CALIFORNIA FACES A REAL CHALLENGE . . .

. . . in a very important area of water management—making the conservation of water an everyday part of our lives. We have made some progress toward this goal, but much more remains to be done. The Department of Water Resources is firmly committed to a policy of maximum practical water conservation and, for the past four years, has been pressing toward this end.

We know that Californians can and will reduce their consumption of water, when they are motivated to do so. Although the 1976–77 drought was a difficult period for many of us, a great deal has been learned from it. For one thing, when absolutely necessary, people will cut their water use dramatically, even when it means greatly altering their habits of living. Those served by the Marin Municipal Water District in Marin County, one of the most critical areas, showed what could be done by dropping 63 percent from their pre-drought level. Such a drastic rate of conservation cannot be expected in normal times, of course. For another, we learned that most people can significantly reduce their water use without seriously hampering their way of life.

The most positive finding has been this: even though the winter of 1977–78 was unusually wet, and water supplies returned to normal, many areas have continued to use less water than they did in 1975, the year before the drought began. In communities on the east side of San Francisco Bay, for example, consumption in 1978 was about 24 percent below that of 1975, and, across the Bay, San Franciscans were using at least 20 percent less than in pre-drought days. In Los Angeles, where the drought's effects were milder, water use in 1978 declined 12 percent below 1975. Although all the figures for 1978 are not yet in, partial reports indicate that many smaller cities also appear to be using considerably less water now than would otherwise be expected. This seems to be true, even when climatic differences and other influences on rates of use are taken into account.

Although water conservation is one of the keystones for future water management in California, several other important elements must also be considered. Among these are recycling water, reaching agreements that will achieve the best for the Delta and its future, using ground water reservoirs for storage in wet years against the demands of dry years, and ensuring future water supplies for the State Water Project.

As the Department moves ahead on these fronts, the tasks it faces are clear. By far, the greatest of these will be unifying the divergent views among the State's many water interests so that we can get on with jobs before us.

RONALD B. ROBIE
*Director*
*Department of Water Resources*
*The Resources Agency*
*State of California*

## CONTENTS

# THE BIG FLOOD THAT DIDN'T HAPPEN

Winter and spring of 1977–78 were extraordinarily wet for the great farmlands of the San Joaquin Valley, particularly in the southernmost portion. Thick falls of snow from the Pacific storms sweeping across the region left behind an accumulation of snow on the peaks and slopes of the Sierra Nevada that ultimately grew to about two-and-a-half times its normal depth. The snowpack was not only extremely deep. It was also a great deal wetter than usual.

Drenching rains fell in double the normal amounts for that part of California, swelling the rivers, and near-empty reservoirs in the western foothills of the Sierras filled steadily to levels that had not been seen since the pre-drought days of 1975.

Although the drastic change in the weather was not entirely unwelcome, the abundance of water that streamed into the valley taxed the flow-carrying capacity of rivers, creeks, and canals, and severely tested the ability of flood control facilities to contain the twice-normal runoff. Conditions became even more trying when the thick, wet snowpack began melting and releasing the water it held. Controlled releases of rainfall and snowmelt water necessary to regulate reservoirs further burdened the already saturated valley floor. As a consequence, some major rivers reached near-flood levels on several occasions from February through May.

More than once the San Joaquin River rose to warning stage, mandating the use of patrols to watch for signs of levee erosion and other damage. The river's high, sustained flows were sufficient to cause seepage in some locations, delaying the planting of crops, and residents of trailer parks and resort areas near the river were evacuated for a time. Flows in the Kings River began rising in March and continued upward, peaking just at the channel's maximum capacity on the first of May.

Considerable flooding did in fact occur in some places but, with very careful management, the flood flows were restricted for the most part to lands devoted to farming. This meant that planting of some of the best crop lands, particularly in the Tulare lakebed, had to be postponed until later in the season when the water could be removed by pumps. The result was a significant dollar loss to farmers. Major expenditures were necessary to strengthen levees to protect additional lands from flooding and to transfer water to areas where it would cause less damage.

The San Joaquin Valley, from the San Joaquin River south, received enough runoff from rain and melting snow, which, if it had not been most energetically controlled, would have caused an estimated $10 million agricultural loss in the Tulare Lake area alone (based on an estimate by Tulare Lake farming interests of about $12 per hectare, or about $30 per acre-foot.)

On the whole, the situation could have spelled disaster, had it not been for a lot of far-sighted planning and the prudent manner in which the water was channeled north and south from the Tulare Basin, as well as throughout it. Some weeks before the onrush of water hit, local water agencies, private farming interests, and federal and State government agencies, noting the above-average precipitation, began laying plans to minimize the flooding that appeared certain to develop. Throughout the spring, as events lived up to their expectations, these many water organizations worked closely together to maneuver water to locations where it could do less damage or, better yet, where it could be put to beneficial use.

The biggest moves took large amounts of water from rivers to canals or flood control bypasses inside the Basin or transported it by canal outside the Basin. Water was diverted to ground water percolation areas to replenish underground supplies, and farmers diverted as much water as they could possibly use for irrigation. For the first time, water flowed through the gates of the Kern River Intertie, a control structure that was built to provide a way of transporting water from the Kern River into the California Aqueduct, a feature of the State Water Project. The Aqueduct normally flows southward, but last spring, to handle the heavy runoff passing through the Intertie, the direction of its flow was altered so that some of the water could be pumped north as well. This water was used for irrigation in parts of San Joaquin Valley. The additional southbound water was pumped over the Tehachapi Mountains through the facilities of the State Water Project for use in southern California.

The high flows in the San Joaquin River also required special action. Water was directed from the river through bypasses in the San Joaquin Flood Control Project, thus relieving the pressure on river levees downstream from the point of diversion.

## HOW THE LAND LIES

The floor of Tulare Basin, which covers more than 13 000 square kilometres in the southernmost part of San Joaquin Valley, is effectively separated from the rest of the valley by a slight, imperceptible east-west ridge of alluvial material deposited by the

Kings River. The gradual but definitive slope, which rises at most only about 8 metres, forms the northern boundary of the Basin and causes streams flowing into the valley north of it to drain north to the Delta and those south of it to drain into the Tulare Basin. The Basin is ringed on its remaining sides by the Sierra Nevada, the Tehachapi Mountains, and the coastal ranges. The result is a vast, saucer-like expanse of land having no natural escape routes for the winter and spring runoff that flows down the streambeds leading in on nearly all sides.

Four principal rivers carry water into the Basin from the western slopes of the Sierras: the Kings, the Kaweah, the Tule, and the Kern Rivers. All are controlled by dams and reservoirs in the Sierra foothills. The Kings River, the most northern of the four, flows along the crest of the cross-valley ridge and then splits near the center of the valley floor, with one branch, Kings River North, flowing north into the San Joaquin River, and the other, Kings River South, flowing south into the bed of Tulare Lake.

The Kaweah and Tule Rivers flow directly into the lakebed. The Kern River, the southernmost of the four large streams, flows down the crest of another smaller alluvial ridge between the cities of Bakersfield and Oildale to a diversion located north of Buena Vista Lake. Some of the river's flow can be diverted by channels south to farmlands on the floor of Buena Vista Lake and north to farmlands on the floor of Tulare Lake. (Neither "lake" has held any water for many years.)

As it crosses the valley floor, the water carried in these four rivers is reduced by irrigation diversions and by natural seepage into the channel beds. Only occasionally do flows reach either of the lakebeds.

Three smaller streams whose flows are not restrained by dams or other control structures also descend onto the floor of the Basin from the Sierra Nevada: Deer Creek, White River, and Poso Creek.

In the valley, the Kings, Kaweah, and Tule Rivers cross the Friant-Kern Canal, an important water conveyance facility of the federal Central Valley Project that carries San Joaquin River water south for use by CVP contracting water agencies. The canal terminates at the Kern River. Water can be released from the canal into any of the rivers, but there are no permanent physical connections for diverting river flows into the canal. However, when necessary, temporary pump installations can be used to withdraw water from the rivers and discharge it into the canal. This action, taken last spring, was in fact a vitally important part of the entire battle to prevent flooding.

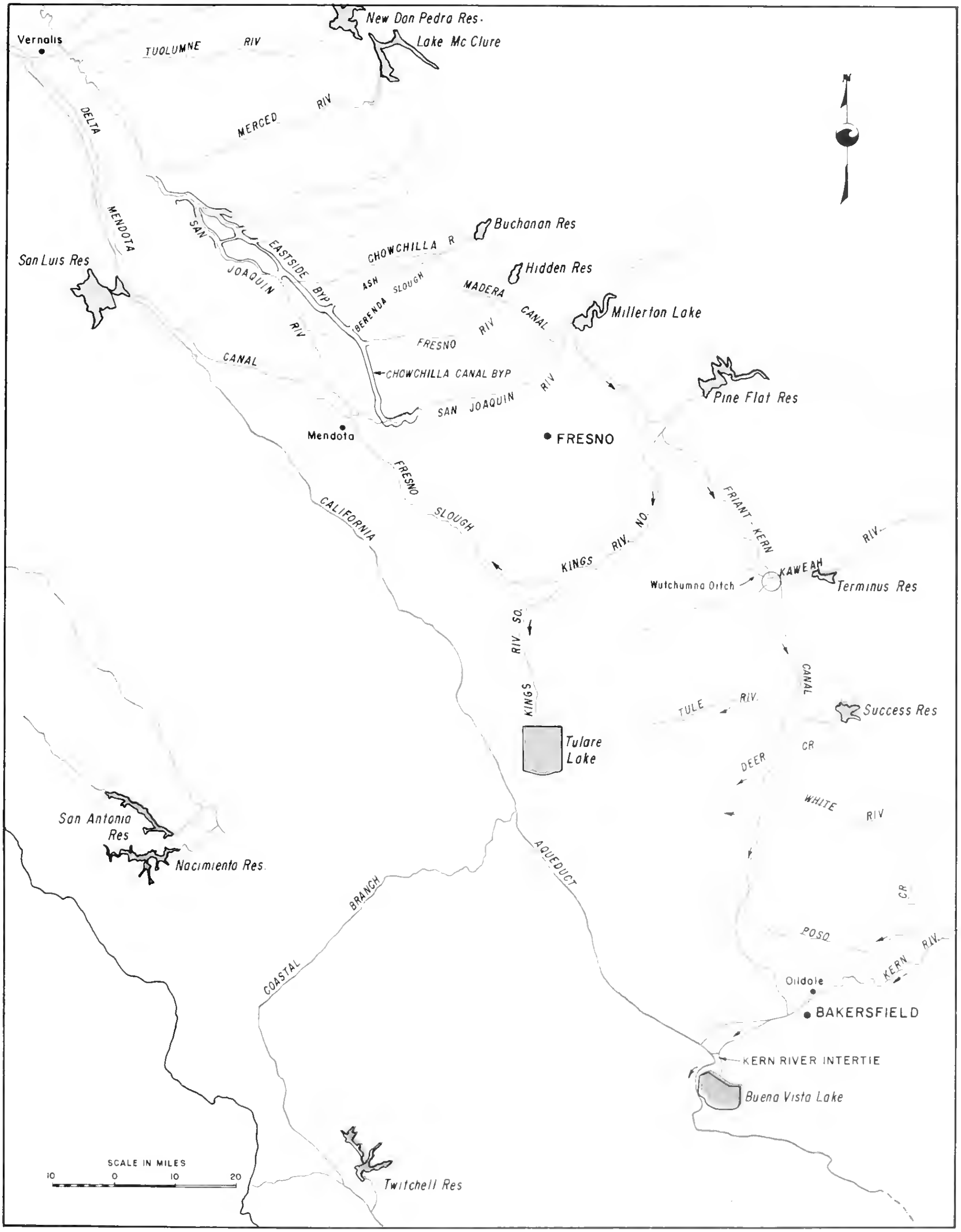
Once a large body of water across which steamboats churned regularly, Tulare Lake has been gradually reclaimed over the years and transformed into one of the most richly productive agricultural regions in California. Because its 777 square kilometres occupy the lowest part of the Tulare Basin, the old lakebed forms a natural sink that receives and holds much of the region's runoff during seasons of heavy rain and snow. All excess water that is not captured by the foothill reservoirs or does not seep below ground flows into the lakebed.

Tulare Lake farming interests, which are represented by several reclamation districts, have developed a highly efficient method of controlling this flood water. They have built an extensive system of levees that crisscross the lakebed, forming large rectangular cells, called polders. The levees may extend for as much as 6½ to 9½ kilometres to a side. Canals, diversion structures, and pumps may direct the incoming flows into certain polders and then move them to portions where the land is less productive, thus protecting the more valuable land in other portions. Because the levee heights are controlled, some of the water may also flow over the lower levees into some polders.

As it turned out, one totally unpredictable factor helped ease the threat of floods somewhat in the spring of 1978. Normally, spring melt-off is under way by April and continues at an accelerating pace in May and June, at which time most of the snow is gone. Sometimes, however, spring temperatures are cooler than usual, and the start of the snowmelt period is delayed. When this happens, some of the water contained in the snow is lost slowly by evaporating into the air or seeping into the ground while the pack still rests on the mountains. Just such a condition occurred in 1978. April, May, and June were markedly cooler, and, fortunately for the flood situation, the deep, wet snowpack failed to produce the immense rates of flow it might have. Even so, things were touch and go for many weeks.

## IMPORTANCE OF THE RESERVOIRS

One principal concern during the spring was regulating the runoff entering several major Sierra Nevada reservoirs—Lake Millerton on the San Joaquin River, Pine Flat Lake on the Kings River, Lake Kaweah (also called Terminus Reservoir) on the Kaweah River, Success Lake on the Tule River, and Isabella Lake on the Kern River. Lake Millerton is operated by the U. S. Bureau of Reclamation, and the others, by the U. S. Army Corps of Engineers.


New Don Pedro Res.
Lake Mc Clure
Vernalis
TUOLUMNE RIV
MERCED RIV
DELTA MENDOTA
San Luis Res
SAN JOAQUIN RIV
EASTSIDE BYP
CHOWCHILLA R
Buchanan Res
Hidden Res
ASH SLOUGH
BERENDA SLOUGH
MADERA CANAL
Millerton Lake
FRESNO RIV
CANAL
CHOWCHILLA CANAL BYP
SAN JOAQUIN RIV
Pine Flat Res
Mendota
FRESNO
FRESNO SLOUGH
CALIFORNIA
FRIANT-KERN
KINGS RIV. NO.
KAWEAH RIV
Wutchumna Ditch
Terminus Res
KINGS RIV. SO.
CANAL
TULE RIV.
Success Res
Tulare Lake
DEER CR
WHITE RIV
San Antonio Res
Nacimiento Res.
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Every year, before the Sierra snowpack begins melting, forecasts of runoff are prepared from field surveys of the depth and water content of the snow. From this information, reservoir operators plan their schedule of releases. Water released to make way for the influx of snowmelt is limited to the capacity of the river channels below each dam.

Timing of releases is critical in operating a reservoir. If the operator fails to reserve enough storage space for inflow from upstream, the reservoir will rise too far and top its spillway, and the rush of water into the stream below can overload the channel, possibly flooding nearby lands. On the other hand, if the operator releases too much water too early in the season, the reservoir may not fill during the runoff period, and the amount of water available later for summer irrigation will be reduced.

To properly regulate the rising reservoirs last spring, flood control releases were made from Lake Millerton in February and from Pine Flat Lake in early March. Local efforts were begun to divert as much water as possible for early-season irrigation of unplanted lands (a regular practice to prepare the soil for some crops) and for ground water storage. The Bureau of Reclamation, operator of the Friant-Kern and Madera Canals, was also delivering maximum quantities of contracted-for water to its water service contractors along the two canals. Contractors served by the Friant-Kern Canal used water to recharge ground water basins. Additional water was diverted by the Bureau to the Madera Canal and released down the Chowchilla River, Ash Slough, and Berenda Slough to be percolated through the permeable beds of these channels to ground water storage.

Despite all these operations, a great deal more water than usual flowed through the San Joaquin Valley Flood Control Projects.

## ACTIONS ON THE SAN JOAQUIN AND KINGS RIVERS

Because of the damage caused by water seeping through and under the levees along the San Joaquin River, the Department of Water Resources asked the Bureau of Reclamation to deliver the potential flood water through the Friant-Kern Canal to lands in the San Joaquin Valley being irrigated by wells pumping from seriously depleted ground water basins. However, present federal reclamation law restricts delivery of water from federal projects to individually owned farms that are no larger than 160 acres (the so-called 160-acre limitation). This prevented the water from being delivered from the canal. The damaging high water continued to flow down the San Joaquin, and irrigation with ground water went on.

Greater success was achieved in managing the high flows in the Kings River. According to the records of the Kings River Water Association, no flood control releases from Pine Flat Lake had to flow south from the Kings to the Tulare Lake area.

The Kings River North began rising in April 1978 until it reached a peak flow of 140 cubic metres per second at Crescent Weir on May 1. That was the limit of the channel's capacity. The stream then fluctuated between 122 and 140 cubic metres per second for more than two weeks and then slowly receded. By the end of May, its flow finally dropped to 28 cubic metres per second.

On May 3, the Department of Water Resources declared a pre-emergency flood condition in the basins of the Kings, Kaweah, and Kern Rivers. This type of declaration means an around-the-clock vigil of the endangered area must go into effect without delay. Crews were dispatched immediately by the Department and the Kings River Conservation District to patrol the levee system on the Kings River North. By the middle of the month, the river's flow had fallen to a safe level, and patrolling ended on May 15. On May 22, the San Joaquin River was added to the pre-emergency declaration because of its extremely high flows.

## FLOODING IN TULARE LAKE

Floods in the bed of Tulare Lake have three sources: intense local rainstorms; prolonged general rainstorms in the Sierra Nevada, the Tehachapi Mountains, and the Coast Range; and rapid melting of the Sierra snowpack. Rain-caused floods, which are characterized by high streamflows lasting only a few days, inflict damage chiefly on unharvested crops and on levees along the rivers.

During irrigation in most years, mobile diesel engine pumps are set in place to pump water from river channels into the lake's canal systems to be distributed for irrigation. Flood water reaching the lakebed does not always seriously impair operations there. If only a small volume of water enters, it can be disposed of by storing it in the innermost leveed polder and pumping it out later to adjacent fields. However, when streamflows are very high, the inflow is distributed into a succession of polders. In 1967, an unusually wet year, the excess runoff was stored in two polders, flooding a total of 7 000 hectares. During the heavy snowmelt

Courtesy Murray, Burns, and Kienlen

*During spring 1978, Tulare Lake interests adopted various means of helping relieve flood-threatened San Joaquin Valley. In one special operation in Tulare County, water was diverted for a time from the Kaweah River near Lake Kaweah into the Wutchumna Ditch, a local distribution channel, and sent down the ditch to the Friant-Kern Canal. In the view shown here, about 10 kilometres west of Lake Kaweah and not far from the town of Woodlake, the water from the Kaweah is being pumped from the Wutchumna Ditch (far left) over an embankment and into the canal (far right). This water was ultimately transported out of the valley through the canal to the California Aqueduct and then to southern California. The five D-7 track layer pump units (center left) were set up at this site temporarily and operated 24 hours a day from May 10 to May 26. During that period, they transferred more than 6 300 cubic dekometres of water into the canal at an average rate of nearly one cubic metre per second. These pumps, which are uniquely suited to very large farming developments, can be loaded on trucks and moved relatively quickly wherever they are needed.*

year of 1969, the last year (until 1978) that the lakebed flooded, many more polders were inundated, covering about 36 000 hectares.

In 1978, with twice the customary rainfall, runoff into Tulare Lake was again high. Flows from local surface drainage and excess water from Lake Kaweah, Success Lake, Deer Creek, and some coastal mountain streams all fed into the area, flooding about 32 000 hectares. The loss to agriculture was about $3.3 million. Nearly a third of the inflow came from westside streams and from water draining from adjoining lands. Deer Creek, an uncontrolled stream, contributed heavily, and so did the Kaweah River, even though it is controlled by a dam and some of its flow was diverted elsewhere. Only a relatively small amount of water came by way of the Kern River because of diversions through the Kern River Intertie and for ground water recharge and irrigation.

Fortunately, not all the watercourses that flow toward Tulare Lake added to last year's inflow. No water released from Pine Flat Lake to the Kings River reached the lakebed because all of it was directed north. And until the White River broke over its bank and flowed into Deer Creek in February, none of this water entered the scene directly either. Despite action by the Alpaugh Irrigation District to control the White River by diverting some of the water for irrigation and ground water recharge, considerable flooding did occur in the Alpaugh area.

Runoff in Poso Creek, another uncontrolled stream, was contained locally. Its excess flows were used to irrigate, to recharge underground reserves, and to supply the Kern National Wildlife Refuge.

## CONTROLLING THE KERN RIVER

Problems related to the flood threat posed by the Kern River were especially critical. Water interests in the area, which had been planning for the period for some time, began taking direct action in March, when releases began from Isabella Lake upstream on the Kern. Representatives of water agencies started meeting once a week in Bakersfield to exchange information and jointly plan the management of Kern River water. Each agency estimated how much of the river flow could be recharged to ground water or used for irrigation within its district. The balance was designated for diversion into the California Aqueduct. Their operations were based on continually updated forecasts of streamflow by federal, State, and private forecasters.

The strategy of the group during the period of abundant runoff was to encourage landowners to make use of surface water, rather than to pump ground water (an important factor because valley farmers had invested heavily in wells drilled during the 1976–77 drought). As one agency representative remarked: "When you've got surface water here, you use it."

The group continued its meetings throughout the spring months. Agencies represented included the Hacienda Water District, the Consolidated Reclamation District No. 812, the North Kern Water Storage District, the Buena Vista Water Storage District, the Delta Lands Reclamation District No. 770, the Henry Miller Water District, the Lost Hills Water District, the Kern Delta Water District, and the City of Bakersfield Water Department, along with federal and State agencies, private farming interests, and some engineering firms.


*Site of the Kern River Intertie, a few miles west of Interstate Highway 5, as it appeared in April 1969, when the heaviest snowpack on record at that time had accumulated on the Sierra Nevada. Intense, prolonged rainfall fell during the winter of 1968-69, causing major flood damage in many places in California. The Kern River, carrying several times its normal flow, spilled over a wide area and some of the water was carried through a weir into the Buena Vista outlet canal, leading toward Tulare Lake. No water appears in the California Aqueduct because it was not yet in operation.*

The Kern River Intertie, a flood control structure located about 32 kilometres southwest of Bakersfield where the Kern River and the California Aqueduct meet, played a big part in the successful control of the river. Built by the Corps of Engineers, in cooperation with the Department of Water Resources (DWR) and Tulare Lake and Kern River interests, the Intertie provides a relief valve for the river's flow. Depending on downstream water requirements, its gates can pass nearly 100 cubic metres of water per second into the Aqueduct.

Operation of the Intertie, the first since it was constructed two years before, began on April 6, when DWR activated the gates. To reverse the Aqueduct's flow and send some water north, six temporary pumps were installed about 37 kilometres north of the Intertie at Check Structure 25, one of the permanent gates positioned across the Aqueduct about every 16 kilometres to regulate its flow. The pumps, which were put in place by the Delta Lands Reclamation District No. 770 and Cohn Central Consolidated Reclamation District No. 761, in cooperation with DWR, were in place from May 5 to June 21. They pushed some of the Kern River inflow north to serve the Lost Hills Water District and the Buena Vista Water Storage District.

Pumps were also installed at another Aqueduct control structure farther north by Consolidated Reclamation District No. 812, but, as it turned out, these did not have to be used. Pumping at Check Structure 25 was halted on May 26, by which time the flows in the Kern River had markedly subsided.


*The Kern River Intertie in operation in May 1978. The river, now more closely confined by levees, is flowing through the Intertie into the Aqueduct, while water in the Buena Vista outlet canal passes beneath it in several large pipes. Fine particles of storm debris floating in the Aqueduct appear as dark streaks.*

The gates of the Intertie were finally closed for the season on June 28, shutting off the river's flow into the Aqueduct.

The operational versatility of the Aqueduct was clearly demonstrated during this period by its ability to reverse its customary direction of flow and send this water northward. While they were in service, the pumps diverted a total of 22 200 cubic dekametres of water that would otherwise have entered the Tulare lakebed. The cost of installing and operating the pumps at Check 25, as well as some costs of Aqueduct operation directly related to the pumping, were met by the two reclamation districts, No. 770 and No. 761.

## OTHER DIVERSIONS OF SURPLUS WATER

A great many more steps were taken to maneuver the oversupply of water in the southern San Joaquin Valley. On May 16, the State Reclamation Board approved an application from Delta Lands Reclamation District No. 770 to reinstall four low-level retention dams in the Kern River that had been removed earlier in the season by local interests because of the heavy runoff. The dams were used to divert excess flows to lands adjacent to the river that are owned or controlled by the district, thus preventing the water from reaching Tulare Lake.

Twenty temporary pumps were installed at weirs along Kings River South to move water north from Tulare Lake to Kings River North and thence to the San Joaquin River. The entire operation called for the cooperation of many organizations and individuals. These included Cohn Central Consolidated Reclamation District No. 761, Delta Lands Reclamation District No. 770, Tulare Lake

Basin Water Storage District, Lower San Joaquin Levee District, Kings County Department of Public Works, the Kings River Watermaster, Kings River Conservation District, the Corps of Engineers, and private landowners along the Crescent Bypass. The pumps were in place between March 29 and April 11. Records indicate that the river level may have been raised only about two centimetres by the short-term additional inflow.

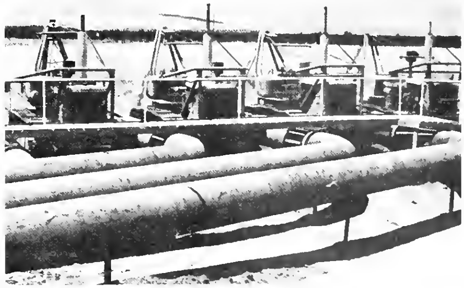
In May a particularly significant operation took place. The Metropolitan Water District of Southern California (MWD) reduced its intake of water from the Colorado River so that it could make greater use of the water available from the California Aqueduct, and, between May 10 and May 26, about 11 200 cubic dekametres of Kaweah River water that had been headed toward Tulare Lake was pumped into the Friant-Kern Canal, carried south, and then released into the Kern River. It then passed through the Intertie into the California Aqueduct for delivery south over the Tehachapis to MWD. This water was limited to industrial and municipal uses by MWD because it had been conveyed in the Friant-Kern Canal, a federal facility, and was therefore subject to the acreage restriction of federal reclamation law. The costs of pumping this water from the river into the canal, the conveyance charges levied by the Bureau of Reclamation for use of the canal, and excess energy costs incurred by MWD were paid for by the Tulare Lake farming interests.

*Courtesy Murray, Burns, and Kienlen*

*Aerial view of the pump installation at the junction of the Friant Kern Canal (center) and the Wutchumna Ditch*

The importance of this particular operation lay in the fact that this was the first time the Bureau had permitted water districts in the Tulare Lake area to pump water from the Kaweah into the canal for ultimate delivery to southern California.

In San Bernardino County, the Mojave Water Agency agreed to purchase about 28 000 cubic dekametres of water from the State Water Project for a program to demonstrate the practicability of "banking" water in natural underground reservoirs. The water was delivered to Silverwood Lake, a surface water reservoir of the SWP, through the California Aqueduct and almost immediately released to the Mojave River, to be percolated into the ground for storage. It will be withdrawn by the Mojave Water Agency over a period of several years. (This operation is discussed elsewhere in this issue in the article, "The Search for More Water for the State Water Project.")



