WATER WORKING GROUP, UNIVERSITY OF CALIFORNIA, BERKELEY
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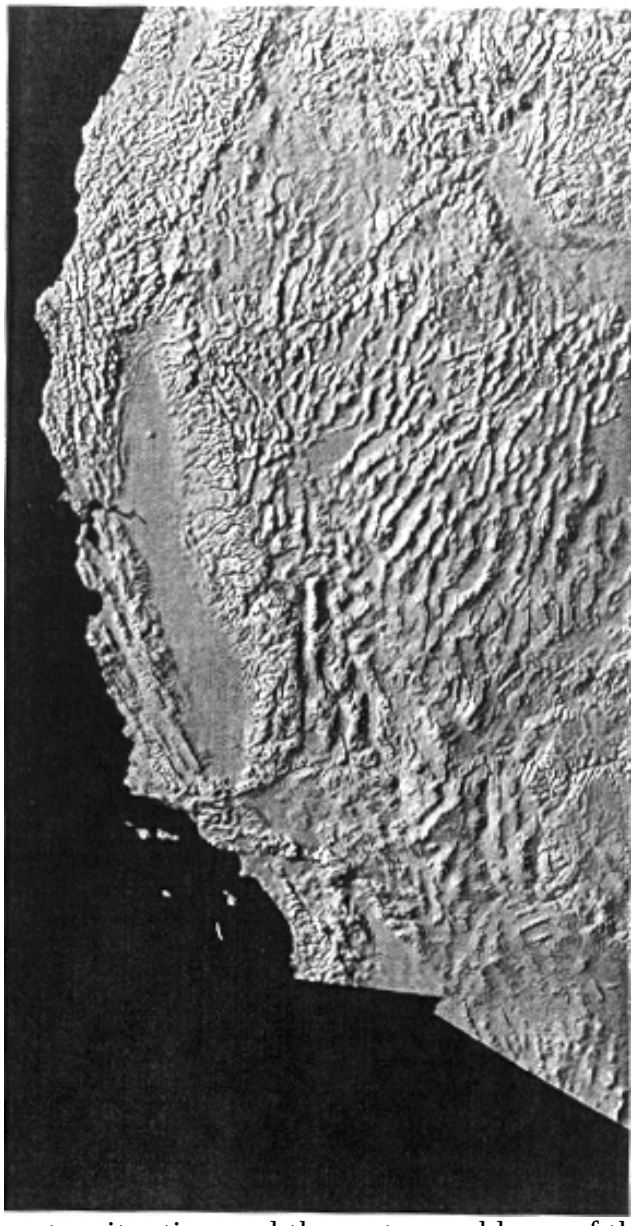
"Natural Resources, Society and Sustainability"

The purpose of my talk today is to look at waters in the San Joaquin and the Imperial Valleys and reflect on water issues in California. I'm not going to make any approach to present any models or give any wonderful solutions, or come up with any ideas to solve all kinds of problems. In keeping with this group here, I'm reminded of an old Hindu tradition. We have a whole body of the ancient metaphysics in India called *The Upanishads*, some of you might have heard of it. The word "*upanishad"* has an interesting meaning – "*upa*" means "at one's side" and "*nishad*" means "to sit". What this really means is that traditionally, the student and the teacher sat side-by-side, not in front of each other, but side-by-side and engaged in a dialogue and discussion. And so in that kind of a way what I'm going to talk about today is more an exchange of my own ignorance, my own idiosyncrasies and pet peeves with you. And I will present it for whatever it is worth, and let's have a discussion.

The perception which I'm going to, I espouse, is how as a society Californians approach their water problems is a reflection on how civilized they are. We all have civilizations, but sometimes we wonder how civilized we are. And my belief is that the conflict issues need to be solved with an ability to make qualitative judgments to guide equitable social policies. Now we are in an age of quantification computation, and everything has to be given a number and put into the computer. And having engaged in the pursuit myself and having tested some of the mathematical equations that stem from physics, and having some idea of to what extent they are actually based in reality, I am not really sure that in broader social problems like water -- which I'm going to talk about today -- trying to be very unduly quantitative is very useful. On the other hand, we must have the ability to comprehend and make qualitative judgments, sometimes the

answers are not black and white, and that is the essence of how civilized we are and how, when, we are able to achieve that. Ultimately, California's water issues are going to be the heart of our notions of democracy. And one of the bottom-line questions is, does freedom imply the right to be irresponsible?



With that very brief mental view I have, let me start with giving you some idea about the water situation in the San Joaquin Valley and the Imperial Valley. jJst give me a little minute so then we'll go on to other issues like salinity and so forth. This is a spectacular relief picture of the United States and here we have these huge gash or scar -- I mean this is visible from deep space -- that is great valley of California, and the San Joaquin Valley is the southern half of it. Here it is the confluence of the San Joaquin, the Sacramento, during the rain, and this is a truly enclosed valley. (*shows map of California*) And if we look at the San Joaquin Valley the very geographic nature of that, that has very challenging influence on the water situation and the water problems of the San Joaquin Valley. It's intuitively, quite easy to understand, it's not very difficult to understand.

