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Come Taste this Cool, Clean Water: History of California's Groundwater Quality Monitoring Program

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By what standards do we assess water quality? How are those standards developed, and over what geographic areas? Groundwater monitoring programs must be designed with specific purposes and goals in mind. Otherwise, the data collected are not meaningful, and are of little use (Ward 1981; Beach 1987, 1990). California's first groundwater quality monitoring goals were mandated by the 1949 California Water Code (Beach 1990). This paper chronicles and assesses the steps California's Department of Water Resources (CDWR) took to meet its broad legislative mandate. Those steps included identifying needs and creating priorities, setting goals, and implementing a groundwater quality monitoring program. California's Groundwater Quality Monitoring Program (GWQMP) offers a successful model of a flexible and robust system that has allowed California to assess, delineate, and maintain the quality of its groundwater resources for the past four decades (University of California Water Quality Task Force 1988). As California and other regions face new water quality challenges, resource managers can look to this monitoring program for guidance.

Legislative Authorization

California's Water Quality Monitoring Program, including both surface and groundwater quality monitoring, was established when Section 229 was added to the California Water Code in 1949. Section 229 states that the California Department (then Division) of Water Resources shall

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> . . . investigate conditions of all waters within the State, including saline waters, coastal and inland, as related to all sources of pollution of whatever nature and shall report thereon to the legislature and to the appropriate regional water pollution control board annually, and may recommend any steps which might be taken to improve or protect the quality of such waters (CDWR 1952).

Beginning in 1950 CDWR conducted studies to determine the extent and geology of California's principal groundwater basins before monitoring actually commenced. CDWR published the results in *Groundwater Basins in California*, one of the first comprehensive reports on California's geohydrology (CDWR 1952). This geohydrological information was collected for planning the monitoring program, and to create a database of California's groundwater systems for future investigations. Begun in 1950, this database would later become California's Water Data Information System (WDIS). These geohydrological investigations also produced the first base map of California's primary regions of groundwater storage (CDWR 1952). The map was intended for establishing a naming and numbering system for California's groundwater basins, and to serve future planning needs for groundwater studies (CDWR 1952).

CDWR first concentrated its data gathering efforts in areas of significant beneficial groundwater use, i.e., developed areas and agricultural areas. Many other groundwater basins were initially left out for lack of information or significant beneficial groundwater use. CDWR envisioned, however, that new areas would be explored and added to the monitoring program (CDWR 1952), and indeed they have. In 1956 CDWR declared that its monitoring "program is flexible and monitored areas will be added or eliminated as changing conditions dictate" (CDWR 1956).

After the preliminary geohydrological studies, groundwater quality monitoring commenced in 1953 and 1954. Groundwater basins distributed in nine regions were monitored in 1953 and 1954 (Figure 1, CDWR 1956). The results of these first monitoring efforts were reported in *Groundwater Quality Monitoring Program in California* (CDWR 1956). The report was the first of its kind to be presented to the Legislature and the Regional Water Pollution Control Boards (CDWR 1956). The report also outlined the monitoring program, including its objectives, and the methodology that formed the structure of the Groundwater Quality Monitoring Program.