*Courtesy Murray, Burns, and Kienlen*

*Rear view of pumps taking water from Wutchumna Ditch (not visible in this view)*

## AN OILY MISHAP

On the night of May 25, there occurred an incident that, while not part of the spring flood control effort, illustrated how effective water management can avert other types of crises too. The Department of Water Resources received word from the Bakersfield police department that oil from a broken pipeline was spilling into the Kern River near Bakersfield. This meant that the oil was moving rapidly down river, through the Intertie, and into the California Aqueduct.

DWR promptly closed the Intertie to stop the flow into the Aqueduct and isolated the oil that had already entered it by shutting two flow control structures on the Aqueduct, one upstream from the Intertie and one downstream from it. That checked the spread of oil in the Aqueduct, alleviating one immediate concern, but it left another: what to do about the great volume of Kern River water that was now deadended at the Intertie. There were no means of controlling this flow below the point of the oil spill, and without some other action, the water would rise rapidly over the river levees upstream from the Intertie and pour over adjoining roads and fields.

Several moves were made to prevent this from happening. The Kern River Watermaster ordered a total shutdown of Kaweah River flow that was entering the Kern River at that time by way of the Friant-Kern Canal. The Corps of Engineers greatly reduced releases from Isabella Lake. Close to the Intertie, the extra water was diverted northward in the Buena Vista outlet canal in the direction of Tulare Lake, significantly increasing the flow in the canal. Quick action by the water districts managing this channel succeeded in diverting the water onto vacant land or onto farmlands whose owners had already been reimbursed for crop damage.

The oil was removed by absorbent booms placed in the Aqueduct by DWR and in the flume just behind the Intertie by the Lion Division of Tosco Petroleum Corporation, from whose pipeline the oil had spilled. Clean-up was not as difficult as expected because much less oil had actually entered the river than had at first been feared. When the task was complete, DWR opened the Intertie again very gradually and, two days after the spill had been reported, the facility was back in full operation.

## FIGHTING FLOODS TAKES TEAMWORK

When a flood fight is under way, hours can count. Decisions must be made quickly and acted upon without delay. Such operation would normally be expected of a well-coordinated organization under the direction of a single authority. This is what happens when, as occurs almost every year somewhere in California, flooding of some type strikes. State and federal agencies responsible for combating floods perform their work together effectively.

The flood crisis that hung over the southern San Joaquin Valley in the spring of 1978 was met in an entirely different way, with local, independent water organizations exhibiting a special kind of teamwork to solve their common problem. The measure of their achievement is shown by the fact that no lives were endangered, no private or public property was seriously harmed, and the flood water that did accumulate was successfully confined within levees and channels until it could be moved elsewhere, most often for some good use. The effects of this flood fight were chiefly economic, involving heavy expenditures of funds to contain and transport the water. Dollar losses were also sustained from delayed planting, which later reduced crop yields.

The spirit of cooperation demonstrated by the large number of local water agencies and the federal and State agencies involved over several very trying months is a credit to every organization and individual that took part in averting certain widespread damage to some of California's finest farmlands.

*This article was prepared in the Division of Flood Management, Flood Forecasting Branch, Sacramento, by*

*Helen Joyce Peters, Branch Chief* and *Kenneth H Lloyd, Water Resources Engineering Associate*

The following organizations were among those involved in flood control operations in the southern San Joaquin Valley in spring 1978.

Alpaugh Irrigation District
Arvin-Edison Water Storage District
Bakersfield (City of) Water Department
Buena Vista Water Storage District
Cohn Central Consolidated Reclamation District No. 761
Consolidated Reclamation District No 812
Deer Creek Storm Water District
Delta Lands Reclamation District No 770
El Rico Reclamation District No. 1618
Hacienda Water District
Henry Miller Water District
Kaweah Delta Water Conservation District
Kern County Water Agency
Kern Delta Water District
Kings County Department of Public Works
Kings River Conservation District
Kings River Water Association
Lindsay-Strathmore Irrigation District
Lost Hills Water District
Lower San Joaquin Levee District
Lower Tule River Irrigation District
Metropolitan Water District of Southern California
Mojave Water Agency
North Kern Water Storage District
Pixley Irrigation District
Terra Bella Irrigation District
Tulare Flood Control and Water Conservation District
Tulare Irrigation District
Tulare Lake Basin Water Storage District
Tulare Lake Drainage District
Wheeler Ridge-Maricopa Water Storage District
Wutchumna Water Company

Kaweah River Watermaster
Kern River Watermaster
Kings River Watermaster
Tule River Watermaster

U S. Army Corps of Engineers
U S Bureau of Reclamation
California Department of Water Resources

## RESOURCE MATERIALS

### DWR Publications

**"Kaweah River: Flows, Diversions, and Storage—1961-1970."**
Bulletin 49-D. January 1977. Free.

**"Kaweah River: Flows, Diversions, and Storage—1970-1975."**
Bulletin 49-E. April 1978. Free.

**"Water Conditions in California."**
Bulletin 120-78. Free.
- Report No. 1 February 1978
- Report No. 2 March 1978
- Report No. 3 April 1978
- Report No. 4 May 1978
- Basic Data Supplement July 1978

### DWR Films

**"Hydro Hercules."** 14 minutes. (1977)
The A. D. Edmonston Pumping Plant lifts water nearly 600 metres to enable the State Water Project to cross the Tehachapi Mountains. This film shows the enormous facilities located south of Bakersfield that accomplish this task.

**"California's White Treasure."** 15 minutes. (1978)
Every winter the Department of Water Resources measures the Sierra Nevada snowpack to determine its depth and water content. This film follows a snow survey team as they ski into the mountains to collect the data from which predictions of runoff are prepared

*Information on the materials listed here is given on the inside back cover.*

# DWR IS SERIOUS ABOUT SAVING WATER

California's yearly supply of water is limited largely by the caprices of the weather. Each winter we receive just so much rain and so much snow, and the widely varying amounts that fall determine whether the ensuing months will be a time of over-abundance, a time of drought, or something between the two extremes. Ground water, our other major source, supplements the supply in many parts of the State, particularly when precipitation is sparse, but this resource also depends on replenishment by runoff from rain and snow.

Since we must live within the bounds set by these sources, the inescapable conclusion is that we must learn to make the most of our water resources. This is already occurring in some communities where people are either using less water than before the drought or, where the rates of use have again risen, they seem to be using less than they would, had there not been a drought. Evidently the relative suddenness with which we discovered that our water is not limitless came as a jolt to many Californians, and they have not forgotten the experience.

Now that conditions are back to normal, for the present, at least, we must remember that drought and water shortages can recur, and it is essential for us to save water wherever practicable. The Department of Water Resources is working hard to bring that message to California through its various water conservation programs.

## HOME SAVINGS TESTS

Starting in 1979, DWR will be looking at the continuing effectiveness of a residential water conservation program conducted in 1977, in which kits containing water-saving plumbing fittings were distributed to more than 450,000 households in the San Diego metropolitan area, Santa Cruz County, and selected communities in Fresno, El Dorado, Los Angeles, and Ventura Counties. The kits included a variety of devices designed to restrict the flow of water from showerheads and toilets so that their relative effectiveness and acceptability could be compared later. They were offered for sale in two study areas and were free in the other four.

Overall, the devices were well received. They are saving enough water to serve about 25,000 persons yearly and, by cutting the need to heat water for showers (the preferred type of bathing in the areas studied), they are saving enough energy to meet the needs of about 3,200 homes a year. Evaluation studies have shown that the program is more than earning its way by returning five dollars for every dollar invested, based on a five-year working life of the devices.

The follow-up study of this program will be carried out in San Diego and in Ventura County to find out how many devices are still in use and how well they are working.

## WATER AWARENESS

Students in kindergarten through the sixth grade in many California schools are learning about water and the whys and hows of water saving, as the result of the Water Awareness Program, a cooperative educational project of the California Department of Education and the Department of Water Resources that began in 1977. Featuring in the fourth-to-sixth grade segment the adventures of "Captain Hydro, the hero of water conservation", a cartoon character created by the East Bay Municipal Water District, the program's instructional materials are teaching children about water conservation and water's vital role in human, animal, and plant life. DWR supplements the curriculum package with teachers' booklets specially tailored to give water information for differing regions of the State.

A Spanish language version for children who are predominantly Spanish-speaking is also available for fourth through sixth grades. It is based on a character called "Capitán Tlaloc" (named for an ancient Aztec water god).

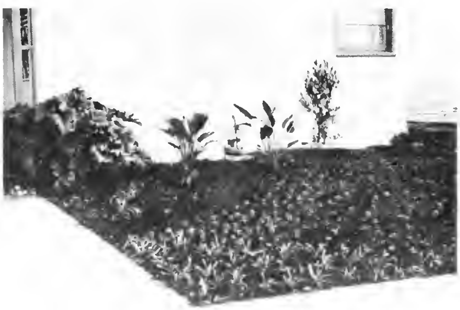
DWR serves as the lead agency to inform local water agencies and schools about the program, to distribute the classroom materials, and to train people to use the materials. About 120,000 sets of workbooks and teachers' guides were sold during the 1977–78 school year at a cost to the schools of about 35 cents per student for the average classroom. About 5,000 teachers have received training at 13 special workshops under the program.

In the coming months, materials appropriate for seventh and eighth grade students will also be published.


## PLANTING TO SAVE WATER

Promoting the use of water-saving landscaping and irrigation practices is another part of DWR's water conservation efforts. As a demonstration of what can be accomplished with low water-use plants, during the drought DWR transformed a vacant city lot in Sacramento into a thriving garden spot, using only selected species of shrubs, flowers, and other plants that require less water. The garden is complete now and is being cared for by a local community service organization. DWR has found that one of the most effective ways of spreading the word about conservation landscaping is getting local groups actively involved in demonstration projects such as this.

In another landscaping project aimed at saving water, DWR recently sponsored a demonstration in Oakland in which the front yards and parking strips in the 1600 block of 84th Street were planted with drought-tolerant ornamental vegetation. The city of Oakland has joined the effort by planning to develop mini-parks in the area, using the same species of plants that DWR selected for use in the demonstration block. Private industry and federal agencies are in the process of considering funding of additional projects based on this program.



The 84th Street project was started by a neighborhood association, and DWR was assisted by several organizations—the Neighborhood Design Center of Oakland, the California Conservation Corps, the East Bay Municipal Water District, Merritt Community College, the University of California, and the California Department of Transportation.

In a related area, this past winter DWR sponsored a Rainwater Cistern Conference, along with the Monterey Peninsula Municipal Water District, to promote the use of stored rainwater for landscaping irrigation. DWR hopes the meeting will lead to a pilot project in Monterey in which cisterns installed on the tops of buildings at a local high school will catch and store rainfall for later use in watering plants on the school grounds.

## RELATED ACTIONS

Other current water conservation activities DWR is engaged in include monitoring more precisely the energy and water savings gained with low-flow showerheads and toilet flush-reducing devices. A test program that began in March 1978 is being conducted at a San Francisco motel. DWR is also working with the California Department of Housing and Community Development and local agencies, all of which are involved in enforcing revisions of the State Health and Safety Code that prohibit tank-type toilets using more than 13.25 litres of water per flush in new construction. The law governing this went into effect in January 1978. In 1979, DWR plans to focus on industrial water conservation. It will also be monitoring regulations of the California Energy Commission covering low-flow shower and faucet fittings.

The savings California can achieve by conserving water are very real. We can gain in dollars by reducing the energy needed to pump, purify, transport, and heat water. We can also ensure ourselves of enough water, even when the weather fails us, if we conserve consistently. DWR will continue to explore every reasonable avenue to accomplish these goals.

## RESOURCE MATERIALS

### DWR Publications

**"A Pilot Water Conservation Program"**. Bulletin 191. October 1978. Eight separately-bound appendixes containing supporting data may be ordered individually. The main report and all appendixes are free.

Appendix A—San Diego Metropolitan Area
Appendix B—Santa Cruz County
Appendix C—City of Sanger
Appendix D—El Dorado Irrigation District
Appendix E—City of El Segundo
Appendix F—Community of Oak Park
Appendix G—Device Testing
Appendix H—Device Selection

**"Water Conservation in California"**. Bulletin 198. May 1976. Free.

**"Agricultural Water Conservation Conference—Proceedings"**. June 23-24, 1976, University of California, Davis, California. In cooperation with the University of California Cooperative Extension Service. Free.

**"An Urban Water Conservation Conference—Proceedings"**. January 16-17, 1976, Los Angeles, California. Sponsored by the California Department of Water Resources. Free.

**"A Selection of Water Conservation Program Aids"**. A catalog that tells where to obtain a wide variety of technical reports, educational materials, brochures, bumper stickers and envelope stuffers, and other publications on saving water. Prepared by the Department of Water Resources and the American Water Works Association. Free.

**"Drought-Tolerant, Water-Conserving Plants for California"**. In preparation.

**"Urban Planning and Design for Water Conservation"**. In preparation.

(A list of other printed materials on water conservation is separately available from the Department of Water Resources, Urban Water Conservation Implementation Section, Room 815-1, P. O. Box 388, Sacramento, CA 95802.)

## DWR Films

**"What You Should Know About H²O"**. (1978)
A series of six films on water for kindergarten through sixth grade, combining animation, on-camera interviews with children, and live-action sequences of water-related activities. Intended for use as a package, the films can also be ordered individually.

**"City Water"**. 5 minutes.
Shows the many ways water is treated to improve its quality and used in urban areas and discusses how people can save water.

**"The Water Cycle"**. 5½ minutes.
Begins with Dewey, an animated drop of water, tracing his journey from river to ocean, to clouds, to rain and snow, and back to lakes and rivers and underground storage. A simple model explains the entire water cycle.

**"Save Water"**. 5 minutes.
An animated cartoon character explains that California does not have enough water to waste, especially in summer. On-camera scenes with children who relate how they, their families, and their neighbors waste water. Live sequences illustrate their comments.

**"Water for Farming"**. 4½ minutes.
An animated cartoon character explains that agriculture is the largest user of water in California and asks where farmers get their water and how they use it. Children provide on-camera answers, and live sequences showing types of irrigation illustrate their comments. Several water conservation practices are shown to demonstrate efficient use of irrigation water.

**"Water for Industry"**. 5 minutes.
An animated cartoon character explains how industry uses water to process food products. On-camera scenes with children and live sequences. Cleaning and recycling of water are shown as important ways of using water more efficiently.

**"Clean Water"**. 5½ minutes.
An animated cartoon character asks why water must be purified before we drink it. Children answer in on-camera scenes. Operation of a fresh-water treatment plant is described, and the need to reuse poorer quality water for industry and agriculture is explained.

*Information on the materials listed here is given on the inside back cover.*

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# WATER RIGHTS LAWS MAY BE IN FOR CHANGE

## Highlights of the Commission

For the first time in 67 years, California is scrutinizing its laws that govern rights to take and use water. Created by the Governor on May 11, 1977, the Commission to Review California Water Rights Law has closely studied the complex matter of water rights in this State and has proposed several changes in existing law, as well as the enactment of important new laws. The work of this 12-member body culminated in December 1978, when it submitted its report to the Governor. That document contains recommendations for legislation that will, if ultimately enacted into law, make significant changes in the way California water users manage their invaluable water resources.

Although the Commission was created in the midst of the 1976–77 drought, it was formed to address pervasive problems of California water rights law that have been around for many years. The drought was aggravating many of California's long-standing water problems and thus offered an excellent time to study the water rights system when the strengths and weaknesses of the existing system were more apparent.

Out of a large possible range of topics and issues to consider, the Commission chose to study six in depth: appropriative rights to surface water; riparian rights; ground water rights; water conservation; water rights transfers; and instream water uses. Following the publication of detailed background papers on each of these subjects, the Commission held workshops in different areas of the State to learn the opinions of experts on each of these subjects and possible approaches to be taken to solve those problems.

After an additional seven months of painstaking deliberation, the Commission released in August 1978 a Draft Report containing proposals for legislation in four areas: achieving greater certainty in water rights; improving efficiency in water use; protecting instream uses of water; and effectively managing ground water resources. What the Commission recommended concerning appropriative rights, riparian rights, water conservation, and water rights transfers was melded into the two new categories of certainty and efficiency.

The Commission's proposals regarding increased certainty and efficiency are very modest. Although the Commission felt that criticism of California's unique dual system of rights to surface water—where appropriative water rights can be obtained by applying for a permit from the State and riparian rights exist by reason of ownership of land along a stream regardless of the permit system—is justified, it concluded that the established structure of water rights should be retained. It decided riparian rights should not be included in the administrative permit system. The Commission stated: "Riparian and appropriative rights have served as the foundation for billions of dollars worth of investment. They are property rights subject to constitutional protection. Their deficiencies are better remedied by making them more secure and their utilization more efficient than by eliminating them in favor of an untried system."

The Commission recommends that greater certainty be achieved by expanding the use of the statutory adjudication procedure, which is primarily an administrative process carried out by the State Water Resources Control Board to make a final determination of water rights on a stream or stream system. Several of the proposed changes would permit the Board to initiate statutory adjudications, include interconnected ground water in the process, if necessary, and require the State to assume more of the costs of statutory adjudications.

The Commission further recommends, in the area of increasing certainty, that existing requirements to report diversion and use of water to the State be strengthened. The Commission also believes that no water rights should be acquired by prescription from now on. (A right is obtained by prescription as a result of actual use of water that belongs to another.)

Other recommendations are designed to increase incentives for more efficient use of water. The Commission recommends that less weight be given to local custom in determining whether water is being used in a reasonable beneficial manner, a fundamental requirement of the State Constitution. The Commission also recommends that the State Water Resources Control Board be permitted to issue an administrative cease and desist order where a person is violating a term or condition of a permit or license or is making an unauthorized diversion, and that the Board have the authority to enforce these orders.

The Commission believes that voluntary transfers of water by sale or lease should be encouraged. Transfers would be of particular value during serious shortages of water. The Commission emphasizes that greater efficiency in the use of water does not necessarily mean that water rights must be transferred permanently. Productivity may well be increased through short-term transfers of rights.

Instream protection is the third major area of recommended legislation. The Commission found that California's instream uses of water are in serious need of protection, particularly fisheries, but also wildlife, recreational, aesthetic, and scenic uses which the law already declares to be beneficial uses of water. Much attention has been given to rights to divert water from streams, but little has been done so far for instream uses. Existing laws are fragmentary, at best.

The Commission has recommended two related remedies. The State Water Resources Control Board should set instream flow standards to use in making its administrative and adjudicatory decisions. These standards should state the amounts of flow needed to protect fishery, wildlife, aesthetic, scenic, and other uses of a stream on a stream-by-stream basis. The Commission recommends that, where instream flow standards are insufficient, the Board should develop compliance programs to ensure protection of beneficial instream uses.

The final and probably most important recommendations made by the Commission concern ground water. Ground water supplies over 40 percent of California's applied water demand. It is a tremendously valuable public resource, and yet its use is essentially unregulated, except in a few areas with management programs under way. The Commission concluded that California is experiencing severe and extensive ground water problems in important areas of the State, such as enormous overdraft costs, seawater intrusion and other types of water quality and environmental degradation, and land subsidence. The Commission also concluded that, for the most part, adequate responses to those problems have not been and will not be developed without new legislation.

The Commission has recommended that existing ground water problems be dealt with by enacting legislation in three areas: ground water management, adjudication of ground water rights, and conjunctive (combined) use of ground water and surface water resources.

The Commission's proposed legislation states forcefully that there is a strong State policy and statewide public interest in protecting the State's ground water resources. The legislation is designed to protect the public's interest in the integrity of ground water resources, while at the same time allowing maximum flexibility in management programs. Flexibility is vital since the physical characteristics, conditions, and needs of different ground water areas differ so greatly throughout the State. A basic premise followed by the Commission is that ground water management should be required only where there are critical problems and only where effective management programs are not already under way.

The Commission believes that the best opportunity for effective control will come from local management. Under its proposal, ground water management areas would be designated, mainly on the basis of the Department of Water Resources' work pursuant to Water Code Section 12924 (Nejedly Bill, SB 1505, 1977). Local entities would have an opportunity to cooperate to select a ground water management authority to develop a management program and perform ground water management functions. Entities in a ground water management area would have the option to form a management district to act as the authority for the area. Ground water management authorities would adopt ground water management programs for their areas and would transmit the programs to the State Water Resources Control Board for evaluation and comment.

Future adjudications of ground water should be based on "fair and equitable apportionment of rights to extract ground water," according to the Commission, leaving to the courts broad discretion in settling disputes that may arise. Doctrines in case law concerning conjunctive water use would be codified, and local ground water management authorities would have the authority to control ground water basin storage.

The Commission's work is now in the hands of the Governor. At the very least, the Commission's efforts have substantially expanded understanding of existing California water rights law and of the problems involved with that law. Change is certainly needed in these areas, and it is to be hoped that the Commission's recommendations will be enacted soon.

*This article was prepared by*

Anne J Schneider
Staff Attorney
The Governor's Commission to Review
California Water Rights Law

## RESOURCE MATERIAL

**"Final Report of the Governor's Commission to Review California Water Rights Law."** December 1978. $3.50.

(Available from the California Department of General Services, Documents Section, P. O. Box 1015, North Highlands, CA 95660. General inquiries on the subject may be directed to the State Water Resources Control Board, Office of Public Affairs, 1416 Ninth Street, Room 615, Sacramento, CA 95814. Phone (916) 322-8353.)

# Water Rights Law Commission

*Donald R. Wright, Chairman*

*Charles J. Meyers, Vice-Chairman*

*David E. Hansen*

*John E. Bryson*

*Arthur L. Littleworth*

*Ronald B. Robie*

*Ira J. Chrisman*

*Mrs. Mary Anne Mark*

*Mrs. Arliss L. Ungar*

*James A. Cobey*

*Virgil O'Sullivan*

*Thomas M. Zuckerman*

C

## GOVERNOR'S COMMISSION TO REVIEW CALIFORNIA WATER RIGHTS LAW

**Donald R. Wright,** Chairman. Born Placentia, California, 1907; graduate, Stanford University, Harvard Law School; one of three original incorporators of Legal Aid Society of Pasadena; member, many educational, charitable, and cultural organizations. Chief Justice, Supreme Court of California, 1970 to 1977. Resides in Pasadena.

**Charles J. Meyers,** Vice-Chairman. Born Dallas, Texas, 1925; graduate, Rice University, University of Texas, Columbia University; dean of Stanford University Law School; member, American Law Institute, American Bar Association; Texas Bar Association; member, Board of Advisors, Ecology Law Quarterly, Environmental Law Reporter. Resides in Stanford.

**John E. Bryson.** Born New York City, New York, 1943; graduate Stanford University, Yale Law School; founding attorney, Natural Resources Defense Council, Washington, D.C.; chairman of State Water Resources Control Board since April 1976. Resides in Carmichael.

**Ira J. Chrisman.** Born Modesto, California, 1910; cattleman, diversified rancher; served 16½ years on California Water Commission, nine years its chairman; former president, Mineral King Savings and Loan Association; currently serving as member of the California Water Advisory Panel. Resides in Visalia.

**James A. Cobey.** Born Frostburg, Maryland, 1913; graduate, Princeton University, Yale Law School and Harvard Graduate School of Business Administration; former California State Senator; chairman emeritus Advisory Council, University of California Water Resources Center; authored water legislation; helped organize the Western States Water Council, and one of California's three initial delegates; since 1966 associate justice, California Court of Appeal, Second Appellate District, Division Three, Los Angeles. Resides in Pasadena.

**David E. Hansen.** Born Sacramento, California, 1938; graduate, University of California, Davis, Iowa State University; associate professor of agricultural economics at the University of California, Davis; member, University Task Force on Critical Issues for California Agriculture in the 1980s, with responsibility for study of water issues; member, State Board of Food and Agriculture. Resides in Dixon.

**Arthur L. Littleworth.** Born Anderson, California, 1923; graduate, Yale University, Stanford University and Yale Law School; attorney practicing in the field of water rights. Recipient of many civic and educational awards; instructor and panelist in seminars and conferences concerning water-related matters. Resides in Riverside.

**Mrs. Mary Anne Mark.** Born New York City, New York, 1942; graduate, Stanford University; civil engineer presently associated with the U.S. Corps of Engineers; active member of American Society of Civil Engineers' Water Policy Committee and Water Committee of Commonwealth Club of California; Associate Water Resources Coordinator for California and Nevada of Sierra Club since 1974. Resides in Palo Alto.

**Virgil O'Sullivan.** Born Colusa, California, 1918; graduate, University of California, Berkeley (Boalt Hall); active farmer and lawyer experienced in water law, reclamation law, and water district organization; State Senator, 1958 through 1966. Resides in Williams.

**Ronald B. Robie.** Born Oakland, California, 1937; graduate, University of California, Berkeley, University of the Pacific, McGeorge School of Law; member, State Water Resources Control Board, 1969–75; member, Western States Water Council; director, California Department of Water Resources since March 1975. Resides in Sacramento.

**Mrs. Arliss L. Ungar.** Born Los Angeles, California, 1935; graduate, Stanford University; member, League of Women Voters, Department of Water Resources' Delta Environmental Advisory Committee, University of California's Water Resources Center Advisory Council, State Water Resources Control Board's Wastewater Reclamation Policy Task Force. Resides in Lafayette.

**Thomas M. Zuckerman.** Born Oakland, California, 1942; graduate, Amherst College, University of California at Berkeley (Boalt Hall); attorney specializing in water law; formerly with the County Counsel's office for San Joaquin County. Resides in Stockton.

*The 1976 drought depleted Marin Municipal Water District's supplies to critical levels. Here, Nicasio Reservoir, MMWD's major source of water, has diminished to a mere puddle, compared to its normal size.*

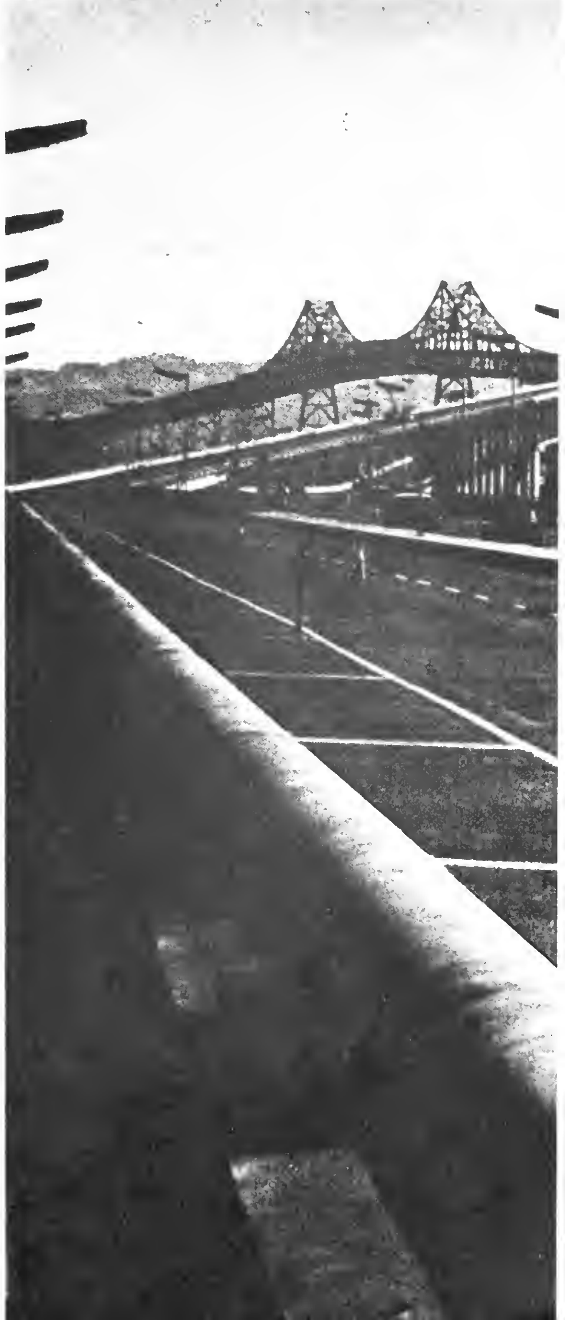
# MARIN COUNTY BATTLES THE DROUGHT–AND WINS

Unlike other natural disasters, such as hurricanes and floods, the California drought of 1976 and 1977 did not visit widespread ruin over great regions of the State. Some areas were relatively untouched, some communities underwent varying degrees of inconvenience, and a few experienced real hardship. People who lived in certain foothill communities of the Sierra Nevada and in some coastal counties were in serious difficulty. One of the hardest hit of all was Marin County, which went through two arduous years, struggling with the most critical shortage of water the area had known in more than 30 years.

