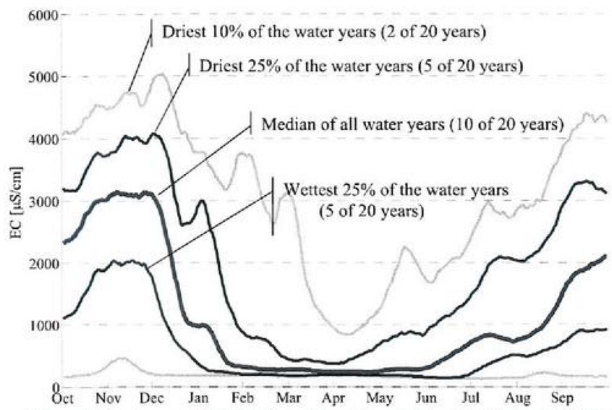

Figure E-3 – Seasonal Distribution of low-tide salinity at Antioch, 1983-2002

Conclusions

- The window, when Antioch is able to pump water with salinity less than 1,000 µS/cm EC, has substantially narrowed in the last 125 years.
- Antioch was apparently able to pump fresh water at low tide year-round in the late 1800's, with the possible exception of the fall season during one or two dry years.
- During 10 of the 20 years between 1983 and 2002, salinity was less than 1,000 µS/cm EC at low tide for only about eight months of the year.
- During the driest 5 years between 1983 and 2002, salinity was less than 1,000 µS/cm for only about four months per year; i.e., no fresh water was available at any time of the day for about eight months of the year.

E.2.3. Salinity at Kentucky Point on Twitchell Island – then and now

The appellants in the Antioch Case, representing the upstream diverters, identified one resident of Twitchell Island who reported the water at Kentucky Landing was brackish on "one or two occasions" between 1870 and 1875 during August and September. During this time, he had to travel up the San Joaquin River to Seven Mile Slough (the eastern boundary of Twitchell Island) and sailed as far as the mouth of the Mokelumne River (approximately 2 miles further up the San Joaquin River than the Seven Mile Slough junction) to obtain fresh drinking water.

For comparison, we look at salinity monitoring data in that region for 1981 and 2002 to see the location of potable water.[11] The source document (Town of Antioch v. Williams Irrigation District, 188 Cal. 451) for the 1870's drought uses up to 100 mg/L chloride concentration as the threshold for a potable water supply. Monitoring data from 1981 shows similar salinity intrusion as described by the Twitchell Island resident; salinity along the San Joaquin River at Bradford Island (about 1.5 miles upstream of Three Mile Slough) exceeded 1,000 µS/cm EC (about 250 mg/L Cl) during August and September. During the same time period, salinity was around 400 µS/cm EC (about 64 mg/L Cl) approximately 5 miles upstream on the San Joaquin River between Seven Mile Slough and the Mokelumne River. This comparison indicates that the extent of salinity intrusion in 1981 is similar to that which occurred in 1870 and 1871.

Similarly, in September 2002, the salinity in the San Joaquin River at San Andreas landing (less than 2 miles downstream of the Mokelumne River mouth) peaked at 977 µS/cm EC, which corresponds to approximately 225 mg/L chloride concentration. Therefore, if the observer was to travel upriver for potable water in 2002, they would have likely traveled up to the mouth of the Mokelumne River as they did in 1870. Salinity intrusion in critically dry years is even farther into the Delta than was found in 2002.

In conclusion, salinity intrusion up the San Joaquin River during the dry years of 1870 and 1871 as described by a Twitchell Island resident is consistent with salinity intrusion in 1981 and 2002 under similar hydrological conditions. There is no evidence that salinity intrusion during the drought of 1870-71 was more extensive than salinity intrusion during similar water years in the current salinity regime.

[11] 1981 and 2002 were both dry water years in the Sacramento River basin as defined in D-1641 with similar annual unimpaired Sacramento River flow to the years 1870 and 1871. Annual unimpaired Sacramento River flow in 1870, 1871, 1981, and 2002 was 11 MAF, 10 MAF, 11 MAF, and 14 MAF, respectively.

No comments

- n/a -

Delta Flow Criteria Informational Proceeding

Before the

State Water Resources Control Board

Scheduled to Commence
March 22, 2010

Exhibit CCWD-6

Historical Fresh Water and Salinity Conditions
in the Western Sacramento-San Joaquin Delta and Suisun Bay

Technical Memorandum WR10-001
Contra Costa Water District
Water Resources Department
February 2010

Submitted on behalf of

Contra Costa Water District
P.O. Box H2O
Concord, CA 94524

No comments

- n/a -

Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay

A summary of historical reviews, reports, analyses and measurements

Water Resources Department

Contra Costa Water District

Concord, California

February 2010

Technical Memorandum WR10-001

Exhibit CCWD-6

No comments

- n/a -

Acknowledgements

CCWD would like to thank the City of Antioch for their contribution towards funding a technical review of CCWD's draft report "Trends in Hydrology and Salinity in Suisun Bay and the Western Delta" (June 2007); their review substantially improved the work and led to the final report "Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay". CCWD is grateful to the many reviewers including Richard Denton, Matthew Emrick, Gopi Goteti, Phil Harrington, E. John List, Susan Paulsen, David Pene, Mat Rogers, and Peter Vorster. We also thank the following for sharing their data and analyses: Roger Byrne, Chris Enright, Spreck Rosekrans, and Scott Starratt, and we thank Ann Spaulding for her contributions.

No comments

- n/a -

Foreword - Establishing the Historical Baseline

The watershed of the Sacramento–San Joaquin Delta (Delta) provides drinking water to more than 23 million Californians as well as irrigation water for millions of acres of agriculture in the Central Valley. The Delta itself is a complex estuarine ecosystem, with populations of many native species now in serious decline. The Delta estuary as we know it began to form about 6,000 years ago, following the end of the last ice age. Because the estuary is connected to the Pacific Ocean through San Francisco Bay, seawater intrusion causes the salinity of Suisun Bay and the Delta to vary depending on hydrological conditions. This seawater intrusion into the Delta affects estuarine species as well as drinking water and irrigation water supplies.

Successful restoration of the Delta ecosystem requires an understanding of the conditions under which native species evolved. Contra Costa Water District's report on "Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay" presents a detailed review of more than 100 years of studies, monitoring data, scientific reports, and modeling analyses that establish an historical record of the salinity conditions in the Western Delta and Suisun Bay.

No comments

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No comments

- n/a -

Executive Summary

The historical record and published studies consistently show the Delta is now managed at a salinity level much higher than would have occurred under natural conditions. Human activities, including channelization of the Delta, elimination of tidal marsh, and water diversions, have resulted in increased salinity levels in the Delta during the past 150 years.

Eighty years ago, Thomas H. Means wrote ("*Salt Water Problem, San Francisco Bay and Delta of Sacramento and San Joaquin Rivers*," April 1928, pp 9-10):

> "Under natural conditions, Carquinez Straits marked, approximately, the boundary between salt and fresh water in the upper San Francisco Bay and delta region of the two tributary rivers—the Sacramento and San Joaquin. Ordinarily salt water was present below the straits and fresh water was present above. Native vegetation in the tide marshes was predominately of salt water types around San Pablo Bay and of fresh water types around Suisun Bay….
>
> The definite statement that salt water under natural conditions did not penetrate higher upstream than the mouth of the river, except in the driest years and then only for a few days at a time, is warranted….
>
> At present [1928] salt water reaches Antioch every year, in two-thirds of the years running further [sic] upstream. It is to be expected that it will continue to do so in the future, even in the years of greatest runoff. In other words, the penetration of salt water has become a permanent phenomenon in the lower river region.
>
> The cause of this change in salt water condition is due almost entirely to the works of man."

In 1928, Thomas Means had limited data over a short historical period from which to draw these conclusions. Nonetheless, his conclusions remain accurate and have been confirmed by numerous subsequent studies, including paleosalinity records that reveal salinity conditions in the western Delta as far back as 2,500 years ago. The paleosalinity studies indicate that the last 100 years are among the most saline of periods in the past 2,500 years. Paleoclimatology and paleosalinity studies indicate that the prior 1,500 years (going back to about 4,000 years ago) were even wetter and less saline in San Francisco Bay and the Delta. The recent increase in salinity began after the Delta freshwater marshes had been drained, after the Delta was channelized and after large-scale upstream diversions of water, largely for agricultural purposes, had significantly reduced flows from the tributaries into the Delta. It has continued, even after the construction of reservoirs that have been used in part to manage salinity intrusion.

No comments

- n/a -

Increased Salinity Intrusion into the Delta

Studies and salinity measurements confirm that despite salinity management efforts, Delta salinity is now at or above the highest salinity levels found in the past 2,500 to 4,000 years. Under equivalent hydrological conditions, the boundary between salt and fresh water is now 3 to 15 miles farther into the Delta than it would have been without the increased diversions of fresh water that have taken place in the past 150 years.

Reservoir operations artificially manage salinity intrusion to conditions that are saltier than had been experienced prior to the early 1900's. While these managed conditions are certainly fresher than would occur in today's altered system if operated without any salinity management, they are still saltier than what the Delta experienced under similar hydrological conditions in the past. While the Delta is being managed to a somewhat acceptable saline condition to meet many beneficial uses, it is still managed at a more saline condition than would have occurred prior to the anthropogenic changes of the past 150 years.

For example, the 1928-1934 drought was one of the driest periods in the past 1,000 years (Meko *et al.*, 2001a), and occurred after tidal marshes within the Delta had been reclaimed and water diversions began removing substantial amounts of fresh water from the Bay-Delta system. Nonetheless, the Delta freshened during the winter in those drought years. This winter freshening of the Delta has not occurred during recent droughts. While salinity intrusion into the Delta was previously only seen in the driest years, significant salinity intrusion now occurs in nearly every year – exceptions are only found in the wettest conditions.

Changed Variation in Salinity

The variability of fresh and saline conditions in the Delta has considerably changed because of upstream and in-Delta water diversions and water exports (Enright and Culberson, 2009). This change in variability results largely from the lack of fresh conditions in Suisun Bay and the western Delta, especially in the winter and spring. Restoring a variable salinity regime that more closely approximates conditions prior to the early 1900's would require much higher flows and much fresher conditions than current management practices provide, with larger outflows in the fall in most years and much larger outflows in the late winter and spring in all years.

Key Conclusions

The major conclusions of this study are:

1. Salinity intrusion during the last 100 years has been among the highest levels over the past 2,500 years. The Delta has been predominantly a freshwater tidal marsh for the last 2,500 years.
2. Human activities during the last 150 years, including channelization of the Delta, elimination of tidal marsh, construction of deep ship channels, and diversion of water, have resulted in the increased salinity levels in the Delta.

No comments

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3. Conditions in the Delta during the early 1900's were much fresher than current conditions for hydrologically similar periods. Salinity typically intrudes 3 to 15 miles farther into the Delta today.
4. The historical record and published studies uniformly demonstrate and conclude the Delta is now managed at a salinity level that is much higher than would have occurred under pre-1900 conditions. Operation of new reservoirs and water diversion facilities for salinity management reduces salinity intrusion somewhat, but the levels still exceed pre-1900 salinities.
5. Seasonal and inter-annual variation in salinity has also been changed; however, this change is largely the result of reduced freshwater flows into the Delta. At any given location in the western Delta and Suisun Bay, the percentage of time during the year when fresh water is present has been greatly reduced or, in some cases, largely eliminated.

Background

Flows and water quality in the Sacramento-San Joaquin Delta (Delta) are strongly influenced by freshwater inflow from the rivers, by the tides in San Francisco Bay and by salinity from Bay waters. Prior to human influence, the historical distribution of salinity in the Delta was controlled primarily by the seasonal and inter-annual distribution of precipitation, the geomorphology of the Bay and Delta, daily tides, the spring-neap[1] tidal cycle, and the mean sea level at Golden Gate. Extended wet and dry periods are both evident in the historical record. Since about 1860, a number of morphological changes to the Delta landscape and operational changes of reservoirs and water diversions have affected flows and the distribution of salinity within the Delta.

Between 1860 and 1920, there was significant modification of the Delta by humans:
(i) marsh land was reclaimed,
(ii) hydraulic mining caused extensive deposition and then erosion of sediment, and,
(iii) Delta channels were widened, interconnected and deepened.

Large-scale reservoir construction began in about 1920 and continued through the 1970's, changing the timing and magnitude of flows to the Delta. Large volumes of water began to be diverted for agricultural use upstream of and within the Delta in the same time period. In more recent times, California's Delta water resources have been extensively managed to meet the water supply needs of the State's municipal, industrial, and agricultural water users, with attempts made to also provide flow and water quality conditions to meet fishery needs.

Proposals for significant additional alteration of the Delta and of flows within the Delta are currently being developed as part of the Bay-Delta Conservation Plan process[2]. To

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[1] During a spring tide, the gravitational forces from the sun and moon are largely the same direction and the high-low tidal range is greatest. During a neap tide, the gravitational forces sun and moon are largely not aligned and the tidal range is the lowest. The spring-neap tidal cycle, from strong spring tides through weak neap tides and back to spring tides, in San Francisco Bay has a period of about 14 days.
[2] www.baydeltaconservationplan.com

No comments

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understand the effect of those proposals, it is important to accurately establish historical conditions. For example, for ecological restoration to be successful, it is necessary to establish and understand the conditions to which native species have previously adapted and survived in order to predict their response to future changes in climate or water management. This report uses available data and modeling to examine the consequences of structural changes in the Delta (channelization, channel dredging), increased diversions of water upstream of the Delta, reservoir operations, climate and sea level effects, and other factors on Delta salinity.

Objective

The objective of this report is to answer two major questions regarding the historical extent of fresh water and salinity in the western Delta and Suisun Bay:

I. What was the extent of fresh water and what were the salinity conditions prior to large-scale reservoir operations and water diversions (i.e., prior to early 1900's) and prior to structural changes in the Delta (i.e., prior to the 1860's)?

II. What are the effects of large-scale water management practices (reservoir operations and diversions) on salinity conditions in the western Delta and Suisun Bay?

Approach

Available data were used to characterize historical and present-day fresh water extent and salinity intrusion into the Delta. The data examined in this report include paleohistorical records (over geologic time scales) of river flow and salinity (Section 2), instrumental observations of hydrology and salinity (Section 3), and literature reports on the extent of fresh water in the Delta (Section 4). Additional details and supplemental information are presented in the Appendices to this report.

No comments

- n/a -

Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay

No comments

- n/a -

No comments

- n/a -

Tables

Figures

No comments

- n/a -

No comments

- n/a -

Acronyms

C&H	California and Hawaiian Sugar Refining Corporation
CCWD	Contra Costa Water District
CDEC	California Data Exchange Center
Cl	Chloride concentration
CVP	Central Valley Project
DPW	Department of Public Works
DSM2	Delta Simulation Model 2
DWR	California Department of Water Resources
DWSC	Deep water ship channel
EC	Electrical conductivity
ENSO	El Niño/Southern Oscillation
ESA	Endangered Species Act
IEP	Interagency Ecological Program
M&I	Municipal and Indutrial
NDO	Net Delta Outflow
PDO	Pacific Decadal Oscillation
PPIC	Public Policy Institute of California
SWRCB	State Water Resource Control Board
SRI	Sacramento River Index
STORET	Storage and Retrieval
SWP	State Water Project
TBI	The Bay Institute
TDS	Total Dissolved Solids

Units

AF	Acre-feet
MAF	Million acre-feet
TAF	Thousand acre-ft
µS/cm	MicroSiemens per centimeter, a measure of EC
cfs	Cubic feet per second
mg/L	Milligrams per liter
ppm	Parts per million
ppt	Parts per thousand

No comments

- n/a -

No comments

- n/a -

No comments

- n/a -

1. Introduction

1.1. Background

The Sacramento-San Joaquin River Delta (Delta) is fed by fresh water from the Sacramento River and the San Joaquin River basins (Figure 1-1). The Delta is connected to the San Francisco Bay through Suisun and San Pablo Bays, and the movement of water back and forth between the Delta and the Bay results in mixing between saline water from the Pacific Ocean and fresh water from the rivers flowing into the Delta. The extent to which salty ocean water intrudes into the Delta is a function of natural processes such as ocean tides and precipitation and runoff from the upstream watersheds. It has also been greatly influenced by anthropogenic activities (e.g. construction of artificial river channels, removal of tidal marsh, removal of floodplain connections to channels, deepening of channels for navigation purposes, reservoir storage and release operations, and water diversions).

Proposals for significant additional alteration of Delta channels and marshland, of flows within the Delta, and of reoperation of upstream reservoirs are currently being developed as part of the Bay-Delta Conservation Plan, which builds upon earlier work by the Delta Vision Blue Ribbon Task Force[3], and others (e.g., see Lund *et al.*, 2007). To understand the context and effect of those proposals, it is important to accurately understand the historical conditions previously experienced by Delta species.

An analysis of the salinity trends and variability in northern San Francisco Bay since the 1920's and the factors controlling those salinity trends has recently been published (Enright and Culberson, 2009), with a focus on a comparison of pre-1968 salinity and flows with post-1968 conditions. This report includes analysis and review of reports, data and information from the period prior to Enright and Culberson's analysis, and includes the review of salinity trends using paleohistorical data.

Historically, reproduction of most species in the Bay-Delta (biotic production phase) occurred during the high-flow periods (winter and spring) and biotic reduction occurred in the low-flow periods (summer and fall) (Baxter *et al.*, 2008). Multi-year wet periods most likely resulted in population increases, whereas drought periods likely resulted in reduced reproduction and increased predation. The recent report on Pelagic Organism Decline (POD, Baxter *et al.*, 2008) indicated that reduced flow variability under the current water management conditions may have exacerbated the effects of predation on the population abundance of pelagic fish species in the Bay-Delta estuary. Native species of the Bay-Delta system adapted to the historical salinity conditions that occurred prior to large-scale water management practices and physical changes in the Delta. The historical salinity conditions in the Delta provide insight into the response of fish species to proposed ecosystem restoration actions, and the response of species to future changes in climate or water management.

[3] Delta Vision Blue Ribbon Task Force was appointed by California Governor Arnold Schwarzenegger in February 2007 and adopted the Delta Vision Strategic Plan in October 2008.

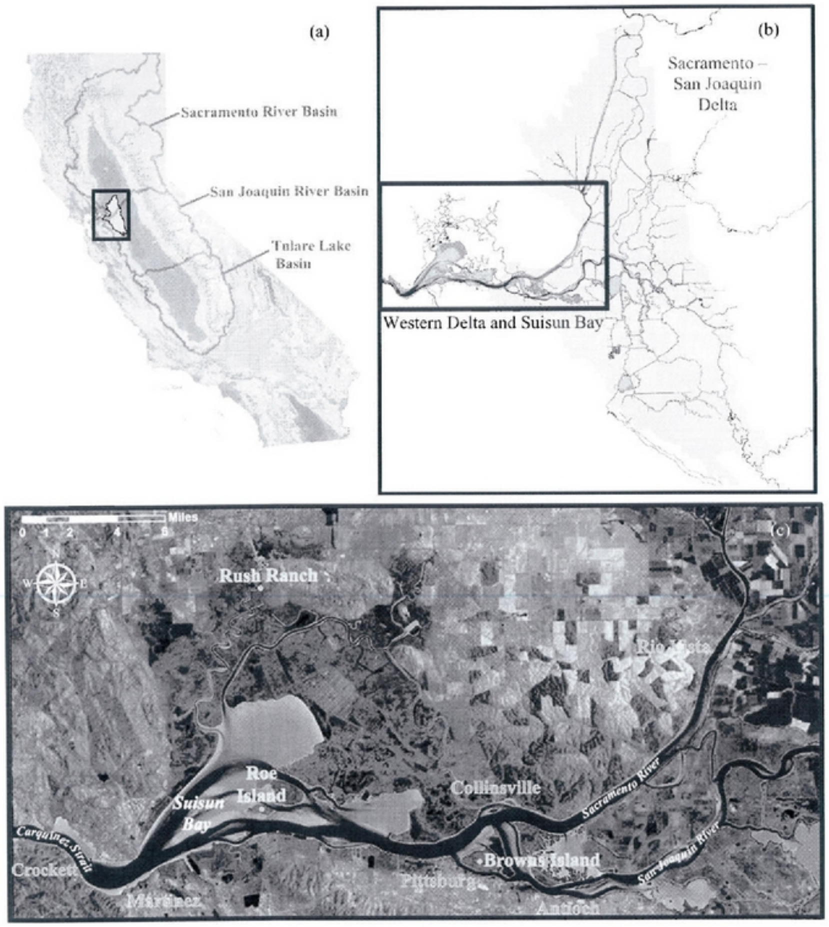

Figure 1-1 – Map

(a) Topographical map of California, with outlines of the Sacramento River, San Joaquin River, and Tulare Lake basins; purple rectangle indicates the extent of the inset in panel (b). (b) Sacramento – San Joaquin Delta and Suisun Bay region; green rectangle indicates the extent of the Western Delta and Suisun Bay enlarged in panel (c). (c) Extent of salinity evaluations considered within this study, including names of locations referenced throughout this report.

No comments

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The salinity concentrations in San Francisco Bay and the Delta are the result of tides that move seawater into the system and are controlled in large part by the amount of fresh water passing through the system (Denton, 1993; Uncles and Peterson, 1996; Knowles *et al*., 1998). The salinity distribution is driven by the motion of the tides, which convey ocean water into the system on the flood tide and draw a mixture of ocean and river water back out again on the ebb tide. These tides act on natural diurnal (repeating twice per day) and spring-neap (repeating every 14 days) cycles driven by the gravitational forces of the sun and moon (Oltmann and Simpson, 1997; Burau *et al*., 1999).

Other factors affecting Bay-Delta salinity (discussed in Appendix A) may be smaller but are not insignificant. When comparing historical salinity conditions in the Bay-Delta watershed, it is often helpful to compare periods with similar hydrological conditions so that the changes due to other factors can be discerned. This will reveal if there is an anomalous change in salinity, even if the specific cause of that change in salinity is not known.

Major anthropogenic modifications to the Delta that affect salinity intrusion began with the European settlement of the region and can be classified into two categories: physical modifications of the landscape (e.g., removal of tidal marsh, separation of natural floodplains from valley rivers, construction of permanent artificial river channels, and land-use changes) and water management activities (e.g. diversion of water for direct agriculture, municipal, or industrial use, and reservoir storage and release operations).

As shown in Figure 1-2, tidal marsh acreage in the Delta decreased significantly from nearly 346,000 acres in the 1870's to less than 25,000 acres in the 1920's and has since continued to decrease. Even after hydraulic mining for gold was banned in California in 1884, large quantities of mining debris continued to be carried by runoff into the Delta, where it was deposited as sediment, filling channels in the Delta and Suisun Bay. Between 1887 and 1920, Suisun Bay became an erosional environment and continued to lose sediment through 1990. Enright and Culberson (2009) discuss the effects of the changes in Suisun Bay bathymetry on salinity intrusion. Major dredging projects on the main Delta channels to create the Stockton and Sacramento Deep Water Ship Channels (DWSC) have also changed how flows and, therefore, salinity are distributed throughout the Delta.

Each of these factors has changed the salinity regime: loss of tidal marsh lands has allowed increased tidal energy deeper into the Delta, increasing tidal flows and salinity dispersion (Enright and Culberson, 2009), net erosion and increasing depth within Suisun Bay likely increased dispersive transport of salt up the estuary (Enright and Culberson, 2009), and deeper channels allow increased salinity intrusion due to increased baroclinic circulation and increased tidal flow and dispersion..

However, these physical modifications generally have had less effect on salinity intrusion in the Delta than the major water management activities that have resulted in large-scale diversion of water for reservoir storage and agricultural, domestic, and industrial water use (Nichols *et al*. 1986; Knowles, 2002). As will be seen in data presented in this document, early diversions before large-scale storage projects resulted in greatly increased salinity intrusion, especially in the summer irrigation season, peaking in September. Later, reservoir operations reduced salinity intrusion in the summer and fall, but increased it in the winter and

No comments

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spring, up until the mid-1980's. Subsequent water operations have resulted in increased salinity intrusion year round.

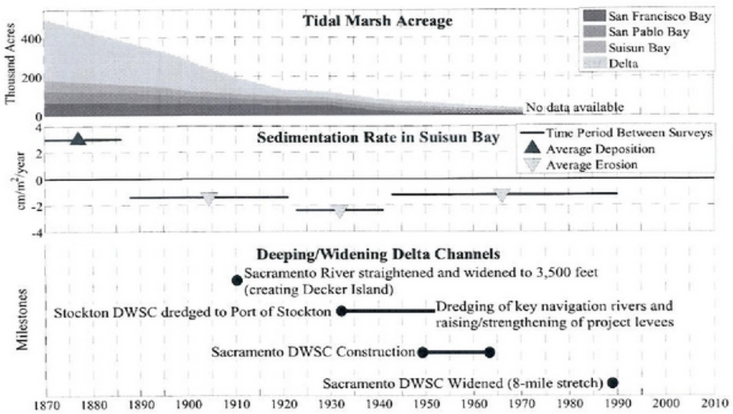

Figure 1-2 – Chronology of anthropogenic modifications to the Bay-Delta landscape
Bay-Delta landscape has undergone significant changes since the mid-1800's. Tidal marsh acreage (top panel) has been significantly reduced (data from Atwater, et al., 1979). Suisun Bay received a pulse of sediment from hydraulic mining in the late 1800's (middle panel), but lost sediment from 1887 to 1990 (data from Cappiella et al., 1999). Numerous efforts to widen and deepen the main channels within the Delta have occurred throughout the 20th Century (bottom panel).

The largest reservoir of the federal Central Valley Project (CVP), Lake Shasta, was completed in 1945, and the largest reservoir of the State Water Project (SWP), Lake Oroville, was completed in 1968. Total upstream reservoir storage capacity increased from 1 MAF in 1920 to more than 30 MAF by 1979. The CVP began exporting water from the southern Delta through Jones Pumping Plant (formerly known as the Tracy Pumping Plant) in 1951, and the SWP began exports through Banks Pumping Plant in 1968. By 1990, the combined export of water from the southern Delta through the Banks and Jones Pumping Plants was about 6 MAF per year.

Figure 1-3 shows that the greatest increase in upstream reservoir storage occurred from the 1920's through the 1960's. Prior to the construction of major water management reservoirs, irrigated acreage grew to about 4 MAF. The construction of the reservoirs allowed irrigated acreage to increase to about 9 MAF. Since 1951, when the first south Delta export facility was completed, annual diversions from the Delta have increased to a maximum of about 8 MAF; total annual diversions from the system are estimated at up to 15 MAF.

No comments

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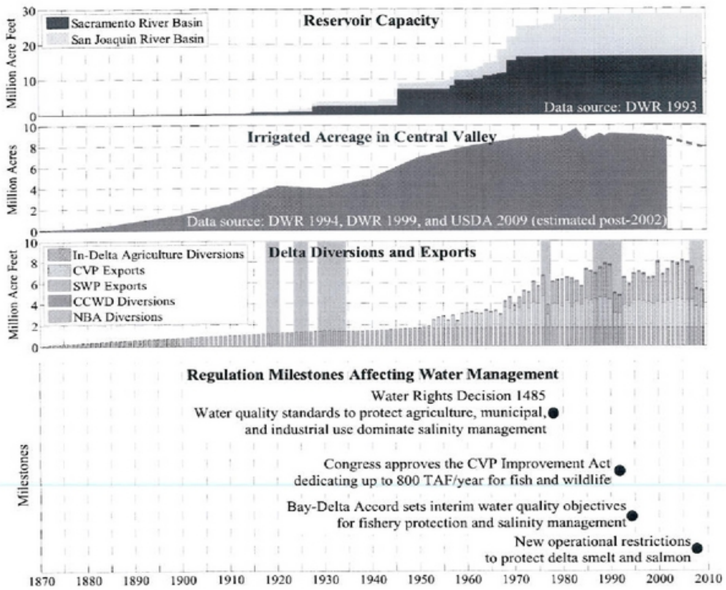


Figure 1-3 – Chronology of anthropogenic activities that affect water management

Reservoirs (top panel) and irrigated crops in the Central Valley (second panel) alter the timing and magnitude of water flow to reach the Delta. Diversions and exports within the Delta (third panel) further reduce the amount of water to flow through the Delta to Suisun Bay. Regulations (bottom panel) require modifications to water management activities to meet specific flow and water quality objectives.

Figure 1-3 also presents the timeline for recent regulatory milestones that have affected Delta water quality. Salinity management was dominated by water quality standards to protect Delta agriculture and municipal and industrial (M&I) uses in the 1978 Water Quality Control Plan and State Water Resources Control Board (SWRCB) Decision 1485. The Bay-Delta Accord of 1994 and subsequent SWRCB Water Rights Decision 1641 made fishery protection the dominant factor for salinity management with new estuarine habitat or "X2 Standards"[4] from February through June, with minimum outflows for the remainder of the

[4] X2 is the distance, in kilometers from the Golden Gate, to the location of the 2 part per thousand salinity line. A larger X2 means salinity has intruded farther into the Delta.

No comments

- n/a -

year. The relationship between X2 and estuarine habitat is discussed in detail in Jassby *et al.* (1995).

These regulations apply throughout the year and have modified how the large-scale water management reservoirs and export facilities are operated. For instance, delta smelt was listed as a threatened species under the federal Endangered Species Act in 1993, and Sacramento River winter-run salmon was listed as endangered in 1994. The subsequent biological opinions, 1994 Bay-Delta Accord, and the adoption of a new water quality control plan by the State Water Resources Control Board in 1995, required increased reservoir releases in some months for temperature control in the Sacramento River below Shasta and for salinity control in Suisun Bay. They also applied additional limits on pumping at the export facilities in the south Delta.

Changes in water diversions and reservoir operations have altered the magnitude and timing of river flows to the Delta, and anthropogenic modifications to the Delta landscape have altered the interaction of fresh water from the rivers with salt water from the ocean, thus changing patterns of salinity intrusion into the Delta.

1.2. Comparing Historical Conditions

Flow and salinity conditions prior to human interference varied according to seasonal and annual hydrological conditions, short-term and long-term drought cycles and other natural changes, so "natural" conditions include variability that must be considered in any analysis. Hydroclimatic variability is described by "unimpaired" runoff, which represents the natural water production of a river basin, unaltered by water diversions, reservoir storage and operation, and export of water to or import of water from other basins.

As discussed above, large-scale water management operations during the last 100 years superimposed on the anthropogenic modifications to the Delta landscape have significantly changed Delta conditions. It is possible to remove the effect that water management operations have had on flows and generate a corresponding set of unimpaired flows. However, it is not possible, without complex assumptions and modeling, to also remove the additional effect of the land use, channel and tidal marsh modifications to the Delta.

The historical conditions presented in this report have been determined from records in paleoclimatic fossils and measured directly with various scientific instruments. The paleoclimatic data start well before human influence, but continue through the 20th Century when anthropogenic modifications became significant.

Because of the natural hydroclimatic variability, no past historical period may fully represent "natural" conditions. Therefore, this report summarizes the available historical salinity information with reference to the time period of the observations, and then compares each period to the salinity regime during present day periods with similar upstream unimpaired hydrology. Where there are significant changes in salinity, despite similar upstream unimpaired hydrology, other factors such as landscape modifications and water management operations must be contributing factors.

No comments

- n/a -

1.3. Objective

The objective of this report is to answer two major questions regarding the historical extent of fresh water and salinity in the western Delta and Suisun Bay:

I. What was the extent of fresh water and what were the salinity conditions prior to large-scale reservoir operations and water diversions (i.e., prior to early 1900's) and prior to structural changes in the Delta (i.e., prior to the 1860's)?

II. What are the effects of large-scale water management practices (reservoir operations and diversions) on salinity conditions in the western Delta and Suisun Bay?

1.4. Report Structure

The remainder of this report is organized as follows:

Section 2: Paleoclimatic Evidence of the Last 10,000 Years

Estimated river flow data and salinity records for the past several thousand years have been obtained from paleoclimatic records, such as tree rings and sediment cores. These records capture the hydroclimatic variations over decadal and centennial time scales and are useful tools in understanding the freshwater flow and salinity regimes before modern instrumentation.

Section 3: Instrumental Observations of the Last 140 Years

Long-term precipitation and river runoff records from the 1870's to the present provide context for the salinity observations. Climatic variability of precipitation and runoff in the upper watershed has a significant influence on salinity intrusion, with greater salinity during dry periods and lower salinity during wet periods. If, for example, the salinity is greater or less than what would be expected based on the natural climatic variability, as measured by unimpaired runoff, other factors must be influencing salinity intrusion.

Reservoir operations, diversions and consumptive use (collectively termed "water management") alter the amount of runoff from the upper watershed that actually flows out of the Delta. Observations and common computer models are used to assess the effects of this water management on Net Delta Outflow (the net quantity of water flowing from the Delta to the Suisun Bay) and on salinity in the western Delta and Suisun Bay. Observations include measurements of salinity indicators by the California & Hawaiian Sugar Refining Corporation (C&H) from the early 1900's and long-term monitoring data from the Interagency Ecological Program (IEP). Modeling tools include the DAYFLOW program from IEP, the DSM2 model from the California Department of Water Resources, the X2[5]

[5] X2 is defined as the distance from the Golden Gate to the 2 part-per-thousand isohaline (equivalent to a salinity of 2 grams of salt per kilogram of water), measured along the axis of the San Francisco Estuary. X2 is often used as an indicator of freshwater availability and fish habitat conditions in the Delta (Jassby *et al.*, 1995; Monismith, 1998).

No comments

- n/a -

equation (Kimmerer and Monismith, 1992) and Contra Costa Water District's salinity outflow model (also referred to as the G-model) (Denton, 1993; Denton and Sullivan, 1993).

Section 4: Qualitative Observations of Historical Freshwater Flow and Salinity Conditions

Qualitative observations on salinity conditions in the western Delta and Suisun Bay from an early water rights lawsuit and from various literature reports are discussed to provide a perspective of the salinity conditions prevailing in the late 1800's and early 1900's. The 1920 lawsuit filed by the Town of Antioch against upstream irrigation districts alleged that the upstream water diversions were causing increased salinity intrusion at Antioch (Town of Antioch v. Williams Irrigation District, 1922). Briefings and testimony from the legal proceedings are indicative of the salinity conditions prevailing in the early 1900's, as are literature reports of conditions in the western Delta and Suisun Bay. These reports contain both qualitative observations and anecdotal information regarding historical salinity conditions. Because the proceedings were adversarial in nature, this report focuses on the testimony of the upstream interests, who were trying to demonstrate the extent of salinity intrusion in the Delta prior to their diverting water. Note that the Supreme Court did not base its final decision on the evidence of whether or not Antioch had continuous access to fresh water. The Court's decision was based on the State policy to irrigate as much land as possible for agriculture; the Court did not pass judgment on the accuracy of the testimony of either side.

Section 5: Conclusions

This section synthesizes the findings from Sections 2 through 4 and presents the overall conclusions regarding trends in the historical Delta salinity.

No comments

- n/a -

2. Paleoclimatic Evidence of the Last 10,000 Years

Paleoclimatic evidence from the watershed of San Francisco Bay (Bay) and Sacramento-San Joaquin Delta (Delta), obtained from proxy information such as tree rings and sediment deposits, provides a history of conditions before modern direct instrumental observations. Evidence of major regional climatic events that represent long-term wet period and drought cycles will be discussed, followed by discussions of Delta watershed runoff and Delta salinity, as measured by flow and electrical conductivity instrumentation.

2.1. Major Regional Climatic Events

The modern Bay-Delta is relatively young in terms of geologic timescales. The estuary started forming around 8,000 to 10,000 years ago (Atwater *et al.* 1979), when rapid sea level rise allowed the ocean to enter the Golden Gate. At this time, there was no Bay or Delta, but simply river valleys. Rapid sea level rise continued, such that approximately 6,000 years ago, the outline of San Francisco Bay, including San Pablo Bay and Suisun Bay, resembled the modern extent. At about the same time, sea level rise slowed to a more moderate pace, allowing tidal marshes to begin to form.

Malamud-Roam *et al.* (2007) review paleoclimate studies in the Bay-Delta watershed, summarizing evidence of climate variability through the development of the present day Bay-Delta system (Table 2-1).

Table 2-1 – Climate during the evolution of the Bay-Delta estuary

Overview of precipitation, temperature, and sea level conditions during the last 10,000 years based on data from Malamud-Roam et al. (2007) and Meko et al. (2001). Time periods are given in terms of number of years ago (represented as age, a; or ka for 1,000 year ago) and the Common Era (BCE/CE) calendar system. The shading indicates relatively dry periods.

Approximate Time Period	*Prevailing Climate and Geomorphology*
10 ka to 8 ka 8000 BCE to 6000 BCE	▪ Rapid sea level rise ▪ Ocean enters Golden Gate ▪ San Francisco Bay is just a river valley ▪ Cooler than 20th Century, but becoming warmer and drier
6 ka to 5 ka 4000 BCE to 3000 BCE	▪ Sea level rise slows to more moderate pace ▪ Outline of San Francisco Bay resembles modern extent ▪ Tidal marsh begins to form in the Delta ▪ Temperature reaches a maximum of the last 10,000 years ▪ Relatively dry conditions ▪ Central Valley floodplain system began to develop

No comments

- n/a -

Approximate Time Period	*Prevailing Climate and Geomorphology*
4 ka to 2 ka 2000 BCE to 1 CE	▪ Cooling trend with increased precipitation ▪ Large flood occurred ~ 3,600 years ago (1600 BCE)

2 ka to 0.6 ka
1 CE to 1400 CE
	▪ Trend to more arid, dry conditions
	▪ Severe droughts:
	  ▪ 1,100 to 850 years ago (900 CE to 1150 CE)
	  ▪ 800 to 650 years ago (1200 CE to 1350 CE)

0.6 ka to 0.2 ka 1400 CE to 1800 CE	▪ Relatively cool and wet conditions ▪ Numerous episodes of extreme flooding ▪ Includes "Little Ice Age" (1400 CE to 1700 CE)

90 a to 50 a
1910 CE to 1950 CE
	▪ Dry period in the Sacramento River Basin.
	  ▪ Longest dry period in the last 420 years (34 years centered on the 1930's)
	  ▪ Driest 20-year period in the last 370 years (1917 CE to 1936 CE)

A number of scientific studies have used paleo-reconstruction techniques to obtain long-term (decadal, centennial and millennial time scale) records of river flow (e.g., Earle, 1993; Meko *et al.*, 2001) and salinity of the Bay and Delta (e.g., Ingram and DePaolo, 1993; Wells and Goman, 1995; Ingram *et al.*, 1996; May, 1999; Byrne *et al.*, 2001; Goman and Wells, 2000; Starratt, 2001; Malamud-Roam and Ingram, 2004; Malamud-Roam *et al.*, 2006; Malamud-Roam *et al.*, 2007; and Goman *et al.*, 2008). The reconstructions described in the following sections focus on the 2,000 years before present. As indicated in Table 2-1, this period was relatively dry with two extreme regional droughts, followed by relatively cool and wet conditions during the "Little Ice Age," then by a return of dry conditions at the early part of the 20th Century.

2.2. Reconstructed Unimpaired Sacramento River Flow

Meko *et al.* (2001a,b) used tree-ring chronologies in statistical regression models to reconstruct time series of annual unimpaired Sacramento River flow[6] for approximately the past 1,100 years (for the period 869 CE – 1977 CE). As discussed in Section 1.2, unimpaired flow is an estimate of the flow that would occur in the basin without the effects of water management activities.

The 1,100-year record shows strong variability between individual water years (Figure 2-1), with annual flow ranging from approximately 8% of average to 265% of average, where average is defined here for practical purposes as the average observed unimpaired flow from

[6] Meko *et al.* (2001a) used the annual unimpaired flow record for the Sacramento River provided by the Department of Water Resources, which is the sum of the following: flow of the Sacramento River at Bend Bridge, inflow of the Feather River to Lake Oroville, flow of the Yuba River at Smartville, and the flow of the American River to Folsom Lake. This definition is consistent with the definition typically used in hydro-climatic studies of this region (e.g., http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST)

No comments

- n/a -

1906 to 2009 of 18 million acre-feet per year (MAF/yr). The reconstructed record shows alternating periods of wet and dry conditions and is consistent with historical droughts (such as the drought in the Mono Lake region of California in the medieval period, around 1150 CE) reported by other paleoclimate studies (Malamud-Roam *et al.*, 2006).