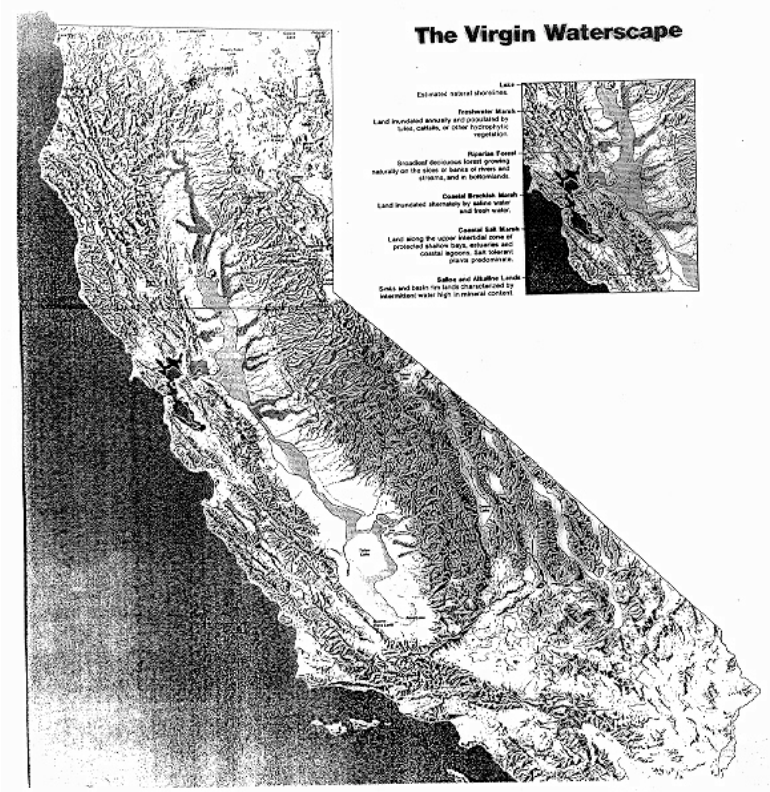


Figure 13: California's virgin waterscape, the natural physiographic setting as might have existed prior to European influence (From California Water Atlas)

This is a more elaborate picture of the same area. So, I'm talking about the San Joaquin Valley, the southern part of the great valley. And it is closed off on the south by the Tehachapi Mountains, by the Sierra Nevada which is fairly high, Mt. Whitney is at 14,000 feet. The Sierra Nevada comes south and then west and it merges with coast ranges. So the San Joaquin Valley actually, is an inter-mountain valley between two mountain ranges, it is highly elongated, about 250 miles long by 550 miles wide, and the southern extremity (Bakersfield) is here. *(Showing maps of California and the San Joaquin – Sacramento area)* In this part is a topographical depression, and it made San Joaquin Valley -- and San Joaquin comes down and goes north -- this is actually an isolated basin, with very, very high floods as water flows from here to the San Joaquin Valley.

And because the land slopes toward the north, and in a moment I'll show you another handsome sketch, water movement, except for this part, is generally to the north, and because water is driven from both sides -- this is a virgin water sketch, which is supposed to be just an impression of how this region might have

looked prior to say the 1800's. And all the way from here, what we call the Tulare range, there were wetlands, all the way to Stockton and beyond. There were actually about 4 million acres of wetlands in California at that time and by 1902 when we started reclamation, and by 1905, it had declined. Now we have 400,000 acres of wetlands, which is about 10% of what we used to. And Tulare Lake has completely disappeared because of further reclamation. So, the land slopes that way and there are many -- in San Joaquin there are many -- tributaries to the San Joaquin river, there is Merced, we have Tuolumne, we have Stanislaus, all these rivers, and because the coastal range doesn't have much rainfall there's no streams coming from over west. So, this is the lay of the land. Water moves reasonably well from east to west laterally, but water moves very slowly towards the mountains, especially grounwater, and that is the reason why we have serious problems in the San Joaquin Valley.