Before the drought ended in a downrush of rain in the winter of 1977–78, Marin's plight had captured State and national attention, and the conservation and rationing measures that successfully alleviated the crisis in Marin County served as models for drought programs elsewhere.

Eastern Marin County is heavily urban. More people live there than in any other section of the county. The largest water agency, Marin Municipal Water District (MMWD), whose service area includes the cities of San Rafael, Sausalito, Mill Valley, Corte Madera, San Anselmo, and Fairfax, delivers water to about 170,000 customers, more than three-fourths the population of the county. MMWD depends almost entirely on a series of five reservoirs for its supplies—Lagunitas, Kent, Bon Tempe, Nicasio, and Alpine Lakes, which are fed wholly by runoff from rainfall. North Marin County Water District, the region's second largest water supplier, serves about 12,900 people living in the city of Novato and elsewhere in parts of northern and western Marin County. In 1976 and 1977, North Marin CWD was drawing 84 percent of its supply from the Russian River and the rest from Stafford Lake within Marin.

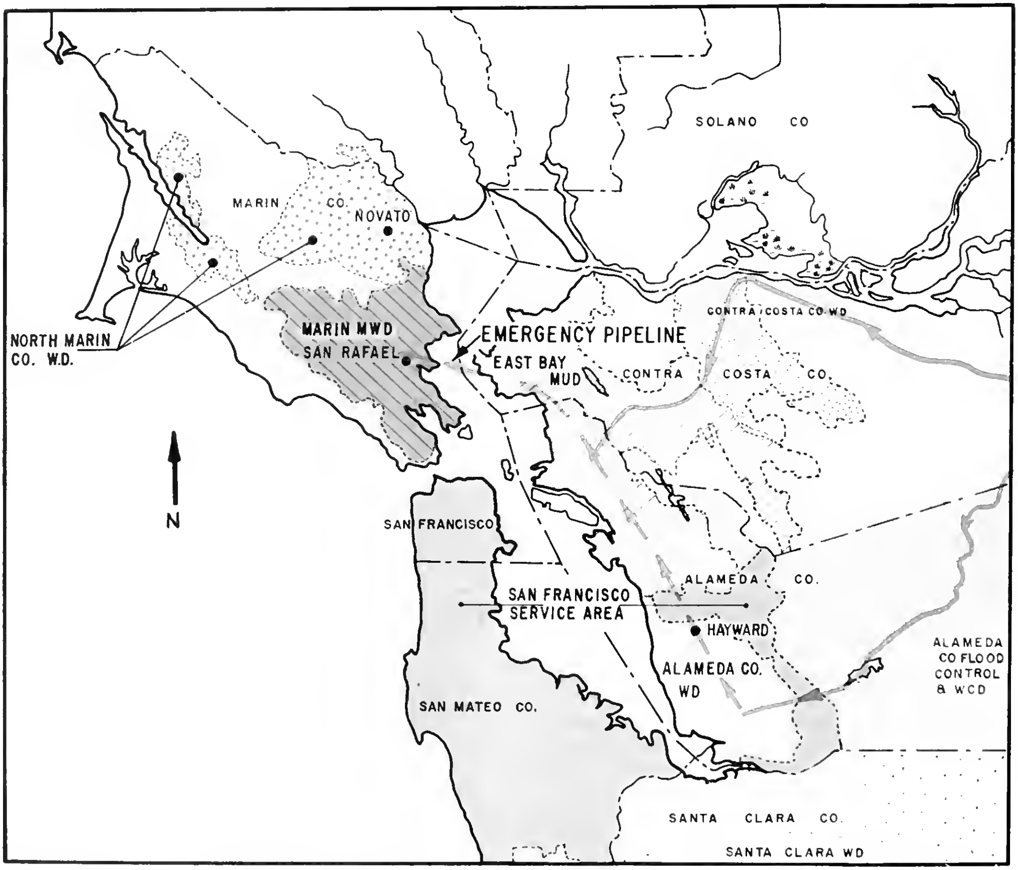
Marin County's trouble began with unusually dry weather during the winter of 1975-76. Slightly more than a third the normal amount of rain fell in 1976 and just less than half in 1977. As the months passed with little rain, the small creeks that supply the coastal communities of Stinson Beach, Bolinas, and Inverness in western Marin County stopped



*The temporary pipeline on the Richmond San Rafael Bridge. It carried the water that saved the day for most of eastern Marin County during the 1976 77 drought. Courtesy Marin Municipal Water District* flowing, and water wells failed on the north side of Tomales Bay. MMWD's lakes started dropping with appalling rapidity, until four of them had finally dwindled to nearly nothing and one dried up completely.

Early in 1977, MMWD's reserves had fallen to an alarming level. Its five reservoirs, which together store 64 400 000 cubic metres of water, had dropped to a total of only 15 000 000 cubic metres by March. Extraordinary measures were clearly needed to avert disaster. What was finally worked out was this: State agencies, including the Department of Water Resources (DWR), and several water agencies outside Marin County cooperated in building a large pipeline to carry an emergency relief supply to eastern Marin County from the Sacramento-San Joaquin Delta. This water was part of a much larger contract entitlement to State Water Project water that The Metropolitan Water District of Southern California had agreed to relinquish. The pipeline supply ultimately saved the day for a lot of people in Marin County.

The water was moved through the facilities of DWR's State Water Project, the city of Hayward, the San Francisco Water District, and East Bay Municipal Utility District, and crossed over San Francisco Bay in the emergency pipeline laid in a traffic lane on the Richmond-San Rafael Bridge. Construction proceeded at top speed, and water was flowing into MMWD's system by early June 1977. In total, about 5 000 to 6 000 cubic dekametres of water were delivered continuously until January 1978.




ROUTE OF EMERGENCY WATER SUPPLY TO MARIN COUNTY

## FIGHTING THE DROUGHT

Marin Municipal Water District went into action early to battle the drought. In February 1976, when the scarcity of water was first becoming apparent, MMWD issued precautionary instructions, prohibiting waste and nonessential uses of water. Sprinkler systems were out. Only hand-held hoses could be used. Driveways, patios, walkways, and other paved surfaces could not be hosed down, and three gallons of water was the limit in washing a car. After two warnings, violators of these rules could have their service disconnected. In March, the price of water went up from $0.43 to $0.61 per 100 cubic feet, and further restrictions were announced.

As conditions worsened, MMWD's restrictions became increasingly tight. In July 1976, a two-step residential rate structure was set: $0.61 per 100 cubic feet, up to certain ceilings, and $0.84 over those limits. The following February, the district set an average residential limit of nearly 174 litres per day per person.* Actual allotments ranged from about 121 to 185 litres per day,* depending on how many people occupied a residence. The greater the number of residents, the lower the share per person. Apartment buildings with three or more units were cut to about 151 litres per person per day.* Allotments for businesses, schools, and other nonresidential places were somewhat higher. MMWD raised the price of water to $1.22, and penalties were high for exceeding the limit—$10.00 per 100 cubic feet for those who used up to double their limit and $50.00 for those who went beyond that.

MMWD operated its rationing program with considerable flexibility. The first two months were a trial run to see how people responded to the new situation. The first billings that included penalties for exceeding allotments were not sent until April, two months after the start of rationing. In cases where excess usage was found to be due to unsuspected water leaks or other malfunctions, MMWD subsequently rebated the amounts of the penalties to the individual consumers.

City dwellers altered their outdoor watering practices, many of them cutting back or entirely ceasing to irrigate their landscaping. Brown lawns and shrubs became more and more noticeable in residential areas. As a result, some homeowners lost hundreds of dollars worth of landscaping, and some even more than that. Residents finally purchased reclaimed and potable water brought in by truck from other areas. Toward the end of the drought, many households were also irrigating with graywater (used bath and laundry water). Indoor use of water was also greatly changed, as people discarded long-standing habits and adopted new ones to live within the limitations imposed by rationing. A large number of households attached water-saving devices to showers and toilets, and the daily use of bathroom fixtures in single-family homes dropped amazingly to nearly half the average pre-drought rate.


*One of the trucks that dispensed emergency supplies of water to residents of Marin County.*

North Marin County Water District also instituted measures aimed at cutting back the use of water. In March 1977, the district began a program of voluntary rationing, with the intent of bringing consumption 30 percent below the 1976 level. Customers were restricted to using hand-held hoses only for outside watering, and those who were newly connected to the North Marin system were required to landscape only with drought-resistant plants and install indoor water-saving devices provided by the district. Customers already being served were also offered these attachments and encouraged to install them. To assist the dairy businesses in its area and persons whose domestic wells had run dry, North Marin CWD also set up emergency water hauling stations.

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* Approximate equivalents:

| | |
|---|---|
| 174 litres = 46 gallons | 185 litres = 49 gallons |
| 121 litres = 32 gallons | 151 litres = 40 gallons |

North Marin's customers cooperated by reducing use far below the expected level. Between March and June, 1977, water use was down an average of 45.8 percent from the previous year.

Western Marin County is largely rural, with a sprinkling of small towns. Dairy farmers and livestock ranchers, particularly in northwestern Marin, rely on springs, small dammed-up ponds, creeks, and wells to water their animals and irrigate some pasture. Most pasture lands are watered by rainfall. Through 1976 and 1977, ponds and wells on many farms dried up and the pastures withered and died, leaving the dairy and ranch operators with no choice but to purchase feed trucked in from as far away as Idaho and fresh water hauled to their farms daily, chiefly from North Marin County Water District and the city of Petaluma's water department in Sonoma County. They saved their livestock, for the most part, but the high cost of importing water and feed left many farmers heavily in debt and forced some out of business, despite substantial financial assistance from the federal government.

Water conservation at the California State Prison at San Quentin in eastern Marin County, also served by MMWD, paid off with a 45 percent reduction in consumption. At that time, total population was about 2,000, including both inmates and resident employees. The State Department of Corrections, which runs the facility, maintained a lower inmate population than usual to help reduce the need for water, and the prison staff and many of the inmates made concerted efforts to conserve.

Laundry went by truck to Vacaville, where no water emergency existed. In the confinement areas, every other shower head was removed and fewer showers were taken. All landscape watering was stopped, except for irrigation of salt-tolerant ice plants with salty water from San Francisco Bay, and water from the Bay also supplanted fresh water for hosing off outdoor exercise yards. Water meters were installed in all 80 employee residences at San Quentin and monitored regularly.

MMWD made persistent efforts to develop additional water from wells in Marin County. It lined up 75 potential well sites and spent $185,000 in drilling but failed to find any significant deposits of ground water. Others were more successful. The city of San Rafael drilled new wells at several of its parks and was able to obtain enough water to irrigate these grounds throughout the drought. This water was also available for emergency fire control. A large number of residents in Ross, Kentfield, and San Rafael put down their own wells and used the water they obtained to irrigate landscaping.

Severe restriction on the use of water is an inescapable but effective part of water management during a drought. However, MMWD found that rationing places heavy burdens on the agency administering the program. It had to hire additional employees to handle the extra work involved in answering requests for information on conservation, providing water-saving devices on showers and toilets and advising on their installation, and demonstrating the correct method of reading a water meter.

## A FUTURE SOURCE

At the onset of the drought, MMWD was developing its Las Gallinas project, a waste water reclamation facility located next to a sewage treatment plant. It is designed to provide reclaimed water for outdoor landscaping at parks, large office complexes, cemeteries, golf courses, condominium developments and apartment complexes, greenbelt areas, and highway median strips. No single-family dwellings will be served. The only residential buildings to receive this water will be those at which landscape irrigation is not controlled by the building occupants.

If construction begins in June 1979, as MMWD expects, the project should be completed by the end of the summer. Peak capacity will be about 40 000 cubic metres per second. The water will cost 95 percent of the cost of fresh water. It will be distributed in a separate but similar transmission system to which each customer can make a permanent connection, just as is done now in distributing fresh, potable water.

Developments built after the project is in operation can tap into the system, but MMWD does not expect to be serving existing buildings because the cost of individual connection would be prohibitive. Dual piping has already been laid for one large development of offices and condominiums in Marin County now under construction. The district hopes to develop 2 500 cubic dekametres of reclaimed waste water through this and other projects within its service area by the end of this century.

Unfortunately, Las Gallinas was not on line when the drought hit, so MMWD found itself in the business of selling treated waste water somewhat earlier than it expected to. To help those who wanted to save their landscaping, the district obtained permission from the San Francisco Regional Water Quality Control Board and the State Department of Health to take reclaimed water from waste water treatment plants in Mill Valley, San

Rafael, Las Molinas, and Ross Valley, and then transported it by truck throughout the county. The water was sold to private trucking firms, which in turn sold it to property owners. MMWD kept close, careful control of distribution of this water by training the truck operators in safe delivery methods and by issuing them special licenses and discharge permits that required delivery only to specific locations for approved uses. No chances were taken that this water would be mistaken for fresh water and be consumed by people or animals. Permission to deliver this water was revoked when rationing ended.

## THE PEOPLE REACT

Marin Municipal Water District's customers responded extremely well to the water rationing limits it set. In 1977, users were asked to take a cut of 57 percent of their normal level of use. Instead they dropped an average of 63 percent. Part of the success of rationing was due to the district's ability to communicate forcefully the true gravity of the situation. In January 1977, Dietrich Stroeh, general manager of MMWD, drew a very clear picture of the district's status. He warned the community that, unless water was strictly rationed and emergency supplies brought from sources outside the county, MMWD's reservoirs would be empty by the end of the year. Reports by the broadcast media and newspapers telling the real facts of the situation also assisted in convincing Marin County water users of the urgent need to conserve. Another reason for the strong cooperation was the element of personal involvement in a formidable community problem. Saving water was something to which each person could contribute individually and directly.

Everything did not always go smoothly, of course. Customers of MMWD were first upset and then angered by increasing water rates and greater restrictions on use. Hard-pressed residents and business people often found it difficult to understand why they should pay more and more for less and less water. Many charged the district with failing to anticipate the drought, to which MMWD replied that, while its system was designed to handle dry periods, it was not equipped to meet such extreme dryness. At one community meeting, the management of MMWD had to explain to several hundred irate customers that droughts, like earthquakes, simply could not be predicted because the technology of long-range weather forecasting has not yet progressed sufficiently.

*As their supplies became increasingly scarce, coastal communities in Marin County asked visitors to cooperate by using less water*

## RELIEF EFFORTS

Toward the end of 1976, MMWD was investigating every possible way of getting emergency water to Marin County, including hauling it in from other areas by tank trucks and railroad tank cars, bringing it down the coast from Oregon on ocean-going barges, and using ballast water from large ships, desalted water from U.S. Navy vessels, and portable desalting devices.

As it turned out, none of these remedies was used because the proposal to pipe a relief supply from the Delta and across San Francisco Bay was already in the works by early 1977, and MMWD knew additional supplies would be arriving in time.

Marin Municipal Water District was in the forefront of water agencies in California that requested emergency drought assistance from the federal government. In August 1977, the district received a loan of $5,550,000 from the Economic Development Administration of the U.S. Department of Commerce to develop and conserve water supplies and to help in alleviating drought effects. The loan is payable over a 40-year period at a five percent rate of interest. An additional $1,387,000 was provided in a grant. As of September 1978, the district had spent a total of $5,828,938 for costs related to the emergency pipeline and other drought-related expenses. These funds were made available to drought areas to make water system improvements essential to protect public health and safety.

## THE MARIN COUNTY SURVEY

The drought dilemma in Marin County was the most dramatic example of extreme water-short conditions in the entire State during a period of severe shortages elsewhere in California. Marin's almost total reliance on rainfall to stock its reservoirs lay at the heart of its problems. Unfortunately, the rains that failed at that time can fail again because alternating years of varying degrees of dryness and wetness are typical of California.

In the belief that learning what happened in Marin County could benefit others with similar difficulties, the Department of Water Resources set about surveying conditions there in the summer of 1976. DWR focused primarily on the Marin Municipal Water District, since most of the county's population lives in the area it serves and the district could thus provide the most representative sampling of urban water users. Special questionnaires were prepared to cover residential, business and commercial, municipal, and institutional water users, as well as dairy and livestock operations elsewhere in the county.

DWR had several objectives:

- To measure the effect of conservation on landscaping and the performance of indoor water-saving devices.
- To determine the effectiveness of conservation techniques adopted by users.
- To find out which users found other sources of water.
- To describe MMWD's rationing and conservation measures, their effectiveness, and when they began, were altered, and were discontinued.
- To document MMWD's experiences and techniques for handling the drought.
- To determine the economic and social costs and losses sustained by the people of Marin County because of the drought.

("The Impact of Severe Drought in Marin County, California", Bulletin 206, a comprehensive report on the results of the survey and the methods used to obtain the data, is scheduled for publication early in 1979.)

Among the more significant findings uncovered by the investigation are these:

In a time of severe water shortage, people begin to save water when they accept the reality of the situation. Rationing is very effective in reducing consumption. The effect of pricing schemes is still a matter for conjecture.

In an emergency, households and businesses can operate on less than half the water they had previously been using, with only minimal loss of landscaping or business losses.

Level of family income is not a factor in saving water during a drought. Under normal conditions, more affluent families tend to use more water than the less affluent, but under strict rationing, all families are able to cut back to about the same low rate of use.

As the drought worsened, acceptance of reclaimed waste water for landscaping increased. In Marin County, 94 percent of those questioned said they would continue to use treated water when the emergency was over.

Privately owned businesses, which were more severely affected by the drought than were schools, government agencies, and community organizations, complained that the level of rationing set in 1977 was too low. In 1976, private business did not reduce the use of water, and in 1977, they did cut back but not to the level of public agencies.

## LOOKING TO THE FUTURE

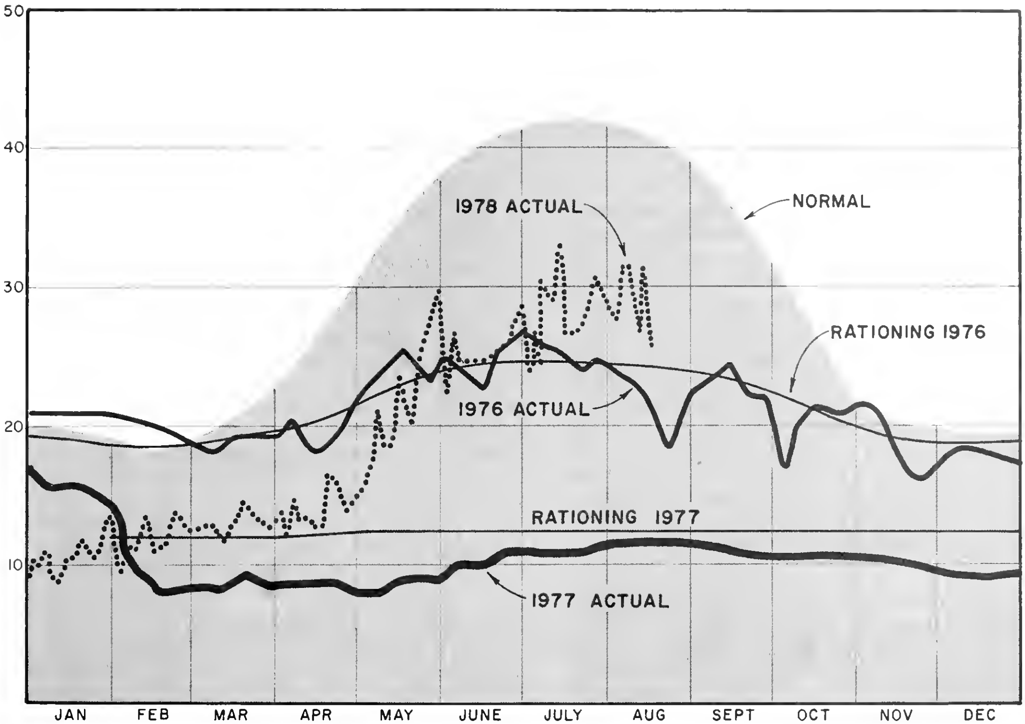
The drought has been over in Marin County for a year now. Marin Municipal Water District declared an end to rationing in February 1978 and told its customers they could use all the water they wanted, cautioning them only not to be wasteful. The price of water was dropped from $1.87 to $0.87 per 100 cubic feet. In July the rate was cut another four cents. As late as August, when demand is usually highest, water was plentiful. MMWD's reservoirs still were at 83 percent of capacity.

The five-year moratorium on water connections and water mains was lifted in June. A total of 1 200 cubic dekametres of water was allotted for new service, allowing 3,000 additional connections, and distribution lines could be extended to serve them.

The emergency pipeline across the Bay is still in place and will remain there by agreement until April 1979. Even though water supplies were excellent in 1978, another dry year can always recur.

Although their tribulations are past, many Marin residents have apparently not forgotten the experiences of the drought. As recently as late summer last year, brown lawns were still visible in residential areas. About half the homes and businesses have replanted, in many cases replacing the lawns and shrubs that did not survive with ornamental rock cover and drought-tolerant species of plants.

As for indoor use, residents may well be continuing to exercise much of the restraint they had used in 1976 and 1977. Water use did not take a sudden upward climb when MMWD removed its restrictions, as might have been expected. The




## LEVELS OF WATER USE, MARIN MUNICIPAL WATER DISTRICT

district's records show that, while overall consumption exceeded both 1976 and 1977, people were still not using as much water as they did in normal years. The level rose quite slowly, in fact, beginning in May, and in August, MMWD customers were still taking only 65 percent of the water they used before the drought.

Altered water use habits are part of the answer. People who have become accustomed to conserving water out of absolute necessity are finding it difficult to resume their former levels of use. Another factor is the use of water that was "banked" with MMWD by customers who found they were able to get by on less than they were entitled to. (Some remarkable consumers cut back to only 34 litres* a day per person.) Individuals who were credited with the unused daily balances they conserved began withdrawing their "drought credits" in mid-1978.

These two factors are having a serious effect on MMWD, which is now in the trying position of fixing rates that will return the same level of revenue as before the drought, while it is selling less water. It is a fact of life in water economics that it costs nearly as much to deliver 50 litres of water as to deliver 150 litres. The overall lessened consumption of water in Marin means less revenue for the district, which has to meet increasing operations costs and long-term fixed capital costs, as well as plan for expansion to develop additional sources of water.

One of the questions now puzzling Marin Municipal Water District is what direction the level of use will take. There is no precedent to tell whether demand will hold at its present rate or will rise gradually to previous years. What eventually happens will have a long-range effect on the future of water development in eastern Marin County. If demand remains down, distribution systems could be designed quite differently. Mains and storage tanks could be smaller, and less electrical energy would be needed to pump water through transmission lines.

MMWD believes now that water demand is most likely to continue at a level somewhat below that of 1975 and before, although not necessarily at the 65

* Approximate equivalent 9 gallons

percent level. Water conservation devices remaining in many homes, and building code revisions that will require water-saving plumbing will most probably have some effect. The heightened consciousness of Marin residents toward water conservation may well linger, perhaps for a long time, further reducing demand.

Conservation is only one part of the development of a more efficient water supply situation for Marin County, however. Two other elements have equal importance: waste water reclamation and development of new sources of water. All three must be considered in any plan of water management today. Marin Municipal Water District is also taking into account the likelihood of future droughts, a process called risk management. The district has recalculated the supply in all its reservoirs, adding the factor of recurring water shortages. This reduces net safe yield—the amount of water that can safely be taken during a dry period. Therefore, MMWD is looking for new sources of water to supply an additional 7 400 cubic dekametres.

The emphasis will be on regional development that goes beyond the boundaries of Marin County, possibly combining a small in-county source with a larger supply elsewhere. The district will be working closely with the Marin County planning department and the cities in its service area.

Looking back on 1976 and 1977, the drought in Marin County demonstrated one simple truth: in a time of crisis, when water supplies are severely depleted, people will make the adjustments, both large and small, that are necessary to live with the situation. When it came to making do with less, the residents of Marin County can be rated high.

For those whose business it is to deliver water, the stresses of the drought carried another message. Water supply agencies may well have to reconsider all the factors that go into meeting their responsibilities to their consumers. If consumers use less water, as Marin residents are now doing, quite possibly they really need less. This fact alone could have far-reaching effects on water development in Marin County and the counties that adjoin it.

*Information for this article was contributed by*
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## RESOURCE MATERIALS

### DWR Publications

**"Special Report on Dry Year Impacts in California."** February 1, 1976. Free.
**"The California Drought—1976."** May 1976. Free.
**"The California Drought—1977; An Update."** February 15, 1977. Free.
**"The Continuing California Drought."** August 1977. Free.
**"The 1976-1977 California Drought; A Review."** May 1978. Free.
**"The Impact of Severe Drought in Marin County, California."** Bulletin 206. In preparation.

*Information on the materials listed here is given on the inside back cover.*

## Farming in Water

# DWR EXPLORES A NEW USE FOR WASTE WATER

The age-old practice of working the land to grow food is familiar to nearly everyone. Even those who may have never visited a farm are aware that most of our edibles come from the soil. But another practice—harvesting crops raised entirely in water—might sound like some scientist's dream for the future, at least until one recalls one real-life example—the trout that are reared in hatcheries and sold at retail markets or released for sport fishing.

Using water as the environment for crops is called aquaculture, an art that, like farming on land, is actually as old as recorded history. Early Egyptians and Chinese raised fish as food, and the inhabitants of ancient Greece and Rome enriched their menus by cultivating oysters. Today in mainland China, large harvests of fish are taken from pond systems, and in Japan, the culture of seaweed is an important aquacultural activity.

Aquaculture is the farming of water-associated plants and animals. The crops obtained are fish, shellfish, grasses, or algae. Overall, aquatic farming operations closely parallel some of those performed in farming on land. In agriculture, the soil is fertilized, weeds are taken out, and when the crop is mature, it is harvested. In aquaculture, fertilizers are often added to the water, undesirable growths of water plants are removed, and the mature crop is harvested from the pond.

Aquaculture systems have typically used either fresh water or sea water. Another use that has become popular in the past few years involves growing aquatic organisms in some form of waste water. (This is not really a third "type" of water because waste water is either fresh or salt water plus contaminants.) The idea in using waste water is to work toward two goals at the same time: to treat the water so that its quality is improved and to produce some form of protein for human and animal consumption. (In the language of water engineering and management, the term "waste water" refers to water that, once having been put to use in some human activity, cannot ordinarily be reused without having been treated. Residential waste water is an example that probably comes most readily to mind, but it is only one type. Other notable sources of waste water are the high water-use industries, such as food processing plants, steel mills, and lumber operations.)

The Department of Water Resources entered the world of aquaculture by a somewhat circuitous path that follows from its role as a water supply agency. As the builder and operator of the State Water Project, DWR maintains the California Aqueduct, which includes the delivery of irrigation water to San Joaquin valley farmers.