As indicated by the shading in Figure 2-1, the driest long-term drought in the Sacramento River basin in the last 1,100 years occurred from approximately 1130 CE to 1415 CE when the 50-year average flow was seldom above normal for nearly 300 years. Following this drought, conditions were relatively wet (from approximately 1550 CE to 1900 CE). The timing of these droughts and wet periods will be compared to paleosalinity records in the following section.

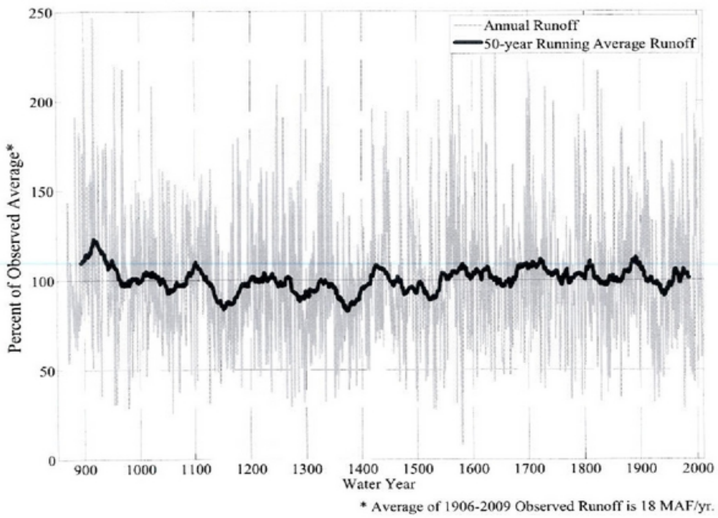


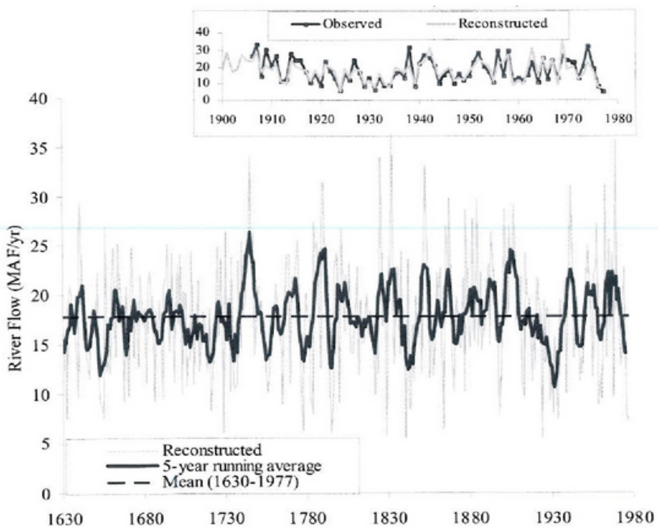
Figure 2-1 – Reconstructed annual unimpaired Sacramento River flow 869 CE to 2009 CE
Annual reconstructed unimpaired Sacramento River flow (grey line) as a percentage of the average annual observed runoff from 1906 to 2009 shows strong variability between years. The 50-year running average (thick black line) illustrates there were extended periods of above-normal and below-normal runoff conditions. The orange shading highlights an extended dry period in the reconstructed unimpaired Sacramento River data when the 50-year average flow is seldom above normal for nearly 300 years. Data for 869 CE to 1905 CE were reconstructed by Meko et al. (2001b); data for 1906 CE to 2009 CE are observed records from the California DWR (2009).

No comments

- n/a -

Meko *et al.* (2001a) indicated that for their 1,100-year reconstructed period, the 1630-1977 data are more reliable than the earlier time period, because of better availability of tree-ring information and superior regression model statistics. Figure 2-2 shows the reconstructed time series of annual unimpaired Sacramento River flow from 1630 to 1977 from Meko *et al.* (2001b). The inset in Figure 2-2 shows there is a good match between the reconstructed flows (grey line) and the observed annual flows (red line) during the period of overlap between the reconstructed and observed records (from 1906 to 1977).

Multi-decadal periods of alternating wet and dry conditions are pervasive throughout the reconstructed record. The wet conditions of the late 1800's and early 1900's, which were followed by severe dry conditions in the 1920's and 1930's, are consistent both with observed precipitation and estimated Sacramento River runoff for these time periods (see Section 3) and with literature reports of historical conditions (see Section 4).



No comments

- n/a -

Figure 2-2 – Reconstructed annual unimpaired Sacramento River flow from 1630-1977.
Annual reconstructed unimpaired Sacramento River flow (grey line in main panel and inset) for the 1630 to 1977 time period was identified by Meko et al. (2001a) as the most accurate period of reconstruction. Inset panel illustrates the comparison between observed (red) and reconstructed (grey) unimpaired flows during the overlap period. The mean of the reconstructed unimpaired flow for 1630-1977 is 17.7 MAF/yr (dashed horizontal line in main panel). The 5-year centered running average (thick solid blue line in main panel) illustrates the decadal trends.

Meko *et al.* (2001a) identified the severe drought periods in the reconstructed Sacramento River flow record (1630-1977) by computing the lowest *n*-year moving average. For instance, to determine the most severe 6-year drought, Meko *et al.* calculated the moving average using a 6-year window for the entire data set and then identified the lowest 6-year average. Meko *et al.* found that the period from the early 1920's to late 1930's experienced the lowest 6-year, 10-year, 20-year, and 50-year averages (or droughts), both in the reconstructed and observed records. The observed droughts in Table 2-2 have been updated through present (1906-2009) using the same analysis; this update did not change the drought time periods identified by Meko *et al.* The reconstructed record of unimpaired Sacramento River flow shows the period from early 1920's to late 1930's experienced some of the worst drought conditions since 1630. Additional data are presented in Appendix B.

Table 2-2 – Periods of drought from the reconstructed and observed records of unimpaired Sacramento River flow
Severe drought periods in the reconstructed Sacramento River flow record (1630-1977) were determined by Meko et al. (2001a) by computing the lowest n-year moving average of the reconstructed annual unimpaired Sacramento River flow. The same method was used to determine the most severe droughts of the observed record (1906-2009).

	Period of lowest *n*-Year moving average Sacramento River flow					
	1-Year	3-Year	6-Year	10-Year	20-Year	50-Year
Reconstruction (1630-1977)	1924	1775 to 1778	1929 to 1934	1924 to 1933	1917 to 1936	1912 to 1961
Observations (1906-2009)	1977	1990 to 1992	1929 to 1934	1924 to 1933	1918 to 1937	1917 to 1966

Conclusions

Reconstruction of unimpaired Sacramento River flow indicates:

- Annual precipitation is highly variable. Even during long dry periods, individual years can be very wet.
- The Sacramento River basin experienced a multi-century dry period from about 1100 C.E. to 1400 C.E.
- The drought period in the 1920's and 1930's represents some of the worst drought conditions in the last 400 years.

No comments

- n/a -

2.3. Reconstructed Salinity in the Bay-Delta Estuary

Tree Ring Data

The interaction between saline ocean water from the Pacific Ocean and fresh water from the rivers flowing into the Delta determines the ambient salinity conditions in the Delta and the Bay. Estimates of historical precipitation derived from tree ring data can therefore be used to estimate the corresponding salinity conditions in the Delta.

Stahle *et al.* (2001) used tree ring chronologies from blue oak trees located in the drainage basin to San Francisco Bay to reconstruct salinity at the mouth of San Francisco Bay. Recognizing that a number of factors influence salinity other than precipitation (estimated from tree rings), the authors chose a time period prior to substantial water development when the salinity data were fairly constant in mean and variance. During the calibration period (1922-1952), annual tree ring growth correlates well with average salinity near the Golden Gate Bridge (r^2=0.81). Using this transfer function, Stahle *et al.* (2001) reconstructed annual average January to July salinity for all years 1604 to 1997.

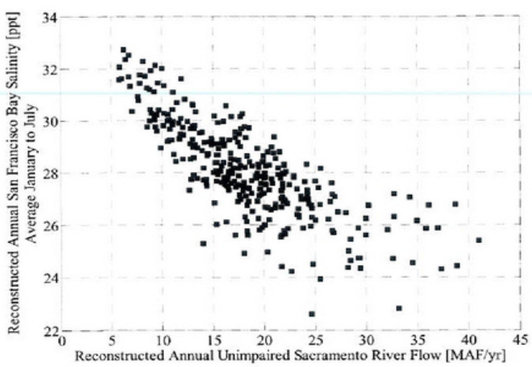


Figure 2-3 – Reconstructed salinity near the mouth of San Francisco Bay compares well with reconstructed unimpaired Sacramento River flow in the upper watershed
For each year from 1630 to 1952, the annual unimpaired Sacramento River flow (from Meko et al., 2001b) is plotted against the annual average salinity at Fort Point (from Stahle et al., 2001).

As shown in Figure 2-3, the salinity reconstruction by Stahle *et al.* (2001) compares well with the unimpaired flow reconstruction by Meko *et al.* (2001b). The data follow the expected inverse exponential relationship between flow and salinity. Over the period from

No comments

- n/a -

1630 to 1952, reconstructed salinity increases as reconstructed unimpaired Sacramento River flow decreases. The agreement is strongest in dry years. The increased scatter in wet years may reflect the limitations in the tree ring methods.

Stahle *et al.* (2001) identified an increasing divergence of observed salinity relative to predicted (reconstructed) salinity after 1952 (Figure 2-4) and suggested that the majority of differences are due to increased water diversions. During the calibration period (1922-1952), the observed salinity is typically within +/- 5% of the reconstructed salinity. However, from 1953-1994, the data show an increasing trend for observed salinity to be greater than predicted, exceeding reconstructed salinity by over 15% in 1978, 1979, 1991, and 1993. Since 1969, observed salinity has exceeded reconstructed salinity in all years except the extremely wet years of 1982 and 1983.

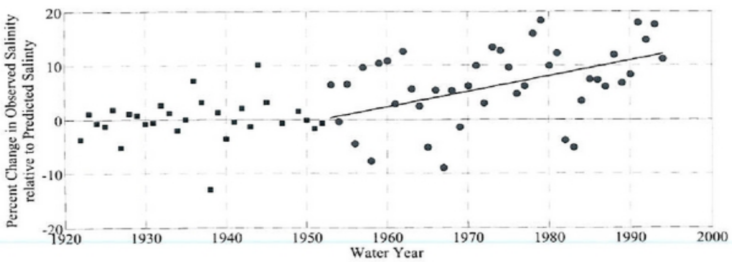


Figure 2-4 – Percent change in observed salinity relative to predicted (reconstructed) salinity for the period 1922 to 1994

The reconstructed salinity record by Stahle et al. (2001) overlaps with the observed salinity record from 1922 to 1994. During this period, the percent change of observed salinity relative to predicted salinity is determined as (observed salinity – reconstructed salinity) divided by reconstructed salinity, with positive values indicating when observed salinity exceeded the reconstructed salinity prediction. The calibration period is indicated with black squares, with the period outside the calibration window indicated by red circles. The straight red line is the linear trend in the post-calibration period, indicating observed salinity is increasingly diverging from predicted (reconstructed) salinity.

These data suggest that since the 1950's, water management operations have increased salinity, with an escalating effect over the period of record. In addition, it is worth noting that significant anthropogenic modifications to the landscape and water usage had already occurred prior to the 1922-1953 calibration period (see Figure 1-2 and Figure 1-3). Although this study is unable to evaluate the effect of anthropogenic modifications prior to 1953, the following section examines salinity prior to human interference at multiple sites in the Bay-Delta.

Tree ring reconstructions such as Meko *et al.* (2001a) and Stahle *et al.* (2001) have the advantage of providing high temporal resolution (i.e. annual) over approximately the last 1,000 years. However, a possible disadvantage of this method is the age of trees, limiting

No comments

- n/a -

high accuracy estimates to approximately the last 400 years. A second possible disadvantage of using tree ring reconstructions for paleosalinity is the remote location of the trees relative to the estuary. Paleosalinity estimates from tree rings in the upper basin necessarily assume that the precipitation patterns archived in the tree rings are representative of the quantity of water that reaches the estuary. However, as observed by Stahle *et al.*, anthropogenic water management affects the amount of water that flows through the estuary.

Sediment Core and Fossil Data

Because of uncertainties in estimates of precipitation and salinity derived from tree ring data, other paleosalinity methods that rely on local fossils to determine local salinity have also been explored. Organic deposits accumulated in the sediments contain signatures of the ambient conditions that can be used to infer the variations in salinity over geologic time scales. Although reconstructions from sediment cores have a coarser temporal resolution than tree rings, the variations in climate and landscape responses to change are better defined geographically because the evidence of localized climate change is preserved as a time series *in situ*, at the site of interest.

The San Francisco Bay-Delta has been the focus of several paleoclimatic reconstructions from sediment cores. Changes in wetland plant and algae communities are the dominant response in the Bay and Delta to climate change and associated fluctuations in temperature and precipitation. Proxies of plant and algae response to environmental conditions are preserved in the sediment cores and determined by:

- quantification and taxonomic identification of
    - (i) diatom frustules (Byrne *et al.*, 2001; Starratt, 2001; Starratt, 2004),
    - (ii) plant seeds and roots (Goman *et al.*, 2008),
    - (iii) plant pollen (May, 1999; Byrne *et al.*, 2001; Malamud-Roam and Ingram, 2004), and,
- measurement of peat carbon isotope ratios (Byrne *et al.*, 2001; Malamud-Roam and Ingram, 2004).

Results from plant pollen identification for three sites in the western Delta and Suisun Bay and Marsh are summarized below in Figure 2-5. The data indicate that Browns Island tidal marsh, near the confluence of the Sacramento and San Joaquin Rivers in the western Delta (Figure 2-5) was predominately a freshwater system for 2,500 years, even during century-long droughts. This condition prevailed until the early 1900's. The shading in Figure 2-5 corresponds to the nearly 300-year dry period identified in the reconstructions of annual unimpaired Sacramento River flow (Figure 2-1). Although salinity intrusion occurred during this period in Suisun Bay at Roe Island, and during earlier long drought periods, salinity did not affect the western Delta to the same degree. This suggests a change in spatial salinity gradient characteristics, and is possibly due to the effect on salinity intrusion of the vast tidal marshes that existed in the Delta until the early 20th Century.

No comments

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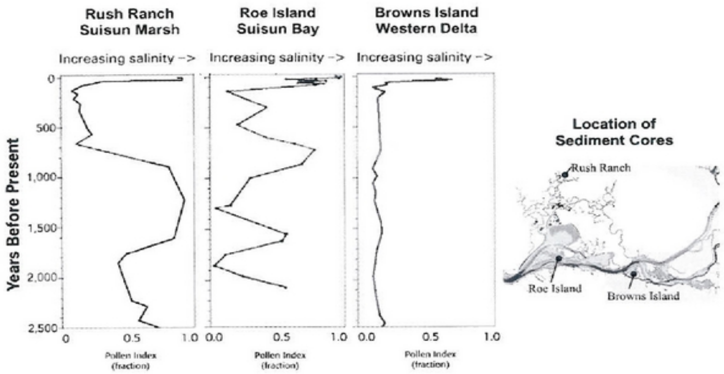

Figure 2-5 – Paleosalinity evidence derived from pollen data

Salinity variability over the last 2,500 years at Rush Ranch in Suisun Marsh (left panel), Roe Island in Suisun Bay (center panel), and Browns Island in the Western Delta (right panel). Data are reproduced from Malamud-Roam and Ingram (2004). Orange shading across each panel corresponds to the nearly 300-year dry period identified in the annual unimpaired Sacramento River flow reconstruction (see Section 2.2) Locations of each of the sediment cores are illustrated in the map on the right.

Malamud-Roam *et al.* (2006) attributed the differences between sites to a combination of methodological issues (such as sampling frequency and core chronology) and site-specific ecological differences (such as site elevation, location relative to channel and sedimentation rates over time). However, all of the paleosalinity reconstructions based on pollen, diatoms and carbon isotopes are in general agreement and suggest that salinity increased abruptly about 100 years ago, reaching or exceeding salinity levels at any other time in the 2,500 years of reconstructed records.

This increase in salinity may correspond to the reduction in unimpaired Sacramento River flow evidenced in the tree ring reconstructions by Meko *et al.* (2001a), which determined that the 1920's and 1930's experienced the worst droughts in the last 400 years. However, the droughts in the 1920's and 1930's do not appear to be as severe as the droughts between 1100 CE to 1400 CE (600 to 900 years ago), as categorized by unimpaired Sacramento River flow. Yet salinity in Suisun Bay and the western Delta appears to meet or exceed the level of the medieval droughts, indicating factors besides natural precipitation and runoff patterns have affected salinity in the last 100 years.

No comments

- n/a -

Conclusions

Reconstructions of salinity in the Bay and Delta indicate:

- Precipitation in the drainage basin for San Francisco Bay (as recorded in tree rings) is a good indicator of salinity near the mouth of the Bay for the period 1922-1953; however, since 1953, increased water diversions have increased observed salinity above the level predicted from precipitation estimates.
- The Delta was a predominately freshwater system for 2,500 years, until the early 1900's, even during century-long droughts.
- The multi-century dry period identified in unimpaired Sacramento River flow reconstruction is evident in Suisun Bay sediments but not in Delta sediments, indicating that salinity did not intrude as far into the Delta during past droughts as it has during the last 100 years.
- The evidence from most sites suggests that current salinity levels are as saline as, or more saline than, previous historical conditions.

No comments

- n/a -

3. Instrumental Observations of the Last 140 Years

Field measurements of rain and snow have far greater accuracy and resolution than the paleoclimate records of precipitation; similarly, field measurements of salinity have far greater accuracy and resolution than the paleosalinity records from sediment cores. These instrumental observations will be used to analyze in more detail the salinity increase identified in the paleoclimate records approximately 100 years ago and determine if the increase in salinity has persisted.

The first sub-section presents observations of precipitation and unimpaired runoff in the upper basin, indicating the natural climatic variability and amount of fresh water available within the Bay-Delta watershed. The second sub-section examines Net Delta Outflow (NDO), which is the amount of water flowing through the Delta into Suisun Bay, directly affecting the level of salinity intrusion into the Delta. NDO is analyzed under both unimpaired (without water diversions and reservoir storage and releases) and historical (actual) conditions; comparison between unimpaired and actual conditions reveals the effect of water management practices. The third sub-section presents field measurements and model-based estimates of salinity at various locations within the Delta and Suisun Bay.

3.1. Precipitation and Unimpaired Flow in the Upper Basin

Precipitation in the Bay-Delta watershed indicates the amount of water available within the system, which could ultimately reach the Bay and affect salinity conditions. However, since precipitation falls as both rain and snow, the timing of runoff to the river channels is often lagged a few months due to snow melt conditions. For this reason, estimates of unimpaired flow (runoff) are generally used to characterize hydrological variability. Unimpaired runoff represents the natural water production of a river basin, unaltered by water diversions, reservoir storage and operation, and export of water to or import of water from other basins.

Figure 3-1 illustrates the total annual precipitation at Quincy[7] in the northeastern Sierra, the total annual unimpaired Sacramento River flow[8] and total unimpaired San Joaquin River flow[9]. Figure 3-2 shows the locations of the eight precipitation stations in northern California used to compute the Sacramento eight-station precipitation index (left panel) and the measurement locations of eight flow gages used to calculate the Sacramento and San Joaquin unimpaired flow data (right panel). Additional information on the annual unimpaired flows is provided in Appendix C.

As discussed in Section 2.2, the total annual unimpaired Sacramento River flow exhibits strong variability between years, both in the reconstructed and observed data. Figure 3-1

[7] Precipitation data are from Menne *et al.* (2009)

[8] "Unimpaired Sacramento River flow" is defined as the sum of the "full natural flows" from the Sacramento River at Bend Bridge, Feather River inflow to Lake Oroville, Yuba River at Smartville, and the American River inflow to Folsom Lake. (http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST)

[9] "Unimpaired San Joaquin River flow" is defined as the sum of the full natural flows from the Stanislaus River inflow to New Melones Lake, Tuolumne River inflow to New Don Pedro Reservoir, Merced River inflow to Lake McClure, and San Joaquin River inflow to Millerton Lake (http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST)

No comments

- n/a -

indicates that the trends revealed in the total annual unimpaired Sacramento River flow (middle panel) are also evident in the total annual precipitation at Quincy (top panel) and the total annual unimpaired San Joaquin River flow (bottom panel). Alternating periods of wet and dry conditions are evident in both river basins. These data indicate there were wetter than normal conditions in the late 1800's and early 1900's, followed by severe dry conditions in the 1920's and 1930's. These were then followed by generally wetter conditions until the mid-1970's.

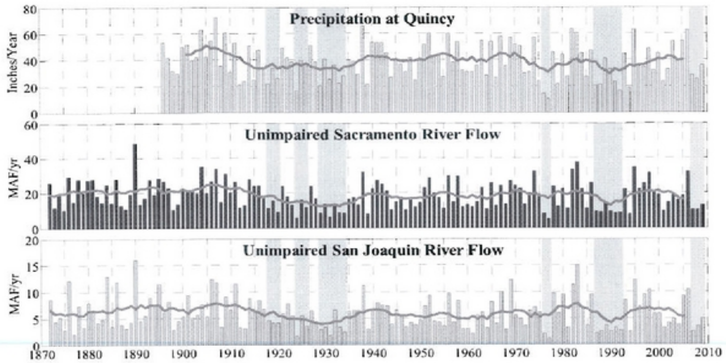

Figure 3-1 – Total annual precipitation and unimpaired flow in the upper Sacramento and San Joaquin River basins (1872-2009)

Total annual precipitation at Quincy in the northeastern Sierra (top panel), total annual unimpaired Sacramento River flow (middle panel), and total annual unimpaired San Joaquin River flow (bottom panel). Bar color on each panel indicates the regional location of the measurements, reflected in the remaining figures of this section (Figure 3-2, Figure 3-3 , and Figure 3-4). Grey line within each panel is the 10-year moving average for each parameter.

No comments

- n/a -

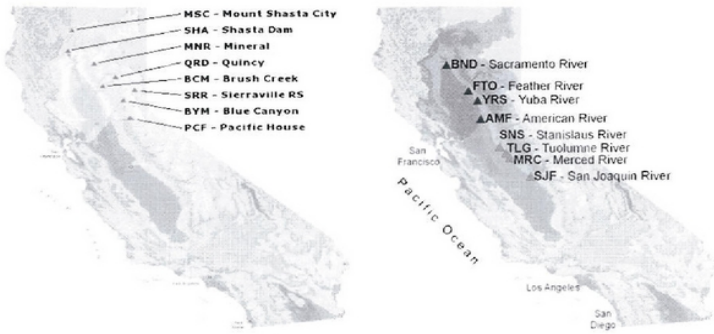

Figure 3-2 – Locations of Precipitation and Runoff Measurements

Location of stations used in the determination of the 8-station precipitation index for northern California (left map), including the location of Quincy (QRD), and the unimpaired Sacramento River flow (red stations, right map) and unimpaired San Joaquin River flow (orange stations, right map).

Knowles (2000) illustrated that the seasonal timing of runoff can significantly alter salinity intrusion without any change to the total annual runoff. For this reason, it is critical to examine the monthly variability in precipitation and unimpaired runoff. Monthly precipitation and unimpaired flow values are available for a shorter time period (generally 1921 to present) than the total annual values (generally 1870's to present).

The monthly distribution of the Sacramento eight-station precipitation index[10] indicates that most of the precipitation in northern California occurs during November through March (Figure 3-3). The variability between years, represented by the vertical bars and '+' marks, shows the distribution is positively skewed, i.e., excessively high precipitation occurs in relatively few years.

Figure 3-4 presents the monthly distribution of unimpaired flow for both the Sacramento and San Joaquin River basins. River flow lags precipitation by about two months because of storage of some precipitation in the form of snow and subsequent snowmelt in the spring. Most of the unimpaired inflow to the Delta originates from the Sacramento Basin, although the contributions from the two basins are approximately the same during the months of late-spring and early-summer snow melt, when unimpaired runoff from the San Joaquin Basin peaks.

[10] Data from 1921 through 2008, downloaded from http://cdec.water.ca.gov/cgi-progs/precip1/8STATIONHIST

No comments

- n/a -

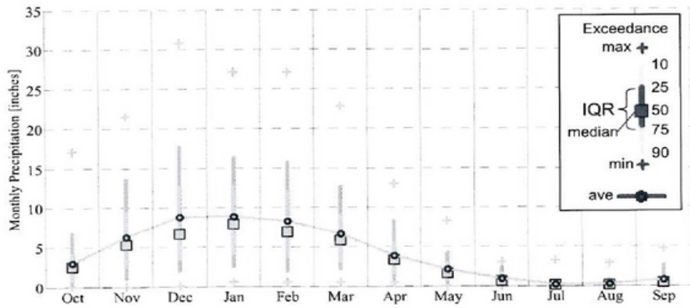

Figure 3-3 – Monthly Distribution of Precipitation in the Sacramento River Basin

Distribution of monthly precipitation for water years 1921 through 2008. Monthly averages are indicated by the blue line with black circles. Monthly median is given by the blue squares, while the interquartile range is indicated by the vertical blue line for each month and the vertical grey line extends to the 10th and 90th percentiles. Maximum and minimum values are indicated by '+' marks.

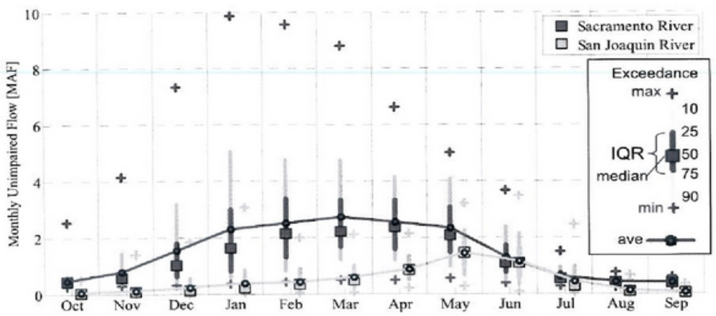

Figure 3-4 – Monthly distribution of unimpaired flow in the Sacramento and San Joaquin River basins

Distribution of monthly unimpaired flows for water years 1921 through 2008. Monthly averages are indicated by the lines with black circles. Monthly median is given by the squares, while the interquartile range is indicated by the vertical line for each month and the vertical grey line extends to the 10th and 90th percentiles. Maximum and minimum values are indicated by '+' marks.

No comments

- n/a -

Conclusions

The long-term observations of precipitation and unimpaired flow indicate:

- Relatively wet conditions occurred in the late 1880's to about 1917 in both the Sacramento and San Joaquin River watersheds prior to large-scale water management operations.
- Unusually dry conditions occurred from about 1918 through the late 1930's; these persistent dry conditions are not representative of the average conditions over the last 130 years.
- Precipitation in Sacramento River watershed peaks between December and March; the unimpaired river flow lags by about 1 to 2 months because of snow melt.

No comments

- n/a -

3.2. *Net Delta Outflow*

The quantity of water flowing from the Delta into Suisun Bay, defined as Net Delta Outflow (NDO), is the primary factor in determining salinity intrusion in Suisun Bay and the western Delta. Unimpaired NDO is calculated using unimpaired flow in the Sacramento and San Joaquin Rivers (Section 3.1) as well as contributions from other minor tributaries.[11] Unimpaired NDO is the hypothetical Delta outflow that would occur in the absence of any upstream diversion or storage, but with the existing Delta channel and upstream channel configuration.

Because the outflow from the Delta at the wide and deep entrance to Suisun Bay cannot be measured accurately, the parameter of historical (actual) NDO is estimated from a daily mass balance of the measured river inflows to the Delta, measurements of water diversions at major pumping plants in the Delta, and estimates of net within-Delta consumptive use (including Delta precipitation and evaporation).

The effect of anthropogenic water management on NDO is illustrated below by comparing monthly estimates of unimpaired NDO[12] and historical (actual) NDO[13] (Figure 3-5). Since unimpaired flow estimates also assume the existing Central Valley and Delta landscape (reclaimed islands, no natural upstream flood storage, current channel configuration, etc.), this comparison reveals the net effect of water management only. This analysis does not address the change due to physical modification to the landscape or sea level rise.

For the period of joint record, when both unimpaired and historical NDO values are available (water year 1930 through 2003), historical NDO decreased even though unimpaired NDO increased slightly. The long-term (74-year) linear trend in monthly unimpaired NDO (the black dashed line in top panel of Figure 3-5) increased on average 0.49 MAF/month; thus, by 2003, the average annual unimpaired NDO had increased 5.9 MAF/year since 1930. In contrast, the long-term linear trend in monthly historical NDO (the black dashed line in middle panel of Figure 3-5) decreased on average -0.29 MAF/month, totaling a decrease in historical (actual) NDO of -3.5 MAF/year. This corresponds to a net increase in diversion of 9.4 MAF/year of water from the Delta upstream watershed relative to the 1930 level[14].

Increased diversion and export of water have decreased historical NDO (middle panel of Figure 3-5), but this has been partially offset by a natural increase in unimpaired NDO (top panel). The difference between historical and unimpaired NDO (bottom panel) is due to the cumulative effects of upstream diversions, reservoir operations, in-Delta diversions, and

---

[11] Unimpaired NDO does not include water imported from the Trinity River system, which is outside the Delta watershed.

[12] Unimpaired NDO data was obtained from Ejeta (2009), which is an updated version of DWR (1987).

[13] Historical NDO data was obtained from the IEP's DAYFLOW program (http://www.iep.ca.gov/dayflow/index.html).

[14] This is consistent with current estimates of approximately 15 MAF/year total diversion from the system, which includes the 4-5 MAF/year diversions established prior to 1930 and approximately 1 MAF/year additional water supply imported from the Trinity River system.

No comments

- n/a -

south-of-Delta exports. During most months, water management practices have historically resulted in historical (actual) NDO that is less than unimpaired conditions, indicated by a negative value for the quantity (historical NDO – unimpaired NDO).

Because the difference between monthly historical and unimpaired NDO has become more negative over time, the periods of excess conditions (when historical NDO exceeds unimpaired NDO) have become very infrequent. The only occurrences are now following the wettest years, primarily due to releases from reservoirs in the fall to make room for winter flood control storage.

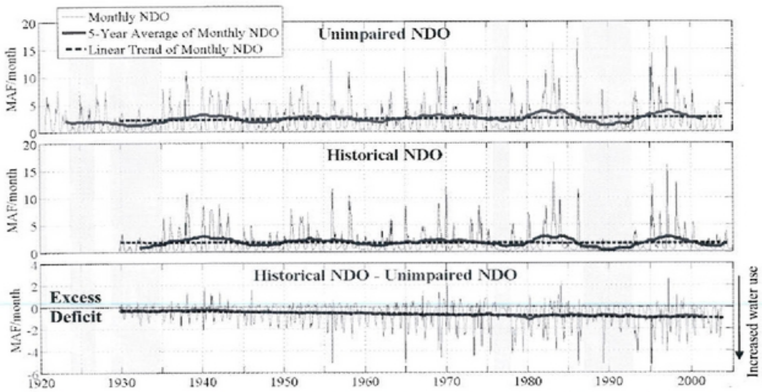

Figure 3-5 – Time series of Monthly Net Delta Outflow under unimpaired conditions and historical (actual) conditions

The thin color line on each panel indicates the monthly NDO, the thick color line indicates a running 5-year average of the monthly NDO, and the dashed black line indicates the linear long-term trend.

The monthly distribution (Figure 3-6) of unimpaired NDO and historical NDO for water years 1930 to 2003 reveals that for all months except September and October (when NDO is low), average unimpaired NDO is greater than average monthly historical NDO. The tendency in the average historical NDO toward greater flow in September and October is influenced strongly by the period prior to about 1975 when reservoir operations resulted in more flow in those months (see Figure 3-7 and related discussion below). On average from 1930-2003, water management practices reduced Delta outflows in the months of November through August (and in all months since about 1975, see Figure 3-7). The greatest reduction in Delta outflow relative to unimpaired conditions occurs in the months of March through June, when spring snow melt is captured in reservoirs and a portion of the river flow is diverted for direct use.

No comments

- n/a -

As also shown in Figure 3-6, water management practices also shift the peak flow periods to earlier in the year. The unimpaired NDO hydrograph peaks in May when snow melt contributes to high river flows, with at least 4.1 MAF in May in 50% of the years (averaging 4.2 MAF in May over all years). The historical NDO peaks in February with at least 2.9 MAF/month in 50% of the years (averaging 3.7 MAF/month over all years). The variability between years, represented by the vertical bars and '+' marks, indicates the distribution is positively skewed, which means a relatively few years have excessively high flows.

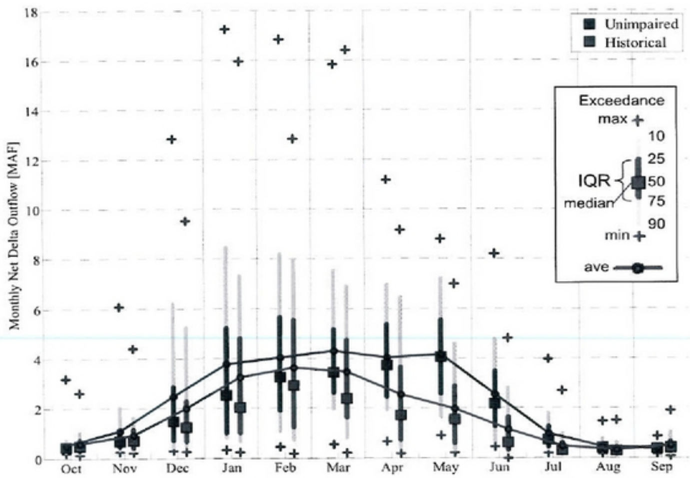

Figure 3-6 – Monthly distribution of Net Delta Outflow

Distribution of monthly NDO for water years 1930 through 2008. Monthly averages are indicated by the lines with black circles. Monthly median is given by the squares, while the interquartile range is indicated by the vertical line for each month and the vertical grey line extends to the 10th and 90th percentiles. Maximum and minimum values are indicated by '+' marks.

Figure 3-7 shows the long-term trends in the difference between historical (actual) monthly NDO and unimpaired monthly NDO. Increased water usage and increased diversion of water to storage has reduced historical NDO relative to unimpaired NDO in most months of the year. In July (and August, not shown in Figure 3-7), the deficit is reduced, likely due to reservoir releases which provide a portion of the water diverted by upstream users prior to reservoir construction. The 1994 Bay-Delta Accord called for higher minimum Delta outflows in July and August to protect Delta fish species, which should also serve to reduce the deficit. However, historical (actual) NDO still remains less than unimpaired NDO.

No comments

- n/a -

In September (and October, not shown in Figure 3-7), historical (actual) NDO exceeded unimpaired NDO from about 1945 to 1975, with an increasing trend in the percent change. Since 1975, the percent change has shown a downward trend with a deficit (historical NDO less than unimpaired NDO) during most years since 1975.

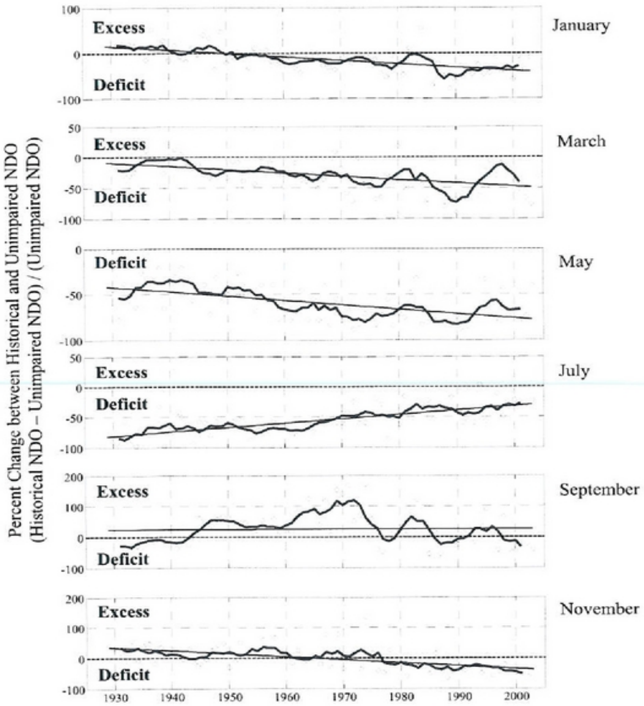

Figure 3-7 – Long-term trends in monthly NDO

Percent change of NDO relative to unimpaired conditions. Circles indicate the percent change for each month of the period of record. The red line indicates a moving 5-year average of the percent change, while the black line indicates the long-term linear trend over the entire period of record.

No comments

- n/a -

Conclusions

Anthropogenic water management practices have altered NDO in the following ways:

- Long-term data demonstrate that the difference between historical (actual) NDO and unimpaired NDO is increasing over time, indicating that water management actions have reduced Delta outflow significantly.
- During most months, water management practices have reduced Delta outflow relative to unimpaired conditions. From the mid-1940's to the mid-1980's, reservoir operations resulted in historical (actual) NDO slightly greater than unimpaired NDO slightly in a number of months, largely in the fall. However, since 1985, reservoir operations have resulted in increased NDO only in the wettest years, and NDO has declined in all other months.
- On average, water management practices have resulted in reduced Delta outflows in all months except September and October. The greatest reduction in Delta outflow relative to unimpaired conditions occurs in the months of March through June, when spring snow melt is captured in reservoirs and some of the remaining river flows are diverted for direct use.

No comments

- n/a -

3.3. *Salinity in the Western Delta and Suisun Bay*

Observations and model-based estimates can be used to examine historical variations in salinity in the western Delta and Suisun Bay. The observations examined in this section include records from the early 1900's from the California & Hawaiian Sugar Refining Corporation in Crockett (C&H) and long-term monitoring data published online by the Interagency Ecological Program (IEP). Estimates of salinity intrusion were obtained using the Kimmerer-Monismith equation describing X2 (Kimmerer and Monismith, 1992).

Section 3.3.1 addresses the importance of consistency among salinity comparisons. The spatial variability of a specific salinity level is examined in Section 3.3.2 and Section 3.3.3, while the temporal variability of salinity at specific fixed locations is explored in Section 3.3.4 and Section 3.3.5.

3.3.1. *Importance of Consistency among Salinity Comparisons*

Water salinity in this report is specified either as electrical conductivity (EC) or as a concentration of chloride in water. EC is a measure of the ability of an aqueous solution to carry an electric current and is expressed in units of microSiemens per centimeter (µS/cm)[15]. Chloride concentration is specified in units of milligrams of chloride per liter of water (mg/L). Conversion between EC and chloride concentration can be accomplished using site-specific empirical relationships such as those developed by Kamyar Guivetchi (DWR, 1986).

Previous studies have evaluated the level of salinity in the Bay and Delta, using a variety of salinity units (e.g. EC, chloride concentration, or concentration of total dissolved solids in water) and various salinity parameters (e.g. annual maximum location 1,000 µS/cm EC, monthly average location of 50 mg/L chloride, or daily average EC at a specific location). Therefore, when comparing studies, it is critical to use consistent salinity units, parameters, and timing, including the phase of tide and time of year. These concepts are discussed further in Appendix D.

3.3.2. *Distance to Fresh Water from Crockett*

The California & Hawaiian Sugar Refining Corporation (C&H) is located in Crockett, near the western boundary of Suisun Bay (see Figure 3-8). C&H either obtained its freshwater supply in Crockett, or, when fresh water was not available at Crockett, from barges that traveled upstream on the Sacramento and San Joaquin Rivers. The barges generally travelled upstream twice a day beginning in 1908 (DPW, 1931). C&H recorded both the distance traveled by its barges to reach fresh water and the quality of the water they obtained. This provides the most detailed quantitative salinity record available prior to the initiation of salinity monitoring by the State of California in 1920. The distance traveled by the C&H barges serves as a surrogate for the prevailing salinity conditions in the western Delta and

[15] The reported EC values are actually specific conductance, i.e., the electrical conductivity of the water solution at a reference temperature of 25° centigrade, as is standard practice.

No comments

- n/a -

Suisun Bay. Operations by C&H required water with less than 50 mg/L chloride concentration.[16] Additional detail on C&H operations and the detailed barge travel data are included in Appendix D.

Figure 3-8 – Map of Suisun Bay and Western Delta with locations of continuous monitoring stations

C&H barges traveled up estuary from Crockett (yellow star). Locations of IEP continuous monitoring stations are shown in red. Scale in miles is indicated in the upper left corner of the map.