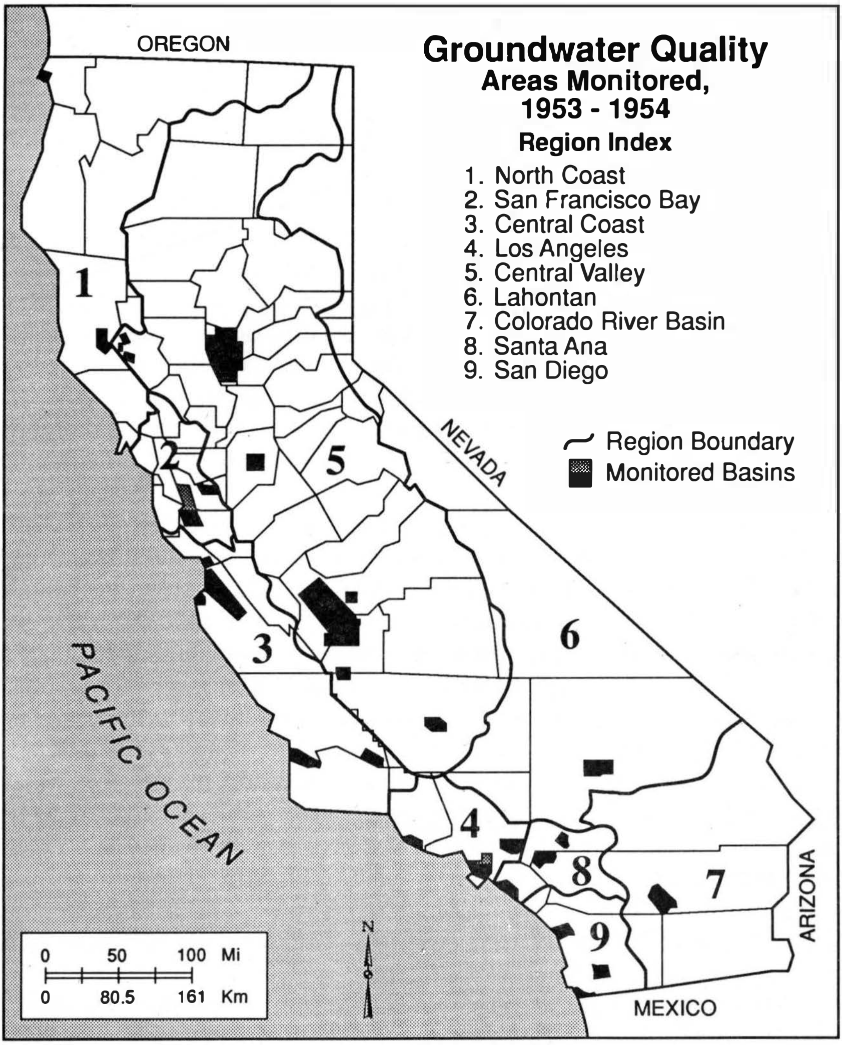

Figure 1
General Location of Groundwater Quality Basins Monitored by the California Department of Water Resources in 1953 and 1954.

Monitoring Program Objectives

Even in the early 1950's CDWR recognized that groundwater was a "vitally important portion of California's water supply," and that population growth increased the risk of its "pollution and degradation" (CDWR 1956). Nearly fifty percent of California's water needs were served by groundwater at that time (CDWR 1956). Following the extensive investigation into California's principal groundwater basins (CDWR 1952), CDWR also recognized that because of groundwater's "widespread occurrence and relatively slow rate of movement, . . . long term observations and records" would be necessary to fulfill the program's main objectives (CDWR 1956). These objectives included: 1) providing current mineral groundwater quality data; 2) detecting "significant changes in groundwater quality"; and 3) delineating areas affected by significant groundwater quality changes (CDWR 1956). The main purpose of this monitoring was evaluating the water's suitability for beneficial use; i.e., domestic, municipal, and agricultural consumption.

Drinking water criteria were first adopted by the State of California in the early 1950's, based on standards established by the United States Public Health Service in 1946 (Table 1, CDWR 1956). All values listed in Table 1, except for fluoride, lead, selenium, and arsenic, are suggested guidelines. The latter four constituent levels are mandatory grounds for rejection of the water supply for human consumption. The State left the option for other agencies to add constituents and limits to the list as necessary (CDWR 1956).

Groundwater quality determination was made mainly for mineral constituents. Heavy metals and radioactivity were recorded for a short time, and pesticides were added to the program in the 1970s. Though they remain as standards, metals, pesticides and radioactivity were dropped by CDWR as other agencies including California's Regional Water Quality Control boards began sampling for them, to avoid duplicating sampling efforts and expenditures.

Criteria for irrigation waters were adopted from recommendations by Prof. L. D. Doneen, U. C. Davis. Constituents of concern included: "Total dissolved solids, chloride, percent sodium, and boron concentrations for three general classes of irrigation waters" (CDWR 1956). The Department's use of the three classifications (Class I: Excellent to Good; Class II: Good to Injurious; and Class III: Injurious to Unsatisfactory) was criticized as "simplistic" (CDWR 1978). Its critics, however (Doneen included) "could not agree upon a mutually acceptable replacement" (CDWR 1978).