The valley is a vast farmland occupied by great acreages devoted to the production of crops. Much of this land lies a few feet above an impenetrable layer of clay that blocks the downward movement of irrigation water, much of which would otherwise filter deep into the soil and join the ground water basin. Normally of excellent quality, irrigation water does contain small amounts of dissolved salts. As the pure water evaporates from the surface of a field, the salt residues accumulate in the upper layers of the soil in amounts that can become more and more harmful to plants. If the irrigation water is able to percolate readily into the ground—as, for instance, where the soil is sandy—the problem can be alleviated by adding more water to flush the salts from the plant roots. But where the underlying clay zone bars the deep downward movement of water, the salts continue to accumulate and, unless something is done to remedy the situation, the now-salty ground water above the clay layer builds up toward the surface, eventually reaching the roots of plants. Plant growth then declines, crop productivity suffers, and in severe cases, the soil becomes sterile.

The nub of the problem—and the reason the Department of Water Resources has long been concerned about irrigation problems in the San Joaquin Valley—is the waste water that is the consequence of this faulty natural drainage. Salt build-up in the valley is a problem of long standing, despite much remedial work that has been done. The importance of sound management of irrigation is no small matter. About 400 000 hectares of farmland, mostly on the west side, either are now or will be affected.

At the site of individual farming operations, the drainage problem can be easily (but not cheaply) resolved by installing networks of perforated below-ground tile drains into which the subsurface irrigation water seeps. (These drains, once made with tile pipes, are now built using plastic.) The drains are laid in trenches about 2½ metres below the surface of a field and covered with a layer of gravel. The rest of the trench is filled with earth. The water enters the tile line and flows to a subsurface collecting sump, from which it is usually pumped for disposal elsewhere. The water from these tile systems often contains such a high percentage of constituents injurious to plants that its potential for direct reuse for irrigation is greatly limited. In addition to its high salt content, it sometimes contains high concentrations of boron, a constituent that impedes plant growth. Plants do vary in their sensitivity to boron, but high concentrations are toxic to all commonly grown crops.

Since installing tile drains is a costly business, less than 10 percent of the potential trouble areas in the valley are tile drained. Farmers in the rest of these areas follow the next best course. They plant crops that can tolerate high levels of salts—barley, for instance, which could grow in sea water, if need be. Raising salt-tolerant crops cannot continue indefinitely, however. In most instances, farmers will eventually have to build tile drain systems or abandon the land.

*Subsurface drainage that percolates from the root zones of crops, such as this field of cotton, supplies the test facility's ponds.*

In addition to tile drain systems, another remedy in use today is blending the drain water with supplies of better quality irrigation water. However, this is only a temporary solution. It does nothing to prevent the long-term accumulation of salts, a condition with potentially disastrous consequences for agriculture in the valley.

The traditional solution to the drainage dilemma is to move the salt-laden water from the area in which it is causing trouble. There are three possible ways of handling the situation: desalting, evaporation, and export. Of these, only through desalting has the drainage water been regarded as a resource worth reclaiming. Evaporation and discharge from the valley are essentially means of getting rid of water that was long considered to be solely a waste product.

At present, small amounts of waste water that contains relatively little salt and other undesirable elements can be recovered at the farm to be used again for irrigation, but the quality of most agricultural drainage is so very poor that it must be taken away from the field. Some is disposed of in sloughs that flow into the San Joaquin River, and some goes farther south to evaporation ponds in the Tulare basin. Although the proposal has aroused opposition in some quarters, most economic analyses indicate that the least costly way of transporting agricultural waste water from the valley is to put it in a gravity-flow canal emptying into Suisun Bay between Antioch and Martinez.

In 1976, the U.S. Bureau of Reclamation, the California Water Resources Control Board, and the Department of Water Resources formed the Interagency Drainage Program to consider the valley's drainage problems. In light of changing views on the concepts of waste water reclamation and reuse, the three agencies decided to take a new approach to the disposal of agricultural waste water and to regard it as a resource, rather than as an undesirable by-product. One thought was to find something of value that would grow in this salty water. With this in mind, the Board contracted with DWR to look into the potential of field drainage as an aquacultural medium. The primary goal of the study was to examine possibilities for producing useful organic products, both animal (chiefly fish) and plant.

The site for this work was the waste water treatment test facility already in operation near Firebaugh, 72 kilometres west of Fresno, where between 1967 and 1970, the Bureau, the U.S. Environmental Protection Agency, and DWR had studied ways of removing nutrients from subsurface farm drainage. In addition to its high salt content and other constituents harmful to plants, such as boron, agricultural waste water contains nitrate, a nutrient that tends to encourage obnoxious growths of plants where it is discharged.

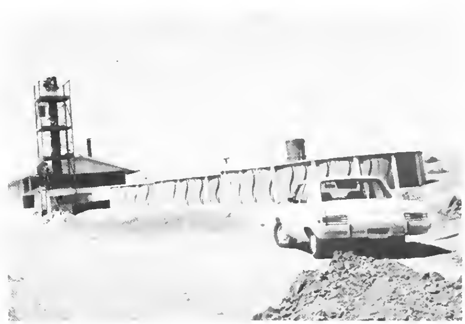
DWR's part of the earlier project was to find methods by which algae, tiny single-celled plants that float about in lakes and oceans, could be used to remove the nitrate from water. During the three-year program, the algae were cultivated in outdoor ponds filled with farm drainage water from surrounding farmlands. They reproduced in masses of countless microscopic cells, taking the nitrate from the water in through their membranes. Periodic harvesting and drying of the algae effectively removed the nitrate from the water. The work performed under this program was an example of aquaculture in that the algae were regarded as a potentially useful by-product.

When the algae studies ended in 1970, DWR's role was limited to advising the Bureau on the conduct of additional water treatment studies at the Firebaugh research facility. This work involved plants similar to tules and cattails that grow in a more-or-less continuously wet environment.

With the emergence of the aquaculture project in 1978, researchers began with studies of four species of fish: the channel catfish (as a food resource), the golden shiner (as a bait fish and an experimental animal), the mosquitofish (as a means of insect control) and the Sacramento blackfish (an algae eater). These were chosen because all four are hardy, grow well in relatively warm, saline water, and are presently or potentially useful, from an economic standpoint. They are being cultivated in several types of farm drainage water—some from near the research station and some from other parts of the valley. The levels of salinity vary, depending on the area from which the water has come.

One very important question was whether small amounts of potentially toxic substances in the water were harmful to the fish and to the people who would ultimately consume them. To find the answer, biochemists from the Department of Toxicology of the University of California at Davis are examining the fish, the water they live in, and any plants growing there for concentrations of possible toxicants. The objective is to determine how the toxic content of the tissues of fish such as catfish reared in agricultural drainage water compares to that of similar fish reared in water from more conventional sources.

To study fish growth, two approaches are being taken—intensive culture and polyculture. The most common example of the intensive culture of fish in California is probably the various salmon and trout hatcheries operated by the State. In these operations, the fish are held in crowded conditions and fed a balanced diet of ready-made food. Intensive culture operation requires that large volumes of water be passed through the ponds to oxygenate the water and prevent the accumulation of toxic fish wastes and uneaten food particles.

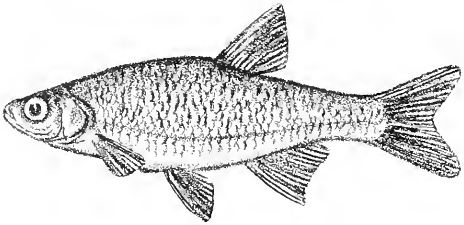


*Outdoor ponds holding the experimental fish. Each pond is slightly more than 7 metres in diameter and 1 metre deep*

The second plan, called polyculture, is based on the highly efficient feeding arrangement that exists among plants and animals in nature. In a natural setting, the energy from sunlight falling on a pond or lake is captured by the algae and other water plants and becomes plant tissue. The algae and other plants are either eaten by small fish and other small animals or fall to the bottom and decompose. The small fish and the dead vegetative matter are consumed by larger fish that are then eaten by even larger ones. Ecologists often call this feeding scheme a food web.

The secret to a successful polyculture system is finding a group of species of fish or other aquatic animals whose feeding preferences fit well together in a particular food web. As long as the various species placed together are not competing for the same types of food, the system works well. The mainland Chinese have based their operations for producing crops of carp for human consumption on polyculture and, according to incomplete reports, in 1965 reared harvests totalling anywhere from

1 ½ to 3 million metric tons of fish. A typical Chinese pond contained grass carp, which feed on emergent vegetation (water plants whose upper portions emerge from the water); bighead carp, which feed on zooplankton (microscopic animals that swim about in water); silver carp, which feed on algae; mud carp and common carp, which feed on small bottom-dwelling aquatic animals; and black carp, which feed on snails and clams.



Golden Shiner

The Chinese system worked because each of these six species restricts itself to a particular food group and does not take the food of the others.

We are not able to use the same species here because the California Department of Fish and Game severely limits the importation of exotic species. Their regulations are designed to protect our native fish. Experience has shown that when fish from other parts of the world are introduced in California, the populations of native species are often seriously reduced.

The only course of action open to us, therefore, is to discover which native fish will live together peaceably, dividing their food supplies in the same manner as the Chinese carp. One fish that looks promising is the Sacramento blackfish, a California species that flourishes in the San Luis Reservoir in Merced County and in Clear Lake in Lake County. Blackfish are caught commercially at both locations, and sold live in Los Angeles and the San Francisco Bay Area. This fish appears to feed extensively on algae. In a polyculture operation, the blackfish would occupy a position somewhat like that of cattle in an agricultural operation.

The next item needed is some water-dwelling animal that lives on zooplankton, just as the bighead carp does. One candidate is the golden shiner, one of the fish being used in the Firebaugh study. Another is the mosquitofish, whose diet consists of zooplankton and insect larvae, including the larvae of mosquitoes. Control of mosquitoes is not as simple as it once was. There are two reasons for this. Mosquito populations are developing resistance to commonly used organic insecticides, and, because of environmental concerns, the business of bringing new pesticides on the market is growing more difficult and more expensive. Mosquitofish produced in an aquacultural program could be a real help with this problem. They could be harvested and sold to mosquito abatement districts for seasonal planting in the rice fields and other open water in which they breed.

*Partial view of a pond in which mosquitofish are being reared.*

Catfish, especially bullheads, may also fit nicely into a polyculture plan. They seek out the decomposing remains of plants and animals and would help keep the pond water clean. Common carp, a species introduced in this country some 100 years ago and now found throughout California, would also work out well, but the market for them is limited at present. Moreover, their habit of muddying the water by rooting about on the pond bottom detracts from their usefulness.

The Asiatic clam is another interesting prospect. Clams tend to clean the water that surrounds them by the manner in which they feed. As they pump water through their systems, they filter out bits of plant and animal matter. These shellfish could also prove to be an economic bonus for farming. Asiatic clams are a common dietary item in the Far East and are sold in food stores in the United States (under a different name).

Although the plant and animal elements we need for polyculture are at hand, the task of putting the system in operation will involve substantial effort. Since the salts in agricultural drain water are present in proportions unlike those found in most natural water bodies, we first have to determine whether the life forms we select can live, grow, and reproduce successfully in this particular blend of salts.

We are also experimenting to find out whether the water we are using will need supplemental fertilizers to increase the growth of plants in the ponds. Agricultural drainage is rich in nitrogen, but it is relatively low in phosphorus and iron, essential elements for plant growth. Our goal is to balance the amount of vegetation grown in the ponds with the amount consumed by the pond dwellers. Plant matter that goes uneaten tends to break down and add wastes to the water. The point is to achieve a delicate ecological balance in which only a very little of the unused plant material leaves the pond system.

Another option for study is the potential for mass production of grasses, with particular attention given to reed canarygrass. This plant will be a prime test species because it is apparently unaffected by standing in water for long periods, it tolerates highly saline water, and it produces a valuable hay crop. In examining grasses, the researchers will also watch for changes in the various dissolved constituents, especially nitrogen, boron, and silicon, as the water flows through the ponds. Even though water treatment methods are not the first consideration in this project, we cannot completely ignore them. Changing environmental standards governing the discharge of waste water could mean that some form of treatment such as nitrogen removal will be required in the future.

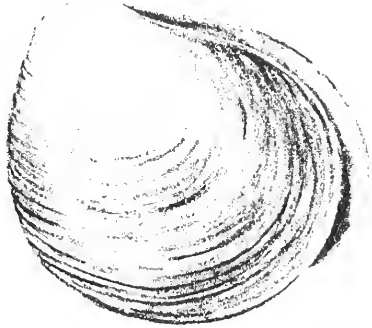
*Reeds and other aquatic plants growing in one of the ponds could benefit an aquacultural project by improving the quality of the pond water. They could also provide a potentially harvestable crop that might be used for livestock feed.*

The ultimate disposal of the drainage water leaving an aquacultural system in the San Joaquin Valley has yet to be settled. The Bureau of Reclamation, the Water Resources Control Board, and DWR, acting as members of the Interagency Drainage Program, presently favor the construction of a gravity-flow drainage canal leading to the Delta or Suisun Bay. Included in their plan is a series of marshes fed by the output of the aquacultural ponds. These will provide much-needed additional habitat for waterfowl in California. There is another side to the picture, however. Although sending this twice-used water to the Delta area has been described as economically sound, a current evaluation of the environmental effect of such an action on the receiving water suggests that the drainage water's high salt content could be detrimental, principally in spring when striped bass are spawning near Antioch.

The whole question of disposal could be compounded by the high rate of evaporation in the San Joaquin Valley, where summer temperatures are typically quite hot. In an average year, evaporation will cause the level of an undisturbed body of water to drop 1½ to nearly 2 metres. Such a loss of water in an aquacultural operation of the type being studied at the Firebaugh facility will concentrate the salts in the drainage water, possibly intensifying salinity problems where the water is finally discharged.

Another factor is the effect the particles of organic materials (fish wastes, for instance) produced by an aquacultural system may have on the receiving water. These substances reduce the amount of oxygen dissolved in the water. An adequate supply of dissolved oxygen is necessary for the growth of aquatic organisms. Tests in this study will establish how best to remove the wastes before the water leaves the ponds.

Although results of the study are not yet in, we expect they will show that the agricultural drainage of San Joaquin Valley can be put to use to support a good growth of aquatic plants and animals that are both safe and nutritious. For a region like the valley, where long, rainless summers are the rule and crop irrigation is a must, this will be a real achievement. Ever since salt build-up in the soil was first recognized as a serious threat to the farmer's



Asiatic Clam

prosperity several decades ago, large quantities of used irrigation water considered no longer usable for any purpose have had to be disposed of elsewhere.

Now it appears we have another route open to us—to "farm" this water and take from it a rich harvest for our tables. Of course, marketability of much of this harvest is a question mark right now. Americans are not by custom big consumers of fish and shellfish, even though nutrition experts have been telling us for some time that these foods are excellent sources of protein. Looking ahead a few years, however, we think demand may rise sufficiently to make commercial aquaculture ventures financially attractive. When that occurs, agricultural drainage may well provide an important part of the water supply for these enterprises, thus proving that a one-time waste product can be turned into something truly beneficial.

*This article was prepared in the Division of Planning, Sacramento, by*
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## RESOURCE MATERIALS

### DWR Publications

**"Removal of Nitrate by an Algal System."** Bulletin 174-10. November 1971. $1.25.

**"Removal of Nitrate from Agricultural Tile Drainage by a Symbiotic Process."** Bulletin 174-18. May 1976. Free.

*Information on the materials listed here is given on the inside back cover.*

## Design for Conservation

# THIS POWERPLANT WILL CREATE ENERGY AND SAVE IT, TOO

The idea that there was any real purpose in saving electricity at the very plants that generated it would have struck a lot of knowledgeable people as faintly ridiculous just a decade ago. After all, wasn't power cheap at the source? The country's great power-producing plants at Grand Coulee Dam in the State of Washington and Niagara Falls in New York blazed with lights every night, as much for the decorative effect as for the illumination.

But the world has taken new directions in the last ten years, and events have forced us to alter our thinking on the allocation of power. As a nation, we have come up against some hard facts: fossil fuels are depletable resources and we are wise to use electric power as efficiently as possible in every situation. This applies not only to the use of power generated by petroleum, natural gas, and coal, but to hydroelectric power as well. Hydroelectric plants supply significant amounts of energy to California, particularly when plenty of water is available.

In view of these changes, the Department of Water Resources this past year embarked on a statewide program to modify the amounts of electricity it consumes at its facilities—offices, maintenance and repair shops, and control centers. This affects installations in locations such as Red Bluff, Oroville, Sacramento, Byron, Los Banos, Fresno, and Castaic. Conservation measures are being put into effect wherever possible, ranging from adjusting thermostats and reducing lighting levels to improving insulation and shading for buildings, installing insulating double-pane glass, and adding solar collectors to supplement present space conditioning (heating and cooling) systems. More sophisticated controls are being planned for heating, ventilating, and air conditioning equipment, and computers are being considered to monitor and control conditioning at the larger, more complex facilities. The overall goal of the conservation program is to cut energy use by at least 25 percent.

*Structure typical of many Department of Water Resources' buildings that are being modified for passive energy conservation*

DWR's operation and maintenance center at Beckwourth in Plumas County, which operates the Upper Feather River section of the State Water Project, is scheduled for a solar collector system to heat the building interiors and to furnish domestic hot water. This will reduce the center's dependence on liquid petroleum gas. The Beckwourth facility was selected for this installation because it is situated where winters are markedly colder than at other Project sites and thus has a greater need for space heating.

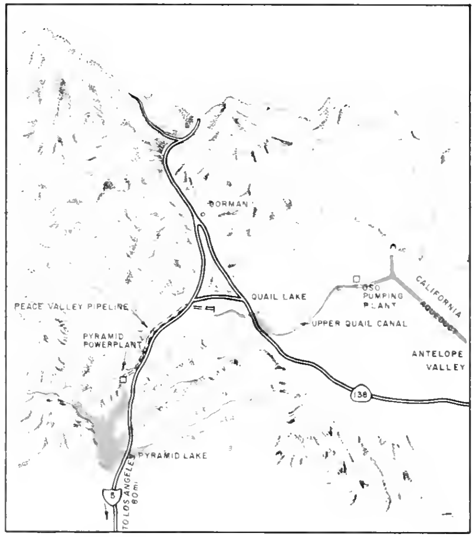
The job of modifying structures that were built when energy was considered cheap is often structurally difficult. Roofs must be strengthened to carry the extra load imposed on them by solar collectors. This is especially true for flat roofs, which would tend to become somewhat concave and trap rain, putting a further strain on the building. Easier access to roof tops and safety railing for maintenance personnel are other necessities. Sometimes finding a good site for a solar collector is a problem because a neighboring building may cast a shadow over the most favorable position, which would hamper the collector's effectiveness. A solar collector can be set up near a building, rather than on it, but to do so reduces its efficiency.

## SAVING FROM THE GROUND UP

Although altering and adding to existing buildings is a good way to conserve, the best way to make the most of the least energy is to begin, as the saying goes, at the beginning, and make energy conservation a fundamental part of a new building. Ideally, this should happen while a project is still a vision in the designer's mind.

Pyramid Powerplant, a hydroelectric facility that is now being built on the West Branch of the State Water Project's California Aqueduct, is an excellent example. Designed for maximum energy savings, the plant will incorporate as many conservation features as present technology has proven practical.

Situated in the northwestern corner of Los Angeles County about 16 kilometres south of Gorman, the plant will generate about 450 million kilowatthours a year. It will take water from the California Aqueduct through Quail Canal and discharge it into Pyramid Lake. Its outflow will be directed toward Los Angeles. Initially, the plant will have two generating units capable of a peak output of 75 000 kilowatts. Two more units can be added later to double the facility's total power production.

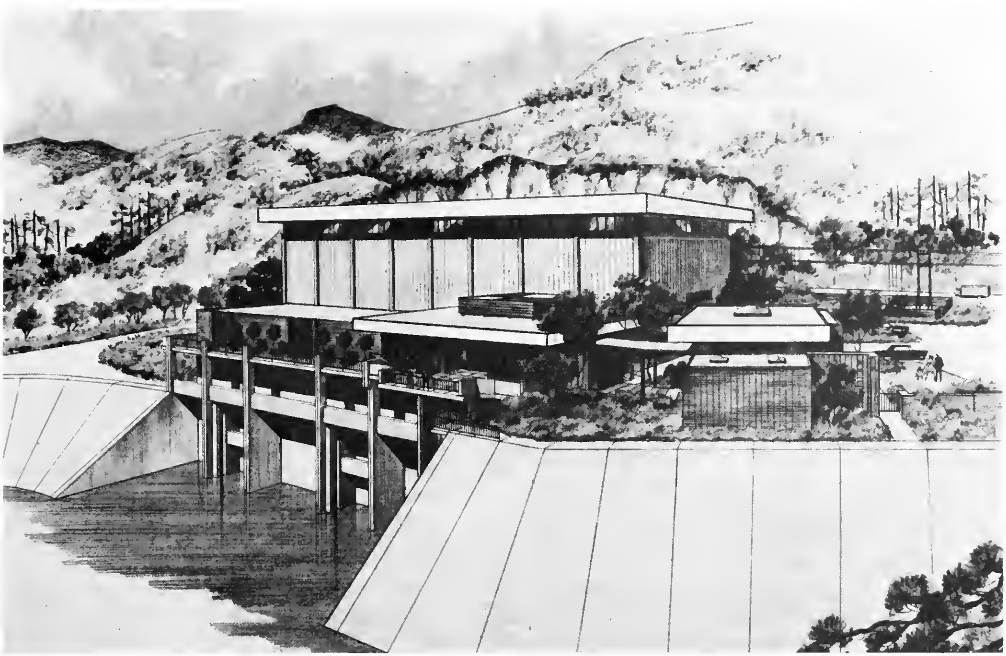



Pyramid Powerplant has been designed to operate as a power recovery plant. The electrical energy it will produce will offset part of the enormous amount of power used to pump the Project's water over the Tehachapi Mountains to southern California.

Work at the site has already begun. The contract to excavate and erect the building was awarded in October 1978.

In designing Pyramid Powerplant, DWR architects and engineers have been guided by the basic premise that energy conservation begins with proper physical design of a structure, a principle more popularly known as "passive conservation". To achieve savings in this way, a designer must put to use such architectural considerations as orienting a building to take advantage of its relation to the sun at all hours of the day year-around and designing windows with overhangs and insulated reflective glass that allow natural illumination but block the sun's direct rays. Complete insulation of the outer shell of a building and weatherstripping doors to prevent the escape of conditioned air are also essential elements of passive conservation.

When the Pyramid Plant goes into operation in late 1982, it will exemplify every one of these methods—and more. A plant of this type normally draws on its own electrical output to heat, cool, ventilate, and illuminate its facilities and to supply its own domestic hot water. At Pyramid, these



*Architect's concept of Pyramid Powerplant.*

needs will be met from alternate sources at the site, reducing this power load on the output of the plant to allow transmission of more power to its customers.

Three sources—direct solar radiation, the waste heat emitted by the generators, and the thermal storage capacity of the water in the reservoir—will all be used to the extent possible to heat and cool the interior of the plant. Heat pumps using the thermal storage of the reservoir will be put into operation when the direct use of the other two methods cannot maintain the required temperatures.

In addition to these processes, the plant will have another big plus going for it. The greater part will be built below ground, with some exterior walls in contact with the water in Pyramid Lake, making the structure a well-insulated thermal mass.

Because of the complexity of the air conditioning system and the countless variables involved in its functioning, the plant will include a fully integrated, computer-controlled energy management system. The computer will receive messages from sensors and make the decisions needed to achieve and maintain the desired levels of heating and cooling.

Solar energy will be received by banks of collectors mounted on the powerhouse roof, facing south and sloping about 30 degrees from horizontal. A mixture of ethylene glycol and water flowing through the collectors will absorb heat from the sun. The heated solution will be pumped to a water-to-water heat exchanger, where the heat will be transferred to pure water and either held in large insulated storage tanks, or directly pumped to the heating coils of ventilation equipment (in the heating mode) or to the absorption chillers (in the cooling mode).

When the temperature in the water storage tanks drops below the required level, the heat pump will take over. At night, the collector's circuit will be shut down, and the stored hot water (and the heat pump, if needed) will come into operation to maintain desired room temperatures. The air conditioning equipment will have an economizing damper system that will allow up to 100 percent use of outside air, if outdoor temperatures are suitable for space conditioning.

In the control room wing of the plant, which will be occupied by DWR personnel 24 hours a day, provision for control of space conditioning is an important part of the total design from the standpoint of human comfort because more people will be working here than in any other section. Also, power generation electronic control equipment operates more reliably at the human comfort temperature range. A solar-powered space heating and cooling system is expected to meet 75 percent of the area's needs. Heated water for personnel use will also be supplied primarily by the solar collectors. Conventional heat pumps will operate a back-up system when the sky remains overcast for long periods.

The rest of the plant will be heated by reclaiming the heat usually wasted during the process of generating electricity. Power generation produces heat. The great amount of heat given off by the generators is normally regarded as an unwanted by-product to be gotten rid of whenever the generators are running. The usual procedure for this is to circulate water in cooling coils. The water absorbs the heat, which is then disposed of when the water is discharged downstream from the plant.

At the Pyramid site, this waste heat will be captured for use by redirecting the heated water to coils in fan units throughout the plant's interior space. When the generators are not being operated, usually during night-time hours, heat pumps will draw heat from the water held in Pyramid Lake and return the resultant cooled water to the reservoir.

Within the generator room, the turbine gallery, and the shops, interior cooling is not as critical a factor as in the control wing because these areas will be largely underground and because few of the plant's personnel will be spending much time there, as a rule. These areas will be cooled sufficiently by directing reservoir water through coils in the same fan units throughout the plant that were used during the heating mode and by using heat pumps that use the reservoir as their "heat sink". (Stated most simply, during the cooling mode, the refrigerant of the heat pump absorbs heat from the room and transfers the heat to the reservoir "heat sink"; in the heating mode, the refrigerant absorbs heat from the reservoir water as its "heat source" and transfers the heat into the interior space.)

The plant will be lighted inside and out by energy-efficient high-pressure sodium lamps. Because sodium lamps permit only an average level of color perception, locations where it will be vital to distinguish color differences accurately—in color-coded wiring, for instance—the latest energy-efficient conventional lamps will be installed. These will possibly be improved types of fluorescent or incandescent lamps. No artificial illumination will be needed during daylight hours for the aboveground parts of the plant. Natural daylight will be sufficient. At night, only the lighting needed for operations and security will be used.

The design of Pyramid Powerplant presents a thoroughly workable solution to the question of energy conservation. However, since the contract to install generators, turbines, and other equipment is not expected to be awarded until 1980, DWR is using the intervening time to watch for and evaluate changes in technology that will affect the choice of materials and equipment used in the plant, such as solar panels, absorption chillers, and controls. DWR is presently considering the use of evacuated tube type solar collectors, which make collection of higher temperatures possible. By monitoring the state of the art during this period, DWR will be able to take advantage of the best of the most recent refinements in a fast-moving field.

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### The Search For . . .

# MORE WATER FOR THE STATE WATER PROJECT

In 1978 the Department of Water Resources embarked on a new venture to test the soundness of an old idea—that "depositing" water in an underground "bank" when it is plentiful and withdrawing it later when water is scarce can provide the large amounts of additional water the State Water Project will need in the future.

While the practice of banking water below the earth's surface has been known for many years, all the conditions required for an integrated operation between State and local interests that would demonstrate its practicability on a large scale are rarely present. The torrential rains and heavy snowfall characteristic of the winter and spring of 1977-78 gave DWR the perfect opportunity by supplying the water needed for such a demonstration.