[16] In comparison, the 50 mg/L concentration required for C&H operations is one-third the concentration of the industrial water quality standard under current conditions in the Delta.

No comments

- n/a -

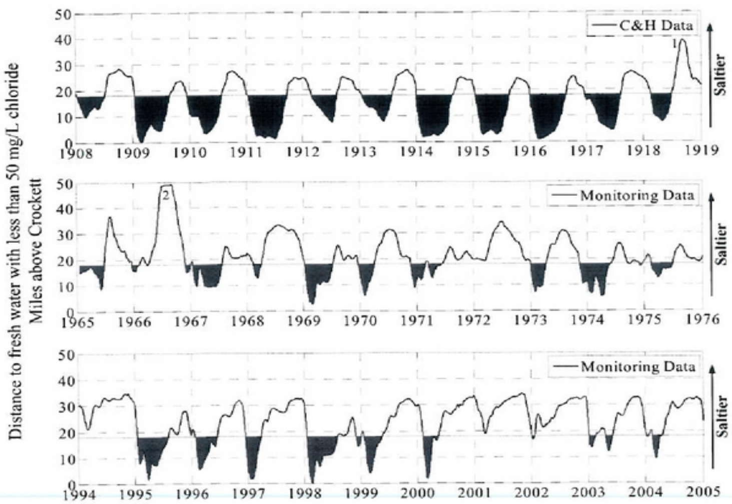

Figure 3-9 – Distance to fresh water from Crockett

"Distance to fresh water" is defined as the distance in miles upstream of Crockett to water with less than 50 mg/L chloride concentration. The horizontal line, at approximately 18 miles, is the distance from Crockett to the Delta. The shading represents the spatial extent and duration of the presence of fresh water within Suisun Bay, downstream of the Delta.

Data notes: (1) During August and September 1918, average water quality obtained by C&H exceeded 110 mg/L chlorides; (2) Salinity during 1966 is likely an overestimate due to relatively sparse spatial coverage of IEP monitoring stations. During 1966, salinity at Emmaton (28 miles from Crockett) exceeded 3,000 μS/cm; the nearest station upstream of Emmaton is near Courtland (58 miles from Crockett) and had a salinity of ~ 300 μS/cm. Location of 350 μS/cm isohaline based on data interpolation between these two stations (which are 30 miles apart) is not likely to be representative of the true location.

Figure 3-9 compares surface[17] salinity data from C&H with estimates derived from a network of continuous surface salinity monitoring stations (Figure 3-8) within Suisun Bay and the western Delta dating back to 1964. The monitoring data are published online by the Interagency Ecological Program (IEP, see http://iep.water.ca.gov/dss). The location of the 350 μS/cm EC isohaline, which approximately coincides with the C&H criterion of 50 mg/L chloride concentration, was estimated from the IEP measurements by linear interpolation between the average daily values at IEP monitoring stations.

[17] Due to the method of collection, C&H water samples are assumed to be from near the water surface.

No comments

- n/a -

As a cautionary note, depending on the source of information, the C&H barges are said to have traveled with the tide, indicating they either took water at high tide (moving up river on the flood and down on the ebb) or at low tide (traveling against the tide, but moving a shorter distance). Thus, the C&H records either represent the daily maximum or daily minimum distance traveled. In contrast, the distances to fresh water calculated from recent monitoring data are based on the average daily values of EC measured at fixed locations. The difference between daily average distance and daily minimum or maximum is approximately 2 to 3 miles. However, since the difference between the data from the early 1900's and the more recent time periods exceed this 2 to 3 mile uncertainty, the conclusions of this section remain unchanged regardless of the specific barge travel timing.

From 1908 through 1918, C&H was able to collect fresh water for a large portion of the year within Suisun Bay, without having to travel all the way from Crockett to the Delta. However, as can be seen in Figure 3-9, that would no longer be possible in many years (e.g., 2001-2004).

Figure 3-10 shows the monthly distribution of distance traveled by C&H barges during water years 1908 through 1917, and the equivalent distance from determined from observed data for water years 1966 through 1975 (top panel) and water years 1995 through 2004 (bottom panel). These two latter periods have similar hydrologic characteristics to the period of the C&H data.[18] The monthly distribution for each dataset illustrates the seasonal fluctuations of the salt field as well as the variability between years for each month.

During the early 1900's, the median distance traveled by C&H barges to procure fresh water was less than 8 miles in the spring (March-June) and about 25 miles (between Collinsville and Emmaton) in the fall (September-October). In contrast, due to water management conditions from 1995 to 2005, the equivalent distances would be 13 to 23 miles in the spring and up to 30 miles in the fall. It is worth noting that from 1966 to 1977, the distance to fresh water in the fall and early winter months (September through January) was generally less than the equivalent distance in the early 1900's, indicating that large-scale water management operations circa 1970 tended to reduce salinity in the fall and early winter. However, this trend has reversed in the more recent water management period (1995-2005), with salinity intrusion significantly increased over levels in the early 1900's during all months.

Figure 3-10 also shows that the range of the average annual distance from Crockett to fresh water from 1995 to 2005 was approximately 15 miles (from about 13 to 30 miles), while the range during the early 1900's was approximately 20 miles (from 6 to 25 miles). This analysis indicates that large-scale water management activities limit the fluctuating nature of the salt field by preventing fresh water from reaching as far downstream as it did in the early 1900's.

Finally, Figure 3-10 indicates that salinity intrusion in the Delta occurred later in the year (beginning in July) in the early 1900's than under more recent time period conditions (beginning in March).

[18] This similarity in hydrological characteristics between the periods was established by approximately matching the distribution of annual Sacramento River flow during these periods (see Appendix E).

No comments

- n/a -

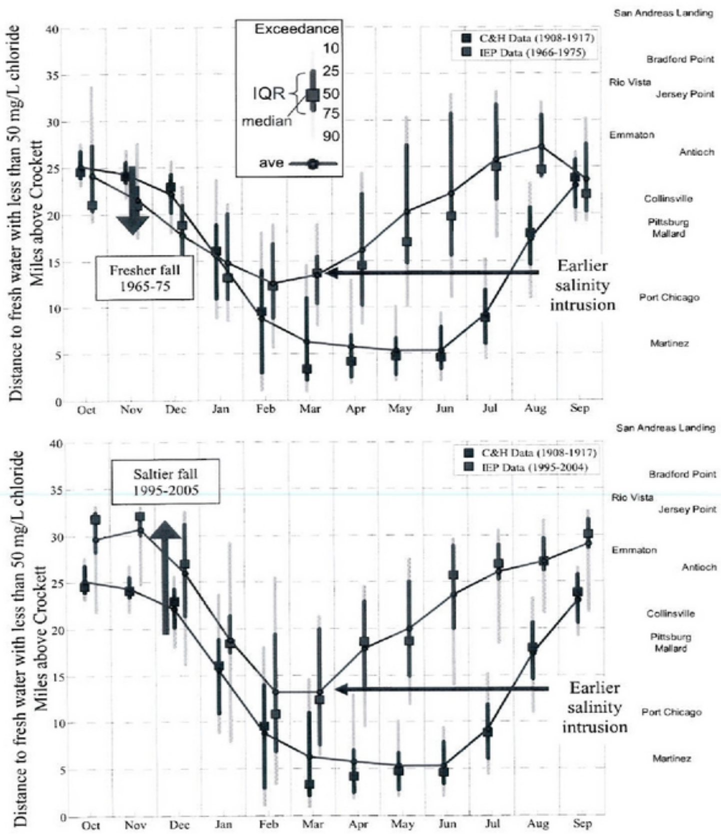

Figure 3-10 – Monthly distribution of distance to fresh water from Crockett

No comments

- n/a -

These comparisons (and other relevant comparisons in Appendix D) show that, on average, C&H barges would have had to travel up to 19 miles farther to procure fresh water under recent large-scale water management conditions than in the early 1900's. These comparisons also indicate that fresh water was present for significantly longer time periods, and over a larger area of the western Delta, in the early 1900's than during similar hydrological periods under current water management conditions. Abrupt changes in salinity just prior to 1920 caused C&H to abandon the Sacramento and San Joaquin Rivers and switch to a water supply contract with Marin County beginning in 1920 (Appendix D).

The distance to fresh water during individual wet years and during individual dry years is presented in Appendix D. The data in Appendix D also show that salinity has been generally higher in recent times than in the early 1900's and that water management has restricted the range in salinity experienced during a water year. The periods when fresh water is present at given locations have been reduced, or, in some cases, eliminated.

Conclusions

The records of the distance traveled upstream from Crockett by C&H barges to procure fresh water and estimates of this distance under large-scale water management conditions (reservoir operations and water diversions) show that:

- Fresh water was present farther downstream and persisted for longer periods of time in the western Delta in the early 1900's than under recent time periods with similar hydrologic conditions;
- Water management practices result in greater salinity intrusion in the western Delta for most months of the year; and,
- Salinity intrusion begins earlier in the year, extends farther upstream, and persists for a longer period each year.

No comments

- n/a -

3.3.3. X2 Variability

An often-used indicator of fresh water availability and fish habitat conditions in the Delta is a metric called X2. X2 is defined as the distance from the Golden Gate to the 2 part-per-thousand isohaline (equivalent to a salinity of 2 grams of salt per kilogram of water), measured near the channel bed along the axis of the San Francisco Estuary. Higher values of X2 indicate greater salinity intrusion. Monthly values of X2 are estimated in this report using the monthly regression equation from Kimmerer and Monismith (1992):

$$\text{Monthly} \quad X2(t) = 122.2 + 0.3278*X2(t-1) - 17.65*\log_{10}(NDO(t))$$

The K-M equation expresses X2 (in units of kilometers) in terms of Net Delta Outflow (NDO, see Section 3.2) during the current month and the X2 value from the previous month. The monthly K-M equation was based on a statistical regression of X2 values (interpolated from EC measurements at fixed locations) and estimates of NDO from IEP's DAYFLOW computer program. Hence, the K-M equation is only valid for the existing Delta channel configuration and existing sea level conditions.

The K-M equation can be used to transform unimpaired and historical NDO data into the corresponding X2 values for unimpaired (without reservoir operations or water diversions) and historical (with historical water management) conditions, respectively.

The seasonal and annual variations of X2 are dependent on the corresponding variations of NDO under both historical and unimpaired flow conditions (Figure 3-11). X2 under historical flow conditions is shifted landward relative to unimpaired conditions by approximately 5 km. During the 1930's, historical NDO was often negative, sometimes averaging approximately -3,000 cfs for several months. This was due to relatively low runoff and significant upstream water diversions. Unfortunately, the K-M equation, which includes the logarithm (base 10) of NDO, is unable to account for negative values of NDO. In the case of historical flow conditions, this results in high variability of X2 in the 1930's. The values of X2 under historical flow conditions during 1930's in Figure 3-11 are likely underestimated.

Figure 3-12 compares X2 under unimpaired and historical conditions for the period from 1945-2003, following initiation of the Central Valley Project (i.e., after the completion of the Shasta Reservoir of the CVP). Figure 3-12 shows that, compared to unimpaired conditions, X2 under historical conditions was higher by about 10 km during April-July and by about 5 km during the rest of the year.

Salinity intrusion under historical water management conditions is, therefore, greater (higher X2) than the intrusion that would occur under unimpaired conditions. Moreover, the switch from declining X2 values during fall and winter months to increasing X2 values (increasing salinity intrusion) occurs in March under historical water management conditions and in June under unimpaired conditions. Thus, recent water management practices have resulted in a saltier Delta with earlier occurrence of salinity intrusion in the year.

No comments

- n/a -

Although current water management practices operate to provide salinity control, both the extent and duration of salinity intrusion are greater under current water management practices than under historical conditions. Likewise, current water management practices have changed the overall annual range in salinity (i.e., the difference between the highest and lowest salinity values during the year).

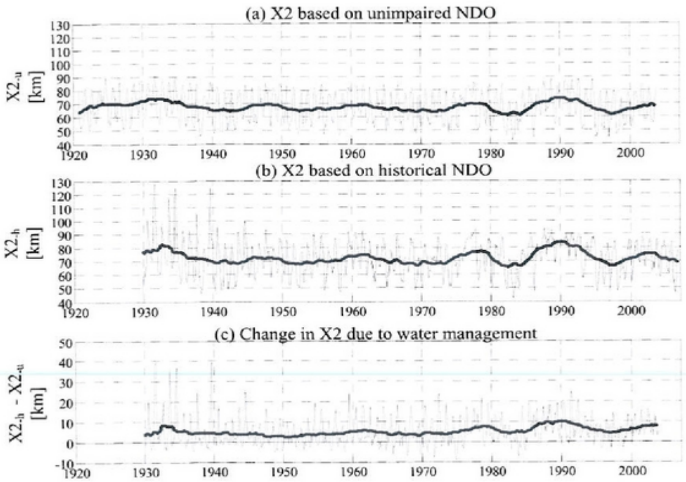

Figure 3-11 – **Location of X2 under unimpaired and historical conditions**
X2 has a strong seasonal and decadal variability under both unimpaired (top panel) and historical (middle panel) flow conditions reflecting the strong seasonal and decadal variability of NDO. The difference between historical and unimpaired conditions (bottom panel) illustrates the net effect of water management activities.

No comments

- n/a -

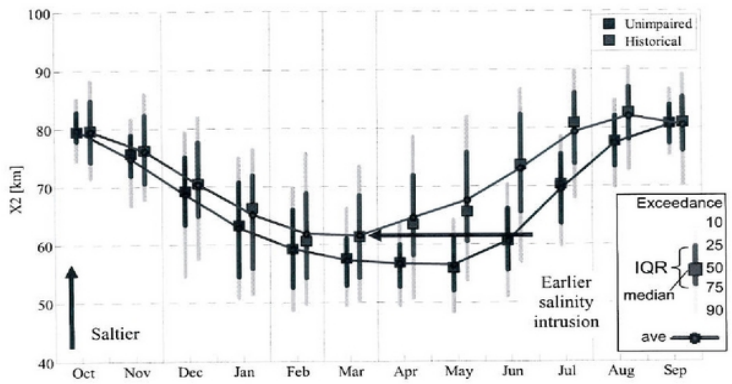

Figure 3-12 – Monthly distribution of X2 from 1945 through 2003

Figure 3-13 presents a comparison of unimpaired X2 and historical X2 during the 10 driest and the 10 wettest years of the CVP period (1945-2006).[19] During dry years (top panel), X2 is substantially greater under historical water management conditions than under unimpaired conditions (i.e., without water management); these effects are less dramatic but still occur during the wet years (bottom panel). Additionally, the annual range in salinity variability is significantly reduced under dry conditions (from approximately 22 km with unimpaired flows to 14 km with historical flows), but not wet conditions. The result of water management practices is a saltier Delta during both wet and dry years, with the greatest amount of salinity intrusion and reduced seasonal variability occurring in dry years.

Conclusions

The analysis of X2 (a measure of salinity intrusion in the Delta) shows that:

- Water management practices (reservoir operations and water diversions) result in a saltier Delta, with earlier salinity intrusion in the year.
- Water management practices result in a saltier Delta during both wet and dry years, but the effect is more pronounced in the dry years when the seasonal variability of salinity is also significantly reduced.

[19] Determination of the ten wettest and driest years is based on the total annual unimpaired Net Delta Outflow. The ten wettest years are 1952, 1956, 1958, 1969, 1974, 1982, 1983, 1986, 1995, and 1998. The ten driest years are 1947, 1976, 1977, 1987, 1988, 1990, 1991, 1992, 1994, and 2001.

No comments

- n/a -

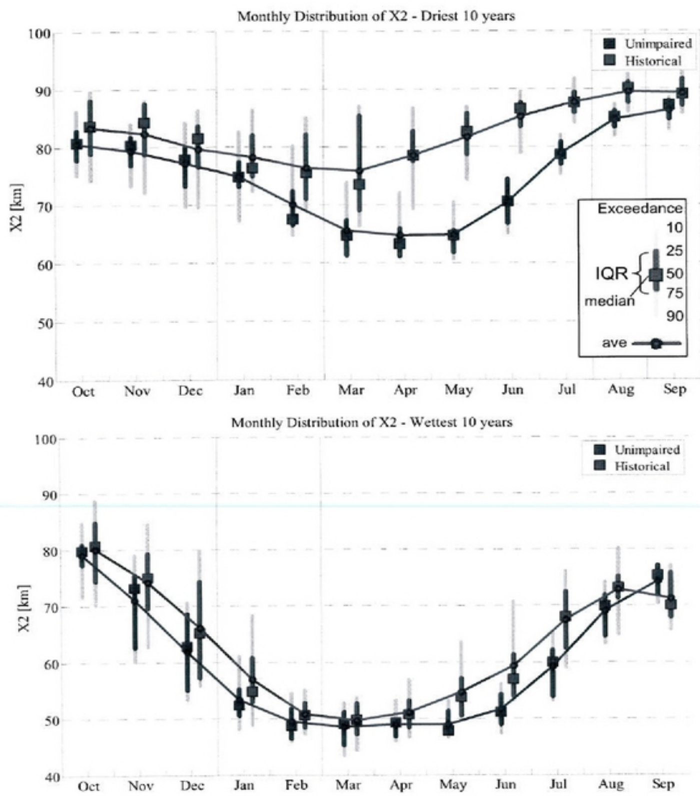

Figure 3-13 – Monthly X2 variability during wet and dry years (1945-2003)

Determination of the ten wettest and driest years is based on the total annual unimpaired Net Delta Outflow. The ten wettest years are 1952, 1956, 1958, 1969, 1974, 1982, 1983, 1986, 1995, and 1998. The ten driest years are 1947, 1976, 1977, 1987, 1988, 1990, 1991, 1992, 1994, and 2001.

No comments

- n/a -

No comments

- n/a -

3.3.4. Salinity at Collinsville

Collinsville, near the confluence of the Sacramento and San Joaquin Rivers, was one of the first long-term sampling locations implemented by the State of California. The Suisun Marsh Branch[20] of the DWR estimated monthly average salinity at Collinsville for the period 1920-2002, using a combination of 4-day TDS (total dissolved solids) grab samples from 1920-1971 and EC measurements from 1966-2002. Data from the overlap period of 5 years between the TDS grab samples and EC measurements were used in a statistical regression model, and the monthly averaged 4-day TDS samples were converted to monthly average EC (Enright, 2004). The result of this regression analysis was a time series of monthly EC values at Collinsville for the period of 1920-2002.

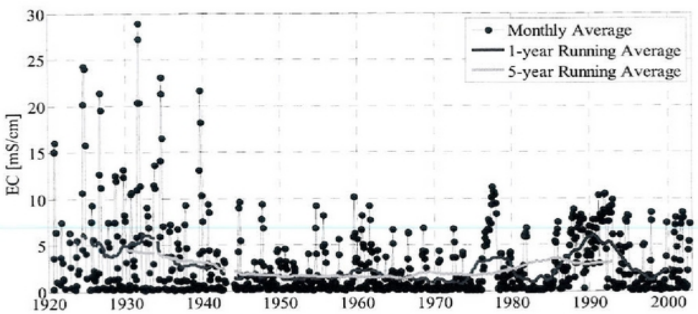

Figure 3-14 – Observed salinity at Collinsville

Monthly average salinity at Collinsville (black dots and black line), with the 12-month running average (red line) and 5-year running average (blue line).

Figure 3-14 shows the monthly average salinity at Collinsville for the period of 1920-2002, and Figure 3-15 shows the long-term trends in monthly salinity at Collinsville. Although the maximum values of salinity in the 1920's and 1930's far exceed subsequent salinity measurements at Collinsville, during the winters and springs of the 1920's and 1930's, the water at Collinsville freshened considerably. During the dry periods of 1920's and 1930's, monthly average salinity was below 350 μS/cm EC (approximately 50 mg/L chloride) for at least one month in every year. The one exception is 1924 which is inconclusive because no data were available from November through March. Monthly average EC data are missing for a portion of the winters and springs prior to 1926, and data for 1943 are missing entirely.

[20] Data provided by Chris Enright (DWR), personal communication, 2007.

No comments

- n/a -

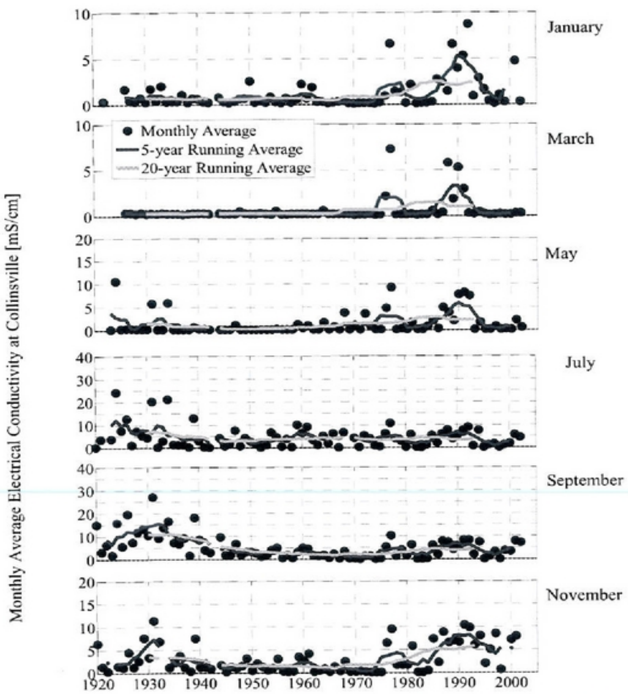

Figure 3-15 – Year-to-year trends in monthly-average salinity at Collinsville, 1920-2002
Monthly average salinity at Collinsville (black dots), with the 12-month running average (red line) and 5-year running average (blue line) for individual months.

Relatively fresh winters and springs during the 1920's are consistent with observations by C&H during that time period. However, monthly EC at Collinsville during the recent droughts (1976-1977 and 1987-1993) was always greater than 350 μS/cm EC, except for one month in both 1989 and 1992. These monthly observations of EC at Collinsville indicate that during the recent dry periods (1976-1977 and 1987-1993), EC at Collinsville was higher than that during similar dry periods in the 1920's and 1930's.

Enright and Culberson (2009) analyzed the trend in salinity variability at Collinsville from 1920-2006. They found increasing salinity variability in eleven of twelve months and

No comments

- n/a -

attributed it to water operations. In seven months (January-May, September-October) the increasing trend was significant ($p<0.05$).

Even in the six-year drought from 1928 to 1934, the Delta still freshened every winter (Figure 3-16). However, as shown in Figure 3-16, the Delta has not freshened during more recent droughts (1976-1977, 1987-1994, and 2007-2009). This indicates that the historical "flushing" of the Delta with fresh water is no longer occurring. This lack of flushing can also allow waste from urban and agricultural developments upstream of and within the Delta to accumulate. Contaminants and toxics have been identified as factors in the decline of the Delta ecosystem (Baxter *et al.* 2007). The data indicate the effect of managing to the X2 standard (implemented in 1995), as the salinity levels attained in the most recent drought are not as high as the 1976-77 and 1987-1992 droughts.

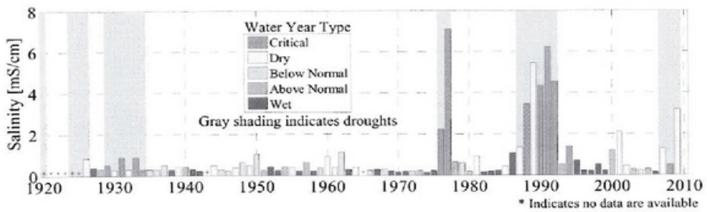

Figure 3-16 – Average Winter salinity at Collinsville

Annual average salinity during the winter (January through March) for water years 1927 to 2009. Bars are colored by water year type as defined by the Sacramento 40-30-30 index. Grey shading indicates multi-year droughts that include at least one critical water year.

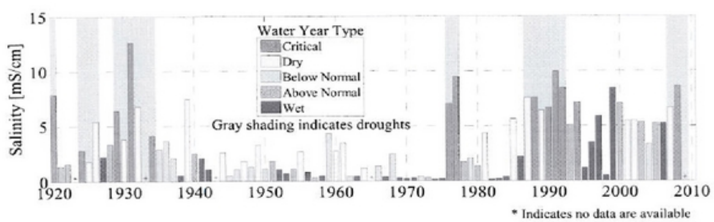

Figure 3-17 – Average Fall salinity at Collinsville

Annual average salinity during the fall months (October through December) for water years 1920 to 2009. Bars are colored by water year type as defined by the Sacramento 40-30-30 index. Grey shading indicates multi-year droughts that include at least one critical water year.

No comments

- n/a -

Figure 3-17 presents the variation in average fall salinity at Collinsville from 1920 to 2008 (October-December). Fall salinity is now high almost every year, while in the past, fall salinity was only high in dry and critical years. High salinity in the fall has been identified as a factor in the decline of the Delta ecosystem. Baxter *et al.* (2008) noted that "fall salinity has been relatively high during the POD years, with X2 positioned further [sic] upstream, despite moderate to high outflow conditions during the previous winter and spring of most years."

Conclusions

- In the 1920's and 1930's, the Delta freshened annually, even during droughts. In recent droughts, the Delta does not always freshen during the winter.
- Prior to 1976, fall salinity was high only in relatively dry years. Recently, fall salinity is high almost every year.

3.3.5. Salinity at Mallard Slough

A 1967 agreement between the Contra Costa Water District (CCWD) and the State of California requires the State to reimburse CCWD for the decrease in availability of usable river water, defined as water with less than 100 mg/L chlorides, at the Mallard Slough intake (CCWD, 1967). The 1967 agreement, and similar agreements between the State and other Delta water users, recognized the State Water Project (SWP) would increase salinity at Mallard Slough. The agreement defined a baseline of 142 days of usable water per year, based on the average number of days of usable water at the Mallard Slough intake from 1926-1967. Since 1967, the average number of days of usable water[21] (for the period 1967-2005) has declined to 122, indicating a 20-day (14%) reduction in the number of days of high quality water at Mallard Slough since the completion of the SWP.

[21] The data are from the USBR-CVO record of EC at Pittsburg, approximately 2 km upstream of Mallard Slough from 1967-2005. Since this station is located upstream of Mallard Slough, the number of days of usable water at Mallard Slough since the SWP was built may be overestimated.

No comments

- n/a -

4. Qualitative Observations of Historical Freshwater Flow and Salinity Conditions

In this section, qualitative observations of salinity conditions in the western Delta and Suisun Bay from the lawsuit filed by the Town of Antioch in 1920 and from various literature reports are discussed to provide a perspective of the salinity conditions prevailing in the late 1800's and early 1900's. Qualitative observations from early explorers and settlers are discussed in Appendix E.

4.1. Town of Antioch Injunction on Upstream Diverters

In 1920, the Town of Antioch filed a lawsuit (hereinafter referred to as the "Antioch Case") against upstream irrigation districts, alleging that upstream water diversions were causing increased salinity intrusion at Antioch. An overview of the Antioch Case is provided in Appendix E. The court decision, legal briefings, and petitions provide qualitative salinity observations from a number of witnesses. Although testimony in the Antioch Case is generally anecdotal, not quantitative, it provides a perspective of the salinity conditions prevailing in the early 1900's. Because the proceedings were adversarial in nature, this report focuses on the testimony of the upstream interests, who were trying to demonstrate that salinity intrusion was common near Antioch prior to their diverting water (prior to 1920). Consequently, the testimony may be biased in support of this "more saline" argument.

The upstream interests in the Antioch Case provided information on the operation of pumping plants along the San Joaquin River at Antioch for domestic water supply and the quality of water obtained from the pumping plants, summarized in Table 4-1.

Table 4-1 – Testimony regarding pumping plant operations and water quality in the 1920 Antioch Case

Time period of observation	Relevant information from the testimony
1866-1878	Mr. Dodge ran a pumping/delivery operation at Antioch ▪ Dodge pumped water into a small earthen reservoir at Antioch and then hauled the water to residents in a wagon. ▪ Cary Howard testified that while he was living in Antioch (1867-1876), the water became brackish one or two years in the fall, when they had to drive into the country to get water. This likely occurred during the drought of 1870-71.
1878-1880	Mr. Dahnken bought and operated the Dodge operation ▪ Dahnken testified that the water became brackish at high tide every year in the late summer, and remained brackish at high tide until it rained "in the mountains."

No comments

- n/a -

Time period of observation	Relevant information from the testimony
1880-1903	Belshaw Company provided water ▪ Dahnken testified that Belshaw Company pumped only at low tide.
1903-1920	Municipal Plant ▪ William E. Meek (resident since 1910) testified the water is brackish at high tide every year, for some months in the year. ▪ James P. Taylor testified that for at least the last 5 years, insufficient storage required the plant to pump nearly 24 hours per day, regardless of tidal phase. ▪ Dr. J. W. DeWitt testified that during October of most years between 1897 and 1918, the water was too brackish to drink. Even when the city only pumped at low tide, the water was occasionally so brackish that it would be harmful to irrigate the lawns.

This testimony suggests that, in the late 1800's, water at Antioch was known to be brackish at high tide during certain time periods, but Antioch was apparently able to pump fresh water at low tide year-round. A possible exception was the fall season during a few dry years. Water at Antioch was apparently fresh at low tide until at least around 1915. At that time, due to increased demand and inadequate storage, the pumping plants started pumping continuously, regardless of tidal stage. The window of time each year when Antioch is able to pump fresh water from the river has been substantially reduced in the last 125 years.

As shown in Appendix A, DWR (1960) estimated that water with a chloride concentration of 350 mg/L or less would be available about 85% of the time if there were no water management effects. DWR (1960) estimated that chloride concentrations at Antioch would be less than 350 mg/L about 80% of the time in 1900 and about 60% of the time by 1940. DWR also projected further deterioration of water quality by 1960 and beyond but did not include the effects of reservoir releases for salinity control.

Observations of salinity at Antioch during recent years indicate that salinity is strongly dependent on ocean tides, and the diurnal range in salinity can be as much as the seasonal and annual ranges in salinity. This is discussed in more detail in Appendices D and E. For instance, salinity at high tide can be more than five times the salinity at low tide (Figures D-1, D-2, and D-3), and the salinity during the course of a single day may vary up to 6,000 μS/cm EC (Figure D-1). Average daily salinity at low tide during the period of 1983-2002 exceeded 1,000 μS/cm[22] EC for about four and a half months of the year (Figure D-3). During the driest 5 years between 1983 and 2002, salinity at low tide was always greater than 1,000 μS/cm EC (i.e., no fresh water was available at any time of day) for about eight months of the year. Fresh water is currently available at Antioch far less frequently than prior to the 1920's.

[22] The current water quality criterion for municipal and industrial use is 250 mg/L, equivalent to about 1,000 μS/cm EC.

No comments

- n/a -

Available data and observations indicate that, prior to about 1918, fresh water was available at least at low tide during almost the entire year, in all but a few dry years. Around 1918, an abrupt change to higher salinity occurred. Although a prolonged and severe drought also began about this time, salinity conditions at Antioch did not return to pre-drought levels when the drought ended, indicating that water management activities (increased upstream diversions and later storage of water in upstream reservoirs) were the primary causes of this increased salinity.

4.2. Reports on Historical Freshwater Extent

Several literature reports discuss the spatial extent and duration of salinity conditions in the western Delta and Suisun Bay during the late 1800's and early 1900's. Salinity conditions at several key Delta locations are summarized below.

Location: **Western Delta**
Source(s): DPW (1931)
Quotation: "*The dry years of 1917 to 1919, combined with increased upstream irrigation diversions, especially for rice culture in the Sacramento Valley, had already given rise to invasions of salinity into the upper bay and lower delta channels of greater extent and magnitude than had ever been known before.*" (DPW, 1931, pg. 22)
Quotation: "*It is particularly important to note that the period 1917-1929 has been one of unusual dryness and subnormal stream flow and that this condition has been a most important contributing factor to the abnormal extent of saline invasion which has occurred during this same time.*" (DPW, 1931, pg. 66)
Summary: Salinity intrusion into the Delta during the period 1917-1929 was much larger than experienced prior to that time.

Location: **Pittsburg, CA**
Source(s): Tolman and Poland (1935) and DPW (1931)
Quotation: "*From 1880 to 1920, Pittsburg (formerly Black Diamond) obtained all or most of its domestic and municipal water supply from New York Slough offshore.*" (DPW, 1931, pg. 60)
Quotation: "*There was an inexhaustible supply of river water available in the New York Slough* [near Pittsburg at the confluence of the Sacramento and San Joaquin Rivers]*, but in the summer of 1924 this river water showed a startling rise in salinity to 1,400 ppm of chlorine, the first time in many years that it had grown very brackish during the dry summer months.*" (Tolman and Poland, 1935, pg. 27)
Summary: Prior to the 1920's, the water near the City of Pittsburg was sufficiently fresh for the City to obtain all or most of its fresh water directly from the river.

Location: **Antioch, CA**
Source(s): DPW (1931)

No comments

- n/a -

Quotation: *"From early days, Antioch has obtained all or most of its domestic and municipal water supply from the San Joaquin River immediately offshore from the city. This supply also has always been affected to some extent by saline invasion with the water becoming brackish during certain periods in the late summer and early fall months. However, conditions were fairly satisfactory in this respect until 1917, when the increased degree and duration of saline invasion began to result in the water becoming too brackish for domestic use during considerable periods in the summer and fall."* (DPW, 1931, pg. 60)

Summary: Until 1917, the City of Antioch obtained all or most of its freshwater supplies directly from the San Joaquin River. Salinity intrusion has prevented domestic use of water at the Antioch intake in summer and fall after 1917.

Location: **Benicia, CA (Suisun Bay)**
Source(s): Dillon (1980) and Cowell (1963)
Quotation: *"In 1889, an artificial lake was constructed. This reservoir, filled with fresh water from Suisun Bay during the spring runoff of the Sierra snow melt water ..."* (Dillon, 1980, pg. 131)
Quotation: *"...in 1889, construction began on an artificial lake for the* [Benicia] *arsenal which would serve throughout its remaining history as a reservoir, being filled with fresh water pumped from Suisun Bay during spring runoffs of the Sacramento and San Joaquin Rivers which emptied into the bay a short distance north of the installation."* (Cowell, 1963, pg. 31)
Summary: In the late 19th Century, fresh water was available in the Suisun Bay and Carquinez Straits for use by the City of Benicia.

The reported presence of relatively fresh water in the western Delta and the Suisun Bay during the late 1800's and early 1900's is consistent with the relatively fresh conditions observed in the paleoclimate records for this time period (Section 2.3) and the relatively wet conditions observed in the Sacramento River runoff and precipitation records (Section 3.1).

Additional observations between 1775 and 1841 are included in Appendix E. These qualitative observations indicated the presence of "*sweet*" water near the confluence of the Sacramento and San Joaquin Rivers in the vicinity of Collinsville in August 1775 (a period of average or above-average Sacramento River flow), and September 1776 (a period of below-average Sacramento River flow). The presence of "*very clear, fresh, sweet, and good*" water was reported in April 1776 (a dry year). Historical observations from 1796 and August 1841 (dry periods) indicated salinity "*far upstream*" at high tide and the presence of brackish (undrinkable) water in Threemile Slough. Current salinity controls and regulations put brackish water (averaged over 14 days) near Jersey Point and Emmaton, each about 2.5 miles below Threemile Slough, on a regular basis annually.

No comments

- n/a -

5. Conclusions

1. Measurements of ancient plant pollen, carbon isotope and tree ring data show that the Delta was predominately a freshwater marsh for the past 2,500 years, and that the Delta has become far more saline in the past 100 years because of human activity. Salinity intrusion during the last 100 years is comparable to the highest levels over the past 2,500 years.
2. Human activities during the last 150 years, including channelization of the Delta, elimination of tidal marsh, construction of deep water ship channels, and diversions of water, have resulted in increased salinity levels in the Delta. Today, salinity typically intrudes 3 to 15 miles farther into the Delta than it did in the early 20th Century.
3. Before the substantial increase in freshwater diversions in the 1940's, the Delta and Suisun Bay would freshen every winter, even during the extreme drought of the 1930's. However, that pattern has changed. During the most recent droughts (1976-1977, 1987-1994, and 2007-2009), the Delta did not always freshen in winter. Without seasonal freshening, contaminants and toxics can accumulate in the system and young aquatic species do not experience the same fresh conditions in the spring that occurred naturally.
4. While half of the past 25 years have been relatively wet, the fall salinity levels in 21 of those 25 years have resembled dry-year conditions. In terms of salinity, the Delta is now in a state of drought almost every fall because of human activity, including water diversions.
5. Seasonal and inter-annual variation in salinity has also been changed; however, this change is the result of reduced freshwater flows into the Delta. At any given location in the western Delta and Suisun Bay, the percentage of the year when fresh water is present has been greatly reduced or even eliminated.
6. The historical record and published studies show the Delta is far saltier now, even after the construction of reservoirs that have been used in part to meet State Water Resources Control Board water quality requirements in the Delta. Operation of reservoirs and water diversions for salinity management somewhat ameliorates the increased salinity intrusion, but the levels still exceed pre-1900 salinities.

No comments

- n/a -

No comments

- n/a -

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No comments

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No comments

- n/a -

Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay

A summary of historical reviews, reports, analyses and measurements

Appendices

Water Resources Department

Contra Costa Water District

Concord, California

February 2010

Technical Memorandum WR10-001

Exhibit CCWD-6

No comments

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No comments

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Exhibit CCWD-6

Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay

Appendices
February 2010

No comments

- n/a -

Tables

Figures

No comments

- n/a -

No comments

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No comments

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Appendix A. Factors Influencing Salinity Intrusion

Salinity intrusion in the Delta is the result of the interaction between tidally-driven saline water from the Pacific Ocean and fresh water from rivers flowing into the Delta. Regional climate change (e.g., sea level rise and change in precipitation regime), physical changes to the Central Valley landscape (e.g., creation of artificial channels and land use changes), and water management practices (e.g., reservoir storage, water diversions for agricultural and municipal and industrial use) affect this interaction between the ocean tides and the freshwater flow, in turn affecting salinity intrusion in the Delta (The Bay Institute (TBI), 1998, Department of Public Works (DPW), 1931, Nichols *et al.*, 1986, Conomos, 1979, and Knowles, 2000).

These factors are grouped into three categories (Table A-1) and discussed individually and qualitatively to provide context for observed salinity variability, which is necessarily due to the cumulative impact of all factors.

Table A-1 – Factors Affecting Salinity Intrusion into the Delta

Natural and artificial factors affect the salinity of the Delta. The factors are grouped into three categories: regional climate change, physical changes to the landscape, and water management practices.

Category	Factors affecting salinity intrusion and specific effect on Delta salinity
Regional Climate Change	• Precipitation regime o Long-term reduction of spring (April-July) snowmelt runoff may increase salinity in the spring, summer, and fall. o A shift to more intense winter runoff may not decrease salinity in the winter because outflows are typically already high during winter storms. • Ocean conditions o Added periodic variability to precipitation (via mechanisms such as the El Niño/Southern Oscillation (ENSO) or Pacific Decadal Oscillation (PDO)) • Sea level rise o Expected to increase salinity intrusion (DWR, 2006). Actual salinity response to rising sea level will depend upon actions taken to protect against flooding or overtopping (e.g., new tidal marsh vs. sea walls or dykes).
Physical Changes to the Landscape	• Deepening, widening, and straightening of Delta channels o Generally increase salinity, but response will depend upon location within the Delta (DWR, 2006)

No comments

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Category	Factors affecting salinity intrusion and specific effect on Delta salinity

	• Separation of natural floodplains from valley rivers
	  o Confining peak flows to river channels would reduce salinity during flood events.
	  o Preventing floodplains from draining back into the main channel would increase salinity after floods (late spring and summer).
	
	• Reclamation of Delta islands
	  o Varies (the effect on salinity depends on marsh vegetation, depth, and location), but marshes generally dampen tides, reducing salinity intrusion
	
	• Creation of canals and channel "cuts"
	  o Generally creates more efficient routes for tidal flows to enter the Delta, thereby increasing salinity intrusion relative to native conditions
	
	• Deposition and erosion of sediments in Suisun Bay (Cappiella *et al.*, 1999)
	  o Deposition of mining debris (occurred from 1860's to approximately 1887) reduced salinity in Suisun Bay and the western and central Delta (Enright, 2004, Enright and Culberson, 2009)
	  o Erosion (occurring since 1887) increases salinity in Suisun Bay and the western and central Delta (Enright, 2004, Enright and Culberson, 2009)

Water Management Practices (reservoir operations, water diversions, and exports from the Delta)	• Decreasing Net Delta Outflow (NDO) by increasing upstream and in-Delta diversions as well as exports
	  o Increases salinity
	
	• Increasing upstream storage capacity
	  o Generally increases salinity when reservoirs are filling. Reservoir releases may decrease salinity if they increase outflow. Historically, this occurred when flood control or other releases were required in wetter years. However, as this study shows, this has generally been small and intermittent; salinity measurements indicate it occurred occasionally prior to 1985, and very seldom since. Increased early winter diversion of runoff to storage will maintain or increase high salinities in the winter.