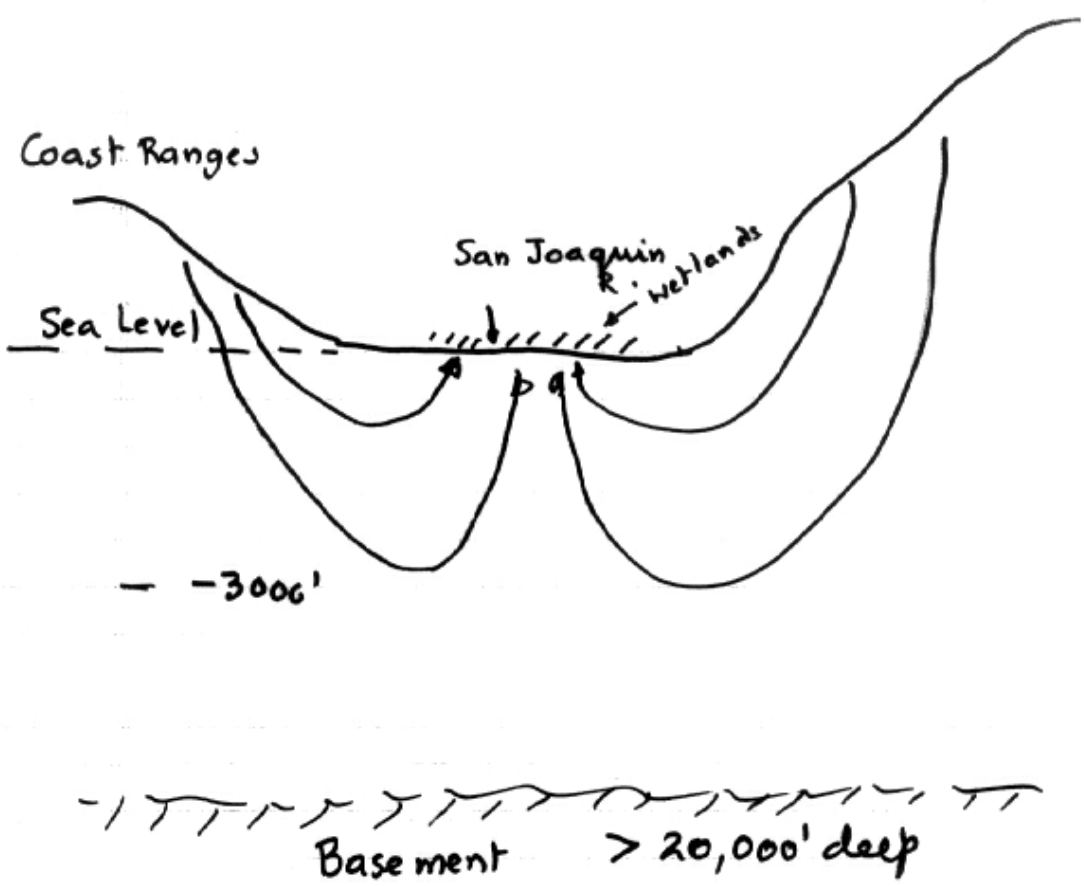
[Q: why does it move so slowly towards the north?
A: Because the gradient is very small. Because we have, in this area to go to the San Joaquin Valley the elevation is probably 100 feet or less.]

The reason why, you see that inter-mountain valley – let me give you one bit of geological information -- about 2 million years ago the (sounds like) coast range did not exist. The coast range came within the last 3 or 5 million years ago. So, this entire basin was actually a a deep sedimentary basin. Today, if you go to the Bakersfield area you can go down 30 or 30 thousand feet and still be in sediment, that's why we have so much oil there and oil fields. So, all through here and all the way up to here (*shows maps*) we have natural gases, so the area, 3 million years ago, was primarily marine rocks, a very deep basin. Then as the coast ranges began to rise, gradually this basin got isolated from the Pacific Ocean except for this bay, this connection to what we now call the San Francisco Bay. That's the only connection between the Pacific Ocean and this.

So successively, this became brackish water and then became fresh water. So, out of these 20,000 feet of sediment, upward 3,000 feet or so you get fresh water. Then probably if you go deeper than that you go into brackish water and

eventually to brine, and to petroleum. So that is the situation we have, and so we have a deep sedimentary basin, and in the very upward part of it -- about 3,000 feet or so -- we have reasonably fresh water. Before all this area this became wetland there was actually a very deep lake here and they want to call it Lake Corporal, there was a lake here, and the lake sediment around it (*referring to the board or overhead*) were very soft. So because the lake sediment was soft they had a lot of porosity, and there was a lot of water in that, so there's all this water trapped in there. This cartoon here gives you an idea of how water moves here. Water moves – rainwater falls from the Sierra and coast ranges, and the coast range is a little bit shorter, the Sierras are much higher, the water moves down just like water always moves down. It comes down but then below here we have heavier water, brackish water, and seawater and because of its many plates and inter-river zones here the water is pushed back up. The water is pushed down and has no place to go except come back up to the land surface. So this whole area is called what we call the "discharge area". The circulating water goes down to about 3000 feet or so, and then comes up. So if you take a water particle and then follow it, the time that it takes to go down and come back up may be of the order of tens, maybe hundreds, of thousands of years. It's a very slow process. But like a steamroller this is a massive drive, it takes a long time, it's very

powerful but it is very slow.