The State Water Project (SWP) is presently supplied by the waterways of the Sacramento-San Joaquin Delta and by above-ground reservoirs such as Lake Oroville in Butte County. The SWP can now deliver about 2 800 000 cubic dekametres of water annually when water supply conditions are normal or better. Eventually it will be capable of delivering almost twice as much—5 200 000 cubic dekametres—an amount that DWR will be required to provide, under the provisions of contractual commitments with a large number of local water agencies. Clearly, then, more water will be needed.

By widening its functioning to include the combined use of surface facilities and underground storage, DWR is demonstrating that the SWP can do more than transport and deliver surface water.

We have other possibilities for expanding our sources of water, one of which is building more surface reservoirs. Although California is a semi-arid region in which years of ample rain and snow alternate with drier years, it experiences enough "good" years to meet its needs at present, provided the runoff is captured when the streams are high and stored for use when precipitation ceases. This has been a successful practice for many years.

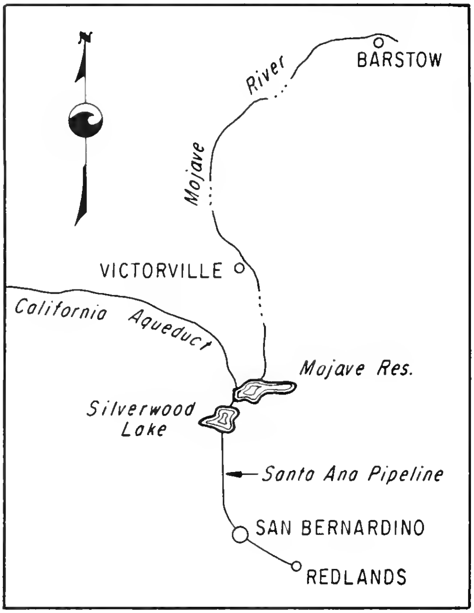
However, building more surface storage facilities to meet higher demand in the future is not the only answer, or necessarily the best one. Most of the better reservoir sites have already been developed, and new sites often have environmental problems or are not economically justifiable. Underground reservoirs, on the other hand, provide an excellent means of storing water. They lie invisibly beneath the earth, making little mark on the environment. (Some land is needed for the spreading grounds through which surface water percolates.) The water held by a ground water basin is generally safe from surface pollution, and it can remain there for long periods until needed.

Moreover, California's underground storage capacity is immense. Its basins extend for thousands of square kilometres, particularly beneath the San Joaquin Valley and southern California.

There are, of course, both pros and cons in comparing surface and subsurface storage. Ground water basins generally provide free storage space, but there are some expenses involved in putting the water in the earth and pumping it out again. Surface reservoirs are relatively expensive to build, but many of them also provide income from the sale of the power they generate (when they are designed to include hydroelectric facilities).

In view of these considerations, the Department of Water Resources undertook the Mojave Demonstration Project, a program that is intended to show how we can take advantage of our vast ground water storage potential to develop a reliable source of additional supplies in years to come. The Mojave project came about through agreements between DWR and two large San Bernardino County water agencies, the Mojave Water Agency and the San Bernardino Valley Municipal Water District.

After canvassing ground water basins throughout southern California, DWR selected the Mojave River basin as the site that offered the most promise. The basin has a lot of unused space and can admit great quantities of water in a relatively brief time, compared to most basins. (The usefulness of some other basins is limited because they have less empty space or they take water from the surface much more slowly.) Furthermore, few other basins were able to take on the added burden of storing water from the State Water Project in the spring of 1978 because, as successive storms brought drenching rains, spreading grounds filled with water that remained on the surface for many months, and water tables rose rapidly to new levels.




The Mojave Demonstration Project began last spring when DWR transported 28 000 cubic dekametres of flood flows from the Kern River in San Joaquin Valley by way of the California Aqueduct to Silverwood Lake, an SWP reservoir in the San Bernardino Mountains about 20 kilometres due north of the city of San Bernardino. (This action is related to events described in another article, "The Big Flood That Didn't Happen".) Then on May 9, DWR started releasing this water from Silverwood Lake north into the Mojave River. It flowed north for some distance, finally sinking into the Mojave River ground water basin between Victorville and Barstow. The releases continued into June. This was the first part of a two-part operation.

The situation was ideal. The Mojave River is normally a dry channel, and, under usual conditions, the water brought from Silverwood Lake would simply have been absorbed by the highly porous soil of the riverbed south of Victorville and never reached Barstow, where it was destined. Because of heavy rains in the area, however, the Mojave River was flowing and the riverbed was

*The Mojave River just downstream from Cedar Springs Dam, with water flowing toward the Majave River Basin.*

saturated. The imported water could be "piggy-backed" on the river's flow, thus reaching the spreading grounds near Barstow with little depletion.

Two months later, on July 7, the second part of the ground water storage operation began when DWR released more water from Silverwood Lake. This time it flowed south in the Santa Ana Pipeline, another SWP facility, to the Bunker Hill-San Timoteo ground water basins beneath San Bernardino and portions of Redlands, which had storage space available. Unlike the water delivered to the Mojave River basin, this water was derived from the State Water Project system and was transported by the California Aqueduct from the Sacramento-San Joaquin Delta. The agreement with the San Bernardino Valley MWD calls for storing 6 200 to 9 900 cubic dekametres of water in these basins during 1978, up to a maximum of 60 000 cubic dekametres at any one time.

The relationship between these two separate operations is a somewhat complex one because it involves a "transfer" of water without a direct physical exchange. Essentially, this is what will take place: during the next four years, the Mojave Water Agency will buy the 28 000 cubic dekametres of water now deposited in the Mojave River basin from DWR, rather than order an equal amount the State Water Project would have delivered through the California Aqueduct. Of the total of 60 000 cubic dekametres of SWP water stored in the Bunker Hill-San Timoteo basins, ownership of which remains with DWR, are 28 000 cubic dekametres of water the SWP will not be delivering to the Mojave Water Agency. This will increase the amount of water the SWP will have in storage, which will help firm up its overall yield. Over the next 15 years, as the water stored in the San Bernardino basins is needed for State Water Project operations, the San Bernardino Valley MWD will pump it back to the surface.

The "exchange" of water between the Mojave and San Bernardino ground water basins is important because DWR needs an extended period of operation in which to determine how effective are its techniques for storing and recapturing ground water. This period is also needed as a means of confirming how much a ground water storage program costs and gaining experience in actually administering such a program.

The Mojave Demonstration Project is the first of its type for DWR. The groundwork was laid in 1974, when DWR made a preliminary study to learn how much space would be available for storage in southern California's ground water basins. The results indicated that their capacity ran into the millions of cubic dekametres. Encouraged by this potential and by the interest expressed by local water agencies, DWR then began looking at the matter in greater detail. As studies continued, it became evident that many legal and institutional issues would have to be resolved before a practical program of ground water storage could be set in motion. A model program appeared to be the best way to find answers. This led to the development of the present project.

At the ceremony marking its inception, the Mojave Demonstration Project was described as a new idea that had become a reality. Storing water below the ground is, of course, a familiar practice to California's water managers, but combining the efforts of State and local agencies is a fresh attack on a recurring problem—providing water when and where it is needed.

*At the ceremony marking the release of water from Silverwood Lake to the Mojave River Basin. From left, William Orchard, Chairman of the Board of Directors, Mojave Water Agency; Ronald B Robie, Director, Department of Water Resources; and Lloyd Yount, Chairman of the Board of Directors, San Bernardino Valley Municipal Water District.*

The results of the Mojave project will not be fully known for some time yet, but DWR has already gained some very useful information for similar projects elsewhere. One thing we are certain of—ground water storage will prove to be one sound and effective method, in conjunction with others, of making ever greater use of California's finite water resources. Ultimately we can apply what we are learning from this trial program to increase the annual yield of the State Water Project by about 3 330 000 cubic dekametres of water. That is enough to serve a population of two million people. To achieve such an output means we will have to gradually build up our underground reserves to a total of about 3 to 4 million cubic dekametres.

The Mojave Demonstration Project is a positive step toward realizing our goal, and the outlook is excellent for the cause of water conservation in California and the continued well-being of the State Water Project.

*Information for this article was contributed by*
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## RESOURCE MATERIALS

### DWR Publications

**"Delta Water Facilities".** Bulletin 76. July 1978. Free.

**"The Water Management Element of the California Water Plan".** Bulletin 4. (Scheduled for release in 1979.)

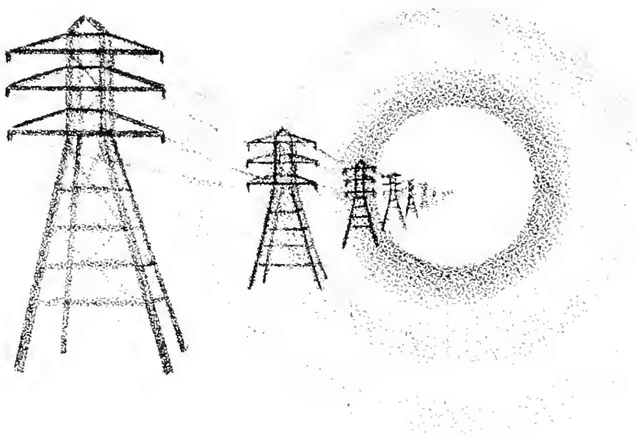
**"A Ground Water Storage Program for the State Water Project: San Fernando Basin Theoretical Model".** Bulletin 186. (Scheduled for release in 1979.)

### DWR Films

**"Ground Water: California's Sunken Treasure".** 14 minutes. (1977)

Describes the importance of ground water development to California and shows how ground water reservoirs can be used to store flood water in wet years and then drawn on in water-short years. Animated sequences illustrate the physical characteristics of ground water basins and depict the changes brought about by degradation and depletion.

*Information on the materials listed here is given on the inside back cover.*



The Search For . . .

# NEW WAYS TO POWER THE STATE WATER PROJECT

The State is relying upon both conventional sources and new, nontraditional sources of energy to help keep water flowing through the State Water Project—economically—after March 31, 1983. Until that time, the Department of Water Resources (DWR), builder and operator of the Project, will continue to supplement its hydroelectric generation with electric energy from California utilities at low-price, fixed rates.

The present low cost of power is the result of contracts that DWR and the electricity suppliers negotiated in the middle and late 1960's, based on conditions and expectations during that period. At that time, no one could foresee that costs of generating electricity in conventional steam plants would skyrocket.

When the present low-price contracts expire in 1983, new contracts will be negotiated with the utilities, and prices are expected to be substantially higher. Even with minimal purchases from the utilities, power costs the Project must charge for pumping water are expected to increase five-fold after 1983, causing about a 70-percent rise in the total cost of water delivered by the Project. Unless DWR can develop less expensive alternatives to widespread purchases from the utilities, the cost of water from the Project will rise even more sharply.

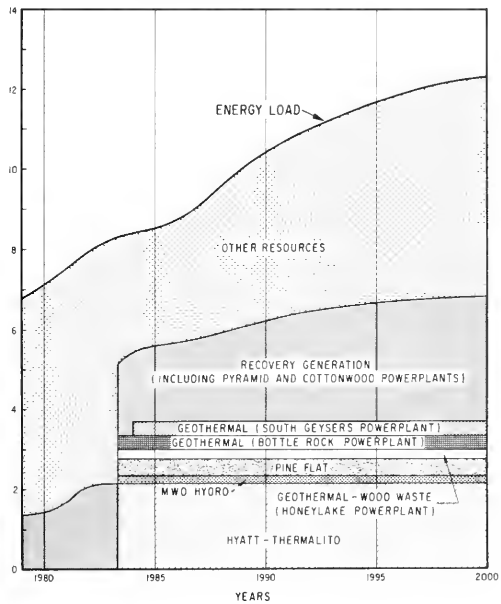
Another factor is that the Project will need increasing amounts of power in the years to come. In 1978, it expended about 4.5 billion kilowatthours to refill reservoir storage depleted by the drought and to deliver about 2 million cubic dekametres of water from its system. To meet expanding water deliveries, the Project will be consuming more than 7 billion kilowatthours annually by 1985 and at least 10 billion kilowatthours annually by 2000. The energy load projected for the turn of the century is equivalent to the electricity requirements of three cities the size of San Francisco.

With rising costs and greater energy needs in mind, DWR is working with the public and private sectors in evaluating the potential use of a number of energy sources as alternatives to widespread purchases from utilities. It is particularly interested in these: coal, geothermal resources, biomass, small hydroelectric plants, cogeneration—the simultaneous production of useful heat and electricity—and wind.

STATE WATER PROJECT

ESTIMATED ELECTRICAL ENERGY LOADS AND RESOURCES

Billions of Kilowatthours Annually, 1979-2000




## ENERGY FROM COAL

Coal technology has come a long way in recent years. The technology for removing sulfur dioxides and particulates, and possibly nitrogen oxides, from the exhausts emitted by coal-fired power plants continues to advance. This factor, along with a new concept called pollution trade-offs, which permits a new power plant to reduce pollution loads of neighboring industries, could mean that DWR can move ahead in developing a new source of power that will not violate any air quality standards.

DWR has been giving close consideration to coal as a potential energy source. Together with the California Energy Resources Conservation and Development Commission (Energy Commission), in 1976 DWR funded studies of this matter by the University of California. This work resulted in a 1977 report, "Study of Alternative Locations of Coal-Fired Electric Generating Plants to Supply Energy from Western Coal to the Department of Water Resources".

DWR has now begun taking the first steps that will eventually lead to a large plant (up to 1000 megawatts) it plans to build somewhere in California. The facility could be in operation by the late 1980s. About one-third of its output would be owned by and operated for the State Water Project, and the remainder would be owned by public and private utility companies, if they desire to participate in the plant. (A smaller plant would be constructed to supply only the needs of the Project.)

A great deal of work must be done before the plant can become a reality, however. Work is presently in the preliminary stage, which includes performing preliminary engineering and environmental studies and preparing and filing applications for needed approvals and licenses from federal, State, and local agencies. A major part of the approval process will be obtaining site certification from the California Energy Commission, which must approve locations in California for all thermal power plants 50 megawatts or larger.

The siting process involves both government agencies and the public. It is carried out in two steps. A Notice of Intent (NOI) must be filed on a minimum of three alternative sites which provides basic information for assessing the technical and environmental suitability of the sites. An Application for Certification triggers more detailed analyses on a site approved during the NOI process, leading to certification of one of the three sites.

This phase includes siting studies, preliminary design of the plant and emissions controls, environmental studies, transmission of electricity, coal transportation, studies of water supply, and filing applications with various regulatory agencies.

In working with all agencies and the public during the entire process, DWR will make every effort to satisfy their various requirements and to make the proposed plant compatible with its environment. Liaison has been established already with other governmental entities, and an advisory committee composed of representatives of public organizations has been formed. DWR has also begun work to set up air quality monitoring stations at critical locations and has met with agencies having jurisdiction over air quality matters.

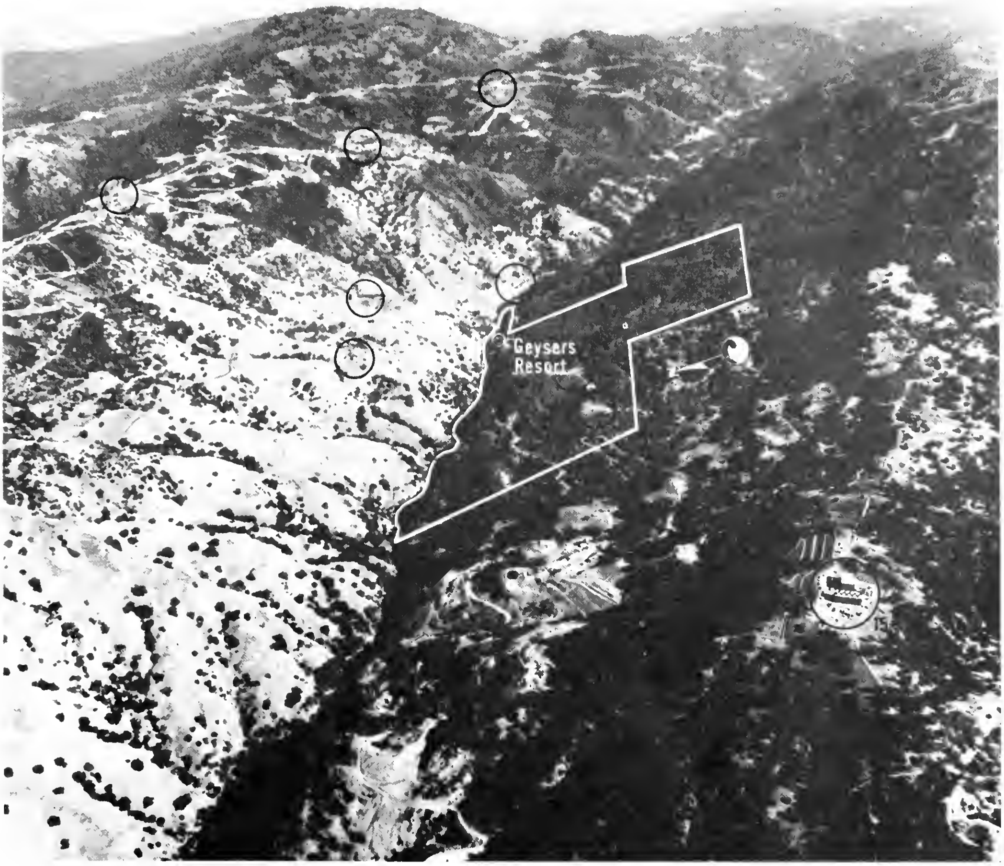
The alternative sites for the proposed plant will probably not be identified before the summer of 1979. Studies of fuel sources and means of transporting the coal to the plant will overlap this work, and preliminary engineering and environmental studies on the selected sites will then follow. DWR expects to be able to file its Notice of Intent with the Energy Commission in the spring of 1980.

Another possible development DWR is pursuing is the Fossil 1 and 2 Project of the Pacific Gas and Electric Company. This two-unit, 1600-megawatt, coal-fired generating plant would be constructed in northern California by PG&E. DWR has indicated an interest in participating in the project and is in the process of negotiating an agreement with PG&E. Initial operation of the plant could be in the late 1980s.

DWR is also considering participation in out-of-state coal-fired projects. For instance, we have established principles with the Nevada Power Company for a unique sharing arrangement to develop a 250-megawatt coal-fired unit at the existing Reid Gardner plant about 45 miles northeast of Las Vegas, Nevada. Both DWR and the company will benefit from the plan. The energy needed by DWR would be supplied for at least 15 years, beginning in 1983, with decreasing amounts thereafter. The peaking capacity needed by the Nevada Power Company would be provided in the mid-1980s, thus relieving the company of the need to install gas turbine peaking units that burn high-cost fuels. The Nevada Power Company would have available the energy it will need in the late 1990s when DWR's participation will have declined.

## GEOTHERMAL ENERGY

DWR has been actively investigating the development of geothermal ("earth heat") resources in California for some time. The State's geothermal reserves, which make up 70 percent of the geothermal resources of the United States, clearly have a large potential for direct thermal uses and for the generation of electricity. This important resource is one of our least expensive sources of energy to date. Dry geothermal steam in The Geysers area in Lake and Sonoma Counties is harnessed and is currently producing impressive amounts of electrical power.




*Future site of DWR's South Geysers Powerplant in the Mayacmas Mountains in Sonoma County, an area of abundant geothermal activity. This facility, which is planned to generate 55 000 kilowatts, will be built on the 163 hectare Rorabaugh leasehold. Circle at lower right indicates Pacific Gas and Electric Company's powerplant Unit No. 15, not yet in operation. Other circles mark sites of operational PG&E geothermal powerplants*

Other locations having favorable prospects include the Mono-Long Valley in Mono County, the Coso Hot Springs in Inyo County, the Imperial Valley, the Honey Lake area in Lassen County, and the Alturas area in Modoc County.

After months of discussion with several oil and other fuel companies concerning conversion of geothermal resources into electricity at The Geysers, DWR signed a contract in September 1977 to purchase steam in that region from the McCulloch Oil Company, Geothermal Kinetics, Inc., and Entex Petroleum, Inc. The contract requires McCulloch, as operator for the three companies, to develop the wells, the steam-gathering system, and an effluent disposal system, and to sell the steam to DWR, which will use it to operate its first geothermal plant, the Bottle Rock Powerplant, a 55 000-kilowatt facility it will build in the area.

DWR recently submitted the Notice of Intent for the Bottle Rock plant to the Energy Commission. The plant is expected to be in operation by spring of 1983. DWR also signed a contract with Geothermal Kinetics for the development of still another 55 000-kilowatt plant, this one near The Geysers resort area in Sonoma County. DWR intends to file a Notice of Intent with the Energy Commission in early 1979 for this facility.

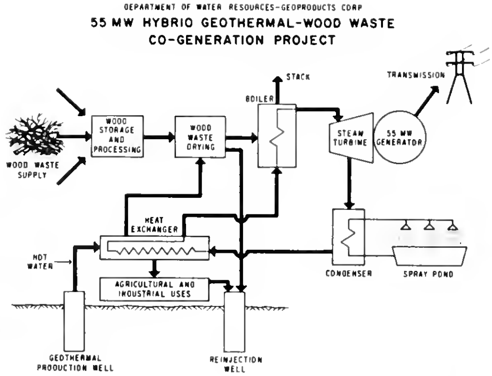
*Site of geothermal activity near Wendel in Lassen County. Vinyl-covered greenhouses warmed by the heat from the ground appear at center left.*

DWR is committed to the development of geothermal energy as a valuable, least-expensive resource for the future operation of the State Water Project and is pursuing additional development possibilities in The Geysers area, as well as in the Imperial Valley and other areas in the State. For instance, DWR has an option with the same developers involved in the Bottle Rock plant for a steam supply for a possible third plant in The Geysers area. If exploratory drilling is successful, and DWR elects to proceed with construction of a plant, the plant could be on line in 1985. In addition, DWR has obtained a lease from the U.S. Bureau of Land Management for geothermal steam rights on 188 hectares of land adjoining the field that will supply the Bottle Rock plant. Again, assuming that drilling proves this lease to be a viable field for geothermal development, DWR would proceed to develop a fourth 55 000-kilowatt unit in The Geysers area.

Looking to the more distant future, DWR has entered into arrangements with developers to share the costs of exploratory drilling to find possible geothermal supplies in the Imperial Valley. Unlike the "dry" steam underlying The Geysers area, geothermal resources (hot water) under the Imperial Valley are considerably lower in temperature. Even if a usable resource is found, many technical problems in developing this hot water source will have to be solved before this potential source of energy can be price-competitive.

## THE COGENERATION-HYBRID CONCEPT

A novel approach to developing electrical power is proposed in Lassen County, where DWR is involved jointly with GeoProducts Corporation of Oakland in building a cogeneration hybrid power




plant. This plant is an example of cogeneration, in that it simultaneously will produce (1) heat for agricultural-industrial processes and (2) electrical energy. It is called a hybrid plant because it will use two types of energy sources, rather than a single source.

The proposed plant, which will be situated near Honey Lake, has been designed to prove the practicability of combining two local abundant resources—low-temperature geothermal steam and raw wastes from lumber mills and tree harvesting—to generate electricity. Scheduled to begin operation in late 1984, the plant will perform several beneficial functions. It will:

- Rid lumber mills and logging areas of wood wastes.
- Provide at least 35 000 kilowatts of electrical output to help run the State Water Project and up to 15 000 kilowatts for the local area, through local utility participation in the project.
- Allow GeoProducts to increase its use of geothermal water to heat greenhouses and to dry vegetables and fruits.
- Provide heat for the cultivation of fish, shrimp, and crayfish in aquacultural ponds.

Collection of forest wastes for fuel offers other benefits to the environment because wood residues left by loggers are likely to contaminate underground water, if they are buried; to pollute the air, if burned; and to increase the danger of fire and provide breeding places for tree-damaging insects, if left on the ground.

The concept behind the Lassen County plant is this: the relatively low temperature of the geothermal steam in the Honey Lake area is capable of removing the moisture from the wood waste to increase the efficiency of its energy output. The geothermal water is also used to preheat the water for the plant's boilers. The dried wood waste is burned to superheat the water which feeds the boilers, producing steam that drives the turbine-generator and thus generates electricity. The spent steam condenses and returns to heat exchangers to repeat the cycle. Meanwhile, the geothermal water, from which some heat has been extracted in the heat exchangers, continues its flow, still providing enough heat to warm greenhouses and for other uses planned by GeoProducts Corporation.

*Tomatoes being raised hydroponically in one of the greenhouses heated by geothermal hot water*

The project has support from local agencies, including the City of Susanville, Lassen County, Lassen College Foundation, and the CLR Consortium (California State University at Chico, Lassen Community College, and the University of Nevada-Reno). Estimated cost of this project is $45 million, and DWR and GeoProducts will seek a grant from the federal government to fund part of this amount.

Successful construction and operation of the demonstration plant could lead to commercial use of the low-temperature geothermal resource to generate electricity, cultivate vegetables and fruits, and increase the State's forestry harvest, at the same time enhancing our natural environment.

## WIND POWER

For thousands of years, the wind's force has been harnessed principally to drive sailing vessels and pump water through shallow lifts. Today we are giving serious consideration to the possibilities of converting wind energy to electrical energy. Energy shortages and the rising costs of fuels are making such a process increasingly advantageous.

But wind-power conversion is not applicable everywhere. It depends on the availability of two essential elements:

- Reliable, low-cost wind turbine generators.
- Sites with strong, persistent winds.

The U.S. Department of Energy has a program to develop wind turbine generating units with capacities in the range of 200 to 2 500 kilowatts. These promise to become commercially available in the near future. The 200-kilowatt prototype units have been installed and tested. The large 1 500- to 2 500-kilowatt prototype units have been scheduled for installation and testing in late 1978 and in 1979.

In anticipation of the coming availability of inexpensive generators, DWR is investigating sites in California having the desired wind characteristics.

Most of California lies outside the world's regions of strong winds, although it does possess certain topographic features that tend to cause fairly constant, high wind velocities in some localities. These may permit the economical extraction of energy from the wind. In 1976, DWR began assessing prospective wind energy sites, including areas along the California Aqueduct in the San Joaquin Valley, a region known for its sweeping winds. The most promising locations appeared to be:

- Pacheco Pass, near the City of Los Banos.
- The Tehachapi Mountains.
- The Sacramento-San Joaquin Delta.

In spring of 1976, DWR installed wind measuring stations at the California Aqueduct near the northern end of Antelope Valley and at the top of Wheeler Ridge in the Tehachapi Mountains. DWR has also obtained and evaluated wind records over a three-year period from an anemometer (an instrument for gauging wind direction and speed) located near Pacheco Pass. These records indicate that the Pass is a promising site for a wind-energy installation.

During July 1978, two meteorological consultants familiar with windflow over mountain terrain were engaged by DWR to survey the Pacheco Pass area. Surveying equipment included an instrumented high-altitude air-foil anemometer. A report on the results of the survey will include recommended anemometer station sites for possible future wind turbine field sites.

DWR will conduct a computer modeling study to map wind velocity distribution at various heights above the ground and will install one or more multiple-level wind measuring stations in the region of Pacheco Pass to confirm the result of the mapping. It is expected that the findings of the above two studies will permit DWR to select the exact sites for turbines when lower-cost models become available. DWR also intends to make similar investigations in the Tehachapi and Sacramento-San Joaquin Delta areas and other potential sites.

## OTHER POWER SOURCES

In addition to searching for new sources of energy for the State Water Project, DWR is seeking to expand an old, reliable source—hydroelectric generation. Using the energy created by flows through the Hyatt-Thermalito facilities near Oroville and the California Aqueduct, the Project generates about half the electricity needed to run it. (The amount varies in accordance with water conditions and Project water deliveries.)