No comments

- n/a -

A.1. Climatic Variability

Changes in precipitation regimes and sea levels, brought about by a changing climate, can affect the spatial and temporal salinity conditions in the Delta. Long-term variations in river runoff, precipitation and sea level are discussed below.

A.1.1. Regional Precipitation and Runoff

Precipitation in the Bay-Delta watershed sets the amount of water available within the system which could ultimately reach the Bay and affect salinity conditions. However, since precipitation falls as both rain and snow, runoff to river channels is spread over more months than the precipitation events themselves; any runoff from rain generally reaches the river channels within days of the precipitation event, but runoff resulting from snow is delayed until the spring snowmelt. For this reason, estimates of unimpaired flow (runoff), rather than precipitation, are generally used to characterize hydrological variability. Unimpaired runoff represents the natural water production of a river basin, unaltered by water diversions, reservoir storage and operation, and export of water to or import of water from other basins.

Knowles (2000) determined that variability in freshwater flows accounts for the majority of the Bay's salinity variability. The spatial distribution, seasonal timing, annual magnitude, decadal variability, and long-term trends of unimpaired flow all affect the hydrology and salinity transport in the Delta. Total annual unimpaired flow in the Sacramento and San Joaquin basins from 1872 through 2009 is presented in Section 3.1, with the seasonal distribution provided for 1921 through 2003.

The total annual unimpaired flow of the upper Sacramento Basin for water years 1906 through 2006 exhibits substantial year-to-year variability with a strong decadal oscillation in the 5-year running average (see Figure 3-1). On average, over the last 100 years, the total annual unimpaired Sacramento River flow is increasing by about 0.06% or 11 thousand-acre feet (TAF) each year. However, increased total annual unimpaired flow does not necessarily reduce salinity intrusion. Knowles (2000) illustrated that the seasonal timing of runoff can significantly alter salinity intrusion without any change to the total annual runoff.

Typically, most precipitation in California occurs during winter in the form of snow in the Sierra Nevada. The subsequent melting of this snow, beginning in the spring, feeds the rivers that flow into the Delta. The four months from April through July approximately span the spring season and represent the period of runoff due to snow melt. The long-term trend in spring (April-July) runoff decreased by approximately 1.3 MAF from 1906 to 2006 (Figure A-1). This effect is believed to be caused by climate change; as temperatures warm, more precipitation falls as rain instead of snow, and what snowpack that does accumulate tends to melt earlier in the year. This leads to higher runoff during winter months, but lower runoff in spring or summer, resulting in the potential for greater salinity intrusion. These observed changes in the magnitude and timing of spring runoff of the Sacramento River watershed are consistent with similar changes in spring runoff observed across river watersheds of the

No comments

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western United States (e.g., Dettinger, 2005; Mote *et al.*, 2005; Stewart *et al.*, 2005). Note that, from 1920 to 2006, the long-term trend in spring runoff actually increased slightly (approximately 0.5 MAF).

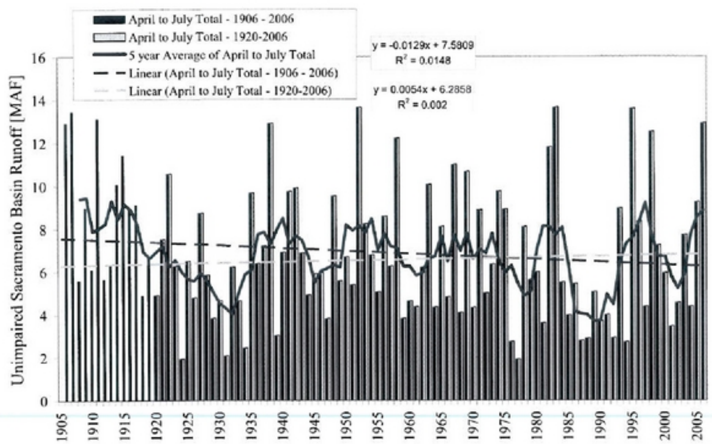

Figure A-1 – Unimpaired runoff from the Sacramento River basins from April to July
Data source: http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST.

Precipitation and runoff are influenced by regional events such as the Little Ice Age (about 1300 to 1850 CE) and the Medieval Warm Period (about 800 to about 1300 CE). During the Little Ice Age, the winter snowline in the Sierra was generally at a lower elevation, and spring and summer nighttime temperatures were significantly lower. This temperature pattern would allow the snowmelt to last further into the summer, providing a more uniform seasonal distribution of runoff such that significantly less salinity intrusion than occurs today would be expected. This expectation is borne out by paleosalinity studies (see Section 2.3).

At shorter time scales, oceanic conditions such as the Pacific Decadal Oscillation (PDO) and El Niño/Southern Oscillation (ENSO) also impact precipitation and runoff patterns. Runoff in the upper watershed is the primary factor that determines freshwater outflow from the Delta. Anthropogenic flow management (upstream diversions, reservoir operations, in-Delta diversions, and south-of-Delta exports) alters the amount and timing of flow from the upper watershed (see Section 2.3). Changes to the physical landscape further alter the amount and timing of flow (see Section 2.2).

No comments

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A.1.2. Sea Level Rise

Sea level fluctuations resulting from the repeated glacial advance and retreat during the Pleistocene epoch (extending from 2 million years ago to 15,000 years ago) resulted in deposition of alternating layers of marine and alluvial sediments in the Delta (TBI, 1998). A warming trend starting about 15,000 years ago ended the last glacial advance and triggered rapid sea-level rise. At the end of this period (known as the "Holocene Transgression") approximately 6,000 years ago, sea level had risen sufficiently to inundate the Delta at high tide (Atwater *et al.*, 1979).

Sea level is estimated to have risen at an average rate of about 5 cm/century during the past 6,000 years and at an average rate of 1-2 cm/century during the past 3,000 years (Cayan *et al.*, 2008). Observations of sea level at the Golden Gate in San Francisco reveal that the mean sea level has risen at an average rate of 2.2 cm/decade (or 0.22 mm/yr) over the past 100 years (Cayan *et al.*, 2008). Future increases in sea level are expected to increase salinity intrusion into the Delta (DWR, 2006); actual salinity response to rising sea level will depend upon actions taken to protect against flooding or levee overtopping (e.g. new tidal marsh would generally reduce salinity intrusion, while construction of sea walls or dykes may further increase salinity).

A.2. Physical Changes to the Delta and Central Valley

Creation of artificial channels, reclamation of marshlands, land use changes and other physical changes to the landscape of the Delta and Central Valley have significantly altered water movement through the Delta and the intrusion of salinity into the Delta. Major physical changes to the Delta and Central Valley landscape have occurred over the last 150 years. As many of these physical changes were made prior to flow and salinity monitoring (which began in the 1920's), only a qualitative discussion is presented below.

A.2.1. Deepening, Widening, and Straightening Channels (early 1900's-present)

The lower Sacramento River was widened to 3,500 feet and straightened (creating Decker Island) around 1910 (Lund *et al.*, 2007). Progressive deepening of shipping channels began in the early 1900's. Original channel depths were less than 10 feet; channels were gradually dredged to depths exceeding 30 feet, and maintenance dredging continues today.

These changes to the river channels have increased salinity intrusion. Deepening the river channels increases the propagation speed of tidal waves, leading to increased salinity intrusion. Similarly, straightening the river channels provides a shorter path for the passage of the tidal waves and increases salinity intrusion. Widening of the river channels increases the tidal prism (the volume of water in the channels), resulting in further salinity intrusion. Larger cross-sections reduce velocities, lowering friction losses and maintaining more tidal energy, which is the driving force for dispersing salinity into the Delta.

No comments

- n/a -

A.2.2. Reclamation of Marshland (1850-1920)

In the Central Valley

The original natural floodplains captured large winter flows, gradually releasing the water back into the river channels throughout the spring and summer, resulting in a more uniform flow into the Delta (reduced peak flow and increased low flow) compared to current conditions. The increased surface area of water stored in these natural floodplains increased total evaporation and groundwater recharge, reducing total annual inflow into the Delta.

Even with less Delta inflow, the difference in the seasonal flow pattern may have limited salinity intrusion. The drainage of floodplains back into rivers during the spring and groundwater seepage back to the rivers in the summer and fall provided a delayed increase in river flows during the low flow period. Raising and strengthening natural levees in the Central Valley effectively disconnected the rivers from their floodplains, removing this natural water storage, increasing the peak flood flows and reducing the low flows. The net effect of these changes in the Central Valley was to reduce salinity during floods, when salinity is typically already low, and increase salinity during the following summers and falls, which is likely to have led to increased maximum annual salinity intrusion.

In the Delta

Reclamation of Delta marshland began around 1850. By 1920, almost all land within the legal Delta[1] had been diked and drained for agriculture (DPW, 1931). Before the levees were armored and the marshes were drained, the channels would have been shallower and longer (more sinuous), which would have slowed propagation of the tides into the Delta, reduced tidal energy and reduced salinity intrusion.

The natural marsh surface would have increased the tidal prism. However, the shallow marsh depth and native vegetation would have slowed the tidal wave progression. The combined effect on salinity intrusion depends on the location and depth of the marsh, the native vegetation distribution, and the dendritic channels that were removed from the tidally active system.

Figure A-2 shows the western, central, and southern portions of the Delta in 1869. For comparison, Figure A-3 shows the same area in 1992, with man-made channels highlighted grey.

A.2.3. Mining debris

Hydraulic mining in the Sierra Nevada began in the 1860's and produced large quantities of debris which traveled down the Sacramento River, through the Delta and into the Bay. Mining debris may have contributed to the extensive flooding reported in 1878 and 1881. Cappiella *et al.* (1999) estimate that, from 1867 to 1887, approximately 115 million cubic meters (Mm3) of sediment were deposited in Suisun Bay. This deposition was due to the inflow of hydraulic mining debris.

[1] The legal Delta is defined in California Water Code Section 12220.

No comments

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Figure A-2 - Map of the Delta in 1869

Channels of the western, central, and southern Delta in 1869, prior to extensive reclamation efforts (Gibbes, 1869)

No comments

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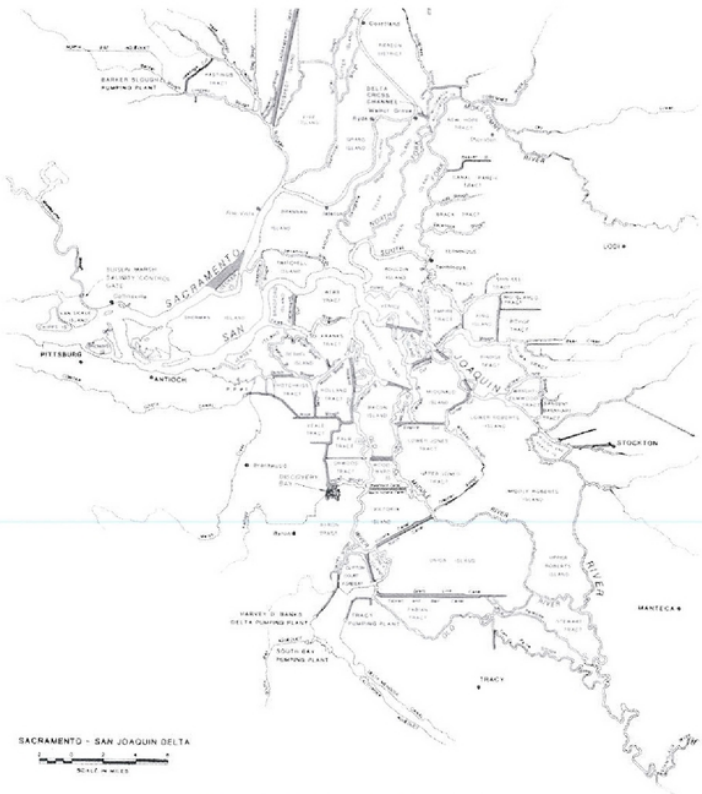

Figure A-3 – Map of the Delta in 1992

Channels of the western, central, and southern Delta from the Delta Atlas (DWR, 1992) Constructed waterways (highlighted in grey) generally create more efficient routes for tidal flows to enter the Delta, thereby increasing salinity intrusion relative to the native tidal marshes.

No comments

- n/a -

Cessation of hydraulic mining around 1884 resulted in erosion of Suisun Bay, which continues to erode even today. From 1887 to 1990, approximately 262 Mm3 of sediment were eroded from Suisun Bay. The net change in volume of sediment during 1867-1887 was 68 Mm3 (net deposition) and during 1887-1990 was -175 Mm3 (net erosion). As a result of these changes, the tidal flat of Suisun Bay increased from about 41 km^2 in 1867 to 52 km^2 in 1887, but decreased to 12 km^2 by 1990 (due to erosion subsequent to the cessation of hydraulic mining). Cappiella *et al.* (1999) attributed the change in the Suisun Bay area from being a largely depositional environment to an erosional environment not only to the hydraulic mining practices of the late 1800's but also to increased upstream water management practices. The Suisun Marsh Branch of the DWR estimated that erosion of Suisun Bay (modeled as a uniform change in depth of 0.75 meters) has increased salinity in Suisun Bay and the western Delta by as much as 20% (Enright, 2004; Enright and Culberson, 2009).

A.3. Water Management Practices

Extensive local, state, and federal projects have been built to move water around the state, altering the natural flow patterns throughout the Delta and in upstream watersheds. For clarity in the discussion that follows, definitions and discussions of actual flow and salinity, unimpaired flow and salinity, and natural flow and salinity, are given below.

Historical (actual) flow and salinity
Historical (or actual) flow and salinity refer to the flow and electrical conductivity, total dissolved solids concentration, or chloride concentration that occurred in the estuary. Historical conditions have been observed, measured, or estimated at various times and locations; they are now measured at monitoring stations throughout the estuary. Historical data are also used to estimate flow and water quality conditions at other locations with the following tools: the DAYFLOW program from IEP, the DSM2 model from the California Department of Water Resources, the X2[2] equation (Kimmerer and Monismith, 1992) and Contra Costa Water District's salinity outflow model (also referred to as the G-model) (Denton, 1993; Denton and Sullivan, 1993). The use of these tools to estimate flow and water quality is necessarily dependent upon the Delta configuration to which they were calibrated. Use of these tools in hypothetical configurations (such as pre-levee conditions, flooding of islands, etc) is subject to un-quantified error.

Unimpaired flow and salinity
Unimpaired flows are hypothetical flows that would have occurred in the absence of upstream diversions and storage, but with the existing Delta and tributary configuration. Unimpaired flows are estimated by the California Department of Water Resources (DWR) for the 24 basins of the Central Valley; the Delta is one of the 24 basins. Additionally, DWR estimates unimpaired in-Delta use and unimpaired net Delta outflow (NDO). Unimpaired NDO estimates can be used to estimate unimpaired water quality using a salinity-outflow relationship such as the X2 or G-model tools discussed above.

[2] X2 is defined as the distance from the Golden Gate to the 2 part-per-thousand isohaline (equivalent to a salinity of 2 grams of salt per kilogram of water), measured along the axis of the San Francisco Estuary. X2 is often used as an indicator of freshwater availability and fish habitat conditions in the Delta (Jassby *et al.*, 1995; Monismith, 1998).

No comments

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Since unimpaired flows assume the existing Delta configuration, the use of these tools should not violate their basic assumptions. However, the results should be taken in context. Water quality based on unimpaired flows compared to water quality based on historical (actual) flows shows how water management activities affect water quality. Water quality based on unimpaired flows cannot be considered natural.

Natural flow and salinity

Natural flow and salinity reflect pre-European settlement conditions, with a virgin landscape in both the Central Valley and the Delta, native vegetation, and no diversions or constructed storage. As discussed above, the natural landscape included natural storage on the floodplains and extensive Delta marsh. Estimation of natural flow requires assumptions regarding the pre-European landscape and vegetation throughout the Central Valley. Estimation of natural salinity requires development of new models to account for pre-European Delta geometry, incorporating the estimates of natural flow. These assumptions induce an unknown level of error. For this reason, no attempt is made in this report to calculate natural flow or the resulting salinity. Instead, paleosalinity studies are examined to provide evidence of salinity in the pre-European era.

Water management practices have continually evolved since the mid-1850's. As discussed in Section 1.1, anthropogenic modification include diversion of water upstream and within the Delta, construction of reservoirs, and system operations to meet regulatory requirements.

The irrigated acreage in the Central Valley has been steadily increasing since 1880 (Figure 1-3), increasing the upstream diversions of water. There were two periods of rapid growth in irrigated acreage: from 1880 to 1920 and from 1940 to 1980. In-Delta diversions (Figure 1-3) began in 1869 with reclamation of Sherman Island; from 1869 to 1930, in-Delta diversions are assumed to have grown in proportion to the area of reclaimed marshland (from Atwater *et al.*, 1979).

Upstream diversions first became an issue with respect to Delta salinity around 1916 with the rapid growth of the rice cultivation industry (Antioch Case, Town of Antioch v. Williams Irrigation District, 1922, 188 Cal. 451; see Appendix E.2). These early "pre-project" diversions for irrigation had particularly large impacts because of the seasonality of water availability and water use. Diversions for agriculture typically start in the spring and continue through the early fall (when river flow is already low). These early irrigation practices, combined with the decrease in spring and summer flow due to the separation of rivers from their natural floodplains, resulted in a significant reduction of the spring and summer river flow, leading to increased salinity intrusion.

Figure A-4 shows the Department of Water Resources' estimates of the effects of upstream diversions and south-of-Delta exports on the salinity in the San Joaquin River at Antioch (DWR, 1960). DWR's 1960 report indicated that water with less than 350 mg/L chlorides would be present at Antioch approximately 88% of the time on average "naturally," and that availability decreased to approximately 62% by 1940 due to upstream diversions. This illustrates that upstream depletions had a significant effect on salinity at Antioch during 1900-1940, prior to the construction of large upstream reservoirs. (For reference, Shasta Dam was completed in 1945.)

No comments

- n/a -

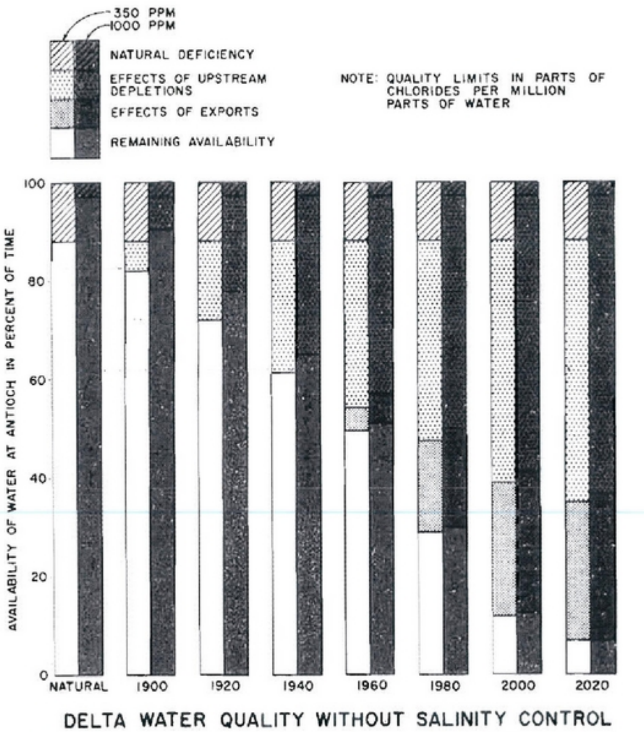

Figure A-4 - Salinity on the San Joaquin River at Antioch (DWR, 1960)

The Department of Water Resources examined the effects of upstream depletions and south-of-Delta exports on salinity in the San Joaquin River at Antioch, estimating the percent of time water that a certain quality of water (with less than 350 mg/L chlorides; or less than 1,000 mg/L chlorides) would be available in the river without reservoir releases to provide salinity control. The estimates for 1960, 1980, 2000, and 2020 assume the reservoirs do not make releases for salinity control and therefore underestimate the actual quality of water during these years.

Figure A-4 also shows estimates of the availability of water in 1960, 1980, 2000, and 2020, without reservoir releases to provide salinity control, demonstrating that upstream depletions and in-Delta exports would have continued to degrade water quality at Antioch.

No comments

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Exports from the south Delta started in 1951 with the completion of the federal Central Valley Project pumping facility near Tracy, California. Exports from the State Water Project Banks Pumping Plant, just to the west of the federal facility, began in 1967. As shown in Figure 1-3, south-of-Delta exports increased rapidly from 1951 through the mid-1970s, and since then the combined exports have averaged more than 4 million acre-feet per year.

Construction of upstream reservoirs also altered natural patterns of flow into the Delta. Figure A-5 and Figure A-6 show the extent and rapid rise of constructed reservoirs in the upstream watersheds of the Delta (DWR, 1993). The location, year of completion and approximate storage capacities (in acre-feet, AF) are shown in Figure A-5. Figure A-6 shows the temporal development of reservoir capacity. Reservoir construction began in 1850. The major reservoirs of the Central Valley Project (CVP) and State Water Project (SWP) are the Shasta (4.5 MAF capacity) and Oroville (3.5 MAF) reservoirs, respectively. These reservoirs capture the flow in the wet season (reducing the flow into the Delta in the wet season) and release water for irrigation and diversions.

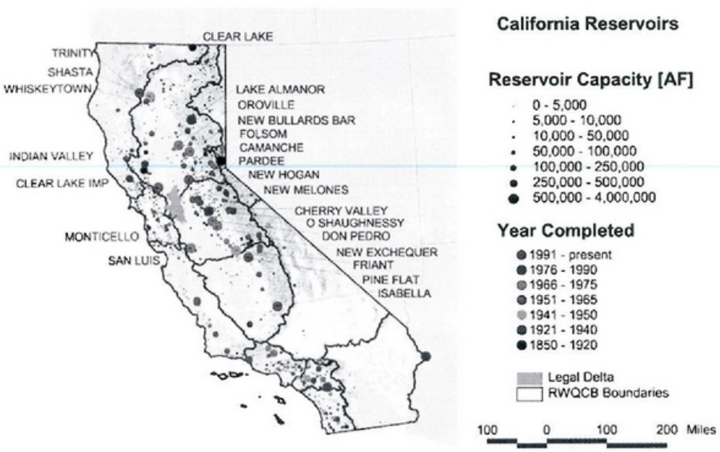

Figure A-5 – Storage reservoirs in California

Location of storage reservoirs within California. Reservoir capacity is indicated by the size of the circle, while the year construction was completed is indicated by color.

No comments

- n/a -

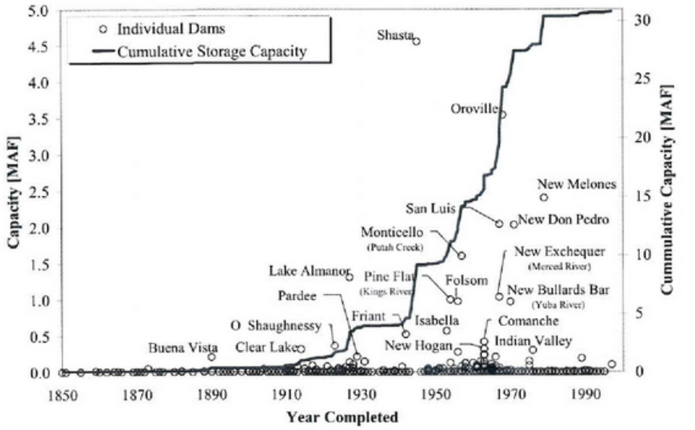

Figure A-6 – Surface Reservoir Capacity

Timeline of reservoir development in California. Individual reservoir capacity is indicated by the blue circles (left axis), while the cumulative capacity is indicated with the red line (right axis).

Water management practices have been altered by regulations that require maintenance of specified flow and salinity conditions at locations in the Bay-Delta region during certain periods of the year. The 1978 Water Quality Control Plan and State Water Resources Control Board (SWRCB) Decision 1485 established water quality standards to manage salinity to protect Delta agriculture and municipal and industrial (M&I) uses. The listing of delta smelt as a threatened species under the Endangered Species Act in 1993, followed by the Bay-Delta Accord in 1994 and the adoption of a new water quality control plan by the State Water Resources Control Board in 1995 changed the amount and timing of reservoir releases and south-of-Delta exports. California's Rice Straw Burning Act was enacted in 1992 to reduce air pollution by phasing out the burning of rice field stubble; by 1999, Sacramento Basin rice farmers were diverting additional water to flood harvested fields to decompose the stubble.

Changes in water diversions and reservoir operations have altered the magnitude and timing of river flows to the Delta, and anthropogenic modifications to the Delta landscape have altered the interaction of fresh water from the rivers with salt water from the ocean, thus changing patterns of salinity intrusion into the Delta.

No comments

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No comments

- n/a -

Appendix B. Paleoclimatic Records of Hydrology and Salinity

This section presents paleoclimate records of hydrology (precipitation and unimpaired runoff) and salinity in the Bay-Delta region, in addition to those presented in Section 2 of the main report.

B.1. Methods of Paleoclimatic Reconstruction

The field of paleoclimatology aims to deduce climatological information from natural "archives" in order to reconstruct past global climate. These archives are created by such Earth processes as the formation of ice sheets, sediments, rocks, and forests. Examples of information sampled from such archives include atmospheric temperatures from ice cores and precipitation cycles from tree rings. When samples are dated, through radiometric or other methods, the data preserved therein become proxy indices, establishing a timeline of major events in the local environment of the sample. Multiple samples collected over larger spatial scales can be cross-dated to create regional climate and landscape process chronologies.

The material sampled for paleoclimatic reconstructions has limitations that decrease the resolution and confidence of data going back in time. Although paleoclimatic reconstructions have a coarser temporal resolution than modern measurements, the variations in climate and landscape responses to change are reliably described "in the first person" because the evidence of localized climate change is preserved as a time series *in situ*, absent of human influence.

The San Francisco Bay-Delta has been the focus of several paleoclimatic reconstructions. Surveys have sampled from Browns Island (Goman and Wells, 2000; May, 1999; Malamud-Roam and Ingram, 2004), Roe Island (May, 1999; Malamud-Roam and Ingram, 2004) Rush Ranch (Starratt, 2001; Byrne *et al.*, 2001; Starratt, 2004), and China Camp and Benicia State Parks (Malamud-Roam and Ingram, 2004).

Sediment cores are the predominate archive used to reconstruct Bay-Delta climate. Changes in wetland plant and algae communities are the dominant response in the Bay-Delta to climate change and associated fluctuations in temperature and precipitation. Proxies of plant and algae response to environmental conditions are preserved in the sediment cores and determined by quantification and taxonomic identification of diatom frustules (Byrne *et al.*, 2001; Starratt, 2001; Starratt, 2004), plant seeds and roots (Goman and Wells, 2000) and plant pollen (May, 1999; Byrne *et al.*, 2001; Malamud-Roam and Ingram, 2004) and measurement of peat carbon isotope ratios (Byrne *et al.*, 2001; Malamud-Roam and Ingram, 2004).

Plant communities in the Delta are characterized by salt tolerance. Salt-tolerant plant communities are dominated by pickleweed (*Salicornia* spp.) while freshwater plant

No comments

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assemblages are dominated by tule (*Scirpus* spp.) and cattail (*Typha* spp.) (Atwater *et al.*, 1979). Plants contribute pollen, seeds, and vegetative tissue in the form of peat to the sediment archive. Plant material deposited to surface sediments are significantly correlated to the surrounding standing vegetation, and thus plant material preserved in sediment cores are considered autochthonous to the type of wetland existent at the time of sediment deposition, allowing reconstruction of the salinity conditions in the Delta over time.

Diatom taxa are classified according to their salinity preference expressed as the Diatom Salinity Index (DSI) (Eq 1) (Starratt, 2004). Starratt (2001) classified salinity preference as freshwater (F; 0-2‰), freshwater and brackish water (FB; 0-30‰), brackish (B; 2-30‰), brackish and marine (BM; 2-35‰), and marine (M; 30-35‰). Samples dominated by marine taxa have a DSI range of 0.00 to 0.30.

$$DSI = \frac{F + FB + 0.5B}{F + FB + B + BM + M} \quad (1)$$

Carbon-isotope ratios ($^{13}C/^{12}C$) (Eq 2) are measured by spectrometry and the δ notation calculated as

$$\delta^{13}C = \left[\left(\frac{{}^{13}C/{}^{12}C_{sample}}{{}^{13}C/{}^{12}C_{std}} \right) - 1 \right] \times 1000 \quad (2)$$

The $\delta^{13}C$ value of peat samples is a proxy for the composition of the plant assemblages contributing vegetation to the formation of the peat. Plants utilizing the C_4 mechanism have higher $\delta^{13}C$ values (~-14‰) than those utilizing the C_3 or CAM (~-27‰) (Table B-1). Using the $\delta^{13}C$ proxy can detect the presence of upland bunchgrasses such as *Spartina* and *Distichlis*.

Pollen can be classified to the taxonomic family level. *Chenopodiaceae (*now *Salicornioideae*) is representative of salt-tolerant *Salicornia*. *Cyperaceae* is representative of freshwater species including *Scirpus*. The ratio of *Chenopodiaceae* to the sum of *Chenopodiaceae* and *Cyperaceae* (Eq. 3) is a proxy of the percent relative abundance of salt-tolerant species (May, 1999).

$$\%ST = \frac{Chenopodiaceae}{Chenopodiaceae + Cyperaceae} \quad (3)$$

To establish chronologies for sediment archives, dates must be established for when material was deposited through the length of the sediment cores. Radiocarbon dating by Accelerator Mass Spectrometry (AMS) determines age by counting the ^{14}C content of plant seeds or carbonate shells calibrated against a northern hemisphere atmospheric carbon calibration curve (Malamud-Roam *et al.*, 2006). Radiocarbon dating is valid to about 40,000 years

No comments

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before present (BP)[3], making it an ideal method for establishing dates through the period of interest for the Bay and Delta. When archived proxies are correlated with the sediment core chronology, a timeline is established reconstructing past climate and landscape response.

Table B-1 – Carbon Isotope Ratios ($\delta^{13}C$) of Plant Species in the San Francisco Estuary
(adapted from Byrne et al. 2001)

Species	Common Name	Photosynthetic Pathway	δ13C (‰)
Distichlis spicata	Saltgrass	C4	-13.5
Spartina foliosa	California cordgrass	C4	-12.7
Cuscuta salina	Salt-marsh dodder	C3	-29.8
Frankenia grandifolia	Alkali heath	C3	-30.2
Grindelia stricta	Gumplant	C3	-26.4
Jaumea carnosa	Marsh jaumea	C3	-27.2
Juncus balticus	Baltic rush	C3	-28.4
Lepidium latifolium	Perennial pepperweed	C3	-26.6
Scirpus californicus	California bulrush	C3	-27.5
Scirpus maritimus	Alkali bulrush	C3	-25.5
Typha latifolia	Cattail	C3	-27.8
Salicornia virginica	Pickleweed	CAM	-27.2

A large number of paleoclimatic reconstructions exist for California and the western U.S., but a complete discussion is beyond the scope of this report. These reconstructions are reviewed by Malamud-Roam *et al.* (2006; 2007) and provide important context to events in the Bay and Delta by recording major non-localized events and larger regional climate shifts. Important examples include: Central Valley oaks, Sierra Nevada giant sequoias, and White Mountain Bristlecone pines used to establish precipitation and temperature from the location of the tree line and tree rings; Mono Lake sediments and submerged tree stump rings for precipitation; and Sacramento and San Joaquin River floodplain deposits for flood events. These studies establish a record of environmental conditions in the Bay and Delta from their formation to the present.

B.2. Major Regional Climatic Events

Formation of the Sacramento-San Joaquin Delta

The Holocene epoch began approximately 8000 BCE at the end of Pleistocene glaciations (Malamud-Roam *et al.*, 2007). In the early Holocene, a general warming and drying period in California accompanied high orbitally driven insolation until insolation reached current values at approximately 6000 BCE. In the Sierra Nevada, western slopes were in the early stages of ecological succession following the retreat of glaciers. The modern river floodplain systems were forming in the Central Valley. Parts of the Delta and Bay were river valleys

[3] Before Present (BP) is a time scale, with the year 1950 as the origin, used in many scientific disciplines. Thus, 100 BP refers to the calendar year 1850.

No comments

- n/a -

prior to approximately 8000 to 6000 BCE, when rapidly rising sea level entered the Golden Gate and formed the early Bay estuary (Atwater *et al.*, 1979). A fringe of tidal marshes retreated from a spreading Bay until approximately 4000 BCE when the rate of submergence slowed to 1 to 2 cm per year, allowing the formation of extensive Delta marshes over the next 2000 years (Atwater *et al.*, 1979). Sedimentation from upstream sources kept up with subsidence from increasing sea-level rise.

2000 – 1 BCE

After 2000 BCE, information from archives indicates climate in the Bay and Delta was cooler with greater freshwater inflows. The Sierra Nevada became more moist and cooler during a period ca. 4000-3500 BP (Malamud-Roam *et al.*, 2006).

1 BCE - Present

The cooler and wetter period ended approximately 1 BCE, replaced by more arid conditions (Malamud-Roam, 2007). Major climatic events, known from other parts of the world, are captured in the regional paleoclimatic reconstructions and help to calibrate or correlate these reconstructions to global events. Unusually dry conditions prevailed during the Medieval Warm Period (approximately 800-1300 CE). Wetter and cooler conditions existed during the Little Ice Age (approximately 1400-1700 CE). These climate variations are reflected in variations in the plant communities.

Droughts

Two extreme droughts occurred in the region from about 900 to 1150 CE and from 1200 to 1350 CE. Low freshwater inflows to the Delta occurred during periods 1230-1150, 1400-1300, 2700-2600, and 3700-3450 B.P.

Flood Events

Periods of increase moisture occurred from 800-730 BP and 650-300 BP. Massive flooding inundated the Central Valley in the winter of 1861 (Malamud-Roam *et al.*, 2006). High periods of inflow occurred during 1180-1100, 2400-2200, 3400-3100, and 5100-3800 BP.

Sampling for paleoclimatic reconstructions captures the modern era, enabling a comparison of current conditions with conditions over the past several thousand years. The erratic nature of precipitation in California observed over the past century have been normal and small compared to natural variations over the past millennia.

Reconstructed River Flow and Precipitation Records

Meko *et al.* (2001a) used tree-ring chronologies in statistical regression models to reconstruct time series of annual unimpaired Sacramento River flow for approximately the past 1,100 years (see Section 2.1). Similarly, Graumlich (1987) used tree ring data from the Pacific Northwest to reconstruct precipitation records for the period of 1675-1975 (Figure B-1). Compared to the average observed precipitation from 1899 to 1975, the reconstructed record has above-average precipitation during the latter half of the nineteenth century (1850-1900) (Figure B-1). These relatively wet conditions during the late 1800's and the severe dry

No comments

- n/a -

conditions from the 1920's trough the 1930's in the reconstructed precipitation record are consistent with the annual unimpaired Sacramento River flow reconstruction from Meko *et al.* (2001) presented in Section 2.1.

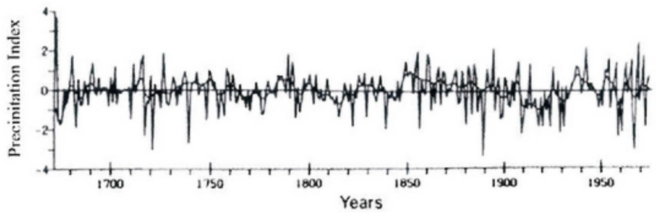

Figure B-1 – Reconstructed annual precipitation, 1675-1975
Data from Graumlich (1987). Precipitation index is presented in units of standard deviation from the 1899-1975 observed mean value.

Estimates of annual precipitation (Graumlich, 1987) and unimpaired runoff (Meko *et al.*, 2001a) from tree ring analysis are used in this study to provide hydrological context, indicating the relative hydrology (e.g. wet or dry) of a specific year and surrounding decade. The reconstructed hydrological data are not used to estimate salinity intrusion for two reasons. First, the seasonal distribution of hydrology is critical in determining salinity variability; two years with the same total annual flow could have significantly different salinity intrusion due to the timing of the flow (Knowles, 2000). Second, since 1850, anthropogenic modifications to the landscape and river flows alter the hydrodynamic response to freshwater flow, somewhat decoupling the unimpaired hydrology from the downstream response (i.e. salinity intrusion).

Malamud-Roam *et al.* (2005) and Goman *et al.* (2008) review paleoclimate as it relates to San Francisco Bay. Generally, they found that paleoclimatic studies showed that a wetter (and fresher) period existed from about 4000 BP to about 2000 BP. In the past 2,000 years, the climate has been cooling and becoming drier, with several extreme periods, including decades-long periods of very wet conditions and century-long periods of drought. As discussed in the next section, the century-long periods of drought are found in paleosalinity records in Suisun Bay and Rush Ranch in Suisun Marsh, but are much less evident in Browns Island, indicating a predominately freshwater marsh throughout the Delta. Citing Meko *et al.* (2001), they note that only one period had a six-year drought more severe than the 1928-1934 period: a seven-year drought ending in 984 CE. They also not the most extreme dry year was in 1580 CE, and state that it was almost certainly drier than 1977. On the whole, however, the last 600 years have been a generally wet period. This is reflected in the salinity records discussed in the next section.

No comments

- n/a -

B.3. *Reconstructed Salinity in the Bay-Delta*

Starratt (2001) reconstructed historical salinity variability at Rush Ranch, in the northwestern Suisun Marsh, over the last 3,000 years by examining diatoms from sediment cores. The taxa were classified according to their salinity preference: freshwater (< 2‰), freshwater and brackish water (0‰ to 30‰), brackish (2‰ to 30‰), brackish and marine (2‰ to > 30‰), and marine (> 30‰). Based on the composition of the diatom assemblages, Starrat identified centennial-scale salinity cycles (Table B-2).

Table B-2 – Salinity Intervals over the last 3,000 years at Rush Ranch

Salinity intervals determined from the diatom populations in a sediment core in northwestern Suisun Marsh.

Approximate Years	*Type of Interval* [a]
1850 CE – present	[not classified]
1250 CE – 1850 CE	fresh
250 CE – 1250 CE	brackish
500 BCE – 250 CE	fresh
1000 BCE – 500 BCE	brackish

[a] Classification according to Starratt (2001)

These results correspond well to other paleoclimatic reconstructions. The most recent broad-scale freshwater interval roughly corresponds to the Little Ice Age, and the most recent brackish interval corresponds to the Medieval Warm Period.

Starratt notes that the post-1850 interval indicates an increase in the percentage of diatoms that prefer brackish and marine salinities compared to the last freshwater interval, indicating an increase in salinity during the last 150 years, in comparison to the previous 600 years. During the post-1850 period, diatoms that prefer "marine" environments constitute as much as 50% of the total diatom population, a percentage that is at or above that of any other period. During the most recent years, "freshwater" assemblages constitute about 20% of the total population, a percentage that is only about 10% higher than the most recent *brackish* interval from 250 to 1250 CE.

Malamud-Roam *et al.* (2006) compared reconstructed salinity records for the past three thousand years from four locations (three tidal marsh locations and one location in the Bay) in the Bay-Delta region (Figure B-2(a)). Figure B-2(b) shows several periods with higher than average salinity (e.g., 1600-1300 and 1000-800 BP and 1900 CE to present) and several periods with lower than average salinity (e.g., 1300 to 1200 BP and 150 to 100 BP). These paleosalinity records are consistent with each other and with the paleoclimatic records of river flow and salinity presented in Section 2.