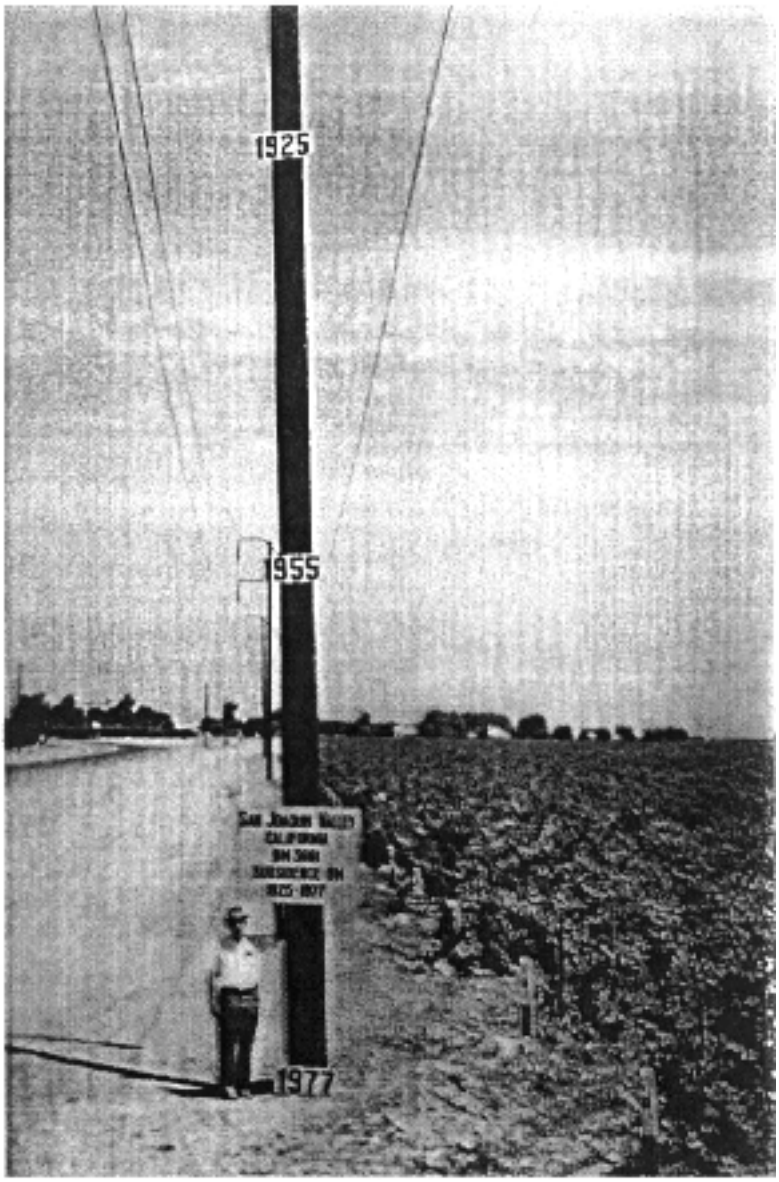
That is why when water was coming here, this area in the 1880s was teeming with artesian wells. There were places in Stockton and Tulare County where they built a well 1,000 feet, and they had 1 million gallons of water per day, just freely flowing to the land surface. So this was teeming with not only wetlands on the surface but also with artesian wells -- all of them indicating that water was going down and coming up again. And the water that was moving down and coming up was not just remaining fresh water because also dissolving and precipitating all the chemicals that were in the creek, so it was also doing a lot of chemistry. So if you start the water particle coming from here, up here then coming up, then it's a whole a lot of…. an enormously interesting chemistry that goes on in the water, the water reaction to the soil, and all the soil formations, and especially the soils that you see in the surface, are all dictated by the nature

of the flow-by. So before they started irrigating the soils were all dictated by this flow-by.

Now, remember that as you come out from northern California your rainfall is decreasing, so all these places tend to be somewhat arid. If you are in San Joaquin Valley going towards Bakersfield you personally know how hot it gets -- so because of that this water that comes up also evaporates and leaves a lot of salts here, so we have some wetlands which were brackish water wetlands, so that was the natural habitat for various fish. Now what we are doing -- in 1902 we started the *quote* "reclamation project" --- this was one of the nicest misuse of words I have ever seen, because they thought that wetlands were having pesky mosquitoes and somehow nature had taken it away from that so we had to reclaim it from nature. So they used these wetlands and wanted to make deserts bloom. So what we did was we irrigated this land. But still on the western side of the valley here close to the coast ranges, there was not much water. So then we started tapping groundwater, and so when we started tapping groundwater the soils were very soft, and as we reduced the water pressure, the land sank. So one of the first effects we had -- this happened in the 50's and the 60's -- one of the first environmental effects we had because of pumping water in the San Joaquin Valley was land subsidence.

In 1925 the land was here (*referring to overhead*); in 1977 the land was here. We had it in some places as land subsidence as much as 30 feet. This happened primarily because these were sediments that sat in sand, a very soft setting, they are not very highly compacted. So as you draw water by heavy pumping you decline the water pressure, as you decline the water pressure, the pressure was supporting some of the sands that gradually fell down, and the land simply got compacted. And so land subsidence gave us this problem. Remember this is the western side, where we have the California aqueduct, and on the California aqueduct between Byron and Los Banos the gradient is 1 or 1.2 feet per mile, a very gentle gradient. If you create major land subsidence, everything will go out of whack. They have now cut down on pumping so you cannot anymore

indiscriminately pump water. That is one of the first consequences.



So we began importing water from these Central Valley projects and so what happened to the Central Valley projects? And the key difficulty we have is….if we now try to inundate this place with water for agriculture, you are going first to try to push water down, so you confront natural flow system. And because you're confronting the natural flow system -- the water that you get from the Delta – Mendota canal -- it's not very fresh water. It comes through the delta, it has about 400 or 500 parts of living salt. And as you put the water here the plants try to bring the water back up by transpiration. And the water eventually

evaporates, but the salt remains there. Now we are estimating that we are importing about 1 million tons of salt every year into the plants.