Under recent agreements, DWR will purchase the generation from two proposed hydroelectric developments: one, a 16 5000-kilowatt plant to be constructed at Pine Flat Dam on the Kings River by the Kings River Conservation District and the other, five small plants (totalling about 30 000 kilowatts of capacity) on the distribution system of The Metropolitan Water District of Southern California.

*Artist's rendering of an experimental wind turbine to be built to develop wind energy systems and test their potential for producing energy. It is designed for use at sites where the average wind speed is 22.4 kilometres per hour. The 90-metre-long rotor is supported on a 60 metre high tower. The generotor will produce 2 500 kilowatts of electricity. Called "the largest windmill in history," the wind turbine is to be built by Boeing Engineering and Construction Company under an Energy Research and Development Administration program managed by the National Aeronautics and Space Administration.*
*Courtesy Boeing Engineering and Construction Co*

In 1974, DWR identified at least 130 sites in California where there existed a good physical potential for further hydroelectric development. Each site was considered capable of generating at least 25 million kilowatthours of electricity annually, and some quite a bit more. How many of these prospective sites may eventually be developed is problematical at this time.

There are also numerous water storage sites or conveyance facilities in existence where energy is being wasted through discharge valves, chutes, energy dissipators, and other structures designed to arrest the force of flowing water. DWR has started to catalog many of these sites by sending inquiries to more than 800 water agencies throughout the State. The response has been significant, and DWR has now an active program to further the development of hydroelectric potential at existing water facilities or to encourage owners of facilities to develop such potential. A number of these sites are currently the subject of negotiation.

Every means of power generation that bypasses the use of petroleum and natural gas holds out a hope for assured and economic future energy supplies to operate the pumps of the State Water Project that deliver water to California's farms and communities. If the present nontraditional power resources only match the conventional resources in cost, their use will still be a great step forward in a bigger frame of reference—helping the nation as a whole to reduce its dependence on imported fuels to replace diminishing supplies of petroleum and natural gas.

DWR's long-range energy program for the State Water Project is well under way. Sources have been secured which will supply about 70 percent of the estimated pumping load for 1983—the year current power purchase arrangements expire. We are now actively pursuing development possibilities and arrangements to supply the remaining need.

*Information for this article was contributed by*
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## RESOURCE MATERIALS

### DWR Publications

**"Water and Power from Geothermal Resources in California; An Overview".** Bulletin 190. December 1974. Free.

**"Water for Power Plant Cooling".** Bulletin 204. July 1977. Free.

**"The California State Water Project—1976 Activities and Future Management Plans".** Bulletin 132-77. January 1978. $5.00.

**"Wind in California".** Bulletin 185. January 1978. $3.00.

**"California Sunshine—Solar Radiation Data".** Bulletin 187. August 1978. $2.50.

**"The California State Water Project—1977 Activities and Future Management Plans".** Bulletin 132-78. October 1978. $5.00.

### DWR Film

**"Geothermal: The Roaring Resource".** 22 minutes. (1973)

The search for new sources of water and energy has led to exploration of vast underground reservoirs of superheated steam. This film explains how the steam is formed and discusses some of the problems in developing this resource.

*Information on the materials listed here is given on the inside back cover.*

# KEEPING OUR STREAMS ALIVE AND WELL

*A clean flowing stream is a precious resource*

On a summer day, high on the Sierra Nevada's western slopes, you can stand on a bridge above the Tuolumne River at Tuolumne Meadows and watch the trout feeding in the clear, free-running water. Here, close to the river's source, you see a vibrant, alive stream. But if you follow its course down toward the San Joaquin Valley, you will see the river change. Downstream near the gold rush town of La Grange, it slows to only a trickle, barely wetting the cobbled bottom. The water is warm, unshielded from the sun because the banks have been stripped of shading vegetation. Birds and mammals, once sheltered by dense growths of trees and shrubs on the banks, have also vanished. The salmon still return, but their numbers are fewer. There were about 40,000 here in 1954 Only 1,700 showed up in 1976.

Regrettably, the Tuolumne is not unique. What has happened there has also happened to many of California's rivers and streams. The cause is rooted in the State's dependence on water, going back to its often reckless use in California's gold rush days.

In more recent times, water is taken from streams for many uses. Vast quantities are diverted to hydroelectric power generation or go to meet domestic supplies, industrial processing, or farmland irrigation. Little remains to flow in the stream channels. Even where agricultural water returns to the streams for reuse, it is often salt- and silt-laden.

As dams and levees have been built to reduce flooding, housing development, industrial growth, and agricultural expansion have transformed floodplains and streambanks. The result is the loss of often irreplaceable natural streamside (riparian) vegetation, wildlife habitats, and natural erosion controls. Out-of-stream uses and streamside developments have made major contributions to our wealth, well-being, and life style, yet they have often been developed without consideration for the natural benefits that are provided in and along full-flowing streams. How do we recognize and take advantage of these benefits?

The "instream" concept originally referred to water flowing between the banks of a natural stream channel. In its 1973 report to the President, the National Water Commission expanded the concept, citing a variety of instream uses and benefits, not all of which are confined to the stream channel but extend to the streambanks, the floodplain, and riparian vegetation. The Commission said that maintaining flows in streams was essential to safeguard the private investment and to protect the public interest in fish, wildlife, recreational, esthetic, and ecological values.

Many beneficial uses of streams rely on maintaining a good flow of water in the stream channel, such as navigation (both for commerce and recreation), hydroelectric power generation, fish spawning and migration, recreation, ground water recharge, scenic and esthetic enjoyment, preservation of rare and endangered animal species, maintenance of freshwater habitat, and preservation of the free-flowing condition or natural character of certain streams.

Beyond the edge of a stream, a riparian forest—a thickly growing mix of grasses, shrubs, and trees—offers many advantages. It provides settings for hunting, nature study, and recreation (camping, picnicking, hiking). It filters airborne dust and controls erosion. Riparian vegetation is also uniquely important to wildlife. It not only provides a home for a wide diversity of resident species, but maintains necessary food, water, and shelter for many transient species of wildlife as well.

*Truckee River, upstream from bridge at Highway 89 rafting enthusiasts enjoy a full running stream*

## WHAT DO OUR STREAMS NEED?

If we are to realize our useful instream resources, we must satisfy certain basic factors, which may be legal, institutional, or physical. Although their characteristics may vary from place to place, depending upon specific site conditions, there are basically three such elements: the flow in a stream channel, improved management of riparian habitat, and some provision for public access.

Seasonally, at least, many streams in California suffer from inadequate flows, either in quantity or in quality. Possible "new" sources of water may be obtained in these ways:

- Creating a "new" supply by building surface reservoirs or extracting ground water.
- Modifying existing water project operations by timing their reservoir releases to allow greater advantage to be taken of the downstream flows.
- Applying water for consumptive uses more efficiently. This will "save" water for use within a stream channel or will postpone the need to divert additional water from the stream. (The term "consumptive use" refers to "lost" water—water that is evaporated, used by plants in their growth, discharged to the ocean, included in manufactured products, or has been so polluted that it is too costly to reuse.)
- Reclaiming treated waste water as a substitute for water diverted from the stream, leaving more natural flow in a stream.

Water of appropriately high levels of purity is a fundamental factor of streamflow. A stream that has become polluted must be flushed or diluted with increased flows to protect both instream and out-of-stream uses.

*Same scene, two months later the dwindling flow has discouraged the rafter.*

We know we can achieve water of an acceptable quality in our streams and lakes. This has already been demonstrated by the rapid clean-up of these water bodies in the past 10 years. We can further improve them by preserving the vigorous riparian vegetation that is still present, by appropriately timing reservoir releases to streams, by following well-founded soil conservation practices on watershed lands, and by effectively treating sewage outflow and industrial wastes.

The wild vegetation that grows along streambanks and adjoining low-lying floodplains needs better protection, if we are to obtain the good to be gained by protecting wildlife habitat and recreation settings and esthetic values and by controlling sediment. Preserving existing stands of shrubs and trees and reestablishing streambank forests means that we should:

Prevent clearing of vegetation (except for special flood control measures).

Limit the grazing that destroys the leafy parts of many plants.

Restore vegetation by replanting and protecting the interdependent mixture of shrubs, bushes, and trees that have reached varying degrees of maturity.

The gravelly stretches where fish spawn and the capacity of a stream to carry flood flows can be preserved by limiting the growth of new vegetation on newly formed sandbars. In some locations, natural flows have been so diminished by upstream diversions that they are no longer able to remove this growth.

*Algae blooms can blanket a stream's surface when the current has slowed.*

Public access to streams is essential, too, so that people can enjoy what these places offer. This calls for rights of way to and along a river. Since such access may involve the rights of private property owners, as well as controls on public lands, we must be careful in designating areas that are open to the public. Moreover, the public needs to learn how easily streams can be damaged by careless or abusive treatment.

## WHAT PROBLEMS DO WE FACE?

Considering all these factors, preserving a presently healthy river is often a difficult task. Public and private resource managers must recognize the many real values of a free-flowing stream and know how to achieve them. When conflicting uses arise, their challenge must be met through economic and personal incentives for the manager to protect this valuable resource.

The legislative route to saving a stream is not always smooth. Only certain streams can be included in the Wild and Scenic Rivers System. Nor is local zoning necessarily the answer, since permits to remove vegetation may be issued too liberally with little or no enforcement of the protection objectives of an ordinance.

Preservation may be difficult, but it is far less costly than trying to repair the damage later. An example of this is the extensive work being done on the Trinity River to restore lost spawning grounds for fish.

Few California streams remain in their native state. Most of our natural waterways, particularly those in urban areas and in the Central Valley, have been greatly changed. Consider again the Tuolumne River. It is 254 kilometres long, yet only 28 kilometres of it flow freely. Some 59 kilometres have been inundated by reservoirs, and 167 kilometres are severely regulated by six dams. Large diversions draw over 136 cubic metres per second, while only 0.08 cubic metre per second is scheduled for release to the lower river each summer.

Other changes are also evident on these altered streams. Their tributaries carry sediment which is deposited in the main channel, burying fish spawning gravels. New vegetation consisting of willows, alders, and rushes rapidly takes hold on new-forming sand bars. The periodic torrents of floodwater which once swept through and removed this vegetation now occur less frequently, allowing it to become firmly rooted. This in turn speeds up the accumulation of sediments, reducing a stream channel's capacity to carry away the flood flows when they do arrive.

The lands along the streams are also changing. In many locations, high, fertile streamside terraces are being eroded because the sediment needed to replace them is no longer being transported and laid down by high flood flows.

Urban development frequently causes another damaging chain of events. Roofs of buildings, paved areas, and streets present vast surfaces that are impenetrable to rainfall, causing storm water to run off rapidly, rather than being absorbed into the earth. The increased runoff accelerates the amount of flow in streams, throwing them into an unstable condition. Bank erosion accelerates, and silt from construction sites fills the beds of steams, decreasing a stream's capacity to carry high flows. The result is more frequent flooding and extensive damage.

Shortsighted economic pressures have encourage farm and urban expansion into flood-plains, despite the fact that these areas are periodically flooded by high river flows. As adjoining lands are cleared by expanding agricultural, residential, and industrial development, the natural stream-associated growths of trees and shrubs that protect the banks from erosion are often cut down and carried away. Additional vegetative habitat is lost when fears of economic losses from flooding of these developments cause construction of stream control structures. These levees and channel linings in turn take the place of native streambanks.

Today's water planners and managers must cope with a greatly different set of circumstances than existed before California's rush to mine gold. Goals and objectives must be set that are realistic in terms of our current and future stream conditions, rather than those of 100 years ago.

Although we face many physical barriers to the fuller use of our streams, our way is barred by obstacles that are really more of an institutional nature. The means to supply streamflows, permit recreation, preserve riparian habitat, and maintain water quality are, for the most part, physically available. Since 1914, California water law governing the right to take water has required a diverter to have physical control over the water to be appropriated. This has favored the operation of dams or other structural controls but not continued instream flows. Historically, applications for permits to appropriate water have been considered on a case-by-case basis. It is therefore quite possible to win one legal battle on a certain stream and lose the next one. There is a dire need to better the position on water rights.

To date, almost all stream maintenance efforts have been oriented towards preservation of fisheries. What is needed now is provision for preserving streamflows for additional beneficial uses, such as recreation, scenic beauty, and navigation. Public use of California streams for navigation and associated activities is protected by the State Constitution. However, access to our waterways is often blocked by private lands next to streams. Similarly, public rights of way at bridge crossings are frequently ignored by local landowners.

Efforts to preserve and improve streams also face the battle of the dollar when competing with traditional land uses and water development sponsors. Economic methods might be used to show the high dollar value of instream benefits. But consider some of the difficulties. How do we measure the worth of a small neighborhood brook? A day spent in steelhead fishing? The exhilaration of whitewater boating? It is not easy to assign an economic value in cases such as these.

Some values can be identified, of course, but like apples and oranges, these are difficult to translate into common terms for comparison. Fish can be measured by population numbers, diversity of species, or weight per stream mile; water quality can be measured by temperature, biochemical oxygen demand, or levels of total dissolved solids; hydroelectric power can be measured by kilowatthours or dollars; recreation can be measured by days of use or personal values relating to escape from workaday life. Yet no common means of stream evaluation has proved workable.

## HOW CAN WE REACH OUR GOALS?

We have a number of strategies we might use to preserve or enhance our streams. Those discussed here represent only part of the picture. Nor are all of them appropriate to every stretch of every river or creek. We present them to indicate some types of actions that are possible.

**Modify existing water projects.** The existing capability of a dam or other control structure to regulate a stream may be used to augment streamflows, thus benefiting fisheries, recreation, water quality, and farmers who draw water for irrigation directly from streams. By altering reservoir release schedules (irrigation releases, and releases for flood control storage and electrical power generation), we now have enough water to make much fuller use of our instream resources. However, we would have to consider the cost of electrical power generation and electrical load management, the capacity of other reservoirs in an overall system for distributing water, and the effect on recreation facilities and fisheries when the water in a reservoir is lowered.

Antelope Reservoir on Indian Creek, a tributary of the North Fork of the Feather River, is maintained by the Department of Water Resources at a relatively stable level to provide a scenic setting for recreation. Studies by DWR have indicated that flows into Indian Creek could be increased, thereby enhancing the stream's recreation potential, without impairing the reservoir. Flows have been stepped up, and DWR is now studying the effects on both reservoir and stream. These flows appear not to affect the recreational uses of the reservoir. Measurement of their impact on the fishery is continuing.

Most of the flow of the Trinity River is diverted to the Sacramento River, and its diminished flows cannot transport the enormous amount of sand carried into it by a tributary stream. The sand has been filling the spawning beds, thus helping to ruin the fishery. Work is under way to alleviate the problem, much of which could have been averted by good watershed management.

**Amend power project licenses.** Between now and 2000, over 30 power project licenses issued by the Federal Energy Regulatory Commission (the former Federal Power Commission) will expire in California. In addition to providing for adequate streamflow, the renewed licenses could also be changed to require public access to project lands, replacement of wildlife habitat lost when the project was built, recreation development at the site, and provisions for public safety.

The Pacific Gas and Electric Company operates the Potter Valley power project, which diverts water from the Eel River into the Russian River. PG&E's application for relicensing of the project, which has gone to the Federal Energy Regulatory Commission, could require the utility company to increase its minimum releases from the project. If this is done, the additional flows could benefit either or both rivers.

**Permit additional stream flows.** When a water development project is planned, the design engineers must include provisions to meet demands far in the future. The period from project completion and full project demand may span many years. During this time, water above the amounts immediately needed could be allowed to flow downstream to satisfy instream uses.

As an example, New Bullards Bar dam and reservoir on the Yuba River, built in 1970 by the Yuba County Water Agency to provide more irrigation water than an older, smaller dam, controls floods and generates electricity. Releases from this reservoir are regulated to minimize seasonal fluctuations, thereby maintaining a fairly even flow year around in the Yuba River.

Unfortunately, project managers have been reluctant to provide such flows. Local water districts believe such suggestions may be an encroachment on their water rights. Furthermore, in cases where these interim flows have been released, the public has insisted on continuation of the augmented flows beyond the interim period. Thus, resumption of lower instream flows has become politically difficult for the water suppliers and has reinforced their reluctance to allow interim flows on other streams.

**Import water from other areas.** The extensive water development that has taken place in California enables us to transport and distribute water far from its place of origin. Places where water is in short supply receive water from areas where it is abundant. This same practice could be applied to streams. Excess water supplies could be transported to streams with inadequate flows or, better yet, substituted to fill a local demand that has been depleting the river. Offsetting effects may include generating losses, higher energy requirements and costs for pumping, reduced water transporting capabilities, potential loss of water rights, and diminished opportunities to supply other service areas.

DWR has begun a two-year study to determine what benefits can be gained by maintaining year-around flows in Alameda Creek near Livermore. If the program is successful, similar efforts may be possible in other areas served by the State Water Project.

**Change points for returning and diverting water.** Water is frequently transported to service areas through artificial channels from diversions at higher elevations. Any water that returns to the stream usually enters far downstream, and the long, intervening stretch of river suffers a deficiency in flow. A stream thus depleted could be revitalized, if the water were taken farther downstream at a point closer to the service area. If this were done, the instream uses would be considerably benefited. Water right holders between the original and relocated diversion points would also receive better quality water. However, the original diverter might experience a decrease in power generation and poorer quality water, and might have to pump the water being diverted, instead of simply letting it flow by gravity.

Unconsumed water is often returned to the stream. The point of return might be moved upstream or downstream, depending upon streamflow requirements, the quality of the return flow, constraints on stream water quality, pumping requirements, and the conveyance facilities needed.

The City of San Francisco is supplied principally by water taken from the Tuolumne River high in the Sierra Nevada and sent to the city by the Hetch Hetchy aqueduct. The river could be improved if the water were allowed to flow instead down the Tuolumne and San Joaquin Rivers to the Delta and from there sent to the city by an existing system.

**Use waste water.** Waste water (unconsumed water remaining after use and commonly degraded to some degree) represents a potential source for instream uses, if the amount of degradation is not too high. Unfortunately, some instream uses require relatively high quality water, and the treatment needed to bring waste water to the desired level of purity may be too costly.

Since this is often the case, we should look at another possibility. Waste water could be substituted for the better water currently being used for irrigation or industry for which poorer water will suffice. The better water could then be applied to instream uses. The disadvantages of using treated water include initital high costs of treatment, the added cost to the users of the waste water that arises from the need to meet public health standards, and effectiveness of the available water quantity in fulfilling stream purposes.

The Ventura River in Ventura County is one of the State's southernmost streams that steelhead travel up to spawn. The increasing demand for water in the area has greatly lowered the river's flow and the fish are in difficulty. Increasing the flow in the stream with reclaimed waste water could save them. An even better method would be to replace the fresh water industries are now taking from the stream with a supply of reclaimed waste water.

**Use water more efficiently.** As the experiences of the 1976–77 drought have illustrated, many water-using processes do not need all the water they took before their supplies were cut. The lessons the drought taught regarding more efficient use of water can be applied to seasons of normal water supply, if water thus conserved is not diverted from stream channels.

The East Bay Municipal Utility District is presently supplied chiefly by water imported from the Mokelumne River. It will also be purchasing more water from the American River. If, for example, users served by EBMUD continue to conserve water as well as they did during the drought, the district will not need this additional water for some time in the future.

**Consider revising water rights laws.** California's laws governing the right to take and use water figure importantly in the whole question of stream management. In determining whether water is available for appropriation, the beneficial uses of water for fish and wildlife and for recreation have not always been viewed on a par with the traditional uses for which water is diverted from streams. In considering an application for water, the State Water Resources Control Board must determine that water is "available for appropriation" and must reject the application if the proposed appropriation would not serve the public interest.

In the language of the California Water Code, water is not "available for appropriation" if the public interest requires that "the amounts of water required for recreation and the preservation and enhancement of fish and wildlife resources" remain within a stream. Terms and conditions attached to permits to take water from streams can thus protect their flows. This issue and other water rights practices have been studied for possible revision by the Governor's Commission to Review California Water Rights Law. (The work of the Commission is discussed in another article in this issue, "Water Rights Laws May Be In For Change".)

**Learn more about needs of streams.** The time is long past in California when the question of "How much water does a stream require?" can be answered with "Full natural flow" or "All that's available". This is due in large part to the natural characteristics of many streams in the San Joaquin and Sacramento Valleys, which have been considerably altered by water projects and watershed developments. If they are to be successful, efforts to manage our streams must supply or reserve enough water to make sure that the desired instream benefits actually will occur. Likewise, such elements as levels of water quality, the extent to which streamside vegetation encroaches on a stream, the amount of shade that trees cast on the water, and the quantities of sand and silt deposited in the stream channel and on ocean beaches at the river's mouth must be managed appropriately.

To do this, we need guidelines that accurately fit California's stream situation. For instance, streambank vegetation that intrudes into spawning gravels could be controlled by reducing the germination of their seeds. Information on the number of people who visit a stream for recreation and the type of leisure activity they pursue needs to be considered in relation to various conditions at the site: how easily the visitors reached the stream, how much water is flowing in the stream, the water's temperature, and the weather.

**Use Davis-Grunsky funds.** The 1960 Davis-Grunsky Act originally earmarked $130 million of State Water Project funds for grants and loans to local public agencies to build local water projects, to better the lot of fish and wildlife, and to develop recreation facilities. In 1976, the California Water Commission agreed to consider grants for well-conceived projects for stream improvement on a case-by-case basis. The grants could be conditioned by contracts requiring agencies to monitor changes in fish populations, vegetation, water quality, and erosion. This could disclose new information for evaluating stream projects in the future. More important, the grants could encourage the agencies themselves to consider improving the streams in their areas.

Marin Municipal Water District is presently building Soulajoule dam and reservoir on Walker Creek, a stream in northwestern Marin County that is normally dry during the summer. The district is seeking a grant from the Davis-Grunsky program to cover the additional cost of slightly increasing the size of the dam and reservoir. The extra water provided will mean a summertime flow can be maintained in the creek.

**Improve methods of managing watersheds.** Vegetative ground cover retards runoff and allows water to penetrate the soil. The soil retains this water, much of which filters through rock crevices, sand, and gravel beneath the ground and seeps into adjacent streams. By the time this water reaches a stream, the initial runoff has already passed. Thus the soil functions as a natural reservoir to augment streamflows during periods of low runoff.

By experimenting with various ground cover species, watershed managers could find ways of accelerating runoff or increasing the capability to retain water. Streams generally benefit when more vegetative cover is grown to repair the damage caused by paved areas, overgrazing, and intensive removal of timber and brush. Decisions made by watershed managers must include consideration of such matters as watershed ownership, erosion, stream silting, replanting or reseeding vegetation, vegetation conversions (for instance, changing from brush to grasslands), and the lengthy periods required for soil and vegetation to recover from misuse.

**Use zoning laws to protect streams.** Valuable streambank habitat can be protected at the local level where much of the power to control the use of land resides. County general plans and zoning ordinances, such as Napa County's Water Course Obstruction-Riparian Cover Ordinance, provide this protection, while still allowing for flood hazards, water quality, wildlife populations, streambank erosion, air quality, esthetics, and land ownership. Establishment of such ordinances can be encouraged at both the State and the local level.

**Purchase streambank property rights.** Vegetation and wildlife habitat along streams can be greatly protected through a combination of private and public ownership, if those who manage a stream are sufficiently preservation-minded. Although full public ownership may be appropriate for the most valuable habitat, it is extremely expensive to acquire enough land to completely maintain the wildlife community that depends on it. The State Lands Division has undertaken a long-term program to clarify titles to land along navigable streams in the Central Valley. Where adjudication indicates the State holds title, wildlife habitat could be protected and public access made available.

A lesser but still useful degree of protection for streambank vegetation can be provided by purchasing easements. This has two distinct advantages: it leaves property ownership in private hands, and it costs less to acquire. Stipulations of a particular easement should be well thought out and clearly stated. Otherwise, activities like overgrazing or excessive timber harvesting might defeat the easement's purpose.

In August 1978, the State Reclamation Board accepted a report recommending retention of streambank vegetation at 38 sites along the Sacramento River. To implement the report, the Board could buy or lease the property involved or obtain environmental easements requiring the vegetation be retained.

## ROLE OF THE RECLAMATION BOARD

The State Reclamation Board, which was established to develop and carry out flood control in the Sacramento and San Joaquin Valleys, acts to protect streambank habitat on both its own land and on privately owned land. A Board policy statement issued in December 1976 stated: "The Board recognizes the vital importance of riparian vegetation to fish, wildlife, recreation and esthetic quality . . . And that all practicable steps, consistent with the primary flood control purpose of these activities, be taken to preserve and encourage riparian growth." The Board is acquiring environmental easements for the Sacramento Riverbank Protection Project. Where the Board owns land that has significant value for wildlife habitat, it has begun to permit the California Department of Fish and Game to manage the land as wildlife habitat.

The Board must approve any plans by private landowners to alter any levee, embankment, or canal under its jurisdiction. When an owner proposes clearing vegetation, and such work will lead to erosion of the levee bank, the Board can step in and halt the operation.

Designated Floodway Plans, which are part of the Reclamation Board's responsibility, generally include some land-use restrictions to ensure adequate flow capacity in designated floodways. In the case of the San Joaquin River Floodway, the Board, the Department of Water Resources, the Department of Fish and Game, and the State Lands Division are working together to preserve major segments of valuable habitat and, at the same time, maintain the capacity of stream channels to carry flood flows safely. This sets an example for multipurpose management of other streams.

## OTHER POSSIBLE ACTIONS

Certain species of trees that grow along streams—oak, alder, and cottonwood, for instance—are valuable in the manufacture of pulp, furniture, and other wood products. Riparian species could be designated as "commercial species", as some already have been, and the land designated as "commercial timberland", under the California Forest Practices Act. Then the State Department of Forestry could protect wildlife, and the land's productivity, to some degree by controlling tree harvesting. The recreational value of the land could also benefit. Unfortunately, the Act, of itself, is not enough to prevent timberland from being converted to other uses less beneficial to wildlife and recreation.

In the past, numerous construction projects have caused environmental damage that has required extensive repairs. Wildlife habitat has been purchased, facilities for recreation and fish spawning have been built, and roads constructed. Future projects, and existing ones which have not yet replaced environmentally damaged resources, might fill their obligation by contributing significantly to the improvement of streams. This could be done by supplying water for recreational boating and for fish, by preserving wildlife habitat, by creating sites for recreation facilities, and by securing public access to streams.

## HOW DWR IS WORKING TO IMPROVE STREAMS

The Department of Water Resources is attempting to improve stream conditions and foster the realization of instream benefits in a number of ways. Fisheries in the Feather River tributary of Indian Creek and in the Trinity River are being examined to see how fish populations respond to flows of different volumes. These studies should help in predicting what flows will bring about desired numbers of fish in California streams.

Another study of instream needs is the river recreation surveys conducted along several California streams. Their purpose is to:

- ▲ Gather data on the intensity and types of recreation use along some of our most popular streams.
- ▲ Find the relation between environmental and streamflow conditions and uses of streamside lands.
- ▲ Develop guidelines that will aid resource managers in determining what flows are desirable for recreation activities on different types of streams.

*California's streams provide countless hours of enjoyment for those who like to fish.*

By supplying staff specialists to The Reclamation Board, DWR is helping find ways of retaining the streambank vegetation that controls erosion. Trial plantings of new growths have been made so that their value in resisting flood flows and making streams more appealing can be evaluated.

Unfortunately, the Department's efforts, even when coupled with those of other State agencies, cannot do the whole job of bringing new life to California's rivers and creeks. This calls for the continuing active support of the public at large.