No comments

- n/a -

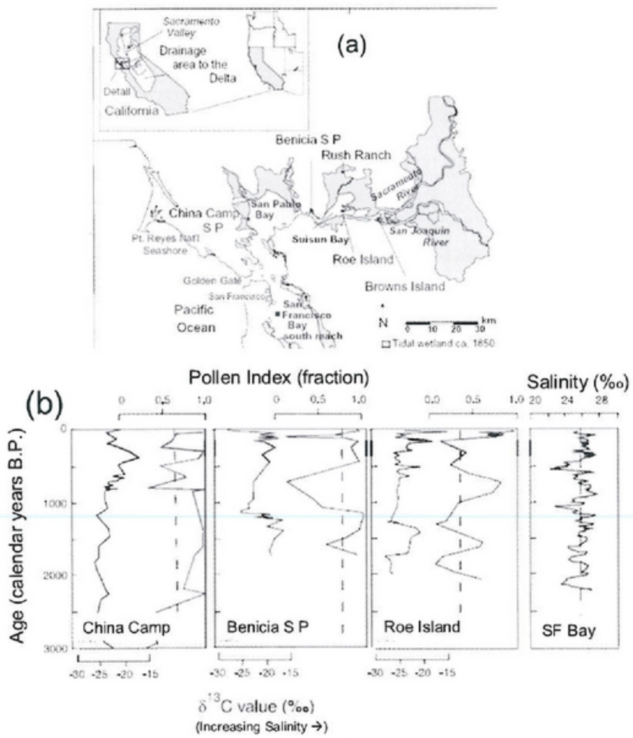

Figure B-2 – Paleosalinity records at selected sites in the San Francisco Estuary

(a) location of the three tidal marsh sites (China Camp, Benicia State Park and Roe Island) and one site in the Estuary (Oyster Point in San Francisco Bay) where sediment cores were obtained.
(b) time series for the pollen index (ranging from 0 to 1, higher values corresponding to higher salinity) and the δ13C values at the tidal marsh sites; salinity at Oyster Point, San Francisco Bay (inferred from δ13O values) is also shown. The broken line shows the estimated mean pollen index prior to European disturbance. (modified from Malamud-Roam and Ingram (2004) and Malamud-Roam et al. (2006))

No comments

- n/a -

No comments

- n/a -

Appendix C. Quantitative Hydrological Observations

Long-term records of river runoff are useful in understanding hydroclimatic variations. Section 3.1 discusses the long-term variations of the unimpaired Sacramento River runoff and unimpaired San Joaquin River runoff. The estimates of these variables from early 1900's to the present are available on the internet . Estimates prior to the early 1900's (late 1800's to early 1900's) were obtained from a 1923 California Department of Public Works report (DPW, 1923). Table C-1 through Table C-4 present estimates of Sacramento River runoff and San Joaquin River runoff for the period of 1872-2008, obtained from DPW (1923) and http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST.

The unimpaired Sacramento River runoff is the sum of the flows from the Sacramento River at Bend Bridge, Feather River inflow to Lake Oroville, Yuba River at Smartville, and the American River inflow to Folsom Lake. The unimpaired San Joaquin River runoff is the sum of the flows from the Stanislaus River inflow to New Melones Lake, Tuolumne River inflow to New Don Pedro Reservoir, Merced River inflow to Lake McClure, and San Joaquin River inflow to Millerton Lake.

Table C-1 – Annual unimpaired Sacramento River runoff for 1872-1905
Data source: DPW (1923

Water Year	Sacramento River @ Bend Bridge	Feather River @ Lake Oroville	Yuba River @ Smartville	American River @ Folsom Lake	Sacramento River Runoff
	Acre-feet (AF)				Million acre-feet (MAF)
1872	10,200,000	7,254,000	4,352,000	4,215,600	**26.0**
1873	4,780,000	3,347,000	1,638,400	1,862,200	**11.6**
1874	7,300,000	5,571,000	3,340,800	3,079,800	**19.3**
1875	4,390,000	2,747,000	1,561,600	1,391,600	**10.1**
1876	14,500,000	6,867,000	3,594,000	4,450,900	**29.4**
1877	9,870,000	2,437,000	1,292,800	1,289,200	**14.9**
1878	17,800,000	4,836,000	2,528,000	2,721,700	**27.9**
1879	8,380,000	5,513,000	2,796,800	3,304,900	**20.0**
1880	12,300,000	7,061,000	3,641,600	4,502,100	**27.5**
1881	15,400,000	5,610,000	3,104,000	3,540,300	**27.7**
1882	8,000,000	4,797,000	2,150,400	3,264,000	**18.2**
1883	6,670,000	3,714,000	1,804,800	2,169,200	**14.4**
1884	11,400,000	6,190,000	3,104,000	4,103,000	**24.8**
1885	6,460,000	3,482,000	2,304,000	1,780,400	**14.0**
1886	14,400,000	6,384,000	3,174,400	3,918,900	**27.9**
1887	6,670,000	2,611,000	1,561,600	1,862,200	**12.7**
1888	5,430,000	2,669,000	998,400	1,575,700	**10.7**
1889	10,600,000	5,126,000	1,612,800	1,903,200	**19.2**
1890	22,700,000	12,090,000	6,176,000	7,725,200	**48.7**

No comments

- n/a -

Water Year	Sacramento River @ Bend Bridge	Feather River @ Lake Oroville	Yuba River @ Smartville	American River @ Folsom Lake	Sacramento River Runoff
1891	6,460,000	3,482,000	1,747,200	1,944,100	**13.6**
1892	7,250,000	5,416,000	1,945,600	2,568,200	**17.2**
1893	12,400,000	7,177,000	3,488,000	4,399,800	**27.5**
1894	8,640,000	4,410,000	2,432,000	3,304,900	**18.8**
1895	12,300,000	7,177,000	4,160,000	4,737,400	**28.4**
1896	11,343,200	7,738,000	3,641,600	3,857,500	**26.6**
1897	10,391,400	5,610,000	3,040,000	3,632,400	**22.7**
1898	5,135,800	2,805,000	1,184,000	1,186,900	**10.3**
1899	5,977,400	3,288,000	1,984,000	2,362,600	**13.6**
1900	8,712,500	6,500,000	2,956,800	3,683,500	**21.9**
1901	9,020,900	6,229,000	2,854,400	3,714,200	**21.8**
1902	11,380,600	4,468,000	2,432,000	3,079,800	**21.4**
1903	9,941,800	4,483,500	2,368,000	3,038,900	**19.8**
1904	16,095,800	9,377,000	4,101,800	5,249,000	**34.8**
1905	10,775,200	4,529,200	2,403,500	2,050,000	**19.8**

No comments

- n/a -

Table C-2 – Annual unimpaired Sacramento River runoff for 1906-2009

Data Source: http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST

Water Year	Sacramento River Runoff (MAF)	Water Year	Sacramento River Runoff (MAF)	Water Year	Sacramento River Runoff (MAF)	Water Year	Sacramento River Runoff (MAF)
1906	26.7	1936	17.4	1966	13.0	1996	22.3
1907	33.7	1937	13.3	1967	24.1	1997	25.4
1908	14.8	1938	31.8	1968	13.6	1998	31.4
1909	30.7	1939	8.2	1969	27.0	1999	21.2
1910	20.1	1940	22.4	1970	24.1	2000	18.9
1911	26.4	1941	27.1	1971	22.6	2001	9.8
1912	11.4	1942	25.2	1972	13.4	2002	14.6
1913	12.9	1943	21.1	1973	20.1	2003	19.3
1914	27.8	1944	10.4	1974	32.5	2004	16.0
1915	23.9	1945	15.1	1975	19.2	2005	18.6
1916	24.1	1946	17.6	1976	8.2	2006	32.1
1917	17.3	1947	10.4	1977	5.1	2007	10.3
1918	11.0	1948	15.8	1978	23.9	2008	10.3
1919	15.7	1949	12.0	1979	12.4	2009	12.9
1920	9.2	1950	14.4	1980	22.3		
1921	23.8	1951	23.0	1981	11.1		
1922	18.0	1952	28.6	1982	33.4		
1923	13.2	1953	20.1	1983	37.7		
1924	5.7	1954	17.4	1984	22.4		
1925	16.0	1955	11.0	1985	11.0		
1926	11.8	1956	29.9	1986	25.8		
1927	23.8	1957	14.9	1987	9.3		
1928	16.8	1958	29.7	1988	9.2		
1929	8.4	1959	12.1	1989	14.8		
1930	13.5	1960	13.1	1990	9.3		
1931	6.1	1961	12.0	1991	8.4		
1932	13.1	1962	15.1	1992	8.9		
1933	8.9	1963	23.0	1993	22.2		
1934	8.6	1964	10.9	1994	7.8		
1935	16.6	1965	25.6	1995	34.6		

No comments

- n/a -

Table C-3 – Annual unimpaired San Joaquin River runoff for 1872-1900
Data source: DPW (1923)

Water Year	Stanislaus River @ New Melones Lake	Tuolumne River @ New Don Pedro Reservoir	Merced River @ Lake McClure	San Joaquin River @ Millerton Lake	San Joaquin River Runoff
	units of acre-feet (AF)				units of million acre-feet (MAF)
1872	1,860,000	2,624,000	1,511,000	2,627,000	**8.6**
1873	959,000	1,543,000	769,000	1,122,000	**4.4**
1874	970,000	1,576,000	791,000	1,862,000	**5.2**
1875	482,000	982,000	439,000	887,000	**2.8**
1876	2,930,000	4,059,000	2,384,000	2,862,000	**12.2**
1877	408,900	561,000	220,000	809,000	**2.0**
1878	1,570,000	2,286,000	1,274,000	2,218,000	**7.3**
1879	823,000	1,353,000	659,000	470,000	**3.3**
1880	1,390,000	2,071,000	1,132,000	3,349,000	**7.9**
1881	970,000	1,576,000	791,000	2,740,000	**6.1**
1882	944,000	1,526,000	764,000	1,000,000	**4.2**
1883	1,020,000	1,600,000	813,000	1,392,000	**4.8**
1884	2,250,000	3,152,000	1,840,000	5,732,000	**13.0**
1885	582,000	1,097,000	505,000	1,218,000	**3.4**
1886	2,070,000	2,929,000	1,692,000	5,211,000	**11.9**
1887	619,000	1,139,000	538,000	1,479,000	**3.8**
1888	540,000	1,048,000	478,000	957,000	**3.0**
1889	718,000	1,262,000	599,000	1,574,000	**4.2**
1890	3,580,000	5,099,000	2,955,000	4,349,000	**16.0**
1891	959,000	1,543,000	769,000	1,227,000	**4.5**
1892	1,050,000	1,650,000	846,000	1,931,000	**5.5**
1893	2,150,000	3,036,000	1,758,000	1,914,000	**8.9**
1894	1,860,000	2,624,000	1,511,000	1,331,000	**7.3**
1895	2,700,000	3,795,000	2,236,000	2,786,700	**11.5**
1896	1,380,000	1,588,100	1,110,000	1,985,700	**6.1**
1897	1,920,000	2,437100	1,566,000	2,219,700	**8.1**
1898	498,000	960,500	450,000	922,300	**2.8**
1899	1,030,000	1,334,700	824,000	1,269,500	**4.5**
1900	1,350,000	1,628,100	1,099,000	1,343,000	**5.4**

No comments

- n/a -

Table C-4 – Annual unimpaired San Joaquin River runoff for 1901-2009
Data Source: http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST

Water Year	San Joaquin River Runoff (MAF)	Water Year	San Joaquin River Runoff (MAF)	Water Year	San Joaquin River Runoff (MAF)	Water Year	San Joaquin River Runoff (MAF)
1901	9.4	1931	1.7	1961	2.1	1991	3.2
1902	5.1	1932	6.6	1962	5.6	1992	2.6
1903	5.7	1933	3.3	1963	6.2	1993	8.4
1904	7.6	1934	2.3	1964	3.1	1994	2.5
1905	5.3	1935	6.4	1965	8.1	1995	12.3
1906	12.4	1936	6.5	1966	4.0	1996	7.2
1907	11.8	1937	6.5	1967	10.0	1997	9.5
1908	3.3	1938	11.2	1968	2.9	1998	10.4
1909	9.0	1939	2.9	1969	12.3	1999	5.9
1910	6.6	1940	6.6	1970	5.6	2000	5.9
1911	11.5	1941	7.9	1971	4.9	2001	3.2
1912	3.2	1942	7.4	1972	3.6	2002	4.1
1913	3.0	1943	7.3	1973	6.5	2003	4.9
1914	8.7	1944	3.9	1974	7.1	2004	3.8
1915	6.4	1945	6.6	1975	6.2	2005	9.2
1916	8.4	1946	5.7	1976	2.0	2006	10.4
1917	6.7	1947	3.4	1977	1.1	2007	2.5
1918	4.6	1948	4.2	1978	9.7	2008	3.5
1919	4.1	1949	3.8	1979	6.0	2009	5.0
1920	4.1	1950	4.7	1980	9.5		
1921	5.9	1951	7.3	1981	3.2		
1922	7.7	1952	9.3	1982	11.4		
1923	5.5	1953	4.4	1983	15.0		
1924	1.5	1954	4.3	1984	7.1		
1925	5.5	1955	3.5	1985	3.6		
1926	3.5	1956	9.7	1986	9.5		
1927	6.5	1957	4.3	1987	2.1		
1928	4.4	1958	8.4	1988	2.5		
1929	2.8	1959	3.0	1989	3.6		
1930	3.3	1960	3.0	1990	2.5		

No comments

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No comments

- n/a -

Appendix D. Instrumental Observations of Salinity

In Section 3, historical variations in the net quantity of water flowing from the Delta to the Suisun Bay (called net Delta outflow or NDO) and salinity in the western Delta were discussed using available observations and a suite of commonly used modeling tools. This section presents additional information on the historical variations of NDO and salinity in the western Delta and Suisun Bay discussed in Section 3.

D.1. Introduction

D.1.1. Salinity Units

Salinity is specified in this report either as electrical conductivity (EC, in units of microSiemens per centimeter, or µS/cm) or as a concentration of chloride in water (in units of milligrams of chloride per liter of water, or mg/L). Conversion between EC and chloride concentration is accomplished using site-specific empirical relationships developed by Kamyar Guivetchi (DWR, 1986). Table D-1 presents a sample of typical EC concentrations and their approximate equivalent chloride concentrations.

Table D-1 – Typical electrical conductivity (EC) and equivalent chloride concentration

Electrical Conductivity (µS/cm)	Chloride (mg/L)
350	50
525	100
1,050	250
1,900	500
2,640	700
3,600	1,000

Qualitative terms such as "fresh" and "brackish" are often used to describe relative salinity. The quantitative thresholds of average chloride concentration that distinguish fresh water from brackish water and the averaging time period vary among studies. For instance, chloride concentrations of 1,000 mg/L, 700 mg/L, and 50 mg/L have been used by different studies (Table D-2).

D.1.2. Temporal and Spatial Variability of Salinity

The main variability in salinity along the length of the Bay-Delta system is due to the gradient from saline Pacific Ocean water (EC of approximately 50,000 µS/cm) to fresh water of the Central Valley rivers (EC of approximately 100 µS/cm). However, the salinity in the Bay-Delta varies both in space and time. It is important to clarify which time scales and measurement locations are being used when comparing and discussing salinity trends.

No comments

- n/a -

Table D-2 – Metrics used to distinguish between "fresh" and "brackish" water

Description	Sample timing or averaging	Salinity Value	
		Chloride (mg/L)	EC (µS/cm)
Isohalines in Delta Atlas (DWR, 1995)	Annual maximum of the daily maximum	1,000 mg/L	3,700 µS/cm
X2 position (Jassby *et al.*, 1995)	Daily average (or a 14-day average)	700 mg/L	2,640 µS/cm
Barge travel by C&H[4]	Monthly average of the daily maximum	50 mg/L	350 µS/cm

Salinity in the western Delta is strongly influenced by tides. The hourly or daily variability of salinity can be much larger than the seasonal or annual variability. For instance, during the fall of 1999 (following a relatively wet year[5]), hourly EC in the San Joaquin River at Antioch varied by about 6,000 µS/cm (from about 3,000 µS/cm to 9,000 µS/cm) while the daily-averaged EC for all of 1999 ranged from about 100 µS/cm to 6,000 µS/cm (Figure D-1).

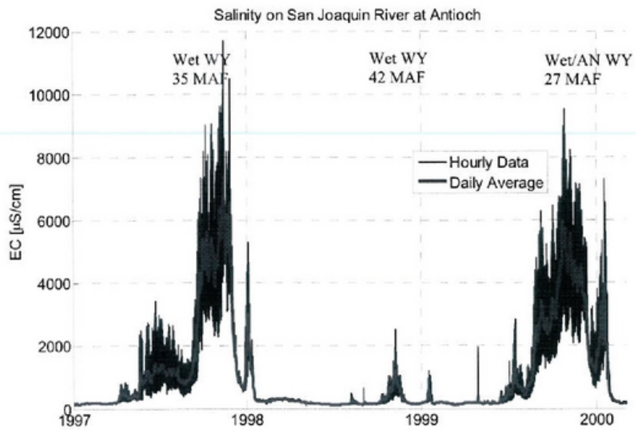

Figure D-1 – Hourly and daily salinity variability in the San Joaquin River at Antioch
Total annual unimpaired Sacramento River flow and water year type is indicated for each water year.
Data Source: IEP Data Vaults (http://www.iep.ca.gov/dss/)

[4] The California & Hawaiian Sugar Refining Corporation in Crockett (C&H) obtained its freshwater supply from barges traveling up the Sacramento and San Joaquin Rivers, generally twice a day beginning in 1908 (DPW, 1931).
[5] Water year 1999 was classified as wet using the Sacramento Valley 40-30-30 index and above-normal using the San Joaquin Valley 60-20-20 index; indices are defined in D-1641.

No comments

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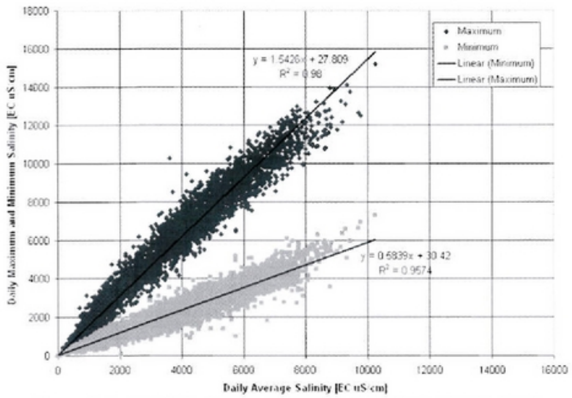

Figure D-2 – Tidal Variability in Salinity at Antioch (1967 to 1992)
Data Source: IEP Data Vaults (http://www.iep.ca.gov/dss/)

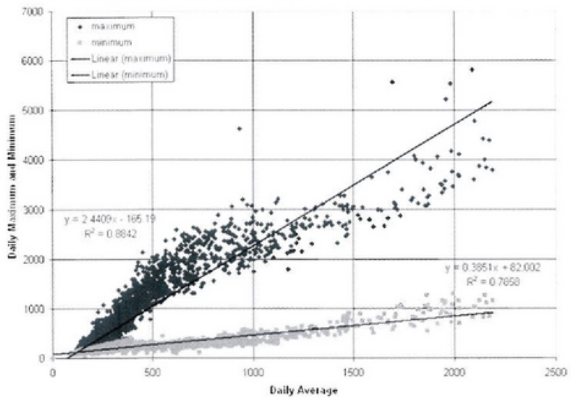

Figure D-3 – Tidal Variability in Salinity at Rio Vista (1967 to 1992)
Data Source: IEP Data Vaults (http://www.iep.ca.gov/dss/)

No comments

- n/a -

The high tide maximum, low tide minimum, and daily-averaged salinity at a given location are very different. As shown in Figure D-2, the daily maximum salinity in the San Joaquin River at Antioch can be double the daily-averaged salinity. Because of the large tidal variability in salinity, any comparisons of salinity observations should be at the same phase of the tide, or at least take into account tidal variability.

Similarly, as shown in Figure D-3, the daily maximum salinity in the Sacramento River at Rio Vista can be 170-400% of the daily average salinity. The daily minimum at Rio Vista may be 10-65% of the daily average.

D.2. *Variations in the Spatial Salinity Distribution*

Observations examined in this section and Section 3.3 include records from the early 1900's from the California & Hawaiian Sugar Refining Corporation in Crockett (C&H) and the long-term monitoring data from the Interagency Ecological Program (IEP). Estimates of salinity at specific locations of interest were obtained from DWR's DSM2 model and Contra Costa Water District's salinity-outflow model (also known as the G-model) (Denton, 1993). Estimates of salinity intrusion were obtained using the K-M equation (Kimmerer and Monismith, 1992).

D.2.1. Distance to Freshwater from Crockett

The California & Hawaiian Sugar Refining Corporation in Crockett (C&H) obtained its freshwater supply from barges traveling up the Sacramento and San Joaquin Rivers, generally twice a day beginning in 1905 through 1929 or later (DPW, 1931). The salinity information recorded by C&H is the most detailed salinity record available prior to the intensive salinity monitoring by the State of California, which started in 1920. This section presents a comparison of the salinity observations of C&H with recent monitoring data and modeling results to determine how the managed salinity regime of the late 20th Century compares to the salinity regime of the early 1900's.

Data Sources and Methods

C&H data: C&H operations required water with less than 50 mg/L chloride concentration. According to DPW (1931), the C&H barges typically traveled up the river on flood tide and returned downstream on ebb tide. Since the maximum daily salinity for a given location in the river channel typically occurs about one to two hours after high slack tide, the distance traveled by the C&H barges represents approximately the daily maximum distance to 50 mg/L water from Crockett. The monthly minimum, average, and maximum distance traveled by C&H barges are shown in Figure D-4 and Figure D-5. For the following analysis, monthly averages of the C&H daily maximum distances were extracted from Figure D-5 for the period of 1908-1918 (after 1917, extensive salinity intrusion was reported and agricultural diversions reportedly started affecting flows into the Delta).

No comments

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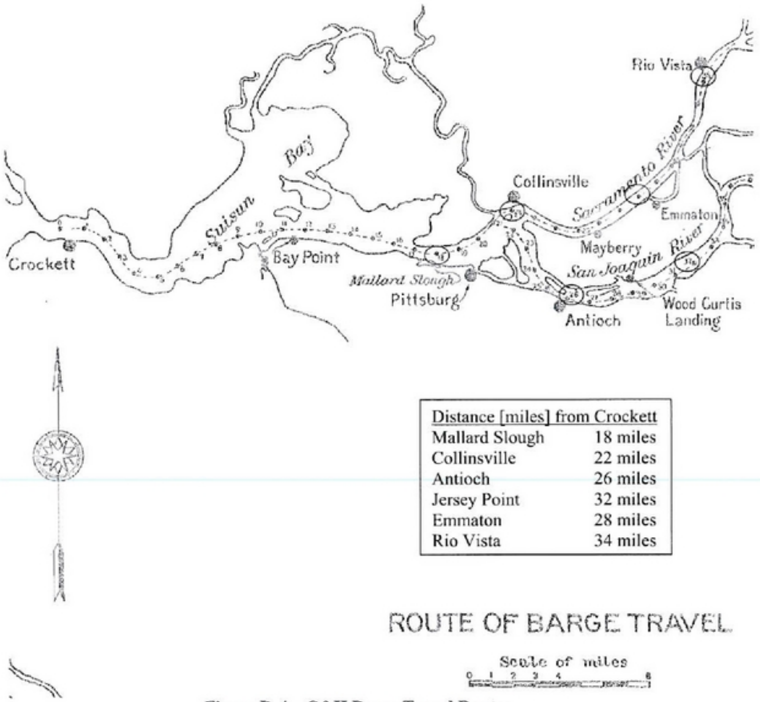

Distance [miles] from Crockett	
Mallard Slough	18 miles
Collinsville	22 miles
Antioch	26 miles
Jersey Point	32 miles
Emmaton	28 miles
Rio Vista	34 miles

Figure D-4 – C&H Barge Travel Routes

Map adapted from DPW (1931). Red circles indicate locations of landmarks, with distance from Crockett listed in the inset box.

No comments

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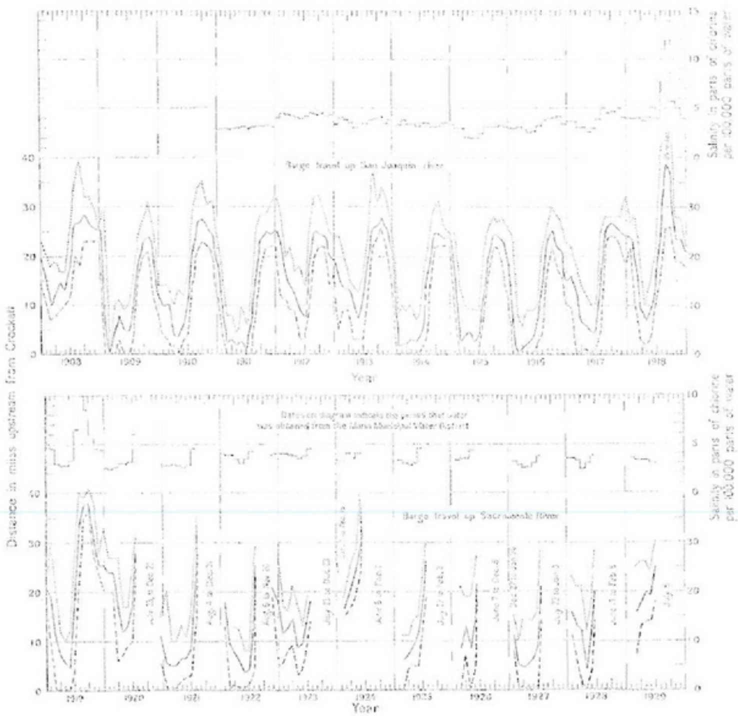

Figure D-5 – C&H Barge Travel and Quality of Water obtained

C&H barge travel up the San Joaquin River (1908 through 1918, top panel) and Sacramento River (1919 through 1929, bottom panel). The lower three lines on each panel (reference to the left axes) indicate the monthly minimum (dashed line), monthly maximum (dotted line), and monthly average (solid line) distance traveled by C&H barges to obtain their fresh water supply. The uppermost solid line on each panel (reference to the right axes) indicates the average monthly salinity of the water obtained by the barges. Figure adapted from DPW (1931)

From 1908 through 1917, C&H was able to obtain water with less than 50 mg/L chlorides within 30 miles of Crockett on average (below Jersey Point on the San Joaquin River). In 1918, the salinity of the water obtained by C&H barges had increased due to a combination of a lack of precipitation and upstream diversions (especially for newly introduced rice cultivation) (DPW, 1931). During August and September 1918, salinity exceeded 60 mg/L chloride, and the C&H barges traveled farther upstream than any time previously recorded.

No comments

- n/a -

In 1919, a wetter year than 1918, salinity was high for an even longer period of time, most likely due to increased upstream diversions for irrigation. Salinity exceeded 60 mg/L chloride during July, August, and September. Beginning in 1920, C&H abandoned the Sacramento and San Joaquin Rivers during the summer and fall seasons, replacing the water supply with a contract from Marin County. However, even during the driest years of the 1920's, C&H obtained water with less than 50 mg/L chloride below the confluence of the Sacramento and San Joaquin Rivers during a portion of every year.

Salinity observations from the Interagency Ecological Program (IEP): Long-term monitoring of electrical conductivity (EC) at multiple stations within the Bay and Delta began around 1964. Publicly-available daily-averaged data were obtained for this analysis from the Interagency Ecological Program (IEP) data vaults (Table D-3).

Table D-3 – Overview of long-term salinity observation records from IEP
(see http://www.iep.ca.gov/dss/)

Location	*Station*	*Source*	*Data*
Selby	RSAC045	USGS-BAY	Historical
Martinez	RSAC054	CDEC	Real-time
Benicia Bridge	RSAC056	USBR-CVO	Historical
Port Chicago	RSAC064	USBR-CVO	Historical
Mallard	RSAC075	CDEC	Real-time
Pittsburg	RSAC077	USBR-CVO	Historical
Collinsville	RSAC081	USBR-CVO	Historical
Emmaton	RSAC092	USBR-CVO	Historical
Rio Vista	RSAC101	USBR-CVO	Historical
Georgiana Slough	RSAC123	DWR-ESO-D1485C DWR-CD-SURFWATER	Historical Historical
Greens Landing	RSAC139	USBR-CVO	Historical
Antioch	RSAN008	USBR-CVO	Historical
Jersey Pont	RSAN018	USBR-CVO	Historical
Bradford Point	RSAN024	USBR-CVO	Historical
San Andreas Landing	RSAN032	USBR-CVO	Historical

Delta Simulation Model (DSM2) Historical Simulation: The DSM2 historical simulation (1989-2006) was used to provide estimates of water quality to complement the limited field data from IEP. Because DSM2 has a very detailed spatial computational network covering the Delta and Suisun Bay, DSM2 can output much more detailed spatial and temporal salinity information than just the water quality at the IEP monitoring stations. DSM2 results include the daily-averaged EC at each model node along the lower Sacramento and San Joaquin Rivers. The location of the 350 μS/cm EC isohaline (corresponding to 50 mg/L chloride) was identified from the DSM2 results and compared with the equivalent C&H and IEP data.

No comments

- n/a -

Analysis time frame: The first decade of C&H barge travel (1908-1917) was a relatively wet period compared to the entire period of record (1906-2006) (Figure D-6). To compare conditions under similar hydrological conditions, specific recent decades (Figure D-6(a)) and select recent years (Figure D-6(b)) were selected that have comparable or slightly wetter hydrology than the C&H years. The periods 1966-1975 and 1995-2004 have similar annual unimpaired Sacramento River flow to the C&H data period (1908-1917) (see Figure D-6(a)). In addition, two wet years (1911 and 1916) and two dry years (1913 and 1918) selected from the C&H time period were compared with two wet years (1969 and 1998) and two dry years (1968 and 2002) from the IEP record.

Limitations of the analysis: The C&H data approximately represent the maximum daily salinity at a given location, whereas recent conditions (IEP or DSM2 data) are represented by the daily-averaged salinity. The estimates of the distance that must be traveled to reach fresh water under current conditions are, therefore, underestimated.

In addition, the C&H barges traveled up the San Joaquin River from 1908 through 1917, yet the equivalent travel distance for C&H barges under current conditions are estimated for the Sacramento River, and not the San Joaquin River. Under present-day conditions, the upstream distance to fresh water on the San Joaquin River is greater than for the Sacramento River, so this approach will also serve to underestimate the actual distance that C&H barges would have to travel under present-day conditions.

No comments

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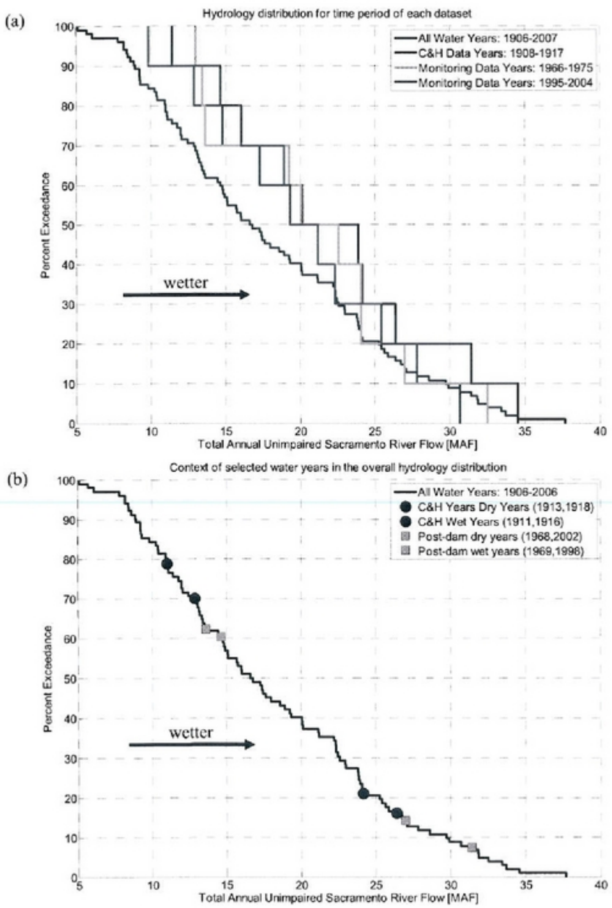


Figure D-6 – Hydrologic Context for Analysis of Distance to Fresh Water

(a) Hydrology distribution for water years 1906 to 2007, and select decades.

(b) Hydrology distribution for water years 1906 to 2007, with select water years shown for context.

No comments

- n/a -

Results and Discussion

Selected Wet Years

As shown in Figure D-7, the salinity patterns during the two selected C&H-era wet years, 1911 and 1916, are similar to each other. During these wet years, the location of 50 mg/L chloride water is west of Martinez for about 4-5 months (late February to early August in 1911 and from early February to late June in 1916). In contrast, during recent wet years 1969 and 1998, water with 50 mg/L chlorides or less was west of Martinez for only about 6 weeks in February and March. This comparison shows that in 1969 and 1998 the western Delta was saltier in the fall and spring than it was in 1911 and 1916, and salinity intrusion occurred much earlier in 1969 and 1998.

If barges were still traveling up the Sacramento River today to find fresh water, they would have to travel farther during the fall, spring, and summer than the C&H barges traveled during similar wet years. In 1916, fresh water retreated upstream about one month earlier than in 1911, possibly influenced by the increasing upstream diversions during 1911-1916 (see Figure 1-3). In recent years with even greater unimpaired runoff, fresh water retreats two to three months earlier than in 1916. Additionally, fresh water reaches Martinez for a much shorter period of time, about less than one month in recent years compared to four and five months during 1916 and 1911, respectively.

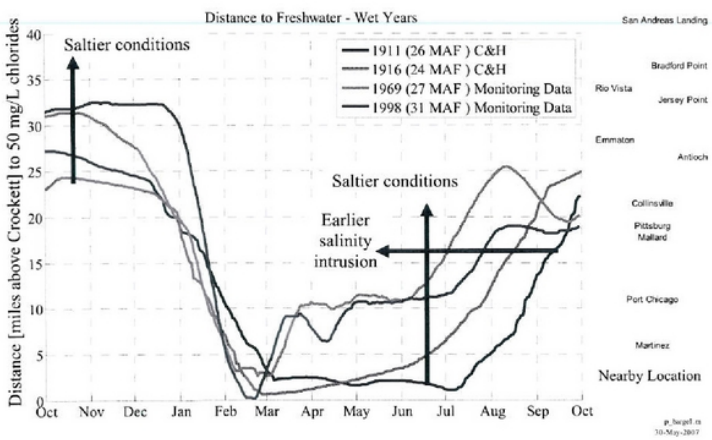


Figure D-7 – Distance to Fresh Water in Select Wet Years

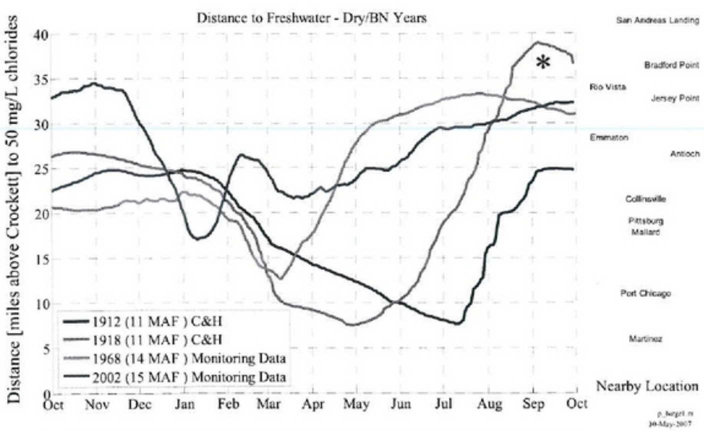
No comments

- n/a -

Selected Dry Years

Figure D-8 shows that the most visible difference between the distance to fresh water in dry years of the early 1900's and more recent dry years is the substantial increase in distance to fresh water, particularly from April through June. This indicates the spring was much fresher during the dry years of the early 1900's, before large upstream reservoirs were built to capture the spring runoff. In dry and below-normal water years under today's conditions, barges would have to travel farther during spring, summer and fall than they traveled in the early 20th Century.

The C&H barge travel distance in the dry years of 1913 and 1918 are quite different, especially the additional 10 miles of distance to fresh water traveled in August and September of 1918. C&H recorded relatively high salinity (greater than 110 mg/L chlorides) above Bradford Point on the San Joaquin in 1918, which is greater than observed salinity on the Sacramento River near Rio Vista in similar water years. This may be partially explained by the development of the rice cultivation industry around 1912 (DPW, 1931) and increased upstream diversions when seasonal river flows were already low.



* During August and September 1918, average water quality obtained by C&H exceeded 110 mg/L chlorides

Figure D-8 – Distance to Fresh water in Select Dry or Below Normal Years

Figure D-9 shows the exceedance probabilities for distance traveled up the Sacramento River for different salinity levels. During 1908-1917, on a monthly-averaged basis, C&H barges had to travel above the confluence of the Sacramento and San Joaquin Rivers (approximately 22 miles above Crockett) about 26% of this time period to reach water with salinity less than

No comments

\- n/a -

350 μS/cm EC (about 50 mg/L chlorides). In contrast, from 1995-2006, DSM2 simulations suggest that barges would have to travel above the confluence approximately 56% of the time to reach water with salinity of 350 μS/cm EC.

The location of the 50 mg/L chloride isohaline during 1908-1917 approximately corresponds to the location of X2 (2,640 μS/cm EC, or 700 mg/L chlorides) during 1995-2006 (Figure D-9). This is equivalent to more than a 7-fold increase in salinity from the early 1900's to the present day.

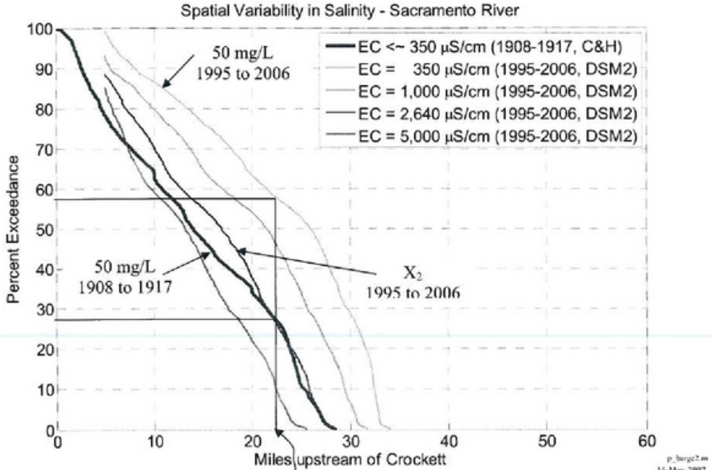


Figure D-9 – Distance along the Sacramento River to Specific Salinity Values

No comments

- n/a -

D.2.2. Maximum Annual Salinity Intrusion Before and After Large-scale Reservoir Construction

Figure D-10 shows maximum salinity intrusion during 1921-1943 (pre-CVP period), prior to the completion of the Shasta Dam of the Central Valley Project in 1945. Salinity intrusion is presented in terms of contours of 1,000 mg/L chlorides. Figure D-11 shows the maximum salinity intrusion during the post-CVP period of 1944-1990. These figures indicate the pre-CVP period experienced greater salinity intrusion than the post-CVP period, with seawater intruding farther into the Delta during 6 of the 24 pre-CVP years (1920, 1924, 1926, 1931, 1934, and 1939) than in any of the 47 years in the post-CVP period (1944-1990).

The extreme salinity intrusion during the pre-CVP period was due, in part, to relatively low runoff during these years. Meko *et al.* (2001a) determined that the period from 1917 through 1936 was the driest 20-year period in the past 400 years; this long-term drought encompassed 16 of the 24 years in the pre-CVP period. In addition, estimates of unimpaired runoff from the Sacramento River (obtained from http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST) indicate that the Sacramento River had 6 critical water years during the 24-year period of 1920-1943, whereas, the Sacramento River had only 4 critical water years during the 47-year period of 1944-1990.

Figure D-12 shows that the peak salinity intrusion during the pre-CVP period occurred between mid-August and mid-September, while peak salinity intrusion during the first portion of the the post-CVP period (1944-1960) occurred between late-July and late-August. Salinity intrusion during the pre-CVP period was not only affected by relatively low runoff, but also by extensive upstream diversions (DPW, 1931).