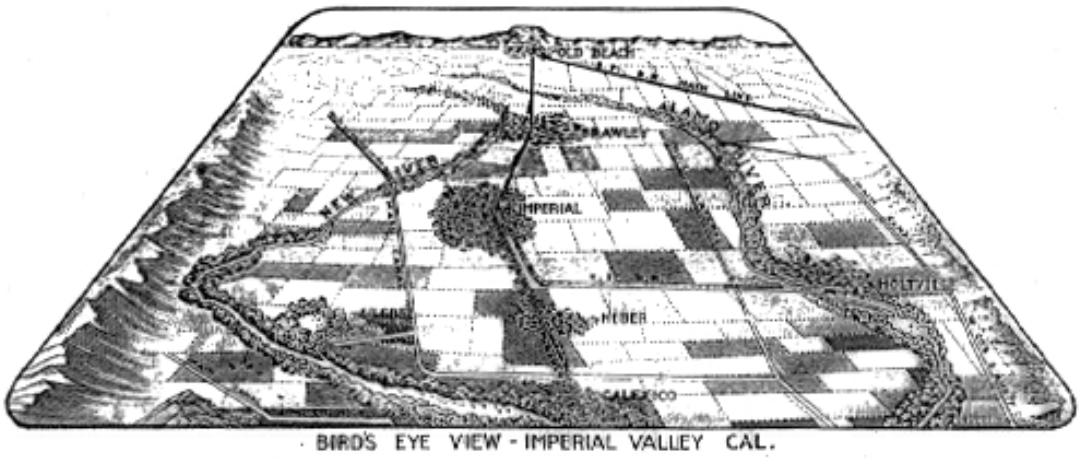


Figure 24: Bird's eye view of the Imperial Valley. The Salton Sea did not exist before 1900 (Heber, 1904)

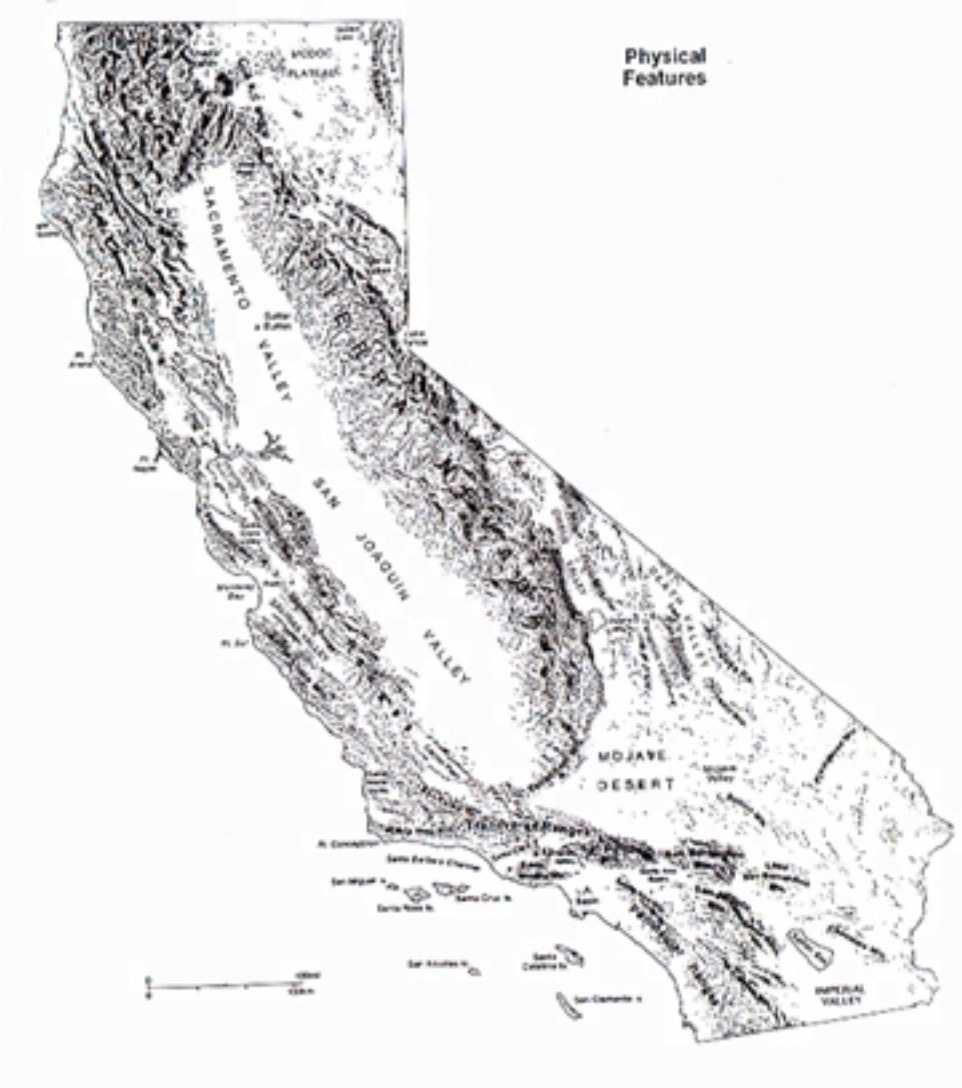
So if you take the agriculturalists who want to enhance production, they have lots of local battles, they do drainage, they do this, they do that, all to improve the efficiency. That is all a local battle. But if you take a time scale of 50 years or 100 years, and every year you bring in a million tons of salt and every year you push water up, unless you take this million ton of salt and transport it out to the bay or someplace -- which you cannot do -- that salt has to remain there. And so we don't have any permanent solution on a 50 to 100 year scale; it is a question of time. The question is the corporations and others who do monetary economics, they factor this in as an optimization probem; they factor in dollars and cents. And at the point that a particular plot doesn't yield crops anymore, they move away from it, so every year I believe 4 or 5 thousand acres of land is simply moved away from agriculture, because they cannot irrigate anymore.