Last May, at a DWR seminar on instream uses held in Sacramento, representatives of many California water organizations were brought up to date on stream conditions and potentials. This has awakened more people to the importance of stream-related values. Much more needs to be done, however. More public contact is essential. Both rural and urban residents will have to be introduced to the problems faced by California's stream resources, so they can bring their support to the preservation and improvement of the State's natural waterways.

*This article was prepared in the Division of Planning, Sacramento, by*
Charles Pike
Land and Water Use Analyst

## RESOURCE MATERIALS

**"Final Report of the Governor's Commission to Review California Water Rights Law."** December 1978. $3.50.

(Available from the California Department of General Services, Documents Section, P. O. Box 1015, North Highlands, CA 95660. General inquiries on the subject may be directed to the State Water Resources Control Board, Office of Public Affairs, 1416 Ninth Street, Room 615, Sacramento, CA 95814. Phone (916) 322-8353.)

### DWR Publications

**"Eel-Russian Rivers Streamflow Augmentation Studies".** Bulletin 105-5. March 1976. $3.00.

**"Instream Use Seminar Proceedings".** October 1978. Sponsored by the Department of Water Resources, the Department of Fish and Game, and the State Water Resources Control Board. Free.

**"The Water Management Element of the California Water Plan".** Bulletin 4. (Scheduled for release during 1979.)

**"Sacramento River Environmental Atlas".** 1978. $20.00.

### DWR Films

**"Up the Down Stream".** 12 minutes. (1977)
Condenses into 12 minutes the 4-year life cycle of the Pacific king salmon. It also delineates the effects of dams and reservoirs that block natural spawning stream areas, and the countermeasures, which include fish ladders, hatcheries, and fish transplanting.

**"Designated Floodways in California".** 15 minutes. (1978)
Describes the California Reclamation Board program designed to control restrictive encroachments in the floodplains of rivers. It explains the program's purpose, the methods used to study a waterway and set floodway boundaries, and public hearing procedures, and shows that the program is administered cooperatively with local government agencies.

*Information on the materials listed here is given on the inside back cover.*

Very respectfully
Your obedient Servant
Wm. Ham. Hall
State Engr.

*William Hammond Hall*

# CALIFORNIA'S PIONEER WATER PLANNER

Just over one hundred years ago, in March 1878, a young man named William Hammond Hall was selected to fill the job of State Engineer, a newly created position in State government in California. It was a post he was to hold through 11 tumultuous years of politicking and squabbling over California's water resources. Hall had turned 32 only the month before, but he had already gained a wide range of experience in the field of engineering.

Hall began his career modestly enough as a draftsman for the U. S. Engineer Corps at the age of 19. A year later he went to work as an engineer for the U. S. Board of Engineers, where he met General B. S. Alexander, who was the ranking engineering officer on the Pacific Coast and the man who would later actively support Hall's appointment as State Engineer. When Hall was 24 years old, he spent a year making the first topographic survey of the Golden Gate Reservation in San Francisco, the large land preserve that would later become Golden Gate Park, and for about five years was the first engineer and superintendent of parks for San Francisco. Following this, Hall was employed by two banking institutions as engineer in charge of large land and water holdings in the San Joaquin Valley. Two years later came the offer from the State of California.

Hall was born in Hagerstown, Maryland, in February 1846. His parents brought him to California when he was seven years old, and he spent his youth in the Stockton area. He was educated at a private academy, and his schooling was directed toward preparation for entrance into West Point military academy. The outbreak of the Civil War in 1861, when he was in his mid-teens, caused his parents to change their plans for him.

Soon after the Civil War ended, Hall obtained his first engineering job, assisting in barometric measurement in the mountains of Oregon with the U. S. Engineer Corps. In 1866, he took the job with the U. S. Board of Engineers and was engaged for about five years in topographic surveying along the entire Pacific Coast of the United States. He served as draftsman and field engineer during surveys of building sites for fortifications, lighthouses, and harbors from the San Diego harbor to Neah Bay in the territory of Washington, then the northernmost harbor on the coast. During the same period, Hall also traveled on surveys of the rapids in the upper Columbia and Willamette Rivers to find ways of improving navigation, and he was involved in topographic contouring of the San Francisco peninsula, particularly at the Presidio and Point Lobos in San Francisco, and hydrographic work for the San Diego and San Francisco harbors.

In 1870, Hall was awarded a contract by the Board of Park Commissioners of San Francisco to make his topographic survey of the Golden Gate Reservation. One year later, after the commissioners had accepted the results of his survey, they appointed him to his post of supervising parks in San Francisco. During his five years there, he took the first successful steps in the process of stabilizing a vast region of sand dunes with transplanted vegetation. Hall's early involvement in this work, which predated the efforts of the famous John McLaren, paved the way for the ultimate transformation of these lands into a world-renowned park.

## THE 1878 WATER SCENE

When Hall entered State service, there was no shortage of problems facing him. He served during a period in which California was wrestling with a number of very knotty questions relating to the development of water. As characterized many years later by Hall, three great water difficulties predominated when the State Engineering Department was formed. He called them "The Irrigation Fight" (the riparian water claimants versus the appropriative claimants), "The Debris Fight" (the hydraulic mining interests versus the lowland property owners and the river navigation interests), and "The Reclamation Fight" (the swampland reclaimers—called the "anti-debris" interest—versus the hydraulic mining companies).

The matter of the control of water for irrigation was a hotly contested issue that finally caused a new group, the Pro-Irrigation Party, to break away from the two major political parties of the day, the Democratic and the Republican. At question were the differences between irrigators who exercised riparian rights by taking all the water they wanted

Entrance to San Francisco

from streams flowing past their property, and the appropriators, who took whatever water they wished from streams and lakes, wherever it was available, and conducted it as far as necessary to reach their land. Competition between the two classes of users was often bitter, particularly when dry years caused a shortage of water. To add to the picture, the two conflicting practices were entirely within the law of the time.

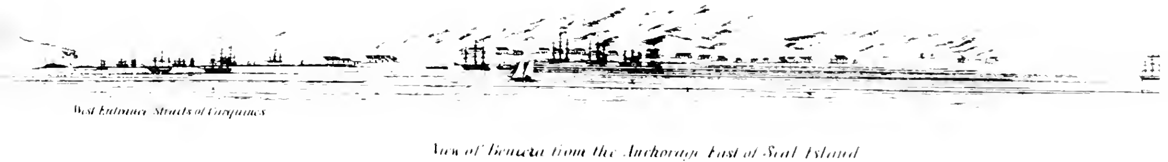
Hall was later to describe his position in the matter in this way: ". . . the office of State Engineer was created apparently with the idea . . . that by some hocus-pocus or feat of 'science' the two interests were by it within a few years to be brought together in harmony." The contenders had no such idea, he said, because he later learned that persons on each side thought they might use his office "to their own ends and the discomfiture of their antagonists." He believed that the water rights tangle that prevailed owed its troubles to the monopoly and waste of water.

The second source of strife, the fight over river debris, centered on the conflict between owners of farming property and the powerful hydraulic mining companies. The miners, who had been investing enormous sums of money in developing their highly profitable enterprises since the late 1850s, were engaged in stripping gold from rich sites in the northern California foothills of the Sierra Nevada. At the renowned Malakoff Diggins near Bloomfield, for example, between $3.5 and $4 million in gold was removed between 1862 and 1884. The high-pressure jets of water they used to dislodge the gold also loosened colossal amounts of silt, sand, and gravel that washed into streams and traveled into the Sacramento Valley, burying orchards and field crops, sometimes to a depth of many metres. The damage was so widespread in some years that the future prosperity of agriculture was seriously threatened. Angry farmers sought relief from the courts for many years. (An injunction granted by a federal court in 1884 made it illegal for miners to discharge tailings into streams and rivers, and put a stop to hydraulic mining for several years.)

The big mining companies also collided head-on with the shipping interests. The great masses of earth materials that were choking the rivers filled the channels and formed shoals, making navigation difficult or, in some locations, impossible. A bar formed across the mouth of the American River at Sacramento as early as 1860, and by 1866, many steamboats were no longer able to land at Sacramento. The situation was critical because the busy inland waterways that ships could travel on were essential to the continued economic well-being of California. Three-fourths of the farm produce of the day were transported to market by water, with as many as 60 river steamers and 40 barges in operation by 1880.

The build-up of mining debris in the rivers was the cause of another great problem—the devastating floods that plagued the Sacramento and San Joaquin Valleys periodically, particularly in years of heavy winter and spring runoff. The constricted channels became less and less able to carry this water safely, and it often spilled over riverbanks and levees, spreading widely across the valley lands. In 1879, about 2 200 square kilometres of the Sacramento Valley were covered, and the water remained in some places for many weeks. The inundated area reached as far north as the mouth of the Feather River.

*Hydraulic Mining*



The third area of disagreement that occupied the attention of Hall and many water interests was the fight over land reclamation. This involved those who wanted the State to bring a halt to hydraulic mining to protect the valleys from further damage so the land could be restored for farming and other settlement. These people believed that the State and federal governments should dredge the rivers and build new river outlets and large relief canals.

In addition to these great areas of conflict, all of which had been brought about by human activity, another type of occurrence that was beyond human control also pointed up the State's perilous position in regard to its water. Natural shortages of water caused by lack of rainfall—in particular, the disastrous drought of 1863-64—greatly impaired agriculture, which was coming to occupy a vital position in California's economy. The then-thriving cattle industry in southern California was so decimated that it never regained its earlier prominence.

Created out of an attempt to achieve some compromise that might end years of struggle between various factions, the office of State Engineer was assigned a great number of duties. The State Engineer was directed to investigate three major elements: the irrigation of low-lying lands, the condition and capacity of the largest streams, and the improvement of navigable rivers. He was also expected to consider the relationship between hydraulic mining and inland navigation. At the time no thought was apparently given to solving the mining debris problem by stopping the mining. It was a booming industry of great economic importance to California. Therefore, one of the State Engineer's responsibilities was to come up with a plan to avert the damage it was causing "without interfering with the working of such mines".

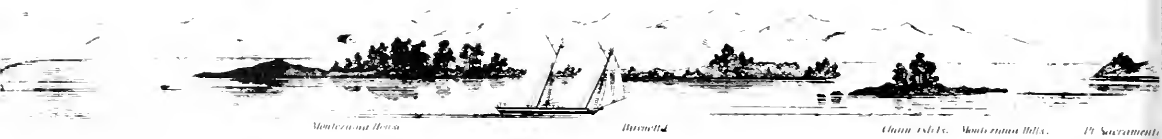
## EARLY FIELD WORK

Despite the bickering, the partisanship, and the intense lobbying by competing interests that marked Hall's tenure, the State Engineering Department was able to accomplish a lot of solid engineering work. Rivers were gauged; floods, rainfall, and runoff were measured; and wells were sounded, all by means of a broad but well-organized study of the physical conditions of California. Some of this work culminated in a singular collection of climatic data that covered measurement of rain, snow, temperature, wind, evaporation, natural drainage, streamflow, and artesian wells.

Hall's first action upon assuming office was to set about immediately to organize and equip several survey parties and send them into the field to collect data. The first surveys began in May 1878, and the last group of men was disbanded in October 1879. In those 18 months, a total of 40 men were engaged in three principal types of investigations: surveying rivers, irrigation, and mining debris damage. Hall himself spent some time in the field.

*One of Hall's surveying parties out in the field measuring the depth and flow of a river. This pencil sketch, drawn by a member of this early-day party, was found at the back of one of the engineer's field books in which the daily survey data were recorded. Under Hall's direction, survey crews ranged widely throughout California during 1878 and 1879.*

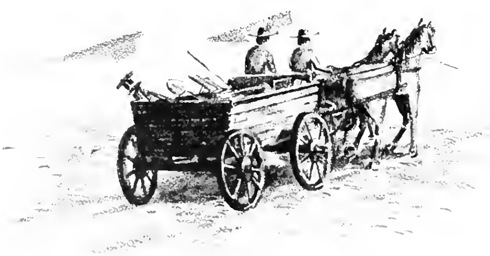
One party was sent to the head of the Kern River to learn how and where the flood water draining from the Sierra Nevada could be stored for irrigation. The group also examined the headwaters of the Tule, Kaweah, and Kings Rivers and noted nine possible reservoir sites among the four rivers. Another party was dispatched to Los Angeles and San Bernardino Counties to determine the extent of irrigable land and the facilities that would be needed to irrigate it. Twenty-three potential



reservoir sites were surveyed in the mountains and foothills of these counties for storage of surplus winter flows.

One survey party sent to make detailed examinations and surveys of the upper Sacramento River traveled several miles along the channel, mapping levees, banks, and former channels. Debris surveyors looked at rivers that were carrying heavy burdens of sediment and silt from mining. River surveyors sounded streams and gauged their flow. A special survey was made of irrigation systems in use in Tulare, Fresno, and Merced Counties, and a drainage investigation considered the flooding potential in the Sacramento and San Joaquin Valleys, where a total of 7 150 square kilometres of land were subject to inundation.

While they were in the field, some parties took water samples to classify the type of debris a stream carried, made tidal and river computations, and devoted much time to closely examining and classifying soils in Fresno, Tulare, Los Angeles, and San Bernardino Counties, section by section and township by township. Boundaries of classes of soils were outlined and the character of soil and subsoil determined for their suitability for irrigation. By 1880, more than 400 000 hectares of land had been studied.



The State's survey teams traveled by boats or by wagons drawn by teams of horses. They were equipped to remain in the field for many weeks or months, carrying among their gear the engineering and surveying instruments that Hall, in many instances, had had specially built to meet their needs. Their wagons and boats were also modified for this particular work, according to Hall's specifications. For travel on water, he had the boats, which were called arks, fitted out as houseboats with living quarters.

The journeys of the survey parties were arduous, taking them into rough, unsettled parts of the State. The men worked in heat, wind, and mud, and sometimes in high water, and parties operating during the winter were often endangered by floods. In the heavily mosquito-infested valley lands along rivers and in marshy regions, malaria caused great hardship. On one trip, almost every member of a river survey party was stricken at the same time. In Hall's words: "Frequent severe attacks of malarial fevers and other ailments . . . few individuals have gone through the season without an attack compelling cessation of work for several weeks; some have been seriously ill, and one death has occurred."

## HALL THE AUTHOR

Hall wrote voluminously about the work of his office and sent comprehensive reports to the various governors and members of the Legislature who served while he was State Engineer. His report to the Legislature in 1880, the first of several that would follow periodically, is a good example. With an engineer's eye for detail and desire for precision, Hall drew a clear picture of the state of irrigation, conditions of rivers, and the effects of mining between 1878 and 1880. He spelled out the ills he saw needing attention and the remedies he thought the most effective.

Finding ways of preventing floods and increasing the drainage of flood water was clearly a pressing matter. Hall recommended uniform treatment of rivers to protect lands from what he called "ordinary

*Mark for entering the second section of the Middle Fork of the Sacramento River*

floods", but he also thought that floods of such great magnitude would occur that they would have to be allowed to spread over some lands. He proposed flood escape weirs to handle the great floods that no levee system, no matter how high, could contain. His suggestion was that a "large escape way" be built on the west bank of the Sacramento River between the city of Sacramento and Knights Landing.

The damaged condition of rivers was another topic Hall covered at length. He reported that a defective levee system on the Sacramento River, where some levees were sound and some had failed, was interfering with the river's flow and causing shoals and sandbars to form, imperiling shipping. Hall saw the need for a uniform plan of levee construction and also proposed straightening the river, removing shoals and bars, and dredging the channel, both to prevent flooding and to further navigation, and wrote specifications for a plan of river improvement. He believed that the injurious flow of sand from mining operations could be halted by building dams and diverting the mud- and silt-laden water to settling reservoirs.

For the San Joaquin River, Hall recommended a number of cutoffs, channel straightening and enlargement, and levees in the downstream portion toward the Delta. These would, he felt, avert flooding and maintain the river's navigability.

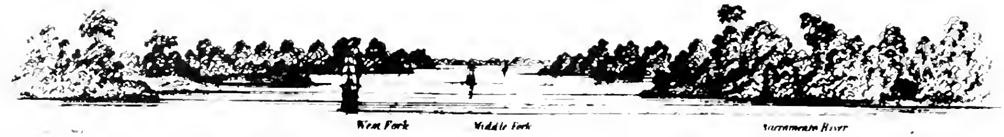
Hall was greatly disturbed by the changes in major northern California rivers due to the influence of hydraulic mining, which had greatly accelerated from 1862 on. He estimated in 1880 that the bed of the Sacramento River at the city of Sacramento had risen at least 1½ metres*, the Feather River at the town of Oroville had risen nearly 2 metres*, and the Yuba River at its mouth had risen about 4 to 4½ metres*, all from the deposition of mining wastes. As one example of the seriousness of the problem, in May 1879, an engineer from Hall's office observed some 600 hectares* of orchards and fields above Marysville, near the Feather River, covered with standing water that had been there for two months. That, noted Hall, was land that had not been submerged for more than two or three days, even during the great flood of 1862.

Hall's remedy: capture the sand and gravel in the river canyons near their source by building barriers of stones quarried from nearby cliffs. The mining debris would settle behind these dams, while the water would flow through them and later, as the sediment increased, over them. This would protect the cities of Marysville and Sacramento, allow the mines to continue operating, and save large agricultural areas. Hall did not consider that the whole answer, however. With his customary emphasis on long-range planning, he said: ". . . a sustained and systematic treatment of the drainage lines of this State are a necessity."

Problems relating to irrigation, which he called "a vital matter . . . a question of life for the people," took a major part of Hall's time. His 1880 report to the Legislature outlined his views of the situation, dwelling particularly on what he thought the State should do. He categorized the irrigation investigation with three questions: Where, how, and how much water shall be allotted? What political organization or legal system shall be used for distribution? What basis of security can be used to build and operate the works needed to do this?

"Great harm has been done," Hall wrote, "to the best interests of California by obstructing the development of her agricultural resources through a defective water right system." In his day, State

* Hall's report gave these figures: the Sacramento River, 5 feet, the Feather River, 6 feet, the Yuba River, 13 to 15 feet; and the land flooded, 1,500 acres.




*Marks for entering the Sacramento and its Forks at their confluence*

government followed a hands-off policy in regard to water rights. The distribution of water was left to those who claimed it, and their disputes were taken to the courts for settlement, a practice he described as "free-to-all rule which brings trouble to all." It was his belief that the only possible means of bringing to an end the wrangling over the use of water was for the State to intervene by providing laws and regulations and acting as a mediator in water rights conflicts. "In my opinion," Hall said, "the solution of the irrigation problem is in the solution of the water rights difficulties."

By 1887, Hall was advancing the idea that California should form a nonpartisan five-member commission on irrigation and water rights that would examine existing laws and frame proposed new laws. This body could draw on the data already amassed by the State Engineering Department and call on the services of the State Engineer for technical advice. Although he thought some State intervention was necessary, he also believed that water should be distributed to farmers through local public or private agencies.

Throughout most of the years he was in office, Hall fought the battle of the dollar with the Legislature. The State Engineering Department was launched in 1878 with a two-year appropriation of $100,000. In 1880, when the funds for the next two years were allocated, the department was cut to $25,000. In 1881, Hall asked the Legislature for $50,000 to complete the Irrigation Investigation. He received $20,000. Reporting to Governor-elect George Stoneman in November 1882, Hall wrote somewhat tartly: "I have been unable to complete with $20,000 that which I had estimated would cost $50,000, and it will devolve upon the Legislature at its approaching session to say what shall be done under the circumstances." Hall received a further blow when only $10,000 was appropriated to cover the operation of his office from 1885 to 1887. In 1888, in his last report before leaving his post, Hall complained of having to spend $3,000 of his own money (in addition to something less than $1,000 of the State's money) to publish a report on irrigation in southern California.

The evident lack of legislative enthusiasm for the work of the State Engineer was a source of deep distress to Hall, who was repeatedly frustrated in his attempts to convince that body of the significance of the Irrigation Investigation. His ultimate bitterness over declining financial support and his inability to complete the task he had been assigned began showing up as early as 1882, when he remarked: "Upon being appointed State Engineer, presuming that the Legislature knew what it was about when it enacted (its) instructions, my work was laid out to cover the more important fields of observation."

By the close of 1888, Hall had decided that he had had enough, and, in his final report on the status of the State Engineering Department, submitted his resignation. Hall left office an angry and disappointed man. Recognizing that efforts to abolish the Department that had occurred repeatedly since it was established would probably be renewed, he said: "I have now accomplished enough in this office . . . to acquit myself creditably, I hope, from a professional standpoint . . . and I want to be rid of the position. Some one else, if required, can now take up this irrigation work, as State Engineer . . . I will not."

Hall summed up the position of his office by repeating his conviction that the State Engineering Department should be placed on a permanent footing, if California wanted to benefit fully from the work it had already accomplished. Liberal support, he urged, was essential to the study of the State's water supply, irrigation, arterial drainage, and reclamation problems. The time would come, he predicted, when the State would be forced to regulate streams for irrigation, drainage, and reclamation, and there would be need for data records of the type his office had amassed.

When he left State service in March 1889, Hall was appointed to the State Examining Commission on Rivers and Harbors but left it almost

*View of Sacramento City from the west bank*

immediately. He was then appointed that same month to the post of supervising engineer of the U.S. Irrigation Investigation (later the U.S. Reclamation Service) for all the region west of the Rocky Mountains. He was one of three engineers who organized and managed the first examination of irrigation by the federal government. In mid-1890 he left that organization and entered a five-year period in private practice as a civil engineer, during which time he was in charge of irrigation and water supply work in southern and central California and in the State of Washington.

In 1896 Hall began four years of overseas employment, commencing with a job in South Africa as a consulting engineer on irrigation and water works. He had charge of building a large plant for supplying water to the principal mines near Johannesburg in the Transvaal for a large mining syndicate, and under contract to the Cape Colonial Government, he reported on irrigation and drafted new laws on water and irrigation. After three years there, Hall took a job as consultant on irrigation and canal projects for the Russian Empire, working in the Russian Transcaucasus and in Central Asia.

He returned to California in 1900 and engaged for many years in the management of properties for investment and development. He gained control of lands in the Lake Eleanor and Cherry Creek watersheds, which lie in and near the western boundary of Yosemite National Park, and was, for a time, engaged in efforts to sell these lands to San Francisco as a source of water for the city. Hall died in San Francisco in October 1934 at 88 years of age.

Despite his far-ranging experience and his demonstrated engineering and organizational abilities, Hall was at somewhat of a disadvantage in dealing with the political pressures typical of his years with the State of California. He was evidently unwilling to compromise in order to accomplish what he sought to do. Judging from his periodic reports to the governor and the Legislature, he had little patience with those who failed to see the value of his recommendations. However, he took on an enormous task and carried out its responsibilities with vigor and determination, and left a rich legacy to water planners of the future.

Under his personal direction, extensive surveys of irrigation, rivers, water storage sites, and land reclamation in California were performed. This work, which has been acclaimed by several of his successors through the years, represented the first systematic study of these important subjects in the United States. Today Hall is recognized as the father of the concept of statewide planning of water management.

In 1904, looking back on his years as State Engineer, Hall wrote: "Great interests were in active contention. The engineer who advocated a plan or measure seeming favorable to any one of these, was condemned by all others; and he who pursued any independent course, as to policy or works, was in favor with none of them; while the great public took no interest in the matter except to condemn anything which contemplated general taxation." He said further: "The truth did not prevail where misrepresentation could be made to serve a desired selfish purpose, and blind prejudice was everywhere present."

Although his plans and recommendations went largely unheeded while he was in office, Hall never lost belief in the rightness of his views, and he was to live to see marked improvement in the political climate regarding the critical need for regional water planning. From his 1904 vantage point, he observed that the public seemed to have a better understanding of the matter and the special interests that made his time as State Engineer so trying "are now apparently saner in their views." One area of progress, Hall believed, was the change in attitude toward State control of drainage and reclamation work. On this point he wrote, with typical assuredness: "If anyone in the State is to be congratulated upon this development, I consider it to be myself who bore the brunt of the fight in its favor when the squad of believers in it was small . . ."

*This article was written in the Division of Planning, Sacramento, by*
Travis Latham
Research Writer

## CHRONOLOGY OF THE OFFICE OF STATE ENGINEER

The position first held by William Hammond Hall took a circuitous path through State government during the years following his term of service. This is a capsule history of what happened.

1878 Office of State Engineer is established; State Engineering Department is formed.

1889 State Engineering Department is extended for two years; State Mineralogist is named ex-officio State Engineer.

1893 Position of State Engineer is merged with a new position, Commissioner of Public Works, which is established to study flood control problems and manage certain public works. Other functions once performed by the State Engineer are delegated to the California Debris Commission, the Department of Highways, and the Lake Tahoe Wagon Road Commission.

1907 Position of State Engineer reappears as executive officer of an advisory board to a new organization, the Department of Engineering, which assumes duties formerly performed by the Commissioner of Public Works, the Department of Highways, the Debris Commission, and the Lake Tahoe Wagon Road Commission. The new department is in charge of engineering work for the San Francisco Harbor Commission; design and construction of State hospitals, prisons and schools; flood control investigations; construction of flood control works; and reclamation and land drainage projects.

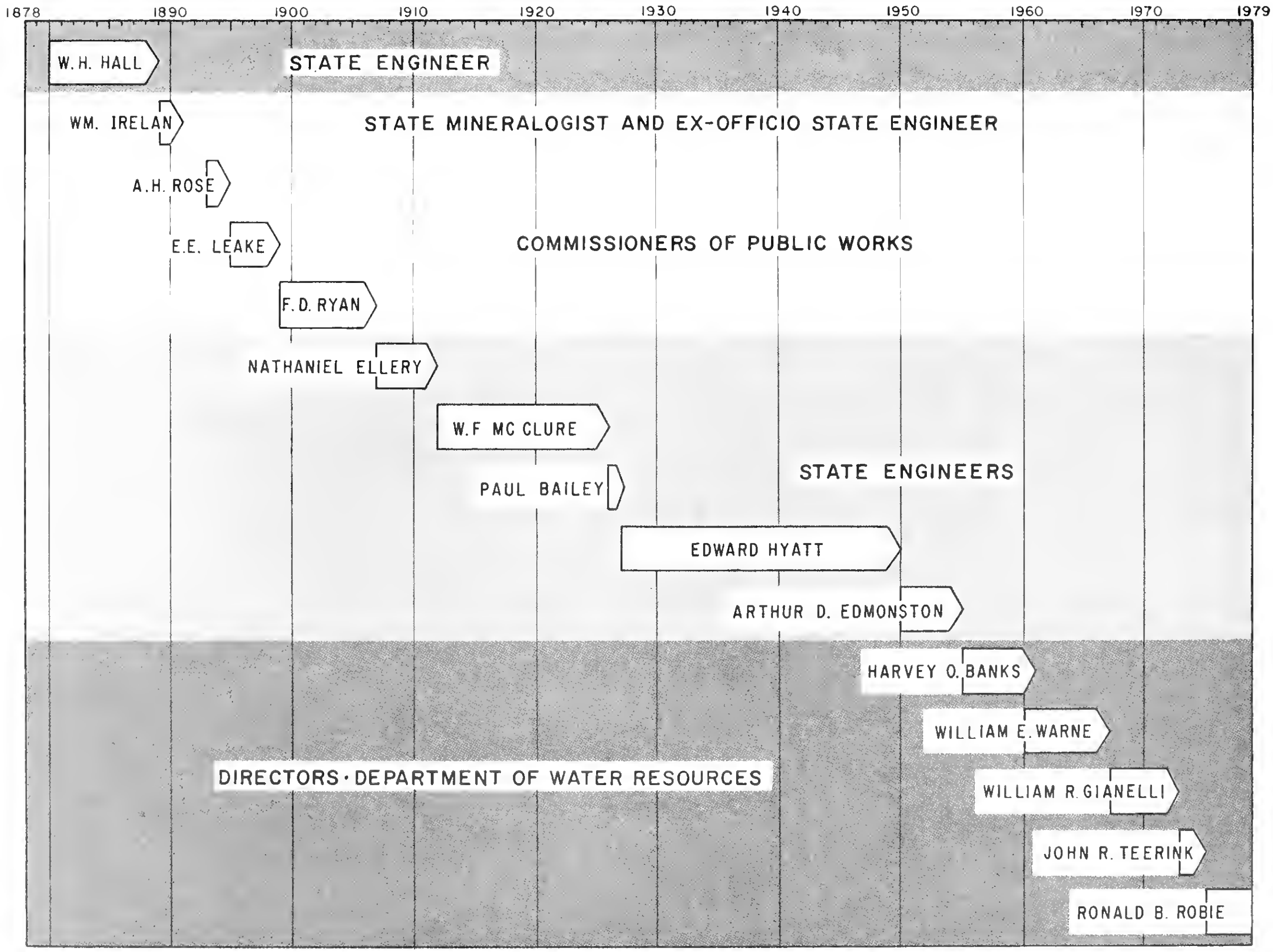
1921 Powers and duties of the State Engineer and the Department of Engineering are assumed by a new organization, the Department of Public Works. Its Division of Engineering and Irrigation, successor to the Department of Engineering, is headed by the State Engineer.