The salinity investigations of the pre-CVP era found that the extreme salinity intrusion was larger than any previous intrusions known to local residents and concluded the intrusion was due, in part, to the extensive upstream diversions. As observed in DPW (1931):

> "Under conditions of natural stream flow before upstream irrigation and storage developments occurred, the extent of saline invasion and the degree of salinity reached was much smaller than during the last ten to fifteen years." (DPW, 1931, page 15)

> "Beginning in 1917, there has been an almost unbroken succession of subnormal years of precipitation and stream flow which, in combination with increased irrigation and storage diversions from the upper Sacramento and San Joaquin River systems, has resulted in a degree and extent of saline invasion greater than has occurred ever before as far as known." (DPW, 1931, page 15)

> "The abnormal degree and extent of saline invasion into the delta during recent years since 1917 have been due chiefly to: first, subnormal precipitation and run-off with a subnormal amount of stream flow naturally available to the delta, and second, increased upstream diversions

No comments

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for irrigation and storage on the Sacramento and San Joaquin River systems, reducing the inflow naturally available to the delta. It is probable that the degree of salinity in the lower channels of the delta and the extent of saline invasion above the confluence of the Sacramento and San Joaquin rivers have been about doubled by reason of the second factor." (DPW, 1931, page 42)

Conclusions from DPW (1931) and similar investigations have been corroborated by paleosalinty studies (see Section 2.3), which indicate that Browns Island in the western Delta was a freshwater marsh for approximately 2,500 years until salinity intruded in the early 20th Century.

No comments

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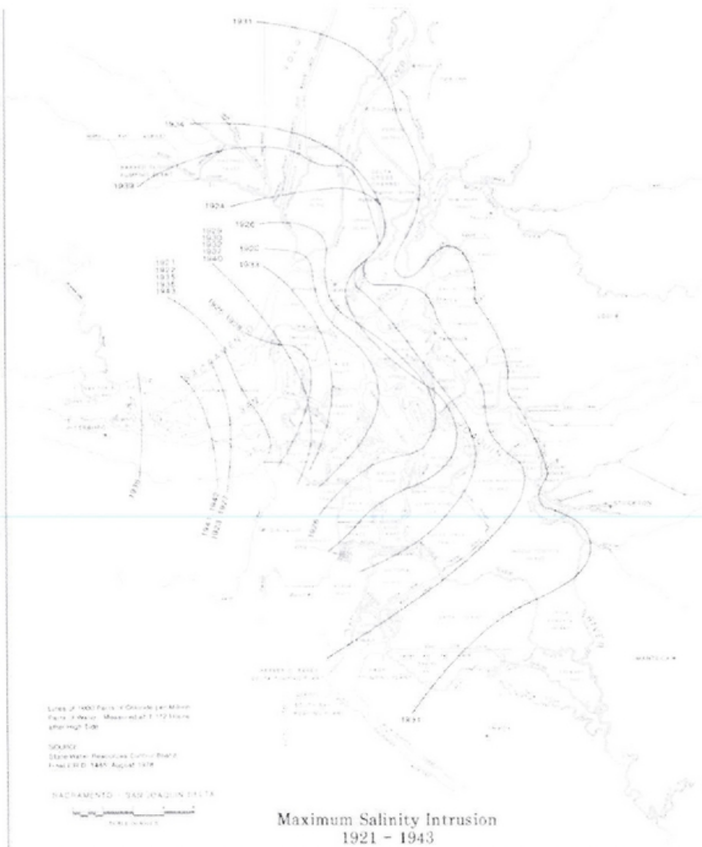

Figure D-10 – Salinity intrusion during pre-CVP period, 1921-1943 (DWR, 1995)

No comments

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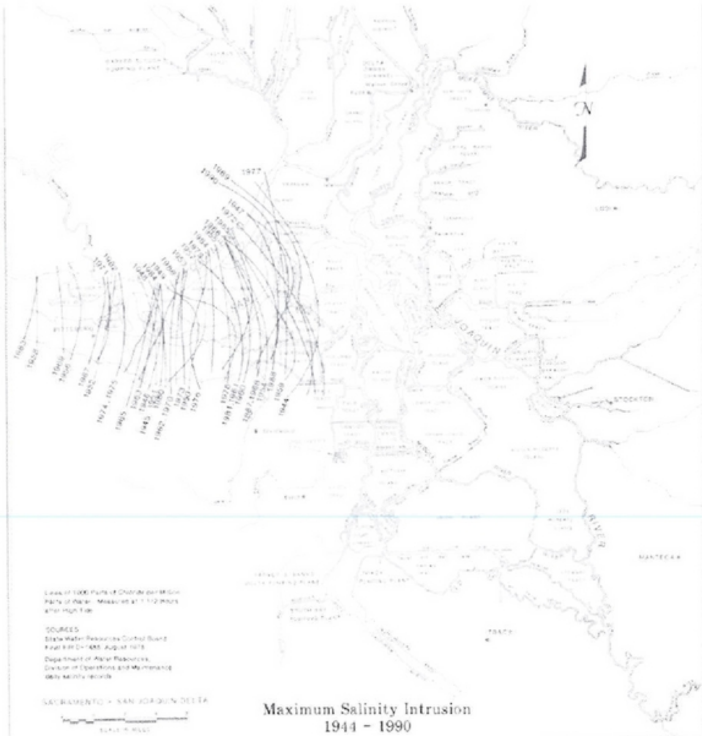

Figure D-11 – Salinity intrusion during post-CVP period, 1944-1990 (DWR, 1995)

No comments

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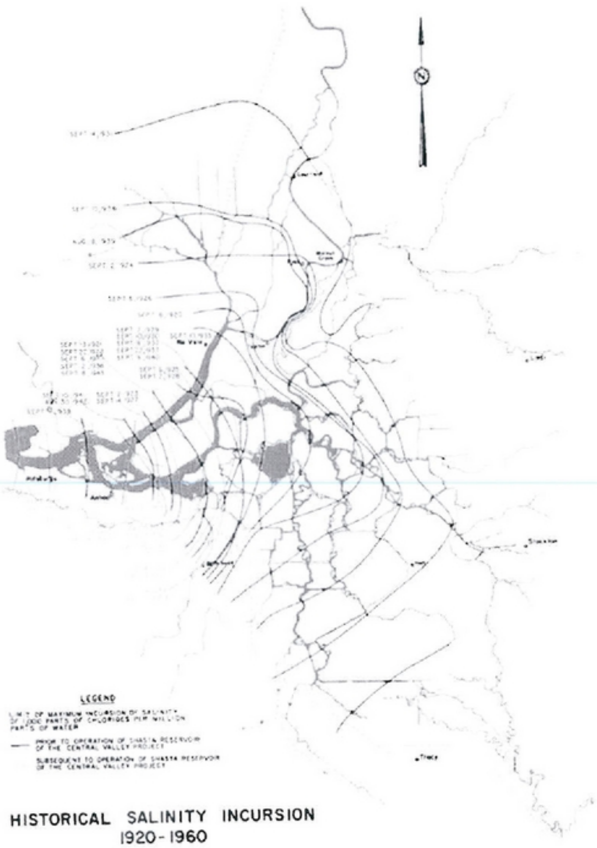

Figure D-12 – Salinity intrusion during 1920-1960 (DWR, 1960)

No comments

- n/a -

Figure D-13 illustrates the maximum annual salinity intrusion for comparable dry years[6]. Water year 1913 experienced the least extent of intrusion, most likely because upstream diversions were significantly less than in later years. Water years 1926 and 1932 were subject to extensive upstream agricultural diversions, while water years 1979 and 2002 had the benefit of the CVP and SWP to provide "salinity control". The CVP and SWP operations now regulate the amount of freshwater flowing through the Delta in order to prevent extreme salinity intrusions such as those observed during the 1920's and 1930's.

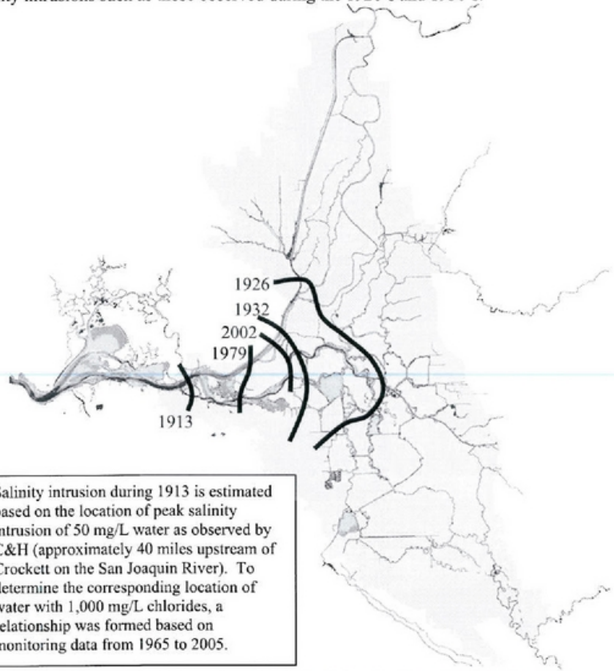

Figure D-13 – Annual Maximum Salinity Intrusion for relatively dry years

Salinity intrusion for relatively dry water years with similar total annual unimpaired runoff, using 1,000 mg/L chloride concentration to distinguish the extent of intrusion.

[6] Hydrological metrics from http://cdec.water.ca.gov/cgi-progs/iodir/wsihist for comparison: total unimpaired Sacramento River and San Joaquin River flow for water years 1913, 1926, 1932, 1979, and 2002 was 15.9 MAF, 15.3 MAF, 19.8 MAF, 18.4 MAF, and 18.7 MAF, respectively; Sacramento River water year type index for water years 1913, 1926, 1932, 1979, and 2002 was 6.24, 5.75, 5.48, 6.67, and 6.35, respectively; and San Joaquin River water year type index for water years 1913, 1979, and 2002 was 2.00, 2.30, 3.41, 3.67, and 2.34, respectively.

No comments

- n/a -

D.3. *Temporal Variability of Salinity in the Western Delta*

D.3.1. Seasonal Salinity at Collinsville

Collinsville, near the confluence of the Sacramento and San Joaquin Rivers, was one of the first long-term sampling locations implemented by the State of California. The Suisun Marsh Branch[7] of the DWR estimated monthly average salinity at Collinsville for the period 1920-2002, using a combination of 4-day TDS (total dissolved solids) grab samples from 1920-1971 and EC measurements from 1966-2002. Data from the overlap period of 5 years between the TDS grab samples and EC measurements were used in a statistical regression model, and the monthly averaged 4-day TDS samples were converted to monthly average EC (Enright, 2004). The result of this regression analysis was a time series of monthly EC values at Collinsville for the period of 1920-2002.

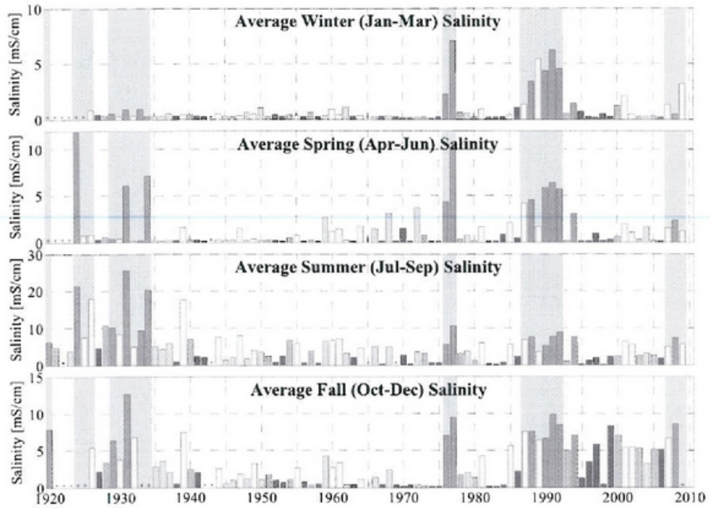

Figure D-14 – Average Seasonal Salinity at Collinsville

[7] Data provided by Chris Enright (DWR), personal communication, 2007.

No comments

- n/a -

D.3.2. Effects of Water Management on Salinity at Collinsville

In order to compare the effects of water management on salinity at Collinsville, an empirical model of salinity transport (Denton (1993), Denton and Sullivan (1993)) was used in the following analyses. Contra Costa Water District's salinity-outflow model (also known as the G-model) estimates salinity in the western Delta as a function of NDO. Estimates of salinity at Collinsville were derived for both actual historical flow (1930-2008) and unimpaired flow (1922-2003) conditions.

Figure D-15 shows the estimated monthly-averaged salinity at Collinsville under unimpaired and actual historical flow conditions. The predicted seasonal and annual variations of EC at Collinsville are dependent on corresponding variations of NDO under both unimpaired and actual flow conditions. Water management practices have a significant effect on the seasonal variability of salinity at Collinsville, particularly during dry years (1930's, 1976-1977 and 1987-1993), when Collinsville experiences a much greater range of monthly-averaged salinity under actual historical conditions than would be the case under unimpaired conditions.

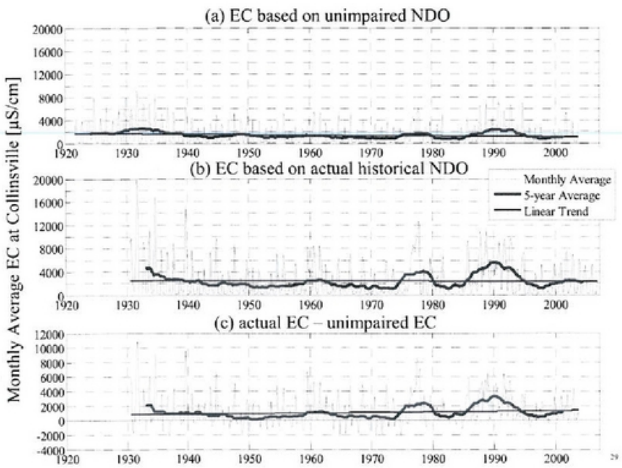

Figure D-15 – Estimates of Collinsville salinity using the G-model for unimpaired and actual historical flow conditions

Historical (actual) NDO during the 1930's was relatively low, sometimes averaging about -3,000 cfs for several months under actual conditions. The low values of NDO result in the high variability of estimated salinity in the 1930's under actual historical conditions.

No comments

- n/a -

The effects of water management on salinity at Collinsville are highlighted in Figure D-16, which shows the estimated salinity under actual historical conditions as a percent change from the unimpaired conditions. The data in Figure D-16 are the change in G-model estimates of salinity at Collinsville for the period of 1956-2003, computed as the difference between actual and unimpaired salinity as a percent change from the unimpaired salinity. Positive values indicate an increase in salinity under actual conditions and negative values indicate a decrease in salinity (freshening).

From April through August, estimated median salinity under actual historical conditions is substantially greater (more than a 100% increase) than median salinity under unimpaired conditions (Figure D-16). For the remainder of the year, there are no substantial differences between the estimates of median salinity under unimpaired and actual conditions. These distributions of estimated salinity indicate that water management practices result in significant increase in salinity throughout the year at Collinsville.

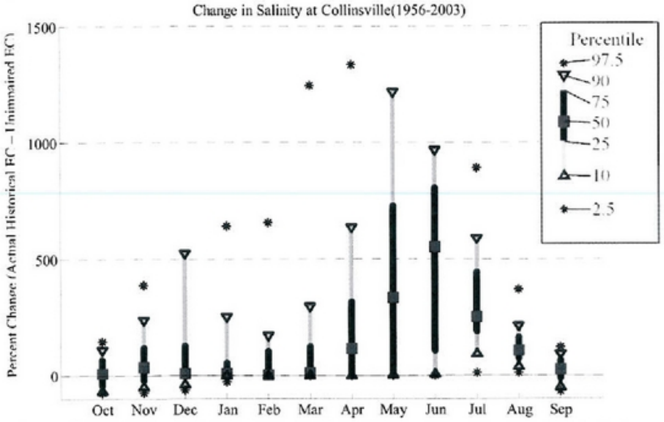

Figure D-16 – Estimated change in salinity at Collinsville under actual historical conditions, as a percent change from unimpaired conditions, 1956-2003

Figure D-17 shows the estimated salinities at Collinsville under actual historical and unimpaired conditions for just the more recent years (1994-2003). Positive values again indicate an increase in salinity under actual conditions and negative values indicate a decrease in salinity. The effects of water management on fall salinity are greater during this recent period 1994-2003 than during the longer period (1956-2003), but the effects during the recent period in the spring and early summer are smaller. This response reflects implementation of the X2 regulatory requirements agreed upon in the 1994 Bay-Delta Accord and regulated by the subsequent 1995 Water Quality Control Plan.

No comments

- n/a -

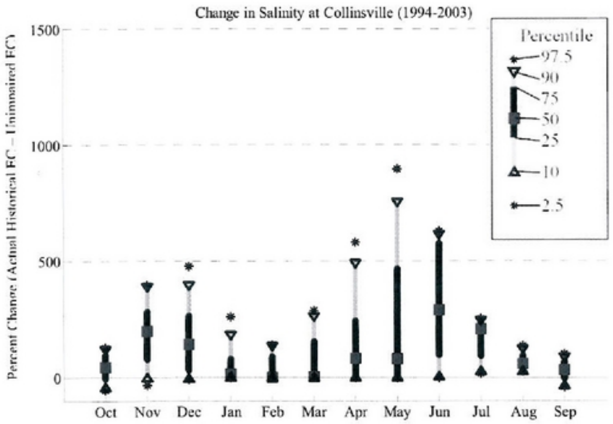

Figure D-17 – Estimated change in salinity at Collinsville under actual historical conditions, as a percent change from unimpaired conditions, 1994-2003

D.3.3. Fall Salinity in the Western Delta

Figure D-18 shows the average fall salinity (October-December) at three stations in Suisun Bay and the western Delta (Chipps Island, Collinsville, and Jersey Point). The fall salinity data categorized according to the pre-Endangered Species Act (ESA) period of 1964-1992 and the post-ESA period (1993-2006)[8]. Figure D-18 illustrates that there has been a noticeable increase in fall salinity since the release of the ESA biological opinions for winter-run salmon and Delta smelt in 1993. These increases occur during normal water years, when total annual runoff ranges from 15 to 30 MAF. During very wet years, there are large Delta outflows and the ESA limits do not affect water operations. Similarly, during very dry years, the biological opinions do not have a large effect on water operations because upstream reservoir storage is low and exports from the south Delta are already small.

[8] In 1993, delta smelt and winter-run salmon were listed under the California ESA, triggering new water management regulations.

No comments

- n/a -

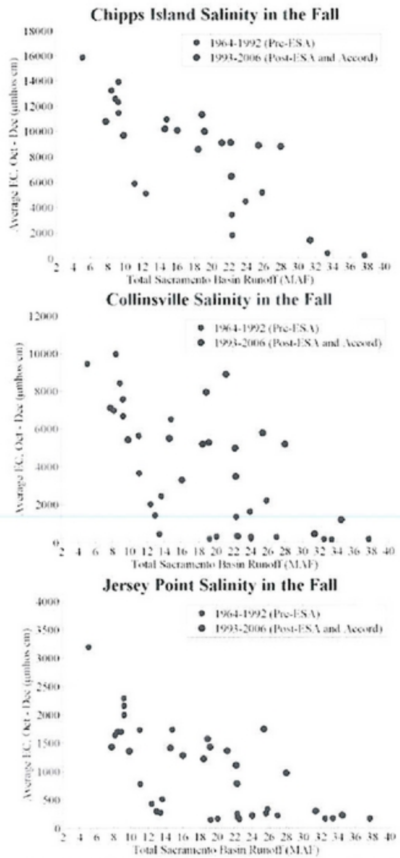

Figure D-18 – Post-ESA salinity in the Suisun Bay and western Delta

Figure D-19 shows the observed salinity at Chipps Island during the fall (October-December) for the period of 1976-1992 (pre-ESA) and 1993-2005 (post-ESA). Fall salinity at Chipps

No comments

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Island during normal years is now comparable to fall salinity during dry and critical years prior to 1994.

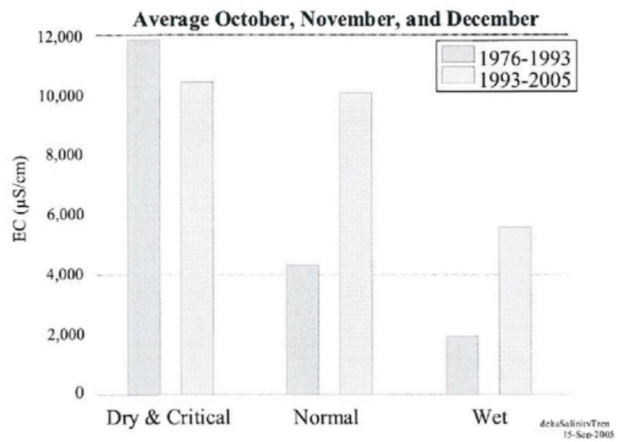

Figure D-19 – Increase in Fall Salinity at Chipps Island

D.4. General conceptual overview of salinity changes

Observed changes in seasonal salinity with time

The salinity regime in the western Delta has changed as the level of development has increased and water project operations have changed due to regulatory requirements. The comparison of three decades with similar hydrology in Figure D-20 presents a conceptual illustration of the changing salinity regime in Suisun Bay and the western Delta.

Monthly-averaged salinity in the spring and summer was substantially greater from 1966 through 1975 than during the early 1900's. However, fall and early winter salinity was lower than the early 1900's. This reduction in salinity in the fall and early winter was likely due in part to CVP and SWP reservoir releases for flood control purposes in the fall, which freshened the Delta. Flood control releases during this period were large because CVP and SWP diversions and exports were not fully developed and upstream reservoirs were often above flood control maximum storage levels in the fall, entering the wet season.

Salinity during 1995 through 2004, however, exceeded the salinities in the early 1900's during all months, for years with similar hydrologic conditions. The dramatic increase in fall

No comments

- n/a -

salinity relative to observed levels from 1966 to 1975 is accompanied by a slight decrease in spring and summer salinity. This is likely due to minimum flow and X2 requirements imposed by the State Water Resources Board in 1995. However, spring and summer salinities remain much greater relative to salinity in the early 1900's.

The range of seasonal variability during 1966-1975 was greatly reduced because the Delta did not get as fresh as it did in the early 1900's. During the last decade, seasonal variability has increased such that the range of salinity observed in the Delta over the course of a year is similar to that in the early 1900's. However, salinity intrusion has moved inland relative to the early 1900's, resulting in saltier conditions in the Suisun Bay and western Delta and a reduction in the period when fresher water is available.

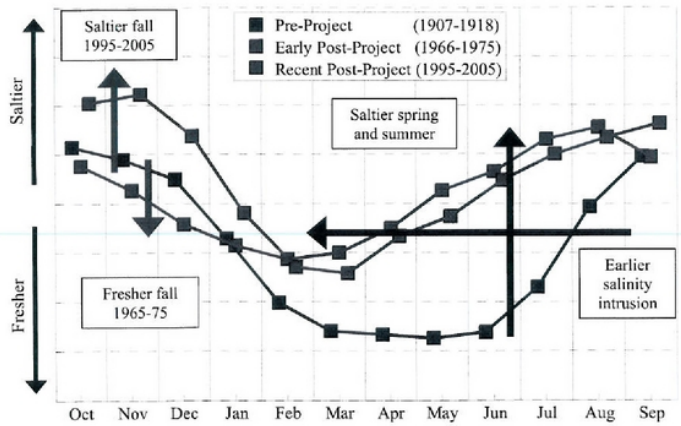

Figure D-20 – Conceptual plot of seasonal variability of salinity in Suisun Bay and the western Delta during different water management eras

The effect of water management for wet and dry years

Water management has the largest effect during dry years when the Delta stays relatively salty throughout the year with limited seasonal variability compared to unimpaired conditions. As shown conceptually in Figure D-21, during wet years the Delta freshens as much as it would under unimpaired conditions, but the Delta does not stay fresh for as long.

No comments

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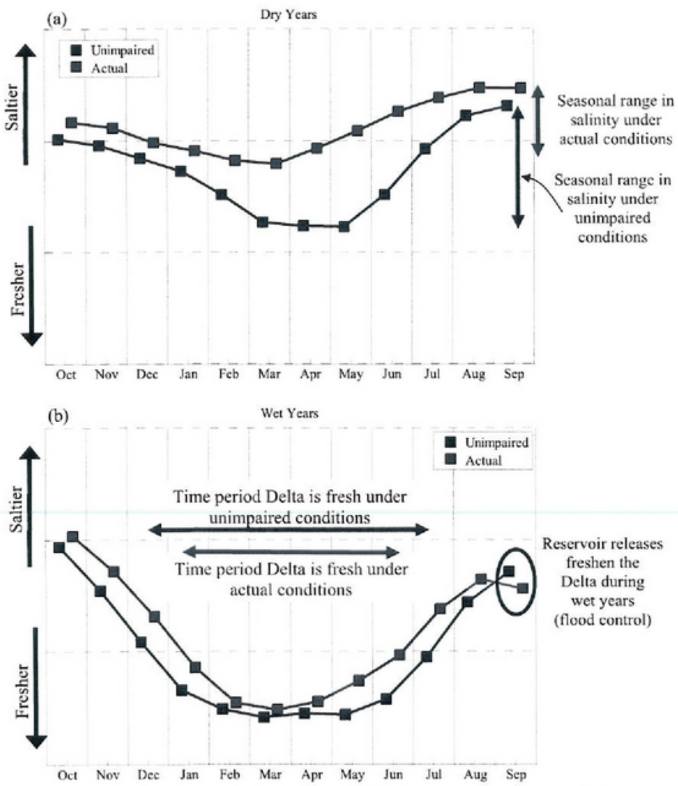

Figure D-21 – Conceptual plot of seasonal salinity variations in the Delta under actual historical conditions compared to unimpaired conditions in (a) dry years and (b) wet years

No comments

- n/a -

Appendix E. Qualitative Salinity Observations

The earliest written accounts of explorers were often concerned with adequate drinking water, and salinity was generally described in qualitative terms, such as "brackish," "fresh," or "sweet." For the purposes of comparing the present-day water quality with the historical conditions, these qualitative observations need to be quantified.

Testimony from Antioch Case (Town of Antioch v. Williams Irrigation District, 188 Cal. 451) indicated early settlers required water with less than 100 mg/L of chloride (approximately 525 µS/cm EC) for municipal use.[9] Similarly, DPW (1931) indicated that a "noticeable" level of salinity was 100 mg/L chloride. The current secondary water quality standard for municipal and industrial use is 250 mg/L chloride (1,000 µS/cm EC) (SWRCB 2006; US EPA 2003). This report assumes a value of 250 mg/L chloride (equivalent to 1000 µS/cm EC) to be the demarcation between "fresh" (or "sweet") water and "brackish" water.

E.1. Observations from Early Explorers

Table E-1 summarizes some reported observations of water quality made by early explorers and settlers. These observations were qualitative and were most likely only a glimpse of the ambient conditions and may not completely represent true historical water quality conditions. Moreover, these observations were from a time period when anthropogenic effects on this region were minimal and this region was close to natural conditions.

Table E-1 also lists the reconstructed Sacramento River annual flow (MAF) from Meko *et al.* (2001b) for the year of observation and for the previous year. For reference, the average Sacramento River flow from Meko *et al.* (2001b) for the period 1860-1977 is 18 MAF/yr.

Table E-1 – Qualitative salinity observations from early explorers

Date	Location	Description	Year / Reconstructed Flow [MAF]	Observer	Reference
1775 August	near the Sacramento-San Joaquin confluence	sweet, the same as in a lake	1774 / 25 1775 / 19	Canizares	Britton, 1987 in Fox, 1987b
1776 April	near Antioch (San Joaquin River)	very clear, fresh, sweet, and good	1775 / 19 1776 / 9	Font	Britton, 1987 in Fox, 1987b
1776 September	near the Sacramento-San Joaquin confluence	sweet	1775 / 19 1776 / 9	Canizares	Britton, 1987 in Fox, 1987b

[9] Supplement to Respondent's Answering Brief, p. 10.

No comments

- n/a -

Date	Location	Description	Year / Reconstructed Flow [MAF]	Observer	Reference
1796	unknown	salinity "far upstream" at high tide	1795 / 6 1796 / 10	Hermengildo Sal	Cook, 1960 in TBI, 1998
1811 October	near the Sacramento-San Joaquin confluence	sweet	1810 / 19 1811 / 23	Abella	Britton, 1987 in Fox, 1987b
1841 August	Three Mile Slough north of Emmaton	brackish (undrinkable)	1840 / 16 1841 / 6	Wilkes	Britton, 1987 in Fox 1987b

E.1.1. Fresh Conditions

Table E-1 indicates that some early explorers observed "sweet" water near the confluence of the Sacramento and San Joaquin Rivers both in relatively wet years (August of 1775 and October of 1811, reconstructed runoff about 19 MAF/yr) and in relatively dry years (September of 1776, reconstructed runoff about 9 MAF/yr). Except as noted, it is unknown whether these observations were made at high tide or low tide.

In order to provide a context for these anecdotal observations, present-day observed monthly salinity (EC) conditions at Collinsville (located near the confluence of Sacramento and San Joaquin Rivers) are plotted against unimpaired annual Sacramento River flow in Figure E-1. The observed data are monthly-averaged salinity (μS/cm) during August-October for the period 1965-2005. The data for the post-ESA years (1994-2005) are shown as shaded circles. Note that the anecdotal observations in Table E-1 are likely "one-time" observations, while those shown in Figure E-1 are average monthly values.

No comments

- n/a -

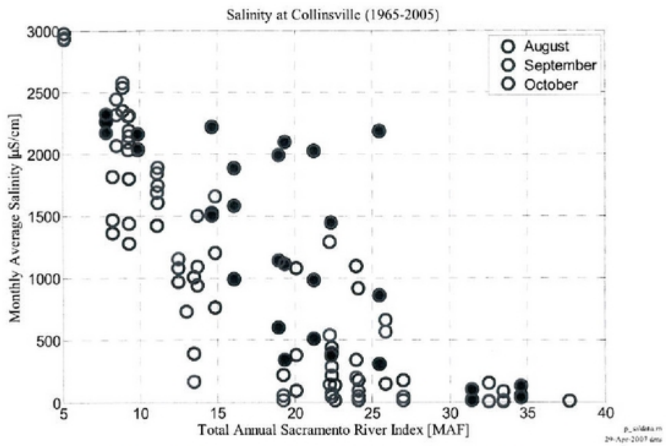

Figure E-1 – Observed salinity at Collinsville, 1965-2005

Under current management conditions, the monthly average salinity at Collinsville from August through October is only less than 1,000 µS/cm EC (the interpretation of the "sweet" threshold for drinking water) when the unimpaired runoff is greater than about 20 to 25 MAF/yr (Figure E-1). This suggests either the "sweet" threshold used in this report is too small, or salinity at Collinsville is higher today than it was in the late 18th and early 19th centuries.

If the definition of the "sweet" threshold is changed to 1,300 µS/cm EC and the post-ESA years (1994-2005) are excluded, then the monthly-averaged salinity at Collinsville during August-October is "fresh" (less than 1,300 µS/cm EC) when runoff is greater than 16 MAF/yr. This corresponds better to the anecdotal observations, discussed above, but suggests a recent increase in salinity at Collinsville during moderately wet years (with runoff between 14 and 26 MAF/yr). In 5 of the 12 post-ESA years (1997, 1999, 2000, 2003 and 2004), the water at Collinsville in October would not be considered "sweet" even under the relaxed criterion of 1,300 µS/cm EC, suggesting that October salinity under present conditions could be greater than it was in 1811.

E.1.2. Brackish Conditions

The qualitative observations of high salinity intrusion in Table E-1 are less specific about location. However, some of these observations have been interpreted by others (Cook, 1960, in TBI, 1998; Fox, 1987b) to indicate intrusion as far upstream as Rio Vista. The drought periods of 1976-1977 and 1987-1992 are similar to these periods when these qualitative

No comments

- n/a -

observations were made. During 1976-1977, daily average salinity at Rio Vista exceeded 1,000 µS/cm for approximately six months of the year. During 1987-1992, salinity at Rio Vista at high tide often exceeded 2,000 µS/cm, particularly during the fall. This is consistent with the anecdotal observations made in 1796 and 1841, which report salt water extending into the western Delta.

Summary: Interpretation of the above observations in the context of the reconstructed Sacramento River flows shows that the Delta is generally saltier than the historical levels for equivalent runoff conditions and does not support the hypothesis that the present-day Delta is managed as a freshwater system in comparison with its historical salinity regime. Moreover, this analysis indicates that salinity in the western Delta has increased during September and October in the recent years (post-1994 period).

E.2. Observations from early settlers in the Western Delta

Observations from early settlers in the western Delta provide a more complete description of salinity in the late 1800's and early 1900's than the observations from early explorers discussed earlier. Assuming the early settlers inhabited a particular region for longer time periods than the early explorers, observations from the early settlers capture the temporal variability better than those from the early explorers.

E.2.1. Town of Antioch Injunction on Upstream Diverters

In 1920, the Town of Antioch filed a lawsuit against upstream irrigation districts alleging that the upstream diversions were causing increased salinity intrusion at Antioch. The court decision, legal briefings, and petitions provide salinity observations from a variety of witnesses. Although anecdotal testimony summarized in these legal briefs is far from scientific evidence, it provides a perspective of the salinity conditions prevailing in the early 1900's. Because the proceedings were adversarial in nature, this report focuses on the testimony of the upstream interests, who were trying to demonstrate that salinity intrusion was common near Antioch prior to their diverting water (prior to 1920). Consequently, the testimony may be biased in support of this "more saline" argument. Nonetheless, these anecdotal testimonies indicate that the western Delta was less salty in the past than it is today. Analyses of some of the testimonies are presented below.

Case History

On July 2, 1920, the Town of Antioch filed suit in the Superior Court of the State of California (hereinafter referred to as the "Antioch Case") against upstream diverters on the Sacramento River and Yuba River. A hearing for a temporary injunction began on July 26, 1920, and lasted approximately three months. On January 7, 1921, Judge A. F. St. Sure granted a temporary injunction, restraining the defendants "from diverting so much water from the said Sacramento River and its tributaries, to non-riparian lands, that the amount of water flowing past the City of Sacramento, in the County of Sacramento, State of California, shall be less than 3500 cubic feet per second" (Town of Antioch v. Williams Irrigation District, Supplement to Appellants' Opening Brief, p. 13).

No comments

- n/a -

The defendants appealed to the Supreme Court of the State of California, which issued its opinion on March 23, 1922. The Supreme Court reversed the lower court and withdrew the injunction, declaring "[i]t is evident from all these considerations that to allow an appropriator of fresh water near the outlet of these two rivers to stop diversions above so as to maintain sufficient volume in the stream to hold the tide water below his place of diversion and secure him fresh water from the stream at that point, under the circumstances existing in this state, would be extremely unreasonable and unjust to the inhabitants of the valleys above and highly detrimental to the public interests besides."

The Supreme Court did not make any comment whatsoever on the evidence of salinity intrusion prior to the upstream diversions in question. The Court indicated that their decision was based on a "policy of our law, which undoubtedly favors in every possible manner the use of the waters of the streams for the purpose of irrigating the lands of the state to render them fertile and productive, and discourages and forbids every kind of unnecessary waste thereof." (Town of Antioch v. Williams Irrigation District (1922) 188 Cal. 451). The Court concluded that allowing 3,500 cubic feet per second (cfs) to "waste" into the Bay to provide less than 1 cfs of adequate quality water for the Town of Antioch would constitute unreasonable use of California's limited supply of water.

The court did not base their decision on historical salinity observations at Antioch, which indicate that Antioch was able to divert freshwater at low tide at all times from 1866 to 1918, except possibly for some fall months during some dry years (Section 3.1).

E.2.2. Salinity at Antioch – then and now

In the present day, the City of Antioch maintains a municipal water intake on the San Joaquin River at Antioch. As a general operating rule, the City of Antioch pumps water from the river when salinity at the intake is less than 1,000 μS/cm EC. Salinity varies substantially with the tide; generally the greatest salinity is observed near high tide and the lowest salinity is observed at low tide. Figure E-2 shows that salinity in the San Joaquin River at Antioch is highly variable and is dependent on tidal conditions and season. Figure E-2 indicates that for water year 2000 (an above-normal water year) the City of Antioch could pump water all day for about four and half months (early February through mid-June) and could pump for a portion of the day at low tide for another three and half months (mid-June through September). For the remaining four months (October-January), water at Antioch's intakes exceeded 1,000 μS/cm EC for the entire day, regardless of tidal phase.

Testimony from multiple witnesses in the Antioch Case indicates that fresh water was always available in the San Joaquin River at Antioch at low tide until just prior to 1920. Antioch's legal position was that fresh water was always available before upstream development. In cross-examination of Antioch's witnesses, the upstream irrigators demonstrated that brackish conditions did occasionally exist at high tide.

No comments

- n/a -

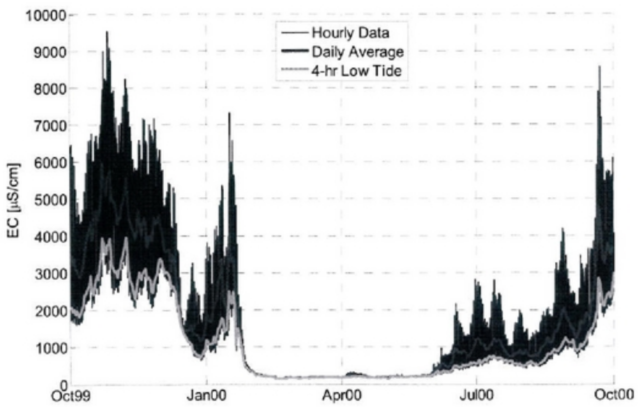

Figure E-2 – Salinity variations in the San Joaquin River at Antioch, water year 2000

Figure E-3 shows the distribution of low tide salinity (salinity during the freshest 4 hours of each day) for the period of May 1, 1983 through September 30, 2002.[10] These data indicate that, on average (in 50% of the water years), low tide salinity exceeds 1,000 µS/cm EC from late-August through December. The data in Figure E-3 provide context for the qualitative observations from the Antioch Case. During the driest 25% of the years (5 out of 20 years), low tide salinity exceeds 1,000 µS/cm EC from June through January, leaving the Antioch intake with no fresh water for eight months of the year.

Under average conditions corresponding to the period 1983-2002, Antioch would have to stop pumping from late August to late December in 10 of the 20 years; i.e., they would have an average of eight months of low-tide pumping per year, compared to the pre-1915 average of twelve months per year (based on the anecdotal information filed by the Appellants (upstream diverters) in the Antioch Case).

[10] Data Source: Interagency Ecological Program, HEC-DSS Time-Series Databases. Station RSAN007. Agency: DWR-ESO-D1485C. Measurement: 1-hour EC. Time Range: May 1, 1983 through September 30, 2002

No comments

- n/a -

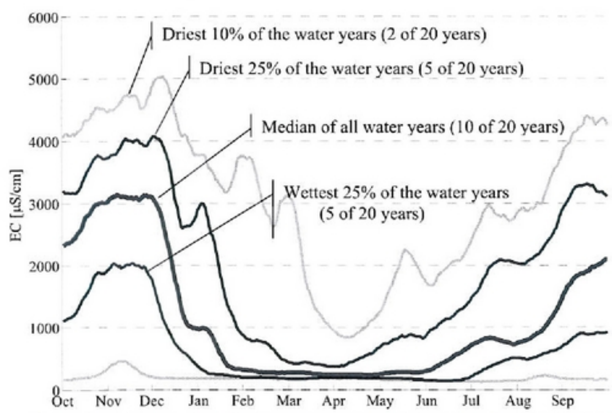

Figure E-3 – Seasonal Distribution of low-tide salinity at Antioch, 1983-2002

Conclusions

- The window, when Antioch is able to pump water with salinity less than 1,000 µS/cm EC, has substantially narrowed in the last 125 years.
- Antioch was apparently able to pump fresh water at low tide year-round in the late 1800's, with the possible exception of the fall season during one or two dry years.
- During 10 of the 20 years between 1983 and 2002, salinity was less than 1,000 µS/cm EC at low tide for only about eight months of the year.
- During the driest 5 years between 1983 and 2002, salinity was less than 1,000 µS/cm for only about four months per year; i.e., no fresh water was available at any time of the day for about eight months of the year.

E.2.3. Salinity at Kentucky Point on Twitchell Island – then and now

The appellants in the Antioch Case, representing the upstream diverters, identified one resident of Twitchell Island who reported the water at Kentucky Landing was brackish on "one or two occasions" between 1870 and 1875 during August and September. During this time, he had to travel up the San Joaquin River to Seven Mile Slough (the eastern boundary of Twitchell Island) and sailed as far as the mouth of the Mokelumne River (approximately 2

No comments

- n/a -

miles further up the San Joaquin River than the Seven Mile Slough junction) to obtain fresh drinking water.