Table 1. LIMITING CONCENTRATIONS OF MINERAL CONSTITUENTS FOR DRINKING WATER

United States Public Health Service
Drinking Water Standards, 1946

	Parts Per Million
Fluoride (F)	1.5
Iron (Fe) + Manganese (Mn)	0.3
Magnesium (Mg)	125
Chlorine (Cl)	250
Sulphate (SO_4)	250
Lead (Pb)	0.1
Selenium (Se)	0.05
Hexavalent Chromium (Cr^{+6})	0.05
Copper (Cu)	3.0
Arsenic (As)	0.05
Zinc (Zn)	15
Phenol	0.001
Dissolved Solids	500 (1,000 permitted)

Source: CDWR 1956

The task of defining agricultural water use guidelines was especially difficult because of wide geographic variations of climate, soil, crop, and moisture balance combinations. In 1974, the University of California Committee of Consultants produced "Guidelines for Interpretation of Water Quality for Agriculture." CDWR adopted the "Guidelines" in October of the same year (CDWR 1978). The "Guidelines" were updated in January 1975 by the UC-Committee of Consultants, and crop tolerance tables for salinity and permeability were added in September 1976 (CDWR 1978).

In addition to the agricultural guidelines (CDWR 1978), CDWR continues to defer to the U. S. Public Health Service for water quality criteria. The "California Domestic Water Quality and Monitoring Regulations" were officially adopted by the California Department of Health in December 1977 (CDWR 1978).

Monitoring Program Methodology

CDWR first gave sampling priority to areas where there were "existing or potential water quality problems" (CDWR 1956). Suspected pollution sources included "waste discharges, . . . improper refuse disposal, poorly sealed or improperly constructed wells, overdraft conditions, connate brines, or seawater intrusion" (CDWR 1956). Despite the mention of "pollution" in Section 229 of the Water Code, the program was not initially set up for pollution detection. Rather, the emphasis was on establishing a data base for later comparisons (Clawson 1987). For example, ambient conditions were determined for areas targeted for later development, in order to provide background data for future comparisons and to detect significant water quality changes (CDWR 1956). This established the background for an extensive, long term groundwater quality data base, compiled in the Water Data Information System (WDIS).

CDWR's task of establishing its monitoring program was accomplished in steps. As previously mentioned, the first monitoring well networks concentrated on basins with known or potential problems (Figure 1). Later, monitoring was expanded to all major basins in California.

Once monitoring commenced in a basin it was important to establish good areal coverage; therefore, more wells than would later be necessary were sampled. As more geologic information became available, from well drillers' reports for example, basin coverage was modified to include water sources (aquifers) of these wells (Clawson 1987). The number of wells sampled in the basin was reduced after wells representative of the same source aquifers were identified. Therefore, "only the minimum number of wells believed necessary to evaluate groundwater conditions (was) incorporated in the program" (CDWR 1956). However, CDWR did not specify this "minimum number" of sample wells.

One might suspect, and correctly, that the formula to derive the "minimum number" of monitoring wells included the availability of funds (Clawson 1987). The Dickey Act of 1949 set up the Water Pollution Control Boards and provided funding for the State Departments of Water Resources, Fish and Game, and Health to conduct water quality investigations (Clawson 1987). Funds, however, were limited to the point where state agencies could not drill their own monitoring wells. Monitoring was limited to existing wells, both publicly and privately owned (Clawson 1987). This situation exists to this day, with few exceptions. The well selection process, therefore, was not spatially ideal because the State could not always monitor where it needed to.

Monitoring well selection was and is limited by a number of variables related to choosing from a population of existing wells. These variables include: availability of water well drillers' reports, representativeness, antecedent analyses, and physical ability to access and sample the well (CDWR 1956).

A well drillers' report (log) is needed to identify a well's source aquifer, depth, and construction. Without a log, an interview with the well's owner may provide needed information. Unfortunately, many extra hours would have to be expended to gather information in this way. Well drillers are currently required to file logs with CDWR, saving precious research time and providing invaluable geologic information. The store of well logs also ensures speedy replacement if a monitoring well representing a certain aquifer or water supply is taken out of production (Clawson 1987).

The "representativeness" of a well is determined partially on the basis of the well driller's report. Based on geology, depth, and construction information, how well does the sample well represent the water source in question?