Major reservoirs of the San Joaquin River Basin: (1) Lake Isabelle, (2) Pine Flats Reservoir, (3) Millerton Lake, (4) Lake Henseley, (5) Lake McClure, (6) New Don Pedro Reservoir, (7) New Melones Reservoir, (8) San Luis Reservoir (Modified from Layman's Guide ———)

And so the deterioration of the land is expanding in the San Joaquin Valley, however much we can try to optimize it out. Eventually you have to address the long-term issues but let me come back to that, let me plant that idea in your mind

about the long-term consequences. And now let me show you the Imperial Valley sketch. Most of us talk about the San Joaquin Valley. They have exacerbated the problem of what we have done in the San Joaquin Valley. These are all streams in San Joaquin Valley. We have the San Joaquin, the Merced, the Tuolumne, the Stanislaus and so forth. Every single one of these river is dammed up. Some of them are big dams. I'm going on Saturday to the Melones Reservoir on the Stanislaus, it has the capacity of 2 million-acre feet. And every single river is dammed and that has greatly reduced the flow of the San Joaquin River -- it cannot take sediments anymore, it cannot take salts anymore, so that further exacerbates the problem. In fact, some people who don't like this very much call this stretch of San Joaquin River from Mendota further down the *colon of California.*

[Audience comment: Just for a scale, 2.4 million-acre feet, that captures 200% of the annual un-incurred run-off. Two times what naturally flows down the river is entirely captured in the dam]



Now we come to, this is another physiographic map . I chose this one because it nicely shows the Imperial Valley here (*shows overhead*). So the Mexican border is here, this is the Salton Sea and we have a series of mountain ranges which ring the Salton Sea – the Colorado is going here (*referring to the map*). The Salton Sea, the bottom of the Salton Sea is minus 278 feet; it is within 4 feet of Death Valley. They say that Death Valley is the deepest, but this is very close. So it is a depression. Actually, the geology part of it is fascinating. The Gulf of California which now has its head in Mexico, actually, it extended as far as the Gulf of Gorgonia near Riverside, a million years ago. And the …what the Colorado did was to bring its sediments and then deposit it into the bay, in the Gulf of California, and cut it up, and so this depression was left. So you go in to this depression to great depths you get salt water, then eventually it becomes fresh

water, and then now we have fresh water sediments there. It is fresh water sediments that render the Imperial Valley suitable for cultivation, but there's no water.

So in the 1850s, the people who came here looked at the topography and said if only we can get water from the Colorado. In 1853 they tried to move the Congress to get money for irrigating 500,000 acres of land. They eventually succeeded in 1890s, but then that led to a catastrophe. What happened was, this is a very nice picture from 1904, and unfortunately you don't see this very well….this is a hand drawn sketch. These are all the mountains here on the left, these are other mountains on the right, and another set of mountains close off -- that was the head of the Gulf of California a million years ago, and that is the Salton Depression. Water from the Colorado flows in here. Actually this was 1904; there was no Salton Sea. They were trying to get a canal from the Colorado River via Mexico to irrigate the land, and the canal got silted up, and there was a private company trying to give water to the farmers. All the farmers went and said where is my water, and so the guy tried to create another canal, and that year the Colorado was hit by a big flood. So he breached it and the Colorado poured into the Salton Depression. Within a matter of two years, they had two successive wet years, 1905 and 1906, and they had a water spread something like 500 square miles or something. That's how the Salton Sea got created. So the Salton Sea is just a depression.

So they started irrigating. They were getting water from Mexico and then finally they built the Hoover Dam and the All-American Canal, and they brought water here. And in this depression with an annual rainfall of 5" a year or less, water cannot go anywhere except up. So salt was accumulating in the soil and in order to keep the soil free of salt they had to have underground drains so in the 1920s they started this humongous drainage system. Now they have 20,000 or 30,000 miles of underground drains and where will the drain water go? It has to go to the Salton Sea. But for the agriculture drainage Salton Sea wouldn't exist because it would evaporate. But this drainage water is poor water, so the Salton Sea, which started up as a fresh water lake in 1906, by 1960s it became brackish water,

and everybody was happy because it was attracting flamingos and pelicans or whatever. So that was a new transitional, temporary ecosystem that developed. And by 1980's the water became 45,000 parts per million salt, or 1.5 times as saline as sea-water. So all the things are dying away. So now the ecosystem is going away. And in the meantime during the 1960s, around the Salton Sea all these beach communities and businesses had started. And now as things become more and more saline that business is going down, so they want to prop up the economy. There are a whole lot of measures now of trying to export salt out of the Imperial Valley. And where it will be exported to we don't know. Because there's a lot of salt and if want to get rid of it to the Gulf of Mexico that's a very, very sensitive, ecologically sensitive area. The United Nations has two observation stations there. So now – what this tells us is that technology and economic optimization are exceptionally good at solving only certain problems. I'll come back to that statement in a moment. But this is what happened with the Salton Sea, this is how all these lands got salted up.