For comparison, we look at salinity monitoring data in that region for 1981 and 2002 to see the location of potable water.[11] The source document (Town of Antioch v. Williams Irrigation District, 188 Cal. 451) for the 1870's drought uses up to 100 mg/L chloride concentration as the threshold for a potable water supply. Monitoring data from 1981 shows similar salinity intrusion as described by the Twitchell Island resident; salinity along the San Joaquin River at Bradford Island (about 1.5 miles upstream of Three Mile Slough) exceeded 1,000 µS/cm EC (about 250 mg/L Cl) during August and September. During the same time period, salinity was around 400 µS/cm EC (about 64 mg/L Cl) approximately 5 miles upstream on the San Joaquin River between Seven Mile Slough and the Mokelumne River. This comparison indicates that the extent of salinity intrusion in 1981 is similar to that which occurred in 1870 and 1871.

Similarly, in September 2002, the salinity in the San Joaquin River at San Andreas landing (less than 2 miles downstream of the Mokelumne River mouth) peaked at 977 µS/cm EC, which corresponds to approximately 225 mg/L chloride concentration. Therefore, if the observer was to travel upriver for potable water in 2002, they would have likely traveled up to the mouth of the Mokelumne River as they did in 1870. Salinity intrusion in critically dry years is even farther into the Delta than was found in 2002.

In conclusion, salinity intrusion up the San Joaquin River during the dry years of 1870 and 1871 as described by a Twitchell Island resident is consistent with salinity intrusion in 1981 and 2002 under similar hydrological conditions. There is no evidence that salinity intrusion during the drought of 1870-71 was more extensive than salinity intrusion during similar water years in the current salinity regime.

[11] 1981 and 2002 were both dry water years in the Sacramento River basin as defined in D-1641 with similar annual unimpaired Sacramento River flow to the years 1870 and 1871. Annual unimpaired Sacramento River flow in 1870, 1871, 1981, and 2002 was 11 MAF, 10 MAF, 11 MAF, and 14 MAF, respectively.

No comments

- n/a -

To protect and restore California Rivers by influencing public policy and inspiring citizen action.

FRIENDS OF THE RIVER
1418 20TH STREET, SUITE 100, SACRAMENTO, CA 95811
PHONE: 916/442-3155 • FAX: 916/442-3396
WWW.FRIENDSOFTHERIVER.ORG

January 11, 2012

Cindy Messer
Delta Stewardship Council
980 Ninth Street, Suite 1500
Sacramento, CA 95814

Re: Exhibits referred to in Comments on Recirculated Draft Programmatic Environmental Impact Report (RDPEIR)

Dear Ms. Messer and Council Members:

Please include the attached three documents in the Administrative Record in your CEQA proceedings on the Final Draft Delta Plan and RDPEIR. These three documents have been or are being referred to in the written comments of the Environmental Water Caucus and/or Friends of the River and are as follows:

Release and Report in Brief, National Academy of Sciences, A Review of the Use of Science and Adaptive Management in California's Draft Bay Delta Conservation Plan (May 5, 2011);

Eberhardt School of Business Forecasting Center, Benefit-Cost Analysis of Delta Water Conveyance Tunnels (July 12, 2012);

California Natural Resources Agency, Gov. Brown and Obama Administration Outline Path Forward for Bay Delta Conservation Plan, "The elements of a preferred proposal include the construction of water intake facilities with a

No comments

- n/a -

total capacity of 9000 cubic feet per second. . . and a conveyance designed to use gravity flow. . ." (July 25, 2012).

Sincerely,

E. Robert Wright
Senior Counsel
Friends of the River

No comments

- n/a -

NEWS FROM THE NATIONAL ACADEMIES

NATIONAL ACADEMY OF SCIENCES
NATIONAL ACADEMY OF ENGINEERING
INSTITUTE OF MEDICINE
NATIONAL RESEARCH COUNCIL

Date: May 5, 2011

FOR IMMEDIATE RELEASE

CALIFORNIA'S DRAFT BAY DELTA CONSERVATION PLAN INCOMPLETE; NEEDS BETTER INTEGRATION TO BE MORE SCIENTIFICALLY CREDIBLE

WASHINGTON — A draft plan to conserve habitat for endangered and threatened fishes in the California Bay-Delta while continuing to divert water for agricultural and personal use in central and southern California has critical missing components, including clearly defined goals and a scientific analysis of the proposed project's potential impacts on delta species, says a new report from the National Research Council. In addition, the scientific information in the plan is fragmented and presented in an unconnected manner, making its meaning difficult to understand.

The delta region receives fresh water from the Sacramento and San Joaquin rivers and their tributaries, and water from the delta ultimately flows into the San Francisco Bay and the Pacific Ocean. Pumping stations divert water from the delta, primarily to supply Central Valley agriculture and southern California metropolitan areas. The effects of an increasing population and the operation of the engineered water-control system have substantially altered the delta ecosystem, including its fish species.

The November 2010 draft of the Bay Delta Conservation Plan (BDCP) aims to gain authorization under the federal Endangered Species Act and companion California legislation for a proposed water diversion project, such as a canal or tunnel that would take water from the northern part of the delta directly to the south while protecting the region's ecosystems. To date approximately $150 million has been spent in developing the BDCP, which is being prepared by a steering committee of federal, state, and local agencies, environmental organizations, and other interest groups. The plan is slated for completion by 2013 and would be implemented over the next 50 years.

The draft BDCP states that the principal component of a habitat conservation plan is an "effects analysis," which the plan defines as "a systematic, scientific look at the potential impacts of a proposed project on those species and how those species would benefit from conservation actions." However, the effects analysis is still being prepared and was not included in the BDCP, resulting in a critical gap in the science. Without this analysis, it is hard to evaluate alternative mitigation and conservation actions.

The BDCP lacks clarity in its purpose, which makes it difficult to properly understand, interpret, and review the science that underlies the plan, stated the panel that wrote the report. Specifically, it is unclear whether the BDCP is exclusively a habitat conservation plan to be used as an application to "take" -- meaning to injure, harass, or kill -- listed species incidentally or whether it is intended to be a plan that achieves the co-equal goals of providing reliable water supply and protecting and enhancing the delta ecosystem. If it is the latter, a more logical sequence would be to select alternative projects or operation regimes only after the effects analysis is completed.

Furthermore, the draft BDCP combines a catalog of overwhelming detail with qualitative analyses of many separate actions that often appear disconnected and poorly integrated, the panel said. There are many scientific elements, but the science is not drawn together in an integrated fashion to support the restoration activities. The panel noted that a systematic and comprehensive restoration plan needs a clearly stated strategic view of what each scientific component is intended to accomplish and how this will be done.

"There is a strong body of solid science to support some of the actions discussed in the BDCP, but because the science is not well-integrated, we are getting less from the science than we could," said panel chair Henry Vaux, professor emeritus of resource economics at the University of California in Berkeley and Riverside. "As our report concludes, a stronger and more complete BDCP -- and the panel identified several areas for improvement -- could contribute importantly to solving the problems that beset the delta."

The study was sponsored by the U.S. departments of the Interior and Commerce. The National Academy of Sciences, National Academy of Engineering, Institute of Medicine, and National Research Council make up the National Academies. They are independent, nonprofit institutions that provide science, technology, and health policy advice under an 1863 congressional charter. Panel members, who serve pro bono as volunteers, are chosen by the Academies for each study based on their expertise and experience and must satisfy the Academies' conflict-of-interest standards. The resulting consensus reports undergo external peer review before completion. For more information, visit http://national-academies.org/studycommitteeprocess.pdf. A panel roster follows.

Contacts:
Jennifer Walsh, Media Relations Officer
Shaquanna Shields, Media Relations Assistant

No comments

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Office of News and Public Information
202-334-2138; e-mail news@nas.edu

Additional Resource:
Report in Brief

Pre-publication copies of *A Review of the Use of Science and Adaptive Management in California's Draft Bay Delta Conservation Plan* are available from the National Academies Press; tel. 202-334-3313 or 1-800-624-6242 or on the Internet at http://www.nap.edu. Reporters may obtain a copy from the Office of News and Public Information (contacts listed above).

# # #

NATIONAL RESEARCH COUNCIL
Division on Earth and Life Studies
Water Science and Technology Board
Ocean Studies Board

Panel to Review California's Draft Bay-Delta Conservation Plan

Henry J. Vaux Jr. (chair)
Professor Emeritus of Resource Economics, and
Associate Vice President Emeritus
University of California
Berkeley

Michael E. Campana
Professor
Department of Geosciences
Oregon State University
Corvallis

Jerome B. Gilbert*
Consulting Engineer, and
Founder
J. Gilbert Inc.
Orinda, Calif.

Albert E. Giorgi
President and Senior Fisheries Scientist
BioAnalysts Inc.
Redmond, Wash.

Robert J. Huggett
Independent Consultant, and
Professor Emeritus
Department of Environmental Sciences
Virginia Institute of Marine Science
College of William and Mary
Williamsburg, Va.

Christine A. Klein
Chesterfield Smith Professor of Law
Levin College of Law
University of Florida
Gainesville

Samuel N. Luoma
Senior Research Hydrologist
Waters Resources Division
U..S. Geological Survey
Menlo Park, Calif.
Department of Environmental Sciences

Thomas Miller
Professor
Chesapeake Biological Laboratory
Center for Environmental Science
University of Maryland
Solomons

Stephens G. Monismith
Obayashi Professor and Chair
Department of Civil Engineering, and
Director
Environmental Fluid Mechanics Laboratory
Stanford University
Stanford, Calif.

Jayantha Obeysekera
Director
Hydrologic and Environmental
Systems Modeling
South Florida Water Management District
West Palm Beach

No comments

- n/a -

Hans W. Paerl
Kenan Professor of Marine and Environmental Sciences
Institute of Marine Sciences
University of North Carolina
Morehead City

Max J. Pfeffer
Professor
Department of Development Sociology
Cornell University
Ithaca, N.Y.

Desiree D. Tullos
Assistant Professor
Department of Biological and Ecological Engineering
Oregon State University
Corvallis

STAFF

Laura Helsabeck
Study Director

* Member, National Academy of Engineering

No comments

- n/a -

NATIONAL ACADEMY OF SCIENCES
NATIONAL ACADEMY OF ENGINEERING
INSTITUTE OF MEDICINE
NATIONAL RESEARCH COUNCIL

REPORT IN BRIEF

A Review of the Use of Science and Adaptive Management in California's Draft Bay Delta Conservation Plan

California's draft Bay Delta Conservation Plan—a draft plan to conserve habitat for endangered and threatened species, while continuing to divert water to agriculture and domestic water users in central and southern California—is incomplete and contains critical scientific gaps. The Bay Delta is a large, complex ecosystem that supplies water from the state's wetter northern regions to the drier southern regions, and also serves as habitat for many species. The Bay Delta Conservation Plan describes a proposal to construct a tunnel or canal to divert water from the northern Delta to the south, thus reducing the need to convey water through the Delta. This report reviews the use of science and adaptive management in the draft Bay Delta Conservation Plan and identifies opportunities to develop a more successful plan.

Credit: California Department of Water Resources

Encompassing the deltas of the Sacramento and San Joaquin Rivers, and the eastern margins of the San Francisco Bay, the San Francisco Bay Delta Estuary was once a great tidal freshwater marsh. But over the last century and a half, the land has been drained, cleared, and used for agricultural and residential purposes. Today, the Delta is a maze of canals and waterways flowing around more than 60 islands of farmland and occupying an area of 1,150 square miles.

The modified Delta plays an integral role in the water delivery system of California. Water flows into the Delta from the watersheds of the Sacramento and San Joaquin rivers, and is transported through a network of engineered canals to supply water to the drier southern regions of the state. This water helps irrigate millions of acres of arid and semi-arid farmlands, and supplies municipal water to approximately 25 million Californians.

Several other forces of change, including land subsidence, sea level rise, and increased urbanization, have also shaped the Delta, making it one of the most modified deltaic systems in the world—and this transformation has come at a cost. The Delta has supported a diverse array of fish, birds, other animals, and plants, but now, some of these species are listed as threatened or endangered. Restrictions on water exports to protect those species during some periods, together with the effects of several dry years, have exacerbated tensions over water allocation, spurring the development of a variety of plans to provide reliable water supplies and protect the ecosystem.

One of those plans is the Bay Delta Conservation Plan, currently under development by a consortium of federal, state, and local agencies; water supply entities; environmental organizations; and other parties. The plan is intended to support authorization, under both state and federal endangered species statutes, for a proposed "isolated conveyance facility," a mechanism to take water from the northern part of the Delta to the south, thus reducing the need to convey water through the Delta. At the request of the U.S. Secretaries of the Interior and Commerce, the National Research Council

No comments

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The Bay Delta Conservation Plan is a Habitat Conservation Plan—a plan that developers must submit to the U.S. Fish and Wildlife Service before undertaking an activity or project that could incidentally take* species listed as threatened or endangered under the federal Endangered Species Act. These plans must outline actions that will be taken to protect the habitat of threatened or endangered species in order to compensate for incidental take. Similarly, the Bay Delta Conservation Plan is a Natural Community Conservation Plan under California's Natural Community Conservation Planning Act. These plans aim, among other things, to help the recovery of the species.

* "Take" includes actions that "harm" wildlife, including habitat modification that actually kills or injures wildlife by impairing breeding, feeding, or sheltering behaviors. For further clarification, please see the full report.

convened a panel of experts to review the use of science and adaptive management in a working draft of the Bay Delta Conservation Plan.

The draft Bay Delta Conservation Plan is incomplete in a number of important areas. For example, at the outset of its review, the panel found that although the Bay Delta Conservation Plan aims to address management and restoration of the San Francisco Bay Delta estuary, it omits any analyses of the potential impacts of the plan's efforts on the San Francisco Bay itself (aside from Suisun Bay). Furthermore, the report identifies other key scientific and structural gaps in the draft plan that, if addressed, could lead to a more successful and comprehensive final Bay Delta Conservation Plan.

The Lack of an Effects Analysis

The Bay Delta Conservation Plan describes an effects analysis as a systematic, scientific look at the potential impacts of a proposed project on the species that the project will potentially affect, and at how those species would benefit from various conservation actions. Clearly, such an effects analysis is intended to be the basis for the choice and details of those conservation actions. However, the effects analysis for the Bay Delta Conservation Plan is still in preparation, and was therefore absent from this draft of the plan, representing a critical gap in the science underlying the plan and the corresponding conservation actions.

The panel noted that a successful effects analysis should include an integrated description of the components of the system and how they relate to each other, a synthesis of the available science, and a representation of the dynamic response of the system.

The Lack of Clarity as to the Bay Delta Conservation Plan's Purpose

The legal framework surrounding the Bay Delta Conservation Plan is complex. In attempting to comply with all the relevant laws and regulations, the authors of the Bay Delta Conservation Plan have undertaken to develop a conservation plan of great importance, scope, and difficulty. The panel recognized these challenges, and also acknowledged that the Bay Delta Conservation Plan it reviewed is a work in progress. However, the panel found that the purpose of the Bay Delta Conservation Plan is not clear, making it difficult to properly understand, interpret, and review the science that underlies the plan.

The central issue is that although the plan states it is an application for the incidental take of listed species as a result of the proposed water diversion project, it also sets out the goals of providing a more reliable water supply for the state of California and protecting the Delta ecosystem. Because different processes would be used to fulfill these different purposes, the panel concluded that it would be difficult to evaluate the Bay Delta Conservation Plan without clarification of the plan's goals.

To obtain an incidental take permit, developers would design conservation methods to minimize and mitigate the adverse effects of a specific project or operation. However, if the Bay Delta Conservation Plan were a broader conservation plan that aims to protect the ecosystem and provide a reliable water supply, then it would be more logical to carry out an effects analysis, and then identify several alternative projects to reach the two goals. Under the latter scenario, choosing the alternative project before evaluating alternative ways to reach a preferred outcome would be post hoc rationalization—in other words, putting the cart before the horse. Scientific reasons for not considering alternative actions are not presented in the plan.

The Use of Science and Synthesis in the Bay Delta Conservation Plan

Many scientific studies have sought to understand the hydrologic, geologic, and ecological interactions in the Delta, efforts that constitute the

No comments

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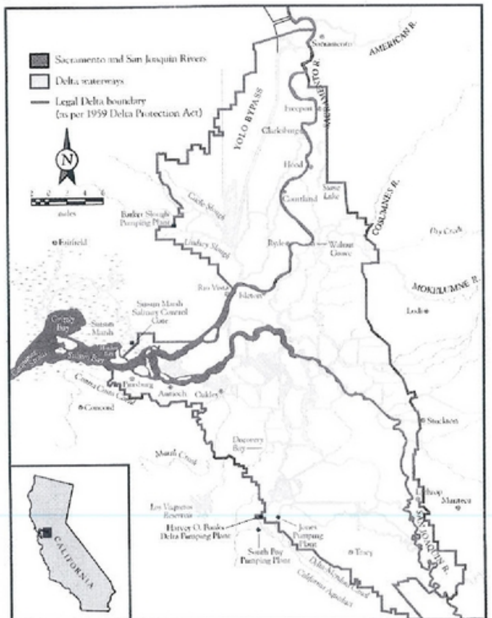

The San Francisco Bay/Sacramento–San Joaquin Delta in California.

Credit: Lund, et al. (2002)/Public Policy Institute of California

scientific foundation of the Bay Delta Conservation Plan. However, it is not clear how the authors of the Bay Delta Conservation Plan synthesized this material and incorporated it into the decision-making process that led to the plan's conservation actions. For example, it is not clear whether the analyses carried out by the numerous other Delta conservation plans and scientific assessments were used in the draft Bay Delta Conservation Plan.

Quantitative evaluation of the environmental stressors that impact species of interest, ideally using life-cycle models, would strengthen the Bay Delta Conservation Plan. For example, much of the analysis of the decline of smelt and salmonids in the Delta has focused on water operations, in particular the pumping of water at the south of the Delta for export to other regions. However, a variety of other environmental factors have potentially large effects on these fishes; and considerable uncertainties remain about the impact that different aspects of flow management in the Delta, especially management of the salinity of the water, have on their survival.

The lack of clarity concerning the volume of water to be diverted through the proposed isolated conveyance facility is another major shortcoming of the Bay Delta Conservation Plan. Without a clear specification of the volume of water deliveries, the expected impacts to the ecosystem cannot be assessed. Overall, the panel concluded that the Bay Delta Conservation Plan is little more than a list of ecosystem restoration tactics and scientific efforts, with no coordinated strategy for reaching the goals of the plan.

Adaptive Management

Numerous attempts have been made to develop and implement adaptive management strategies in environmental management, but many of them have failed for reasons such as a lack of resources, the high cost of implementation, or the inherent variability of natural ecosystems. Despite these challenges, there often is no better option for implementing environmental management regimes, and therefore the panel

Adaptive management is a formal, systematic, and rigorous program of learning from the outcomes of management actions and using this information to inform the next steps of the plan. Predicting the outcomes of management alternatives in natural systems is difficult, due to the many uncertainties involved. Adaptive management, at least in theory, can provide resource managers with iterative strategies to deal with uncertainties and use science, with a heavy emphasis on monitoring, for planning, implementation, and assessment of restoration efforts.

No comments

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concluded that the use of adaptive management is appropriate for the Bay Delta Conservation Plan, although adaptive management applied to a large-scale problem such as the California Bay Delta will not be easy, quick, or inexpensive. These considerations further emphasize the need for clear goals.

Adaptive management programs cannot be fully described in advance, because the program must evolve as it is implemented. However, some aspects of the program could be laid out more clearly than they were in the draft Bay Delta Conservation Plan, the panel found. The plan developers would benefit from experience with adaptive management efforts in other large-scale ecosystem restoration projects, such as the Comprehensive Everglades Restoration Program.

Management Fragmentation and a Lack of Coherence

The management of any science-based process has a profound impact on the use of science and adaptive management in that process. The absence of scientific synthesis in the draft Bay Delta Conservation Plan draws attention to the fragmented system of management under which the plan was prepared, lacking coordination and accountability. No single public agency, stakeholder group, or individual was made accountable for the coherence, thoroughness, and scientific integrity of the final product. Rather, the Bay Delta Conservation Plan reflects the differing perspectives of the federal, state, and local agencies, and the many stakeholder groups involved. Unless the management structure is made more coherent and unified, the final product may continue to suffer from a lack of integration, in an attempt to satisfy all discrete interests and, as a result, fail to achieve its goals. Development and implementation of large restoration and conservation programs such as the Bay Delta Conservation Plan often require a complex structure to incorporate technical, political, and legal realities and the evolving dynamics of both the physical and organizational environments. The panel suggests the agencies responsible for implementing the plan review other examples of large scale restoration programs that have been developed and implemented. In conclusion, the panel underscores the importance of a credible and a robust Bay Delta Conservation Plan in addressing the various water management problems that beset the Delta.

Read or purchase this report and locate information on related reports at http://dels.nas.edu/wstb

Panel to Review California's Draft Bay Delta Conservation Plan: Henry J. Vaux, Jr. (*Chair*), Professor Emeritus, University of California; **Michael E. Campana**, Oregon State University; **Jerome B. Gilbert**, Private consultant, Orinda, CA; **Albert E. Giorgi**, BioAnalysts, Inc., Redmond, WA; **Robert J. Huggett**, Professor Emeritus, College of William and Mary, Seaford, VA; **Christine A. Klein**, University of Florida College of Law, Gainesville; **Samuel N. Luoma**, U.S. Geological Survey, Emeritus, Menlo Park, CA; **Thomas Miller**, University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory, Solomons; **Stephen G. Monismith**, Stanford University; **Jayantha Obeysekera**, South Florida Water Management District, West Palm Beach; **Hans W. Paerl**, University of North Carolina, Chapel Hill; **Max J. Pfeffer**, Cornell University; **Desiree D. Tullos**, Oregon State University; **Laura J. Helsabeck** (Study Director), **David Policansky** (Scholar), **Stephen D. Parker** (Water Science and Technology Board Director), **Susan Roberts** (Ocean Studies Board Director), **Ellen de Guzman** (Research Associate), **Sarah Brennan** (Senior Program Assistant), **National Research Council**.

The National Academies appointed the above committee of experts to address the specific task requested by the U.S. Department of the Interior. The members volunteered their time for this activity; their report is eer-reviewed and the final product signed off by both the committee members and the National Academies. This report brief was prepared by the National Research Council based on the committee's report.

For more information, contact the Water Science and Technology Board at (202) 334-3422 or visit http://dels.nas.edu/wstb. Copies of *A Review of the Use of Science and Adaptive Management in California's Draft Bay Delta Conservation Plan* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; www.nap.edu.

No comments

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EBERHARDT SCHOOL OF BUSINESS

Business Forecasting Center

Benefit – Cost Analysis of Delta Water Conveyance Tunnels

July 12, 2012

Summary

This report updates an initial benefit-cost analysis of the water conveyance tunnels at the center of the Bay Delta Conservation Plan (BDCP). We find the tunnels are not economically justified, because the costs of the tunnels are roughly 2.5 times larger than their benefits. The economic benefits of the tunnels include water supply, water quality, and earthquake risk reduction to areas served by export water agencies. The economic costs include capital costs, operating and maintenance costs, and the costs to in-Delta and upstream water users.

Benefit-cost analysis is an essential and normal part of assessment and planning of large infrastructure projects such as the $13 billion water conveyance tunnel proposal, but has not been part of the BDCP. This report fills an important information gap for policy makers and water ratepayers who will ultimately bear the multi-billion dollar costs of the project.

This is a revision of an earlier white paper dated June 14, 2012. This version has been updated to reflect new project and economic information from BDCP, and some minor technical and editorial changes.

The principal author of this report is Dr. Jeffrey Michael, Director of the Business Forecasting Center (BFC) at the University of the Pacific. The BFC is among the most recognized economic research centers in California, and is known for its expertise on the Central Valley economy, growth resource issues facing the region. On water issues, the BFC is known for being the only academic or government entity to accurately assess employment impacts during the 2009 drought, and recently led the development of the Economic Sustainability Plan for the Delta Protection Commission. This report is part of the Center's mission of independent research and analysis of economic issues and trends in the state and region. No funding was solicited or received to support this report.

No comments

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Contents

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No comments

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Benefit – Cost Analysis of Delta Water Conveyance Tunnels

A pair of large water conveyance tunnels is being considered as the centerpiece of the Bay Delta Conservation Plan (BDCP). The tunnels would divert water from the Sacramento River and convey it around the Delta to state and federal water projects serving southern California rather than continuing to convey the fresh water through Delta channels. The construction cost of the tunnels is estimated at $13 billion. Essentially, the project is an updated version of the peripheral canal defeated by California voters in 1982.

This report updates an initial comprehensive economic benefit-cost analysis of the proposed tunnel with the latest information from the BDCP. Primarily using the results of the BDCP's own economic benefit and cost studies, we find benefit-cost ratios ranging from 0.3 to 0.5, meaning that there are between $1.90 and $3.36 of costs for every $1 in economic benefits. When these very low benefit-cost ratios are considered alongside the inconsistent and incomplete financial plans, it is clear that the Delta water conveyance tunnels proposed in the draft BDCP are not justified on an economic or financial basis.

The BDCP is considering a variety of sizes and operating criteria for the water conveyance tunnel. This analysis focuses on a scenario that is reported to be the preferred alternative emerging in BDCP negotiations.[1] Two large tunnels will be built to convey water below the Delta along with three intakes on the Sacramento river that can divert 9,000 cfs (cubic feet per second) from the river. The project would result in average annual water exports in a range between 4.3 maf (million acre feet) and 5.5 maf. The level of water exports through the tunnel depends on a 15-year decision-tree process based upon scientific studies of the effectiveness of the BDCP's habitat investments in recovering endangered fish populations. The studies and decision-tree process would be concurrent to the tunnel construction, so the water yield of the tunnels would not be known until after they are built.

This assessment examines a favorable water supply scenario for the water agencies that would finance the tunnels, average water exports of 5.3 maf, near the maximum level. This analysis looks only at the water conveyance proposal in the BDCP, and does not evaluate habitat creation proposals that provide their own benefits and would have several billion dollars in additional construction costs that would be primarily financed by the water bond recently moved to the 2014 ballot. As noted in a later section, this separate analysis of water conveyance infrastructure and habitat is consistent with Department of Water Resources' economic analysis guidelines.

This preliminary benefit-cost assessment can be updated with new information as it becomes available. Our intention is to motivate public agencies and others to conduct comprehensive benefit-cost analysis, and to provide appropriate economic justification of the project. Given the poor performance of the tunnel in this initial benefit-cost analysis with several assumptions favorable to tunnel construction, we believe it is highly unlikely that any subsequent benefit-cost analysis will find that the project is economically justified.

[1] For example, see "Gov. Jerry Brown's delta fix is not much of a plan." *San Francisco Chronicle*, July 9, 2012, and presentations at the June 20, 2012 meeting of the Bay Delta Conservation Plan.

No comments

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Benefit-Cost Analysis

Benefit-cost analysis of large infrastructure projects is common practice, and broadly considered to be an essential part of good public policy analysis of large capital projects. For example, high-speed rail, the other California mega-project in the news, has included multiple benefit-cost assessments as the plan has evolved. The most recent accompanied the revised business plan and found most scenarios had about $2 in expected benefits for every $1 in expected costs.[2] The benefit-cost ratio of high-speed rail is five times higher than the benefit-cost ratio we have calculated for the Delta water conveyance tunnel.

Benefit-cost analysis of the tunnel conveyance has been called for in numerous reports and reviews of the BDCP, but still has not been appropriately conducted by any state agencies or published in any independent academic studies before this report. The Department of Water Resources (DWR) has an Economic Analysis Guidebook that provides a comprehensive description of DWR's approach to benefit-cost analysis.[3]

The DWR Economic Analysis Guidebook states the importance of benefit-cost analysis well,

> Economic analysis is a critical element of the water resources planning processes because it not only evaluates the economic justification of alternative plans but it can assist in plan formulation. (p. 1)
>
> The economic analysis should answer questions such as, Should the project be built at all? Should it be built now?, Should it be built to a different configuration or size? Will the project have a net positive social value for Californians irrespective of to whom the costs and benefits accrue? (p. 5)
>
> Benefit-cost analysis is the procedure where the different benefits and costs of proposed projects are identified and measured (usually in monetary terms) and then compared with each other to determine if the benefits of the project exceed its costs. Benefit-cost analysis is the primary method used to determine if a project is economically justified. A project is justified when:
>
> - estimated total benefits exceed total estimated economic costs;
> - each separable purpose (for example, water supply, hydropower, flood damage reduction, ecosystem restoration, etc.) provides benefits at least equal to its costs;[4]
> - the scale of development provides maximum net benefits; and

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[2]The April 2012 high-speed rail benefit-cost analysis can be downloaded from http://www.cahighspeedrail.ca.gov/assets/0/152/431/6515fa4a-a098-4b88-9f19-19f0e1475e19.pdf. The business plan and benefit-cost analysis of high-speed rail have been criticized for optimistic ridership projections, but this debate has strengthened the policy and planning process for the high-speed rail project. Many of the economic benefits of high-speed rail are health related such as reduced traffic fatalities and air pollution from reduced highway travel and the benefit-cost analysis attached monetary values to health and environmental benefits.

[3] The DWR Economic Analysis Guidebook is on the web at http://www.water.ca.gov/pubs/planning/economic_analysis_guidebook/econguidebook.pdf

[4] This bullet point is critically important to the BDCP which some argue can only be evaluated as a package of water conveyance and habitat improvement projects. The DWR economic analysis guidebook is correct in stating that water supply and habitat projects should be evaluated separately.

No comments

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- there are no more-economical means of accomplishing the same purpose. (p. 13)

The benefits and costs of an investment occur at different points in time, and can extend for very long time horizons. Benefit-cost analysis examines a full stream of costs and benefits over the expected life of the project. For this analysis, we examined 50 years after the expected completion of the tunnels in 2025.

The long streams of benefits and costs are compared using a present discounted value in current dollars. A discount rate, comparable to an interest rate, is used to account for the time value of money or the opportunity costs of using funds for a public investment. Public investment has opportunity costs, because it competes with and crowds out funding for private consumption, investment or alternative public investments.

Benefit-cost results can be sensitive to the level of the discount rate, and the choice of discount rate is sometimes controversial in benefit cost analysis. Federal government guidelines recommend the use of a 7% discount rate.[5] The DWR Economic Analysis Guidebook endorses a 6% discount rate. Many economists recommend a lower discount rate, such as 3%, when looking at long-lived investments or regulations to combat long-run, global issues such as climate change. This analysis uses scenarios with a 3% and 6% discount rate.

Benefit-cost analysis is not just a pass/fail test to be taken after an investment proposal is finalized. It should be conducted and refined throughout a planning process as it yields valuable insights about a projects strengths, weaknesses, and overall merit. The absence of benefit-cost analysis throughout the BDCP process is a significant weakness that has left policy makers poorly informed to make a decision about a very costly investment with far ranging economic effects.

The objective of this report is to fill an important information void, and to challenge tunnel proponents to make their economic case using an accepted and established benefit-cost framework. Most of the values for benefits and costs in this report are taken directly or clearly derived from BDCP documents or reports sponsored or cited by tunnel proponents. Most assumptions required to derive values are made in ways that favor building the tunnel. The detailed sources and discussion of study assumptions are in the sections that follow.

Benefits of a Delta Water Supply Tunnel

The delta water supply tunnels would provide four types of potential benefits: higher export water supply, improved export water quality, earthquake risk reduction for water exports, and possible environmental benefits for endangered fish species. There is a trade-off between increasing water supply from the tunnels and their potential benefits for fish.

[5] See Office of Management and Budget, Circular No A-94. http://www.whitehouse.gov/omb/circulars_a094#7

No comments

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The California Department of Water Resources has recently contracted with the Brattle Group to conduct an Economic Benefit Analysis of the BDCP led by Dr. David Sunding.[6] The quantification of economic benefits in this section follows the framework in the scope of work in the "Benefits Analysis," and the values used in this report are taken directly from the preliminary results presented by Dr. Sunding at the BDCP public meeting on June 20, 2012.[7] The benefits in the Brattle presentation are for the period of 2022 to 2050, whereas this analysis assumes the tunnels would open in 2025 and considers benefits from fifty years of operation, 2025 to 2074. To make the adjustment, we calculated the average annual benefit in the 29 years of the Brattle analysis, and assumed it was constant over the fifty year period from 2025 to 2074.[8]

The Brattle analysis is not a comprehensive statewide benefit-cost analysis, but has a more narrow purpose to "assess whether the benefits of BDCP are sufficient to justify the costs to the agencies receiving project water supplies." In addition to providing reliable, current estimates for several components of benefit-cost analysis, the Brattle "Benefits Analysis" raises some additional considerations for financial feasibility that are discussed later in this report.

Export Water Supply:

The Brattle group estimates the present value of water supply benefits from 2022 to 2050 at $1.898 billion for urban users and $1.138 billion for agricultural exporters using a 3% discount rate. This equates to average annual operating benefits of about $361 per acre foot, averaged across both agricultural and urban water exports. The average annual benefit of $136 million for urban agencies and $81 million for agricultural agencies creates a present value of export water supply benefits of $3.916 billion using a 3% discount rate and $1.700 billion using a 6% discount rate when this annual benefit of the tunnels is extended over the 50 year period beginning in 2025.

Export Water Quality Benefits:

Improved export water quality is a significant benefit of the proposed Delta tunnel. The Brattle group estimates the present value of water quality benefits from 2022 to 2050 at $1.802 billion

[6] The Economic Benefit Scope of Work is available at http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/Economics_Benefit_Scope_of_Work.sflb.ashx

[7] Dr. Sunding's presentation from the meeting is available on the BDCP website, http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/June_2012_Public_Meeting_Presentation_6-20-12.sflb.ashx. Some minor adjustments to the Brattle results have been made to reflect two differences in the scenario analyzed in this report. We assume the tunnel begins operation in 2025 as stated in BDCP documents, not the more optimistic 2022 used in the Brattle modeling. Also, we analyze benefits and costs out to 2075, 50 years of operation, rather than the 2050 end date in the Brattle analysis by assuming benefits continue at a constant annual rate beyond 2050. This assumption may understate total benefits somewhat, but by a much smaller amount than cutting the analysis off in 2050.

[8] This simplifying assumption may somewhat understate benefits since the benefits of the tunnel grow slowly over time and are likely to be somewhat higher in the post 2050 period than the pre-2050 period. However, it may also overstate benefits in the early years that are less affected by discounting. Overall, it has little effect on the results. An alternative option to ignore years after 2050 would result in much lower benefit estimates and significantly bias the analysis against the tunnels.

No comments

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for all water exporters using a 3% discount rate. This equates to average annual benefits of $129 million after the tunnels are operating. If this annual benefit is extended over a 50 year period beginning in 2025, the present value of export water quality benefits are $2.328 billion using a 3% discount rate and $1.010 billion using a 6% discount rate.

When considering water quality benefits, it is important to note that the tunnel itself does not do anything to purify water supplies. It improves export water quality, because the tunnel moves Delta water exporters' diversion points to a stretch of the Sacramento River between Clarksburg and Courtland where water quality is better. The new intake would be upstream of the existing diversions of Sacramento River water by most Delta farmers, the Contra Costa Water District, and the cities of Stockton and Antioch, whereas the current intakes are downstream of these users. Thus, any water quality benefits received to the export projects will be at least partially offset by a degradation of water quality to those water users who will now be downstream of the massive intakes of the new tunnel. Many of these offsetting costs have not been thoroughly analyzed, but are at the root of much of the opposition to the proposed Delta tunnels. Some of these potential costs are included in the In-Delta and Upstream Impacts section in the cost assessment that follows.

Earthquake Risk Reduction:

A massive earthquake that floods Delta islands and disrupts water conveyance is frequently cited as the most important economic justification for an isolated water conveyance facility around the Delta. This is inaccurate. The Delta tunnels are often incorrectly portrayed as the only way to protect the economy from a catastrophic earthquake risk, and economic risks of water supply disruption are often inflated by including non-water supply economic losses. In this section, we first assess the economic benefit from the tunnels' earthquake protection assuming that there are no seismic upgrades to the Delta levee system. We use these values in the benefit-cost analysis. Second, we discuss alternative options for reducing seismic risk that protect against a broader set of economic risks at lower cost than the tunnels.

The scope of work for the BDCP "Economic Benefit" analysis described a correct approach for an economic assessment of seismic risks, "After developing estimates of the probability of various outage scenarios, Contractor will calculate expected losses and characterize the risk inherent to the current system." In the June 20 presentation at the BDCP meeting, the Brattle analysis did not include probabilities of outage scenarios or calculate expected losses. It only showed losses from a scenario when a massive earthquake occurs on the first year the tunnels are operating. However, it is straight forward to use these results to derive the expected annual losses called for in the scope of work.

The length of seismic outages that are currently being discussed as likely, especially in light of recent and planned responses to the levee and emergency response system and the effect of freshwater flushing out the Delta, is on the order of 6 to 12 months. According to the June 20 presentation by the Brattle Group, the estimated present value cost of an outage occurring in 2022 as $722 million for 6 months, and $2.093 billion for a 12 month water supply outage. The effect of discounting needs to be eliminated to calculate an expected annual loss. The undiscounted cost of a 6 to 12 month outage in 2022 is $970 million to $2.812 billion.

No comments

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To calculate an expected value, these undiscounted expected annual losses would be multiplied by an annual probability of such a seismic event and failure occurring. According to Figure 5 in the executive summary[9] of the Delta Risk Management Strategy Phase 1 report, the annual probability of 10+ islands failing from earthquake is about 3%, and the annual probability of 30 or more islands failing is about 1%. Many engineers feel that these failure probabilities are far too high[10], but we utilize them below in the absence of more current published probabilities.

Table 1 Expected annual urban losses from a Delta earthquake

Annual Probability	6 mos outage ($970m)	12 mos outage ($2,812m)
.03	$29.1 m	$84.4 m
.02	$19.4 m	$56.3 m
.01	$9.7 m	$28.1 m

The median value in the table is about a $29 million expected annual urban losses that could be avoided if the Delta water supply tunnels were built. The Brattle presentation did not calculate agricultural losses, but assuming that the urban to agriculture ratio of earthquake protection benefits is similar to the water supply benefits, the expected annual benefits from earthquake protection are $48 million annually for urban and agriculture combined. If this annual benefit is extended over a 50 year period beginning in 2025, the present value of earthquake protection benefits are $866 million using a 3% discount rate and $376 million using a 6% discount rate. Although we use these values in the benefit-cost analysis, they are likely to be far too high as the earthquake probabilities are lower, and, as explained below, there are less costly options that could lower the risk of seismic water export outages to near zero.

If a massive earthquake were to cause ten or more Delta islands to simultaneously flood, the human and economic losses that would result are much larger than the impact on water supplies. According to the Delta Risk Management Strategy (DRMS) reports, hundreds of people in the Delta would drown in such a catastrophic flood, possibly more. In addition, the DRMS reports found that interruptions of export water supply would be only 20% of the economic loss of such a catastrophe. Much larger economic losses would come from disruptions to natural gas systems, electricity transmission and generation, state highways, ports, railroads, and significant losses of in-Delta businesses, homes, and farmland. Given the scale of these potential losses to multiple types of economic infrastructure, it makes sense to consider seismic upgrades to the Delta levee system that protect all economic values in the Delta, including water exports. Unlike a tunnel, seismic levee upgrades could also save hundreds of lives and prevent environmental destruction of such a catastrophic flood.

Two reports by state agencies have identified seismic levee upgrades as a viable earthquake risk reduction strategy in the Delta.[11] The Delta Protection Commission Economic Sustainability

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[9] http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/docs/drms_execsum_ph1_final_low.pdf

[10] For example, Dr. Robert Pyke, a well-known geotechnical engineer states that the probability of an earthquake flooding ten or more islands is much lower than 1%.

[11] "Economic Sustainability Plan for the Sacramento-San Joaquin River Delta." Delta Protection Commission. January 2012. http://www.forecast.pacific.edu/desp.html. "Risks and Options to Reduce Risks to Fishery and Water Supply Uses of the Sacramento/San Joaquin Delta." Department of Water Resources and Department of

No comments

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Plan estimated the cost of 300 to 600 miles of seismic levee upgrades at between $2 billion and $4 billion, including riparian habitat enhancements on the enlarged levees. The Department of Water Resources' January 2008 AB 1200 found an "Improved Levees" scenario with 100 miles of seismic upgrades to eight islands in the south Delta was the lowest cost of three promising risk reduction strategies, including a peripheral canal.[12] In addition, a 2007 PPIC report estimated the cost of a similar Dutch style, "Fortress Delta" strategy at $4 billion.[13] Seismic levee upgrades are 1/6 to 1/3 the cost of the proposed water conveyance tunnel, and provide a much larger and broader range of risk reduction benefits to the economy.