Background geochemical information (from antecedent analyses) for a well can also help determine its source. In the absence of a log, often a well's source was determined by comparing its water quality to adjacent wells for which logs existed. This meant sample points could be established despite the lack of a well driller's report. Also, antecedent analyses formed a basis for comparison to detect future significant groundwater quality changes. Other factors CDWR considered for "final selection of observation wells" included well owner permission and cooperation, physical access to the well site, a tap close to the well itself, and the well's pumping schedule (CDWR 1956).

Once sample sites were established, water quality samples were drawn beginning in 1950 (CDWR 1952). As is current practice, CDWR collected groundwater quality samples once per year, during summer "irrigation season when there is maximum pumpage" (CDWR 1956). It was also foreseen that problem wells could be sampled more frequently if necessary (CDWR 1956).

The summer collection schedule was adopted to ensure that the sample drawn would be representative of the water being applied to crops. If a sample of a domestic water supply was taken, the tap was run until the well pump turned on. The pump was allowed to run for at least five minutes, to clear water from the pipes, casing, and water tank. If an agricultural well was not pumping, the sampler had the option of starting it up (with owner permission) and clearing the casing in order to take a sample. It was and is important to sample while a well pumps, because water residing in a casing or tank may take on some of the characteristics of the material it contacts, depending, in part, on the water's pH and temperature.

Furthermore, samples were (and are) taken from the tap, sprinkler head, or discharge pipe nearest the well itself, to again avoid chemical alterations caused by the water's contact with pipes and water tanks, and possible water softener or fertilizer treatment. A more representative sample temperature is achieved in this way, as well as better geochemical veracity. Finally, a sample is obtained of the water's baseline conditions as it is applied to a crop or consumed by the public.

Conclusion

California has had a groundwater quality monitoring program for four decades. The program successfully met its original goals: to determine background (ambient) mineral groundwater quality for waters intended for beneficial uses. CDWR, indeed, has compiled a vast and valuable data base, currently stored in its Water Data Information System. These water quality data are valuable for their continuity in both time and space, important constants when one is making comparative studies. CDWR continues to monitor for current conditions and changes, and is in a good position for meeting future water quality challenges.

Because the monitoring program was designed to be flexible, CDWR has been able to concentrate monitoring efforts where they have been most needed, and has continued to maintain an extensive monitoring network across the state. Actual monitoring network design was left to the individual district offices, where those most familiar with the respective regions and their resources could decide when and where to monitor. Attempts to standardize spatial sampling procedure had been made by a central committee in 1969 and 1986. The recommendations were met with resistance by the district offices, however, who argued that they were more familiar with the resources, and that the resource was simply too variable geographically to standardize spatial sampling to the extent recommended by the committees (Clawson 1987; Steel 1987). These arguments are acknowledged and validated in current expert opinion survey methodology for resource management and decision-making (Tobin and Rajagopal 1990). Standardizing would reduce the program's flexibility, the very feature that made it successful for nearly four decades.

In the past decade, California's attention has moved to water quality issues beyond assessing, delineating and maintaining of its waters. For example, California counties are currently grappling with interbasin transfer issues and impacts, with mixed results. Senate Bill 867, The California Groundwater Management Act, was introduced to create locally managed groundwater districts, intended in part to regulate groundwater export from these districts and prevent damage to groundwater supplies (Porter 1992, Tehama County 1992). Possible degradation of water quality is as important a concern as declining water tables. California ground water law only prohibits interbasin transfers for beneficial use if there is permanent damage to recharge (supply) of streams or aquifers in the source region. In other words, groundwater may be exported from a basin if it is considered "surplus water", as summarized by Meyers and Tarlock:

> Any water not needed for the reasonable beneficial uses of those having prior rights is excess or surplus water. In California surplus water may rightfully be appropriated on privately owned land for nonoverlying uses, such as devotion to a public use or exportation beyond the watershed . . . (Meyers and Tarlock 1971).

Water quality degradation and its impacts on those users with prior rights is therefore an important and relevant consideration. California's program's background information on groundwater quality and quantity should allow planners to model possible impacts before interbasin transfers and possible damage occurs. Determining and modeling these impacts is beyond the scope of this paper, but is a recommended area for future research.

As the California Department of Water Resources' example has demonstrated, the initial expense of running a well-designed and flexible monitoring program can be balanced by long-term benefits gained through improved information. Our ability to anticipate and react to groundwater quality changes, pollution events, or to model future scenarios is therefore improved. As resource managers we can all look to this proven model for future planning needs.

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