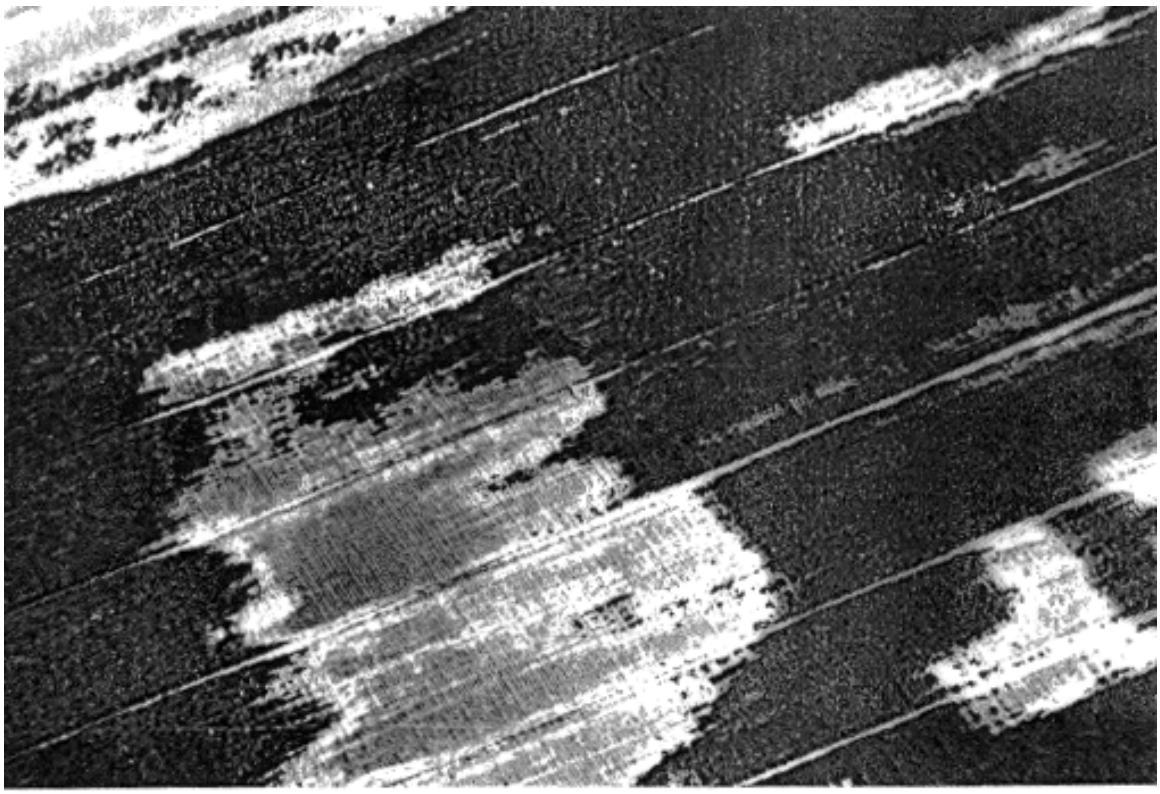


Figure 46 Salt buildup in agricultural lands of Coachella Valley. Both in the San Joaquin Valley and in the Imperial Valley, the evaporative accumulation of salts in low-lying areas caused by irrigation is unavoidable (From Hundley, 1992)

Now let me very quickly give you my nickel's worth of what I understand by sustainability -- as a hydro-geologist I would like to look sustainability as the ability of the infrastructure, of land, water and soil, to support plant and animal life in a desirable way. But this is sort of… we can have a hierarchy of definitions of what sustainability is. If you are involved in any particular industry or agriculture or whatever, you say how long can you do agriculture o this land? And my definition doesn't quite, it's not quite compatible with monetary economics because some of the values we talk about you may not be able to translate to dollars and cents. And that became wonderfully clear during the Mono Lake debate. And by the way, I don't know how many of you know about this -- that the Mono Lake court judgment which eventually saved Mono Lake was initiated by an undergraduate here at Berkeley. He was a student in natural resources and they had some professor -- I don't know who the professor was -- gave an assignment to find out about an environmentally damaged area that

everyone knew about, but nobody was doing anything about it. So this young fellow found out about Mono Lake, and started asking how you could do something about it. People said: There's no possible way you can fight Los Angeles city, except if you can find a legal principle, and the legal principle he found was Public Trust Doctrine. And that doctrine essentially said that there are certain things you cannot place dollars and cents values on -- that's what happened in the case of Mono Lake. The court said that saving the Mono Lake ecosystem was more important than providing water for 80,000 households in Los Angeles. And Los Angeles city argued that we are bringing water to 80,000 families. The high court said No! Clearly we are in a situation where you cannot make all decisions based on dollars and cents.