Understanding the larger picture of earthquake risk is essential because benefit-cost analysis is based on "with and without" comparisons to the next best alternative. It is hard to envision that the state and federal governments would allow the seismic risk to human life and other economic assets in the Delta to remain unaddressed even if water exporters moved ahead with a Delta tunnel. Since necessary seismic upgrades to Delta levees could be completed by the time a Delta tunnel conveyance was constructed, a water supply tunnel would create no additional seismic protection for water exports. In this scenario, the earthquake risk reduction benefits of the water supply tunnel are zero.[14] Although we believe zero is a more appropriate value for benefit-cost analysis, we utilize the higher estimates that assume that alternative strategies to reduce seismic risk are not implemented, and thus the risks to the broader economy and public safety are ignored.

Environmental Benefits:

At equal levels of water exports, a water supply tunnel could have environmental benefits for endangered fish over the current diversion location in the south Delta that causes reverse flows in some Delta rivers and entrainment of endangered fish in the pumps. However, as water exports are increased beyond the no-tunnel estimate of 4.7 maf of average exports, the marginal environmental benefits of a tunnel diminish. The BDCP's most recent "effects analysis" found that an operating plan that includes 5.9 maf of average exports would harm many of the endangered species the BDCP intends to help. This benefit-cost analysis assumes an increase in water exports to a slightly lower level of 5.3 maf, near the top of the 4.3maf to 5.5maf range that is reported to be under current consideration. At higher levels of water exports, most if not all environmental benefits that could directly result from a tunnel are consumed or monetized in the form of higher water exports, and the environmental benefits of

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Fish and Game. January 2008.
http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/docs/AB1200_Report_to_Legislature.pdf.

[12] The seismic upgrade of only 8 islands was found to reduce the cost of water export interruptions from the largest Delta earthquake by 2/3, and the strategy had the largest overall economic risk reduction because it also protected other economic assets from flood in the case of an earthquake.

[13] The PPIC ruled out a "fortress Delta" solution in 2007, because its $4 billion cost was seen as too high, and they assumed a peripheral canal cost only $3 billion. The PPIC also ignored or downplayed public safety and the risk to non-water supply infrastructure. See "Envisioning Futures for the Sacramento-San Joaquin Delta" Public Policy Institute of California, February 2007. http://www.ppic.org/main/publication.asp?i=671

[14] If the tunnel conveyance were implemented as part of a Delta policy package that prevented or delayed seismic levee upgrades in the Delta, it could be argued that that the net earthquake risk reduction benefits of a tunnel are negative compared to the next best alternative.

No comments

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the BDCP would come from an extensive program of habitat restoration separately funded by state and federal taxpayers. If the tunnel did not result in increased water exports, there could be an increase in environmental benefits, but the water supply benefits would drop to zero. This trade-off between export water supplies and environmental benefits has been at the center of much of Delta discussions. Because increased water exports are essential to financing the tunnel by water contractors, we believe that a more environmentally beneficial scenario of tunnel conveyance that does not result in increases export water supplies is financially infeasible and irrelevant. Thus, we focus on the most realistic case of high water exports.

Costs of a Delta Water Supply Tunnel

Capital Costs:

We use the $12.7 billion construction cost estimate from Chapter 8 of the February 29, 2012 Draft Bay Delta Conservation Plan (BDCP).[15] There are news reports that tunnel cost estimates have risen to $14 billion[16] and possibly more. However, the proposed design change to a 9,000 cfs system with three intakes and large gravity fed tunnels may reduce construction costs. The elimination of two intakes and an intermediate pumping plant from the original 15,000 cfs design could reduce the cost estimate by about $2 billion. However, the gravity flow tunnels may have to be larger than originally estimated[17] which would increase costs. Since there are conflicting reports that costs have increased or decreased by roughly $2 billion, we stay with the original cost estimate. These figures are easy to revise once updated cost estimates are available. In addition, this construction cost estimate does not include costs for "avoidance and minimization" measures associated with construction of the tunnel conveyance, since no cost estimate for this component was included in the most recent draft of BDCP.

Chapter 8 of the BDCP describes a financing strategy for construction that would involve issuing a series of 4 revenue bonds with 40 year repayment terms. Debt servicing costs are estimated at $1.1 billion annually from 2021 through 2056, and the last of the bonds would be retired in 2061. Table 8-61 of BDCP Chapter 8 details the distribution of the $12.7 billion in construction costs over time. The present value of these construction costs are $10.777 billion using a 3% discount rate and $9.205 billion using a 6% discount rate.

Operating and Maintenance Costs:

The February 29, 2012 draft BDCP estimates operation and maintenance costs for the Delta tunnel at $85 million annually, including $17.8 million in electricity costs.[18] For the 50 year

[15] http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/BDCP_Chapter_8_-_Implementation_Costs_and_Funding_Sources_2-29-12.sflb.ashx

[16] Weiser, M. *Sacramento Bee,* February 20, 2012. "Water Tunnels Would Be Huge Project—If They Clear Huge Obstacles."

[17] Chapter 8 of the BDCP states that the tunnels would accommodate 7,000 cfs gravity feed, and DWR representatives at the June 20 meeting says that sizing had not been finalized but acknowledged that 9,000 cfs gravity feed tunnels may have to be larger than 15,000 cfs tunnels with an intermediate pumping plant.

[18] The electricity share of operating costs could decrease if tunnels are sized for gravity flows. Since electricity is a relatively small share of operating costs, we have not made an adjustment without further details of the impact.

No comments

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period beginning in 2025, the present value of operating and maintenance costs are $1.533 billion using a 3% discount rate and $665 million using a 6% discount rate.

In-Delta and Upstream Costs:

The water supply tunnel will generate a variety of costs on in-Delta and upstream uses. As discussed before, the large new diversion on the Sacramento River will degrade water quality for those who divert Sacramento River downstream from the proposed intakes. These users include Delta farmers, the Contra Costa Water District, the Cities of Antioch and Stockton, industrial user such as power plants in eastern Contra Costa County, and the North Bay Aquaduct that serves Napa and Solano. In addition, the footprint of the tunnel facility will eliminate Delta farmland and property (although less than a surface canal), and three massive new water intakes will create substantial visual and noise pollution along a scenic, rural stretch of the Sacramento River, harming Delta residents and detracting from recreation and tourism in the area. Upstream users, such as the North State Water Alliance, are concerned that the tunnel operation could reduce upstream water supplies, and result in lower reservoir levels which could affect hydroelectric power generation and recreational use of reservoirs.

Economic values have not been estimated for most of these impacts. The Delta Protection Commission Economic Sustainability Plan estimated a water conveyance tunnel would result in an average of $65 million in annual losses for Delta agriculture; including about $50 million in losses from reduced water quality, and an additional $15 million in annual crop losses from roughly 8,000 acres of farmland lost to construction impacts and the physical footprint of the facilities.[19] It is possible that a tunnel with fewer intakes and operated for environmental benefits would be more protective of in-Delta water quality and result in lower impacts on Delta agriculture. Even if Delta agriculture impacts were lower than $65 million, the other impacts to in-Delta urban water intakes, Delta communities, and upstream water users would surely push the overall cost of in-Delta and upstream impacts higher. We use $65 million as a very conservative, preliminary estimate of the annual costs to in-Delta and upstream interests, and have not made any estimate of in-Delta costs associated with the construction activity itself. For the 50 year period beginning in 2025, the present value of estimated in-Delta and upstream costs are $1.173 billion using a 3% discount rate and $509 million using a 6% discount rate.

Benefit-Cost Ratio

Table 2 summarizes the benefits and costs detailed in the previous section. Using both a 3% and 6% discount rate, the economic benefits of the tunnels are about $7 billion less than the costs. Even without discounting, meaning that the time value or opportunity cost of money is ignored, the benefits are still $500 million lower than the cost through 2074. The benefit-cost ratio ranges from 0.3 to 0.5 depending on the discount rate used. Alternatively, costs are two to three times higher than the benefits.

[19] http://www.forecast.pacific.edu/desp.html

No comments

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Table 2 Benefits and Costs of Delta Tunnels through 2074
Results are expressed as present discounted values calculated with 3% and 6% discount rates. Ending year of 2074 is fifty years after estimated completion of tunnels in 2025. (millions of current dollars)

Benefits ($ millions)	3% Discount Rate	6% Discount Rate
Export Water Supply at 5.3 maf of exports	3,916	1,670
Export Water Quality	2,328	1,010
Earthquake Risk Reduction	866	376
Environmental Benefits at 5.3maf of exports	0	0
Total Benefits ($ millions)	**7,110**	**3,056**
Costs ($ millions)		
Debt Service Capital Cost	10,777	9,205
Operation and Maintenance	1,533	666
In-Delta and Upstream Impacts	1,173	509
Total Costs ($ millions)	**13,484**	**10,380**
Net Benefits ($ millions)	**-6,374**	**-7,324**
Benefit-Cost Ratio	**0.527**	**0.297**
Cost-Benefit Ratio	**1.90**	**3.36**

Table 3 Estimated Annual Benefits and Costs in 2030

Benefits ($ millions)	2030 Benefits/Costs
Export Water Supply at 5.3 maf of exports	217
Export Water Quality	129
Earthquake Risk Reduction	47
Environmental Benefits at 5.3maf of exports	0
Total Annual Benefits ($ millions)	393
Costs ($ millions)	
Debt Service Capital Cost	1,100
Operation and Maintenance	85
In-Delta and Upstream Impacts	65
Total Annual Costs ($ millions)	**1,250**

Although we have been careful to use the most recent reliable values from the BDCP and reports of other state agencies, there is uncertainty surrounding any assessment of this kind. The uncertainties and any omitted values are balanced between items that help and harm the economic case for the tunnels. For example, the in-delta and upstream costs are almost certainly underestimated, and include no in-Delta impacts from the construction process, in-Delta municipal water supply and quality impacts, and a host of potential upstream impacts on water supplies from the Sacramento Valley to the east side of the San Joaquin Valley. As discussed in a previous section, the earthquake risk reduction benefit is likely overstated since it ignores the alternative of seismic upgrades to the Delta levee system. The water supply benefits and capital costs may also prove to be too optimistic, further weakening the case for the tunnels. On the other hand, the tunnels would facilitate water transfers from areas north of the Delta, benefits that have not been valued in this analysis. In addition, the initial Brattle

No comments

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results did not include urban benefits to Santa Clara which receives some of their water supplies from the Delta. The cost of the tunnels may also be reduced if an alternative with fewer intakes is selected. Overall the uncertainties and omissions are balanced and it seems very unlikely that any of them could be large enough to change the conclusion given the size of the gap between costs and benefits.

Some socio-economic considerations are also not included in the analysis. Most notably, the values of agricultural water do not include multiplier effects to capture the broader regional economic benefits created by water supplies. There are legitimate reasons why these indirect impacts are generally excluded from benefit-cost analysis, but the special role of agriculture in supporting the economic base of the Central Valley should be acknowledged. If these socio-economic values of agricultural production were included, the benefits would increase by about $100 million per year, a roughly 25% increase in total benefits. However, it is important to note that these socio-economic impacts are present for both areas that benefit from water exports from the tunnels, and for the in-Delta and upstream areas that are potentially harmed. Incorporating socio-economic impacts would increase both the benefits and the costs of the tunnels.

Financial Feasibility and Ratepayer Impacts

Benefit-cost analysis is sometimes confused with financial analysis and ratepayer impacts. Benefit-cost analysis does not estimate rate increases as these depend upon a number of financing assumptions, the amount of public investment, cost recovery principles, and business considerations of individual utilities. Benefit-cost analysis is a tool for policy analysis and decision making that informs whether a project is economically justified and should be built.

In contrast, financial feasibility analysis simply investigates whether a project can be financed and paid for, whether or not it is economically desirable or the most cost-effective way to meet a given objective. Financial feasibility must be demonstrated for certain regulatory requirements, and also must be proven to investors who are needed to buy bonds to finance construction. Financial feasibility is clearly linked to estimating ratepayer impacts since increased water rate revenue will be required to finance the bonds.

Despite the differences, the benefit-cost calculations raise serious questions about financial feasibility. If only the benefits and costs to water exporters in Table 2 are considered, the total benefits of the tunnels are still about $6 billion shy of the total costs that would be paid by the water agencies. However, there could be additional benefits to water agencies that are not accounted for in Table 2, such as the value of regulatory assurances that would be part of the BDCP. Financial feasibility also raises concerns about how the costs would be distributed across the state and federal water projects and urban and agricultural agencies.

Regulatory Assurance under the Endangered Species Act:

The tunnels are proposed as part of the BDCP, a habitat conservation plan (HCP) that may reduce regulatory risk to the exporting water agencies from further cuts in Delta water exports due to Endangered Species Act protections for endangered fish. This regulatory assurance would have tremendous value to the water agencies.

No comments

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Despite its value to water agencies, we did not include regulatory assurance in the comprehensive benefit-cost analysis because the assurance does not create any value from a comprehensive, statewide perspective. Regulatory assurance transfers the risk of a negative environmental outcome from the export water agencies to the environment, taxpayers, and in-Delta and upstream resource users who might have to pay in place of water agencies if the tunnels turn out to be negative for endangered fish. If the value of the fisheries and the Delta environment are as high as the Brattle Group and BDCP estimate, then shifting this risk away from water exporters could actually be a net negative from a statewide perspective.

Despite the lack of statewide value, there is no denying that regulatory assurance is valuable to water exporters and contributes to their financial feasibility. But what is it worth? Preliminary modeling from the Brattle Group presented at the June 20, 2012 BDCP meeting suggests the value of regulatory assurance could be as high as $11 billion. That would exceed the $6-7 billion shortfall suggested by the benefit-cost analysis. However, this issue begs another important question.

Does regulatory assurance and a valid HCP granting incidental take permits for the water agencies require the peripheral tunnels? According to this analysis, the water agencies could pay up to $6 billion in habitat improvements for an HCP on the current through Delta conveyance system, and still come out economically ahead of paying for the $13 billion tunnels. It seems logical that the necessary investments for an HCP and regulatory assurance on a no-tunnel alternative would be no more expensive than the $4 billion expense of habitat creation in the current BDCP proposal. Taxpayers would benefit greatly from this approach since a water bond that further burdens the state's beleaguered general fund would be unnecessary to finance Delta habitat upgrades.

Will Costs Be Allocated Proportional to Water Supply, Economic Benefits, or Population?

Although the BDCP has yet to release a detailed financial plan with cost allocations between Delta export water agencies, the agencies have said that the cost of the tunnel would be paid in proportion to the water received through the tunnel. For example, Metropolitan Water District, has said it expects its ratepayers to pay for 28% of the cost of the tunnel, equivalent to their share of Delta water exports. However, the high cost of the Delta project raises serious affordability questions for the agricultural users who receive the majority of water exported from the Delta. The cost of irrigating with water exported through the tunnels would exceed the profits of many crops grown in the Central Valley.

A proportional financing plan is simple to implement, prevents cross-subsidies between urban and agricultural users and is consistent with California Proposition 218. However, financial feasibility for a proportional financing plan requires the benefits to exceed the cost for every water agency, a much tougher standard than assessing whether the collective benefits to the agencies exceed the collective costs to the agencies. As discussed above, a proportional cost allocation means the tunnels are clearly financially infeasible for agricultural water agencies who receive the majority of water exported from the Delta under proportional cost allocation.

The most recent draft of the BDCP suggests a non-proportional financing approach, and compares the cost of the tunnel to urban rather than agricultural water supply projects. In fact,

No comments

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the draft BDCP financial analysis states the project is feasible because its per capita cost is smaller than some urban water projects financed by local urban water agencies. But the per capita financial feasibility analysis in the draft BDCP is inconsistent with the statements water contractors have made about proportional financing for the past five years. At the June 26, 2012 board meeting of the Metropolitan Water District (MWD), directors clearly expressed disapproval of the per capita financing suggested in the latest draft BDCP and MWD staff concurred.

Despite the fact that proportional cost allocation will clearly not work for financing the tunnels, water agencies have not put forward any other approach with their boards or ratepayers. The facts are that the tunnels are financially marginal for water agencies collectively, and that urban water use produces 2/3 of the benefit with 1/3 the water, and agricultural water use is 1/3 the benefit with 2/3 of the water. Financing the tunnels will either require a subsidy for agricultural users from urban ratepayers or taxpayers, or significant sales of water from agricultural to urban water agencies that will lead to fallowed fields in the Central Valley but more funds for bond repayment. But urban agencies and the government are adamant that there will be no ratepayer or taxpayer subsidies for farmers. And farmers insist that they have no intention of selling their water supplies to urban areas.

The result is that mere days from the Governor's expected announcement that the state is building the tunnels, water agencies still can't provide details on how much it will really cost their ratepayers or explain how they would generate the nearly $1.2 billion per year necessary for debt service and operating costs. There has been some informal discussion about pricing strategies that would yield more revenue for debt service such as differential pricing by reliability or allocating costs proportional to economic benefits instead of water quantity. However, it is unclear if such new pricing schemes are practical, supported by ratepayers or consistent with Proposition 218.

Of course, the main reason that financing the tunnels is so challenging is that the project does not provide economic benefits that exceed its cost. The recent recession is a powerful reminder that no amount of financial engineering can change the fundamental economics of an investment from bad to good.

Conclusion

This report updates an initial benefit-cost analysis of the water conveyance tunnels at the center of the Bay Delta Conservation Plan (BDCP). Primarily using the results of the BDCP's own economic benefit and cost studies, we find a benefit-cost ratios ranging from 0.3 to 0.5, meaning that there are between $1.90 and $3.36 of costs for every $1 in economic benefits. To put this in perspective, this benefit-cost ratio is 80% lower than those estimated for the State's high-speed rail project.

When these very low benefit-cost ratios are considered alongside the inconsistent and incomplete financial plans, it is clear that the Delta water conveyance tunnels proposed in the draft BDCP are not justified on an economic or financial basis.

No comments

- n/a -

Date: July 25, 2012
Richard Stapler (California): (916) 653-9402
Blake Androff (DOI): 202-208-6416
Jim Milbury (NOAA): 310-245-7114

Governor Brown and Obama Administration Outline Path Forward for Bay Delta Conservation Plan

California, Interior, NOAA Reaffirm commitment to comprehensive solution to California's water supplies and a healthy ecosystem

SACRAMENTO, CA – California Governor Edmund G. Brown Jr., Secretary of the Interior Ken Salazar, and National Oceanic and Atmospheric Administration (NOAA) Assistant Administrator for Fisheries Eric Schwaab today outlined revisions to the proposed Bay Delta Conservation Plan (BDCP) that, along with a full range of alternative proposals, will undergo a rigorous public environmental review in the coming months. In announcing the path forward for an enhanced BDCP process, the officials emphasized that California's water system is unsustainable from an environmental and economic perspective, and that the BDCP is a key part of a comprehensive solution to achieve the dual goals of a reliable water supply for California and a healthy California Bay Delta ecosystem that supports the State's economy.

Population growth, habitat loss and ongoing threats to levee stability and water supply have crippled the California Bay Delta, threatening the health and economies of California communities. The revised approach, which is grounded in science, is designed to help restore fish populations, protect water quality, and improve the reliability of water supplies for all water users who receive deliveries from state and federal projects. It improves on key aspects of previous proposals and offers a strong governance model, financing options, a scientific review process and a steadfast conservation foundation for a new water conveyance facility to move water and help restore the health of the ecosystem.

"A healthy Delta ecosystem and a reliable water supply are profoundly important to California's future," said Governor Brown. "This proposal balances the concerns of those who live and work

No comments

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in the Delta, those who rely on it for water and those who appreciate its beauty, fish, waterfowl and wildlife."

"As broken and outdated as California's water system is, we are also closer than ever to forging a lasting and sustainable solution that strengthens California's water security and restores the health of the Delta," said Secretary Salazar. "Through our joint federal-state partnership, and with science as our guide, we are a taking a comprehensive approach to tackling California's water problems when it comes to increasing efficiency and improving conservation. Today marks an important step forward in transforming a shared vision into a practical, effective solution. With California's water system at constant risk of failure, nobody can afford the dangers or costs of inaction."

"The status quo isn't working for fish, communities around or dependent upon the Bay Delta, economic development, or water resources management," said Dr. Jane Lubchenco, Under Secretary of Commerce for Oceans and Atmosphere and NOAA Administrator. "Our proposed changes to the BDCP reflect important improvements in shaping a comprehensive strategy to fix a broken system. Because this is a complicated issue and we do not have all the answers today, we will continue to evaluate and refine the proposal. We call upon the many participants throughout California to join us in staying focused on science-based solutions."

The elements of a preferred proposal include the construction of water intake facilities with a total capacity of 9,000 cubic feet per second -- down from an earlier proposal of 15,000 cfs – operations of which would be phased in over several years and a conveyance designed to use gravity flow to maximize energy efficiency and to minimize environmental impact. Many other alternatives, including no conveyance facility, and facilities with capacities ranging from 3,000 to 15,000 cfs, will also be fully considered as part of the upcoming environmental review process.

Governor Brown and Secretary Salazar affirmed their commitment to continue working with water users, non-governmental organizations and local governments to achieve the co-equal goals in a manner that incentivizes reduced, efficient water use throughout California and that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta.

Having identified the key elements of a proposal, the parties expect to issue a draft Bay Delta Conservation Plan and corresponding Environmental Impact Report/Environmental Impact Statement for public review this fall. In recognition that water supply reliability and affordability elements are vitally important to the public water agencies who are expected to pay for any proposed facilities, the state and federal agencies will work intensively with the public water agencies and other interested parties over the next 90 days to address these important questions. State and federal agencies will continue to refine the proposals announced today and will issue a major progress report after the completion of this initial work.

The proposal outlined today is based on shared objectives, including:

- ***Science:*** In order to determine the benefits of additional habitat and Delta outflow to fish, the State and U.S. governments are developing a process, including independent scientific review, to

No comments

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ensure that science is playing a neutral and informative role in determining a way forward for the BDCP. All parties, including water users, conservation groups and public agencies will be invited to fully participate in the process. Science will guide how to best restore the ecosystem and how much water can be exported.

- ***Conservation:*** The BDCP will contain biological goals and objectives to improve the status of a wide variety of listed species and species of concern under the Endangered Species Act, and will quickly implement new habitat projects in the Suisun Marsh and the Delta upon completion of appropriate environmental reviews.
- ***Cooperation and Governance:*** State and U.S. governments will work cooperatively with local water agencies, environmental organizations, and Delta governments and districts under a proposed governance structure to achieve an open, transparent, and inclusive process, allowing affected parties to play an appropriate role in the governance and implementation of the BDCP.
- ***Finance:*** State and U.S. governments are committed to the "user pay" principle, and the state and federal water contractors agree that the costs of the new water conveyance facility and associated mitigation of that facility will be paid through charges to the water users who would benefit from its development and operation. Habitat and other conservation measures in the BDCP would be financed in part by the contractors, but would mostly be paid by the state over a period of 40 years, with likely additional investment by the federal government through existing programs.
- ***Adaptive Management:*** The proposal reflects the shared commitment by state and U.S. governments to incorporate adaptive management to ensure flexibility as factors such as climate change, new invasive species, and unexpected prolonged drought continue to affect the biology and water supplies of the Delta.
- ***Sustaining Delta Communities:*** The State and U.S. governments recognize the need to preserve the unique communities and agricultural productivity of the Delta. State and federal agencies will continue investment in the Delta for flood protection, community development, and biological restoration.
- ***Protecting Upstream Water Users:*** State and U.S. governments will make sure implementation of BDCP will not result in adverse effects on the water rights of those in the watershed of the Delta, nor will it impose any obligations on water users upstream of the Delta to supplement flows in and through the Delta.
- ***Improved Water Management State-wide:*** State and U.S. governments will continue to explore new ways to satisfy competing water demands, including commitments to an Integrated Water Management approach, reducing water demand, increasing water supply, and improving efficiency of operations. The Metropolitan Water District of Southern California and the Santa Clara Valley Water District - the two largest urban regional water agencies-- have committed to exceed the urban water savings target established in the 2009 Delta Reform Act by saving 700,000 acre-feet a year based on predicted future demands. This includes a commitment by Southern California to annually save more water through conservation and recycling than it

No comments

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receives, on average, from Northern California, as well as a commitment from the Santa Clara County Water District to meet Silicon Valley's future increases in demand through conservation and recycling. With respect to agricultural water use, the Bureau of Reclamation has worked with local water agencies to invest close to $50 million over the last eight years in efficiency improvements in California. Reclamation is now partnering with the Natural Resources Conservation Service to provide funding for projects that improve water management and create new supplies for agricultural irrigation. In the last two years, approximately $15 million in federal funding has been invested in this effort. The State of California has invested more than $47 million in similar programs since 2001.

For more information on today's announcement, including a q&a document and information on how the proposal is expected to improve fish species, please visit: http://baydeltaconservationplan.com

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No comments

- n/a -

To protect and restore California Rivers by influencing public policy and inspiring citizen action.

FRIENDS OF THE RIVER
1418 20TH STREET, SUITE 100, SACRAMENTO, CA 95811
PHONE: 916/442-3155 • FAX: 916/442-3396
WWW.FRIENDSOFTHERIVER.ORG

January 11, 2013

Cindy Messer
Delta Stewardship Council
980 Ninth Street, Suite 1500
Sacramento, CA 95814

Re: Comments on Final Draft Delta Plan (DP), Recirculated Draft Programmatic Environmental Impact Report (RDPEIR) and Proposed Delta Plan Rulemaking Package (Regulations) **including Presentation of New Alternatives 2A and 2B**

Dear Ms. Messer and Council Members:

This organization, Friends of the River, objects to approval of the Delta Plan (DP), RDPEIR, and Regulations. This organization is included as a commenter in the detailed comments submitted by the Environmental Water Caucus (EWC). These brief additional comments are submitted solely on behalf of this organization. A fundamental threshold CEQA violation carried out by the Delta Plan, RDPEIR and Regulations is that they call for carrying out the "alternative" of developing new conveyance facilities to divert huge quantities of freshwater from the Sacramento River upstream from the Delta for the benefit of exporters south of the Delta. These documents call for that even though no true alternative to developing new conveyance has ever been considered by either the Council or by the exporters creating the BDCP project. This failure to consider an alternative that would avoid or substantially lessen the massive environmental impacts that would occur with construction and operation of new water delivery conveyance must be remedied by full consideration of a reasonable range of alternatives in a recirculated Draft EIR.

No comments

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The Council Process Violates CEQA by Failing to Develop and Consider a Range of Reasonable Alternatives to Developing New Conveyance

Close to two years ago, the National Academy of Sciences declared in reviewing the draft BDCP that: "[c]hoosing the alternative project before evaluating alternative ways to reach a preferred outcome would be post hoc rationalization— in other words, putting the cart before the horse. Scientific reasons for not considering alternative actions are not presented in the plan." (National Academy of Sciences, Report in Brief at p. 2, May 5, 2011).

In all that time, nothing has changed in this regard. The Council is still succumbing to the will of exporters who still want a conveyance that will take 15,000 cfs of freshwater out of the Sacramento River upstream from the Delta. The Delta would be left to face ever worsening salinity intrusion from the Bay due to a projected rise in the sea level by as much as 55" by 2100 (DP 80, 91) while the Revised Project further worsens salinity intrusion by taking out massive quantities of freshwater before it even reaches the Delta.

Conclusions in an EIR must be supported by substantial evidence. CEQA Guidelines section 15384 defines substantial evidence as "enough relevant information and reasonable inferences from this information that a fair argument can be made to support a conclusion, even though other conclusions might also be reached." "Substantial evidence shall include facts, reasonable assumptions predicated upon facts, and expert opinion supported by facts." "Argument, speculation, unsubstantiated opinion or narrative, evidence which is clearly erroneous or inaccurate, or evidence of social or economic impacts which do not contribute to or are not caused by physical impacts on the environment does not constitute substantial evidence."

All that the subject documents contain to support the Revised Project alternative and the call for improved, meaning new conveyance, is argument, speculation, and unsubstantiated opinion and narrative. A new Draft EIR must be prepared and recirculated because "the draft EIR [and RPDEIR] was so fundamentally and basically inadequate and conclusory in nature that meaningful public review and comment were precluded." (CEQA Guidelines, § 15088.5 (a)(4).) This entire process has been permeated from the outset with pre-decisional bias to develop the massive new conveyance capacity. As set forth in detail in the EWC comments there has been incomplete compliance with CEQA and there has been no public trust doctrine analysis performed.

We strongly support the EWC alternative which has been labeled Alternative 2. However, we present two additional alternatives in an attempt to help the Council and its EIR preparers to start down the road finally, of complying with CEQA and satisfying the obligations created by the public trust doctrine. These two alternatives are set forth below. Because the Council has been presented with three alternatives that substantially lessen significant and unavoidable impacts identified in the Draft Plan, recirculation of a new Draft EIR is now

No comments

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required. CEQA Guidelines section 15088.5(a)(3) requires recirculation when a feasible project alternative considerably different from others previously analyzed would clearly lessen significant environmental impacts of the project, but the project's proponents decline to adopt it. Alternative 2, 2A, and 2B are feasible alternatives that must be analyzed in a recirculated Draft EIR.

New Alternatives 2A and 2B Would Avoid the Adverse Impacts of the Revised Project

Alternative 2A: This alternative can be thought of as "think before you act." Under Alternative 2A, the Delta Plan and the Regulations would not encourage or recommend new or improved conveyance, water intakes, conveyance facilities, exporting more water in the wet years, optimizing diversions in wet years, and the like at this time. The decision whether to call for new conveyance would await the determination of such fundamental issues as water supply availability and the environmental impacts of supplying the water under CEQA including a helpful guide as to what is necessary, set forth in the California Supreme Court's decision in *Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova* (2007) 40 Cal.4th 412. The decision whether to call for new conveyance would also await your determination that would take into consideration a cost-benefit analysis and public trust doctrine analysis. The decision would also await the Council's preparation and circulation of a new Draft EIR so that the decision-making public agencies, and the public itself, would have the benefit of full environmental disclosure, consideration of the true project and its environmental impacts, and thus the ability to make an informed choice among reasonable alternatives.

The RDPEIR demonstrates the lengths the EIR preparers are willing to go to in order to reach the desired pre-decisional conclusion that the Revised Project is environmentally superior. They may assert that the detailed CEQA analysis, water availability determinations, and public trust doctrine analysis will and/or should be made by other agencies such as the BDCP lead and responsible agencies and/or the State Water Resources Control Board (SWRCB). On the contrary, in order to proceed in a manner required by law ***some*** public agency must make these critical determinations ***before*** the threshold choice of alternatives is made to call for new conveyance. If the Council is unable or unwilling to do this work, a policy or recommendation calling for new conveyance cannot lawfully be adopted unless and until the CEQA and public trust doctrine analysis has been done in the BDCP process and/or the SWRCB process.

We maintain that Alternative 2 is the environmentally superior alternative that should be adopted at this time. If, however, the Council does not do that, Alternative 2A must be adopted if any alternative is adopted because there has not been sufficient CEQA analysis and compliance or any cost-benefit and public trust doctrine analysis to support calling for, encouraging, or recommending new conveyance at this time. Alternative 2A would lessen the significant environmental impacts of the project by not calling for new conveyance and diversion of significant quantities of freshwater upstream from the Delta.

No comments

- n/a -

Alternative 2B ("Phased Reduced Exports Alternative"): Alternative 2B is also similar to Alternative 2 in that no new conveyance would be recommended prior to a robust CEQA, water supply and public trust doctrine analysis. This Alternative, however, lowers reduction in exports compared with Alternative 2, and/or, phases in reductions in exports over time by phasing out exports to impaired agricultural lands that will or should eventually cease production. This Alternative eases the practical constraints involved in reducing exports within a reasonable amount of time, given that any new conveyance would not be projected to be in operation before about 2026.

Analysis of these additional Alternatives would help the Council achieve its legal obligation to consider a reasonable range of alternatives. Thus far, the Council has failed to develop any reasonable alternatives to have more conveyance to export more water. Alternative 2 was presented to the Council by the EWC. As a public agency responsible for complying with CEQA, it is the Council that has the responsibility to ***develop a reasonable range of alternatives***. The Council should not simply reject Alternative 2 by characterizing the export reductions as being too severe. Rather, the Council should undertake to develop an alternative that on the one hand, like Alternative 2 does not call for new conveyance, but on the other hand, does not reduce exports to as great a degree as is done by Alternative 2. For example, Alternative 2B could include assessing limitations of exports to a maximum of 3,500,000 acre-feet/year which is more than the exports under Alternative 2.

An EIR must "describe ***a range*** of reasonable alternatives to the project, . . which would feasibly attain most of the basic objectives of the project but would avoid or substantially lessen any of the significant effects of the project, and evaluate the comparative merits of the alternatives." CEQA Guidelines, § 15126.6(a) (emphasis added). "Because an EIR must identify ways to mitigate or avoid the significant effects that a project may have on the environment (Public Resources Code Section 21002.1), the discussion of alternatives shall focus on alternatives to the project or its location which are capable of avoiding or substantially lessening any significant effects of the project, even if these alternatives would impede to some degree the attainment of the project objectives, or would be more costly." CEQA Guidelines, § 15126.6, subd. (b). The Council has not described ***a range*** of reasonable alternatives to the project which would avoid the adverse impacts of adding large new diversions of freshwater upstream from the Delta even though these alternatives would not reduce exports as much as would be accomplished by Alternative 2. This deficiency in the CEQA process is so profound that a new Draft EIR describing and considering new alternatives 2A and 2B must be prepared and circulated. Adopting the Delta Plan, Regulations, and certifying a Final EIR without doing so would be failure to proceed in a manner required by CEQA. These are not violations that can be cured simply by responding to comments in a Final EIR.

No comments

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Finally, the Council may continue to make the lulling statements already made in the subject CEQA documents claiming, so to speak, that the Council is not really doing anything now in terms of developing new conveyance and that environmental impact analysis will take place in the future. It appears that the Council is trying to mislead the public into believing that the Delta Plan is not a real threat to the Delta, but that later on, the BDCP preparers will jump up and say that the Delta Tunnels are consistent with the Delta Plan call for new conveyance and that the threshold decision to develop new conveyance was made in the Delta Plan. Unless the Council eliminates the call for improved, new, conveyance and the like from the Delta Plan and Regulations, it will be necessary to challenge the Delta Plan, RDPEIR, and Regulations if approved and adopted, in court to prevent that "not now, not ever" unlawful end run on CEQA from being successful. Approval of any calls for new conveyance, optimizing diversions in the wet years and the like must be deferred until CEQA has been complied with and the public trust doctrine analysis has been performed.

Failure to Effectively Require Mitigation or Describe a Truly Environmentally Superior Alternative under CEQA and the Endangered Species Act

As pointed out in detail in the EWC comments, the RPDEIR concedes that the Revised Project would have significant and unavoidable environmental impacts including violation of water quality standards and adverse effects on special status species. (RPDEIR 24-10). Alternative 2 (and 2A and 2B), however, would result in far fewer significant and unavoidable environmental impacts than any of the other alternatives analyzed in the PDEIR or RPEIR. The RPDEIR concedes that "Alternative 2 contributes more to improving conditions for biological resources and arresting ecosystem decline than the Revised Project." (RPDEIR 25-7). Alternative 2 clearly meets the project objectives reducing reliance on the Delta in meeting the state's future water needs through regional self-reliance, is consistent with the Delta Reform Act, is implementable in a comprehensive, concurrent, and interrelated fashion, and can be accomplished as rapidly as realistically possible without jeopardizing ultimate success. Under CEQA, if an alternative is presented that meets project objectives and can reduce significant impacts to a less than significant level, the lead agency must adopt this alternative if feasible. *Mountain Lion Foundation v. Fish & Game Com.* (1997) 16 Cal.4th 105, 134. "CEQA compels government first to identify the [significant] environmental effects of projects, and then to mitigate those adverse effects through the imposition of feasible mitigation measures or through the selection of feasible alternatives." *Sierra Club v. State Board of Forestry* (1994) 7 Cal.4th 1215, 1233, Pub. Resources Code, § 21002. To simply accept such significant impacts while ignoring viable alternatives violates CEQA.

The proposed mitigation measures offered by the Plan also fail to meet CEQA's standards. Proposed mitigation is not sufficient unless such mitigation is implemented as a condition of future development. In its current state, there are no repercussions if subsequent

No comments

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project proponents choose to adopt some mitigation measures but not others or no mitigation measures at all. Proposed mitigation cannot be mere suggestions, and instead must be fully enforceable. *Federation of Hillside & Canyon Assn. v. City of Los Angeles* (2d Dist. 2000) 83 Cal.App.4th 1252, 1259.

The failure to require mitigation for endangered species impacts also violates the Federal Endangered Species Act. There is no discretion under the Endangered Species Act to authorize a project that would jeopardize survival of listed fish or adversely modify critical habitat. *Center for Biological Diversity v. United States Bureau of Land Management(Ruby Pipeline Case),* 698 F.3d 1101 (9th Cir. 2012). In the *Ruby Pipeline* case, the Fish and Wildlife Service's Biological Opinion analyzing the impacts of a natural gas pipeline incorporated voluntary conservation actions as mitigation measures which factored into its determination that the project would not jeopardize the continued existence of several endangered species and would not adversely affect critical habitat. The Ninth Circuit found the Service's determination to be arbitrary and capricious because the conservation measures were mislabeled and unenforceable. The *Ruby Pipeline* case confirms the standard that valid mitigation measures must be enforceable under the Endangered Species Act and may not be simply voluntary suggestions.

If the Fish and Wildlife Service concludes that jeopardy or adverse modification is likely, then any take resulting from the proposed action is subject to Section 9 liability. *See Sierra Club v. Babbitt,* 65 F.3d 1502, 1505 (9th Cir. 1995). In its discussion of section 7 of the ESA in *TVA v. Hill,* the Supreme Court made clear that "Congress considered and rejected language that would have permitted an agency to weigh the preservation of species against the agency's primary mission." *Ctr. for Biological Diversity, supra*, pp.1115-16, citing *Sierra Club v. Marsh* (1987) 816 F.2d 1376. Thus, the Council may not summarily reject alternatives and mitigation measures that would avoid impacts to endangered species simply because the Council would rather increase export conveyance capacity.

In addition, mitigation measures here are dependent on actions that may never come to pass. Bond measures that have already been pulled from the ballot twice and that may never pass are not the effective mitigation required under the Endangered Species Act. Mitigation measures must be an integrated part of the project, so that if a measure is not implemented, re-initiation of consultation under the Endangered Species Act is automatically triggered. *Sierra Club v. Marsh* (1987) 816 F.2d 1376. The Delta Plan allows exporters to avoid all costs of the worsening salinity intrusion in the Delta that will result from the BDCP and shifts those costs on to the taxpayers. The problem for the Council in that regard is that mitigation must be real and assured. In the words of the Ninth Circuit, "any risk to listed species thereby created [by the project] 'must be borne by the project, not by the endangered species.'" *Center for Biological Diversity,* 698 F.3d 1101, 1115.

No comments

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The EIR Fails to Adequately Analyze the Impacts to Upstream Areas that Will Result from the Delta Plan Policies.

The EIR does not include an analysis of how the proposed BDCP conveyance will affect upstream reservoir operations, and how regulatory restrictions on these reservoirs will affect proposed project operations. Such an omission frustrates the public participation goals of CEQA. The decision in *Friends of the Eel River v. Sonoma County Water Agency* (2003) 108 Cal.App.4th 859, held an EIR insufficient to comply with CEQA in analyzing cumulative impacts with respect to a proposed increase in an agency's withdrawal of water from the Russian River. By failing to consider possible curtailment of water from the Eel River, the EIR failed to alert decision-makers and the public "to the possibility that the Agency will not be able to supply water to its customers in an environmentally sound way." 108 Cal.App.4th at 871. The failure to discuss the nature of altered reservoir operations and the related environmental impacts has frustrated the ability of public to understand the true nature of the Delta Plan, and has resulted in a failure to develop accurate mitigation measures and a reasonable range of alternatives.

Please call if you have any questions on our comments.

Sincerely,

E. Robert Wright
Senior Counsel

Kathryn Cotter
Legal Counsel

No comments

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