1923 Department of Public Works is reorganized into three divisions: Engineering and Irrigation, Water Rights, and Architecture. The Director of Public Works also acts as Chief of Engineering and Irrigation and as State Engineer.

1929 Division of Engineering and Irrigation and Division of Water Rights are combined as the Division of Water Resources (within Public Works). The State Engineer heads the new division.

1956 Position of State Engineer comes to an end with the establishment of the Department of Water Resources, which now performs water and flood management planning for the entire State and operates the State Water Project, and with the formation of the State Water Rights Board, which administered California water rights matters. (The board's function is now part of the duties of the State Water Resources Control Board.)

## STATE ENGINEERS AND DIRECTORS OF WATER RESOURCES 1878-1979



*New Ways to Save Water*

# RESEARCHERS LOOK AT WATER USE BY AGRICULTURE

Farming is big business in California. Taken as a whole, we produce close to 10 percent of the dollar value of all food grown in the United States. Not surprisingly, the amount of water needed to support that kind of output is also big. Agriculture accounts for 85 percent of all water used by consumers in the State. It takes more than 40 million cubic dekametres of water each year to supply the 3 600 000 hectares of farmland under irrigation. That is enough water to meet the needs of almost four times the urban population of the State for a year.

However, net demand is somewhat less. Streams, reservoirs, and wells have to provide only about 80 percent of the total (32 million cubic dekametres) because some of the water taken for irrigation is recycled.

California farmers in general often use water efficiently. However, with the growing emphasis on conservation in many areas of activity these days, the large amount of water used by agriculture has brought considerable attention to bear on possibilities of increasing water savings on farms. Other factors generating interest in this area are the rapid rise in costs of energy to pump water from wells, the great difficulties many farmers experienced during the recent two-year drought, and the high cost of developing new water supplies.

Making the present water supply go farther is a potentially important way of meeting some of our future food needs without building more dams and reservoirs. With only a very small reduction in the yearly net demand—say, one percent—farmers could conserve 370 000 cubic dekametres, which is as much water as could be provided by a major new reservoir.

Agricultural water can vanish during use in three ways: it evaporates into the atmosphere; it seeps underground to ground water reservoirs, possibly mixing with salty water deposits; or it is carried from irrigated fields to surface drain systems, for subsequent discharge to places where it cannot be reused, such as the salty sloughs on the northern shores of San Francisco Bay. All three are considered losses. (From the standpoint of hydrology, water is never really lost. It moves through a great cycle in nature, changing form as it goes from atmospheric vapor to rainfall to streams, lakes, and oceans, with interruptions for human use, and back into the air as a vapor.)

## WATER USE ON THE FARM

In the farming regions of this State, water is typically diverted from a river or a reservoir or pumped from the ground (often from more than one source). It is routed to the fields and applied to soak the soil and make it available to crops. The water then follows many paths. It evaporates from the soil, it is given off (transpired) by plants, it collects in the root zone of plants, it percolates down to ground water, and it runs off the land back to the river (surface return flow).

In portions of California that receive less than about 50 centimetres annual rainfall, a small surface or subsurface outflow is essential to flush and carry away the salts in irrigation water that accumulate in the soil. This condition is particularly true for the San Joaquin Valley.

*Farm irrigation system, showing distribution ditch, well pump (upper left), check gate for controlling flow in the ditch, and siphons to carry the water from ditch to furrows*

Some of the water delivered for irrigation slips from use, usually unavoidably as a matter of routine farm operation. What happens is this: as a rule, surface irrigation begins at the highest elevation, and the water is siphoned from open ditches or canals running past the fields or from subsurface pipes. It flows onto successive fields, ending at the lowest. When the last field has been watered, the farm has no further means of using the water that remains in the conduit (unless it is recycled by pumping it back to the highest fields and applied as before.)

If ditches are being used, this water must be emptied into a drain that removes it from the farm and conveys it elsewhere, usually for some distance. If pipes are being used, no such loss need occur for the farmer. The flow can be halted by closing a valve at the end of the pipe and the water stored there for later use.

Other losses occur when pipes must be cleaned or when breaks in a line must be repaired. Water is sometimes spilled from the distribution system on a farm when orders and deliveries have not been synchronized. Rainfall may have made irrigation unnecessary, although the water has already been delivered.

Losses are arrested in a number of ways. Ditches and canals are lined or pipes installed to reduce seepage; automated gates or valves are installed; and regulatory ponds or tanks are built to store water that would otherwise be disposed of as off-farm drainage. Water is also saved when deliveries are scheduled and applied so that losses from surface runoff and percolation to ground water are reduced.

Even if it were possible to do so, eliminating all loss from any given farm's distribution system may not be wise from the standpoint of total water management because new sources of water would then have to be found for users dependent on this waste water supply. Moreover, not all water that escapes is truly wasted. Some of it benefits fish and wildlife by helping support the marshes and wetlands they inhabit; some helps replenish ground water reserves; and some is returned downstream. However, controlling losses remains a sound practice.

Techniques for reducing water loss and for lowering the amount of water needed by irrigating more efficiently are well known to farmers, but ways of decreasing the water lost through evapotranspiration (evaporated from the soil and transpired by plants) are only now being developed. In both cases, little information is available on the quantity of water that might be saved or the incidental benefits that might be obtained, such as energy savings, a decline in the number and frequency of crop and soil pests, or reduced costs for pumping water from lower to higher fields.

*Agroclimatic station with evaporation pan containing water (center), rain gauge (left), and weather shelter, which holds instruments to measure air temperature and relative humidity. This station is recording climate data that relates the water consumed by the nearby orange trees to the rate at which water is evaporating from the pan.*

## CURRENT IRRIGATION RESEARCH

The Department of Water Resources is keenly interested in encouraging investigation into the effects of improved irrigation methods on water conservation and has a program of financial support for irrigation research. Several studies that relate to more efficient use of water in farming were in progress in California during 1978.

The University of California at Davis has been studying the amounts of energy required for several irrigation methods with differing types of soils and climates. Investigators have identified desirable and undesirable ways in which crop irrigation might be changed, from the standpoint of conserving both energy and water. For example: irrigation by sprinkler systems, which is commonly believed to always be the most efficient method. Sprinklers allow greater control of the water, but they also experience high rates of evaporation, especially in hot weather; they lose water by drift in high winds; and they consume a great deal of electric power.

*Sprinkler irrigation. A center pivot set up is in use.*

The Davis studies indicate that sprinkler irrigation may be unsuited to hot, dry areas, such as the Imperial Valley and the Mojave Desert, because of great evaporative and drift losses. The information gained in this research program, which was financed primarily by the University and the State Energy Commission, will provide a basis for selecting the desirable irrigation methods to be advocated through educational programs.


*Neutron probe used to measure changes in soil moisture. The radioactive source of neutrons (A) fits into the access tube (B) leading into the ground. The probe (C) counts the neutrons. This instrument is used in agricultural research to determine how much water is being consumed by trees.*

Field studies of the comparative efficiency of drip, sprinkler, and furrow irrigation systems for orange trees have been conducted by the San Joaquin Valley Agricultural Research and Extension Center operated by the University at the town of Parlier, near Fresno. Researchers also looked into the relationships between fertilizer use, level of crop production, quality of water, and rates and amounts of water use. The two-year study, which began in 1976, will provide a means for estimating the quantity of water that could be saved by altering irrigation practices.

A five-year field study that began in 1978 in Kern County is demonstrating the cultivation of cotton grown with brackish (moderately saline) irrigation water. The work is being done by the U. S. Salinity Laboratory. Shallow ground water of unusable quality is being diluted with good quality water from the California Aqueduct and applied to the fields at several levels of quality. If the program is successful, it could prove that substituting poor quality drainage from other crops or from shallow ground water could lower the demand for fresh water in the San Joaquin Valley. The program is sponsored by the Kern County Water Agency, with additional financial support from the U. S. Bureau of Reclamation, the State Water Resources Control Board, and the Department of Water Resources.

Irrigation of orchards in mountainous areas is being studied in El Dorado County to determine rates of water use for various combinations of slope, exposure, prevailing winds, air temperatures, and types of cover crops. Mountain orchards grow under conditions that differ widely from those on flat valley lands. The terrain is much steeper than is usually considered irrigable, and the ground around the trees must be protected from erosion by low-growing vegetative cover. These orchards need more water to support the ground cover and to compensate for the higher incidence of winds, but this is offset by generally cooler weather, which reduces water need. In cases such as this, where variable factors work in opposition, it is important to find the balance by measurement in the field.

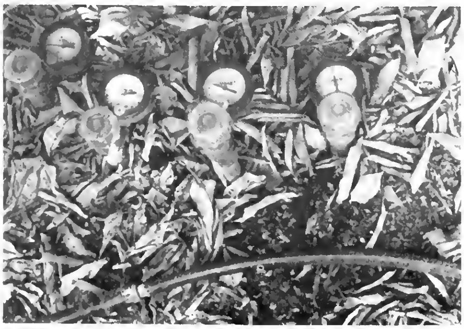
At some of the El Dorado County orchards, investigators are also measuring amounts and changes in soil moisture in order to determine how much water should be applied and when it should be applied. This study, which began in 1977, was designed to last for two years. It is being conducted cooperatively by the University of California and the Bureau of Reclamation.

The University and the Department of Water Resources are developing a soil moisture management program to be used by farmers throughout California in scheduling irrigation and estimating amounts of water to apply. The intent is to save water by greatly expanding the use of evapotranspiration (ET) data prepared by DWR and the Bureau of Reclamation. If more farm operators can be encouraged to plan their irrigation on the basis of soil moisture, the amount of water that is lost to deep percolation to ground water and surface runoff should be significantly reduced.

The initial phase of the program to manage soil moisture consists of developing curves for rates of ET versus time, preparing a soil moisture accounting system, and conducting a field trial of record-keeping material for farmers. Later DWR will collect and distribute ET data through the public media. The UC Agricultural Extension Service will distribute workbooks for maintaining ET records and instruct farmers in their use.

Starting in 1978, the Department of Water Resources undertook a statewide program of collecting and evaluating information on how special districts and privately owned utilities distribute irrigation water. DWR is using this data to identify water service areas with high rates of water use and those in which water use is low. The objectives are to (1) identify agencies that might be receptive to water conservation by virtue of high water costs or water shortages, and (2) identify practices characteristic of efficient distribution to be advocated through information programs. Agencies in the Central Valley are being surveyed first. Later on other agricultural regions of the State will be considered.

Claremont Graduate School is cooperating in the study to discern the possible social and political reasons for differences in relative efficiencies of water use. Among the questions they will answer are: do water districts that serve the smaller family farms operate more or less efficiently than agencies serving areas held by large farm corporations, and do districts having boards of directors elected by popular vote operate more or less efficiently than those in which the vote is according to the acreages owned?



*Irrometer tensiometers with gauges, measuring soil moisture. These instruments are useful in scheduling irrigation. They are inserted into the ground at depths ranging from 0.3 metre to 1.2 metres to determine whether moisture is available to plants in the area.*

This program will also examine the relationships between the cost of water, types of crops grown, and amounts of water used. These data will be used to determine which method of charging for water is the most conducive to conservation and what price tags will be needed to lower use. The information will also be used to estimate how future water use will be affected by higher costs and changes in rate structures brought about by the passage of Proposition 13.

## FUTURE IRRIGATION RESEARCH

The investigative programs now in progress cover a wide range of concerns for agriculture and water management generally, but more work is needed. Some of the more promising ideas being considered include improved management of orchard irrigation, conservation benefits to farmers, and the relationship between rates of water use and crop production.

Researchers working at the University of California have suggested a five-year field research study to be conducted at the Davis campus and at Parlier. The objective: to establish whether orchard irrigation can be cut back to less than a full supply,

*Resistance of a Thompson grape leaf to water loss, or diffusion, being measured by an autoporometer. The instrument, also called a diffusive resistance meter, indicates the amount of pores in the leaf's surface.*

reducing evapotranspiration without damaging the trees. The study would also determine how the size and spacing of the trees in a grove affects evapotranspiration. If the findings are positive, important water savings might be achieved for the 348 800 hectares of deciduous orchards in the State.

California farmers are frequently encouraged to conserve irrigation water. The Department of Water Resources would like to define more precisely how conservation can benefit each farm operator. In other words, why save water? Some possible answers include lowered costs of pumping ground water, reduced need for fertilizer, improved quality of drainage water, alleviation of drainage problems, fewer soil and plant pests, and better fruit quality. If research into this question is carried out, the results would be used by the Agricultural Extension Service, the U. S. Soil Conservation Service, and the Department of Water Resources to emphasize the real gains to be realized from more careful irrigation.

A third area for possible study is related to the amount of water applied to a crop and the yield obtained. At present, the relationship between the two appears to be uniform—the more water used, the greater the crop yield. In actuality, past a certain point, plants become waterlogged and production suffers. If water were to become progressively more expensive, it might be desirable to reduce water use and crop production to a level that would provide maximum net income.

This relationship for cotton, dry beans, and tomatoes has already been studied by the University of California. Useful information could be gained by investigating crops such as alfalfa and pasture, which also take a large part of the State's irrigation water. The information obtained from this further research would be used by the Agricultural Extension Service to encourage farmers to apply only the water that will secure the greatest net profit, rather than all the water a crop can take.

For the most part, California farmers are good irrigation managers, but it is the expectation of the Department of Water Resources that, with the increase of knowledge to be gained from research programs such as those described here, even greater efficiency in the use of water on farms will be achieved.

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## RESOURCE MATERIALS

### DWR Publications

**"Water Conservation in California"**. May 1976. Free.

**"Agricultural Water Conservation Conference; Proceedings"**. June 23–24, 1976. (In cooperation with the University of California Cooperative Extension Service.)

*Information on the materials listed here is given on the inside back cover.*

# CONVERSION FACTORS

## Metric to Customary System of Measurement

| Quantity | Metric Unit | Multiply by | To get customary equivalent |
|---|---|---|---|
| Length | millimetres (mm) | 0.03937 | inches (in) |
| | centimetres (cm) for snow depth | 0.3937 | inches |
| | metres (m) | 3.2808 | feet (ft) |
| | kilometres (km) | 0.62139 | miles (m) |
| Area | square millimetres ($mm^2$) | 0.00155 | square inches ($in^2$) |
| | square metres ($m^2$) | 10.764 | square feet ($ft^2$) |
| | hectares (ha) | 2.4710 | acres (ac) |
| | square kilometres ($km^2$) | 0.3861 | square miles ($mi^2$) |
| Volume | litres (l) | 0.26417 | gallons (gal) |
| | megalitres | 0.26417 | million gallons ($10^6$ gal) |
| | cubic metres ($m^3$) | 35.315 | cubic feet ($ft^3$) |
| | cubic metres | 1.308 | cubic yards ($yd^3$) |
| | cubic metres | 0.0008107 | acre-feet (ac-ft) |
| | cubic dekametres ($dam^3$) | 0.8107 | acre-feet |
| | cubic hectometres ($hm^3$) | 0.8107 | thousands of acre-feet |
| | cubic kilometres ($km^3$) | 0.8107 | millions of acre-feet |
| Flow | cubic metres per second ($m^3/s$) | 35.315 | cubic feet per second ($ft^3/s$) |
| | litres per minute (l/min) | 0.26417 | gallons per minute (gal/min) |
| | litres per day (l/day) | 0.26417 | gallons per day (gal/day) |
| | megalitres per day (Ml/day) | 0.26417 | million gallons per day (mgd) |
| | cubic metres per day ($m^3$/day) | 0.0008107 | acre-feet per day |
| Mass | kilograms (kg) | 2.2046 | pounds (lb) |
| | tonne (t) | 1.1023 | tons (short, 2,000 lb) |
| Velocity | metres per second (m/s) | 3.2808 | feet per second (ft/s) |
| Power | kilowatts (kW) | 1.3405 | horsepower (hp) |
| Pressure | kilopascals (kPa) | 0.145054 | pounds per square inch (psi) |
| | kilopascals (kPa) | 0.33456 | feet head of water |
| Specific capacity | litres per minute per metre drawdown | 0.08052 | gallons per minute per foot drawdown |
| Concentration | milligrams per litre (mg/l) | 1.0 | parts per million |
| Electrical conductivity | microsiemens per centimetre ($\mu S/cm$) | 1.0 | micromho per centimetre |
| Temperature | degrees Celsius (°C) | (1.8 × °C) + 32 | degree Fahrenheit (°F) |

# DWR JOINS THE MOVE TO METRIC

For the past two years, the Department of Water Resources has been engaged in moving gradually from the traditional English system of measurement toward the metric system, a decimal method in which all units are related by ten and multiples of ten. DWR's transition began as an outgrowth of the passage of the Metric Conversion Act of 1975, signed by President Ford late that year. Among other goals, the act was designed to assist the United States in encouraging and coordinating the wider application of the metric system on a voluntary basis.

Following the adoption of the Metric Conversion Act, the Department of Water Resources decided in 1976 to switch over to the metric system of units. The system in use in most metric nations today is a modernized version of the metric system. It is known by the initials "SI", which stand for Le Système Internationale d'Unités, or International System of Units.

DWR established a Metric Task Force to consider the timing for eventual full-scale conversion and then began the step-by-step process, including short training courses to familiarize employees with SI units, as well as modifying its numerous public reports by adding SI equivalents wherever English units appeared and including a table of factors for converting English units to SI units. This was another move to accustom DWR personnel to the use of the system.

DWR's efforts to "go metric" were strengthened by the California Legislature in 1977, when the California Metric Conversion Council was created within the Department of Food and Agriculture. The Council's function is to complement the work of the U. S. Metric Board and foster a cooperative relationship with State agencies and local government during the period of conversion.

DWR's changeover was further expanded during 1977 when it began adding SI units to its maps and graphs, along with the customary units. In mid-1977, the English-first, metric-second arrangement in publications was reversed to place metric units as the prime measurement, followed by their English equivalent. Outgoing correspondence was treated in the same manner. This was done to put greater emphasis on SI usage.

## SOME "METRIC" HISTORY

A look at the past will help put the matter of metrics in perspective.

Thanks to the ingenuity of civilizations that have flourished during various periods of history, we Americans are the heirs of a curiously illogical system of weights and measures. For many thousands of years, people of many cultures that inhabited the shores of the Mediterranean Sea, and later spread into Europe, devised their own means of measurement or adopted those developed by earlier nations. Egyptians, Greeks, Romans, and the countries of Islam have each in their time contributed to what has become for us a veritable melting pot of methods for identifying distances, sizes, and weights. Some of their designations have long since vanished, and some we are using today.

No one knows exactly when or how the art of measurement began, but we do know that the pyramid builders of ancient Egypt had worked out some very useful techniques as much as 5,000 years ago. The Egyptian units were based on parts of the human figure. A *digit* was the width of a finger, a *palm* was four digits wide, and a *cubit* represented the length from elbow to the tip of the middle finger. A *pace* (one step) equalled ten palms, and a *fathom* (four cubits) was the measurement of the distance between one's outstretched arms.

In light of the extreme precision we can now achieve, when necessary to do so, such a system seems pretty primitive, but it worked surprisingly well. The mathematical exactitude of those long-ago engineers is proven at the Great Pyramid of Khufu, for example, whose sides differ in length by only one unit in four thousand.

We are indebted to the Romans for the ounce, the pound (as a measure of weight), the inch, the foot, and the mile. Through their far-ranging conquest and commerce, these practical folk were responsible for introducing and spreading the Eastern systems of weights and measures around the Mediterranean lands and across Europe, ultimately reaching the British Isles. In doing so, they added a duodecimal (12) basis for their foot and pound measurement units. Our 12-inch foot is a direct descendant. The yard we use now to measure length has come to us from the early Britons, who modeled it on the distance around the belt line (*girth*) of the Saxon kings.

As the nations of Europe began slowly taking shape after the Romans departed, people devised ways of measuring that would suit their particular needs. Goods were traded in wildly diverse units, depending on location and type of merchandise being bought or sold. In many cases, similar commodities such as corn and wheat were traded in differing units. Tradespeople and those in some professional occupations further compounded the confusion by developing special measurements that bore no relation to any others. So great was the muddle that various rulers enacted laws from time to time intended to establish dependable standards, but these efforts had little real effect.

Then in 1795 an event occurred that was to have far-reaching influence on the situation. France, which was caught up in the throes of revolution, adopted the metric system, the world's first complete, interlocking system of weights and measures. A French clergyman had devised the plan 100 years earlier, but it was not until the French Revolution, when old ways were being abruptly discarded for new ones, that France gave the system its official sanction.

Embodying the latest scientific thinking of the day, the metric system was based on a new unit, the metre ("measure"), which equalled one ten-millionth of an arc extending from the North Pole to the Equator. From this single unit were derived the basic standards for length, weight, and volume. Full adoption of the metric system was delayed by political upheavals in France until 1840, at which time it was declared to be the law of the land. The new concept caught on quickly, as nation after nation switched over to it. By 1900, 35 countries were using the new system. Great Britain and the United States were the only hold-outs among the major industrial nations at that time.

## METRIC EVENTS IN THE U. S.

In 1790, the year ratification of the United States Constitution was completed, several proposals were put forth regarding the establishment of a standard for weights and measures for the new nation. One of these ideas was to improve on the system already in use—the "customary" system—which was essentially based on units carried over from England. Another proposal concerned a system based on decimal units, or units of tens, as is the metric system. Thomas Jefferson, the first Secretary of State, who reported to the Congress on the matter of weights and measures, advocated a system of his devising based on a 10-inch foot measure. Jefferson's plan was supported by President George Washington, but despite the fact that the country had already settled on a decimal system of coinage, Congress failed to come to any decision on the matter of standardizing weights and measures, then or for many years.

In 1832, the Secretary of the Treasury designated the yard and the pound (avoirdupois) as the units of measure for the U. S. Custom Service. The next official action occurred in 1866, when Congress declared that the metric system was legal for use in this country. To this day, this has been the only instance in which Congress has sanctioned any system of measurement. The effect of that action was to provide us with two coexisting measurement standards.

An interesting point to note: despite the fact that the United States elected, by its failure to act, to stay with the standards that people were using at the time of the American Revolution, the units that make up the U. S. Customary System have since been defined in relation to metric measurements. In 1893, the U. S. Treasury Department defined the yard in relation to the metre, and the pound, to the kilogram.


*One of the mile point markers (94.00) originally used along the California Aqueduct is supplemented by its metric equivalent in kilometres.*

## WHY GO METRIC?

Until 1960, the metric nations of the world were also using systems with local variations in units. Then those countries standardized their systems by adopting the International System of Units.

In 1965, Great Britain joined the world's move to metric by announcing her intention to convert gradually to the metric system over a 10-year period. This left the United States as the only large country still using an unrelated system of weights and measures.

President Johnson signed legislation in 1968 that provided for a three-year program to determine how the increased use of metric units would affect this country. Then in December 1975, the Metric Conversion Act became a reality. At the time of signing, President Ford remarked: "The Government's function, through a U. S. Metric Board that I shall appoint, will be to coordinate and synchronize increasing use of metric measurement in various sectors of our economy."

## ANOTHER ASPECT FOR DWR

Adopting SI units and adding them to reports and letters, as the Department of Water Resources has been doing since 1976, is a simple, economical method of getting used to the new system. However, changing complex modern machines, equipment, and tools is another matter.

The State Water Project, which DWR operates, is the largest water delivery system ever built. In its first phase, completed in 1973, the Project consists of 18 reservoirs, 15 pumping plants, 5 power plants, and 928 kilometres of canals or aqueducts. Because construction of this enormous network predated the adoption of the metric system by DWR, it is based on the English measurement system. To alter the costly control mechanisms that regulate the flow of water through the Project before they need to be replaced would certainly be unsound. Therefore, the existing equipment will continue in use to serve its remaining useful life. However, some gage dials are being modified to indicate SI units, and when economically justified, new instruments are being obtained that bear SI scales. As other new equipment is purchased for the Project, consideration is given to its compatibility to future conversion.

Mileage markers on concrete canal linings also state the corresponding measurement in kilometres. Both types of units will be retained in a legible condition until 1980, when DWR will have finished converting all essential documents, such as maps of the Project.

*Bridge in Fresno County across the California Aqueduct displays both mile-point and kilometre markings*

Staff gages that monitor water surface elevations in the Project's aqueducts and canals are coordinated with electronic monitoring and recording systems by which water operations are controlled. Since this control system involves computer programming, the task of converting various components to the metric system will not begin until 1981. The work is scheduled to be completed in 1983.

In addition to running the State Water Project, DWR shares responsibility with the United States government for operating a system of levees, flood bypass channels, and reservoirs during flood seasons to contain the water that once devastated California's Central Valley. Kilometre markings will be placed on mileposts along flood control levees in the near future, and metric staff gages will be added to flood forecasting points to help in equating present flood stage measurements given in English units with metric units.

In its surveying activities, DWR has been using metric equipment in first-order leveling for some time. It also uses the metric mode in electronic measuring equipment. For aerial mapping, DWR can convert its equipment to metric quite easily by replacing some gears.

The foregoing examples of conversion by DWR are instances of "soft" conversion, or adopting a new system without physically changing the dimensions of objects. "Hard" conversion is the more radical step, where the change involves a move to engineering standards based on SI units.

Since the nationwide conversion to the metric system is voluntary, hard conversion is chiefly a marketing and engineering responsibility of private industry. Some change has already taken place. Pharmaceuticals, soft drinks, and alcoholic beverages packaged in SI units are now on the market, and some automobiles are being built to SI specifications. As manufacturers find it economical to convert in order to expand sales in metric countries, we will see more American products with SI dimensions. But until standards have been developed that allow American machinery, steel beams, valves, pipes, and machine parts to be interchanged with products manufactured throughout the metric world, the United States cannot make a complete change to metrics.

This, of course, affects the transition of the Department of Water Resources. DWR has selected a project to improve the quality of water in the Suisun Marsh. Plans and specifications for contracts to build low levees, canals, and culverts will state quantities and dimensions in metric units followed by English units in parentheses, although the culverts and other materials will be manufactured by the English system of measurements.

By the end of 1978, DWR took the final step in the publications area by issuing selected reports expressed in metric units without the accompanying conversions of the past two years. This issue of CALIFORNIA WATER is a good example of this move. Measurements throughout are stated only in metric units (except for a few instances where English units are necessary for historical or other reasons).

DWR will continue to press forward toward greater use of the metric system in an orderly manner.

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