The consequence of this, as a geologist, I find is that we have to somehow learn to manage the complexities of natural systems, and nobody can even claim that you can predict this system's behavior over very long periods. So what we have to do is have some humility. Have some practical plans, and monitor the system and adapt ourselves as we go along. We have to have an open-ended approach to management and we must be able to monitor and collect data on a long-term basis so that we can learn from history. If we go back to the Bureau of Reclamation contracts, they all signed contracts for 40 years or 50 years. Now there is so much opposition that if they want to terminate contracts they cannot, they have to keep them going. In principle, these contracts were all right – they knew that things were unknown. The Bureau of Reclamation itself has undergone a tremendous paradigm change -- and they find it very hard to implement this paradigm change, because they cannot terminate these contracts.

So what is happening because of this ethic, or lack of ethics, in trying to go for short term gain and accountability? The U.S. Geological Survey used to be an institution for gathering basic data about water and ecosystems and natural resources, but it was almost shut down 5 years ago. Now the U.S. Geological Survey -- every scientist has to justify his existence by producing something or the other for the "customer". We don't have recognition that there are certain components of society which are not to be just based on this kind of business

ethic. We cannot do this with education for example. There must be key institutions which are repositories of basic information, so that society can benefit from it. We don't have it now!! And about 10, 15 years ago it started with the AT&T – Bell Laboratories, for example. The At&T – Bell Laboratories had some of the most distinguished scientific researchers. But because of pressure from stockholders, they completely abandoned those long-term research goals, which had produced a lot of good results. We don't have… almost all of the business institutions don't care for anything long-term. And whether society can be guided by the same principle, all components of society – we may have to think a little bit about that.

Now, this is my last viewgraph. *(shows overhead)* I think in our society we have this… we are in a remarkable democratic society, we are here because we migrated here -- most of us -- to so called freedom. We have tremendous freedom to make profits and prosper but are we equally cognizant of the responsibility for the common good, the notion of common good that goes with freedom? And I think the notion of common good was epitomized, in my view, in the Public Trust Doctrine -- 1928.

Very quickly I wanted to say how the Public Trust was started. Actually it started in 1878, in California's first constitutional convention. During the first 20 years of statehood California gave unlimited freedom for anybody to develop natural resources. And so private companies started providing water supplies for all the cities like San Francisco, Los Angeles, and so forth. By 1875 both San Francisco and Los Angeles discovered that private companies' goals of making profit were not quite compatible with the water supply for their citizens. So even as far back as 1880 San Francisco and Los Angeles tried to move towards buying those companies and managing the water supplies themselves. It was around this time that mining was going on. There was a tremendous amount of land speculation based on water, and they had an 1878 constitutional convention because some article (14 or 24?) of the constitution declared that all use of water in California is public property. That every water use, every user of water must get the state's approval for use of the water. 1878. But after 1878 our legal system

is mainly legal interpretations, not necessarily justice, we know that justice can be one way, and legality another. So if it was not explicitly written, they were not going to interpret. And things came to a head in 1926 when the Central Valley there was a court case between Southern California Edison, and a lady who had a lot of land here and riparian rights. It was clear she was doing flood irrigation. And Southern California Edison wanted to do build some hydraulic power plant and so they came to a head. And the plaintiff, the lady, argued that no matter that the water is basic, my right is my right. That's when the people of California said: enough is enough, and passed a constitutional amendment which is now called the Public Trust Doctrine. 1928. I think it is a landmark event.

Now there are some who when they talk about not getting water -- supposing I get water in Fresno, saying I'm going to do agriculture, and then turn around and sell it to somebody. Is it in violation of public trust? When I asked this question one economist said: we'll change the Public Trust Doctrine. Anyway, so finally my question is, as a geologist, and also as a person who enjoys the beauty of water, is water merely a commodity? Can all the components of society, its education and knowledge infrastructure, be guided by commodities? When I say knowledge infrastructure I mean, for example, the USGS. Can all of these institutions be subjected to accountability to stockholders, to taxpayers, as seems to be the current paradigm? Thank you.

Let me finish up, I'm sorry. You know I think we must also be aware that there's a strange convergence now. Back in the late 19th century Muir and others argued about the spirituality of water, and said we do not want to misuse and lose water because it is not right. But strangely, now we are slowly coming back to the preservation of wilderness, to the flora and fauna. For more mundane reasons, not necessarily spirituality. We have a new word, *stakeholders.* What kind of stakes they hold I don't know. They come in, join together, and we are beginning to get new institutions, where everybody now talks to everybody else. I don't know how well it's going to work, but it is kind of interesting that they now want to listen to Muir, or the Sierra Club – not for the sake of spirituality,

but now because their salmon business is going away or something. They are coming back to Muir now.

(*Note*: This is a transcribed talk. It has been only minimally edited, so that the speaker's individual "voice" still comes through -- Isha Ray.)