International Journal of Engineering& Scientific Research
Vol.5 Issue 4, April 2017,
ISSN: 2347-6532 Impact Factor: 6.660
JournalHomepage:http://www.ijmra.us,Email:editorijmie@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

GROUNDWATER ISSUES IN CALIFORNIA: A TALE OF SHORTAGE, MISMANAGEMENT AND CLIMATE CHANGE

Bhavna Karki

Abstract

United States also has been facing severe water crisis. There are hundreds of cities and towns in US that are at severe risk of sudden and severe shortage. Water scarcity is in fact ranked as a major threat to national security alongside terrorism by the U.S. Office of the Director of National Intelligence. California's rivers, groundwater provides about a third to half of the state's water supply and it has been a leader in many types of environmental management, but groundwater has been an exception to that rule. The crisis has been blamed on climate factors but deep insights shows that it is more due to shortcomings of governance and policy actions. Absence of timely statewide framework for managing this resource would put the danger the rights of future generations. Apart from recent legislative action more concrete actions at policy levels, more judicious use of water and actions to conserve resources is the only hope for California's long-term water security and sustainability.

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Keywords:

First keyword; National Threat
Second keyword;Water security
Third keyword; Sustainability
Fourth keyword; Legislative
Fifth keyword. Climate policy

Author correspondence:

Bhavna Karki
Environmental Sciences Professional
Email: bhavnakarki@gmail.com

1. Introduction

Water is one of the most important natural resource. Survival of life and sustainability depends on it. In spite of this water has also been most neglected and wasted resource. The situation differs according to the geographical location, demography and economic situation of a nation. Earlier water crisis was seen only as a problem of the poorest nations but lately it has come up as a major issue for the world's richest nations as well.

United States has been facing water crisis and reports state that US is on the verge of a national water crisis and availability of clean and cheap water could soon be a challenge. There are hundreds of cities and towns in US that are at severe risk of sudden and severe shortages. There are two main reasons for this; one there is no availability of water and secondly, the available water is not fit for drinking or other use due to contamination. Even the U.S. Office of the Director of National Intelligence has ranked water scarcity as a major threat to national security alongside terrorism[1]. The water crisis is more acute in the West US, where continuous dry seasons have increased severe drought like conditions and unplanned, increased water use lead to decreased water availability further.

California is the considered the most drought affected state in the USA. It has a long history of severe droughts that date back to year 1929. Water crisis here has a grave impact on economic as environmental situation. The situation of drought or crisis here is a combination of weather or climate conditions; increasing population and pressure due to agriculture as well as economic or political actions. All these factors have impacted the ground water availability here. Ground water is among the nation's most important natural resources. California's rivers and groundwater provides up to half of the state's water supply for drinking, farming and industry. It is of utmost importance for maintaining the health of water bodies like rivers, wetlands, and estuaries. Excessive use of ground water accompanied by less recharge has raised serious questions on the future availability of ground water to meet all needs (domestic, agricultural, industrial, and environmental). But the way the water is used and managed here does not give picture of a drought stricken state. Lots of water is wasted in the USA. As a comparison only 4% of water in the U.S. is reused, versus between 90% to 100% in Israel. About a third of the

drinking water also gets lost through leaky pipes and 20% of California's energy use goes toward water[2.]

The discussion of water issue in California State is important because it has the strictest environmental laws in the US[3]. It has also been a leader in various environmental management practices historically, but sadly groundwater has been neglected and left out. Without a statewide framework for managing this resource, there has been, in many cases, a tragedy of the commons. A closer look at the situation in the state makes it clear that the problem lies more in the way it is dealt at political and economic level and weather or climate has lesser role to play in the current situation. The important question is how to make the public sector to think strategically about a resource no one can live without. This paper deals with looking into various reasons for the water issues in the state of California, the impacts and actions taken and suggestive future actions.

The following sections attempt at assessing the current situation, the causes and effects of decreasing ground water availability. It also looks at the actions taken up by the state in conserving this resource and what more can be done to secure the future water situation.

2. Research Method

This work is based on the data available with concerned authorities on ground water, climate and actions taken so far. The thrust of the work is to that California's water problem is more of human induced mis-management and less nature driven.

It is done in three steps:

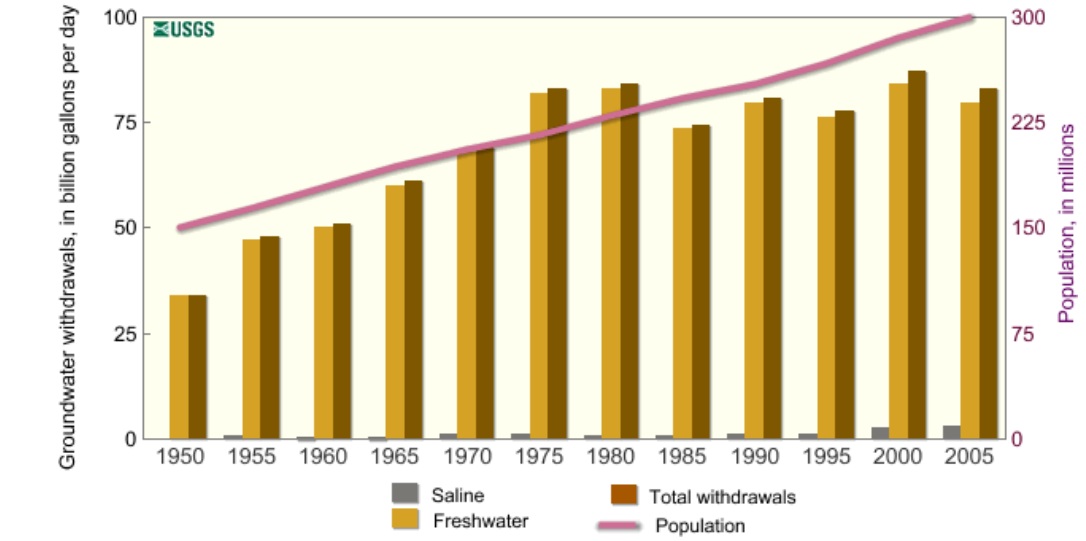
a) Assesses data on the state wide water use, ground water withdrawals and precipitation

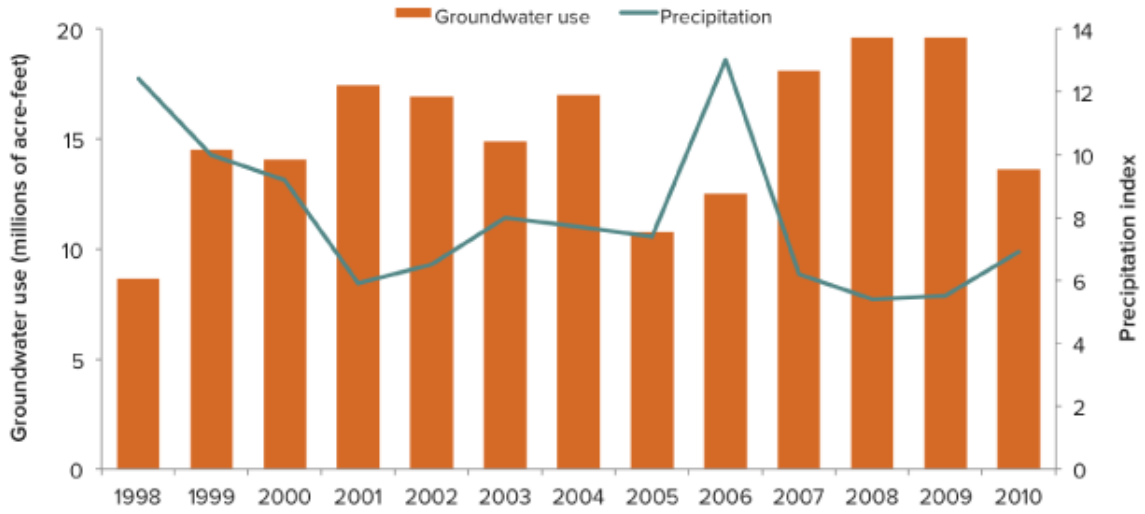
b) Study the history of water laws and actions taken to tackle the problem in the State

c) Illustrate the causes and impacts and possible solutions

Data in support:

Figure 1: Trends in groundwater withdrawals, 1950-2005





Groundwater withdrawals by water-use category, 2005, in million gallons per day.

[Values may not sum to totals because of independent rounding]

Figure 2: Total Groundwater Pumping

SOURCE: Department of Water Resources.

NOTES: The figure shows total groundwater pumping, excluding active groundwater recharge (1–11% of total pumping, depending on the year). Precipitation is measured by the Sacramento Valley Water Year Index, which accounts for water in storage from the previous year.

Table 1: State wide Dependence on Groundwater

Hydrologic Region	Reliance on groundwater(Share of total farm and urban use)		Total average groundwater (Thousands of acre-feet per year)	Share of statewide groundwater use
	Lowest (Wet Year)	Highest (Dry Year)		
Coastal				
North Coast	33%	58%	363	2%
San Francisco Bay	2%	18%	145	1%
Central Coast	81%	89%	1,111	7%
South Coast	25%	39%	1,576	10%
Central Valley				
Sacramento River	26%	31%	2,669	18%
San Joaquin River	26%	45%	2,783	18%
Tulare Lake	23%	71%	5,704	38%
Mountain and Desert				
North Lahontan	20%	39%	156	1%
South Lahontan	58%	75%	409	3%
Colorado River	1%	10%	309	2%
Statewide	29%	44%	15,203	100%

SOURCE: **Department of Water Resources**.

NOTES: The table shows total groundwater pumping as a share of total applied water use in the agricultural and urban sectors from 1998–2010, excluding active groundwater recharge. The wet and dry years show the minimum and maximum shares of groundwater. Total statewide use is based on statewide values and does not equal the sum of the regions.

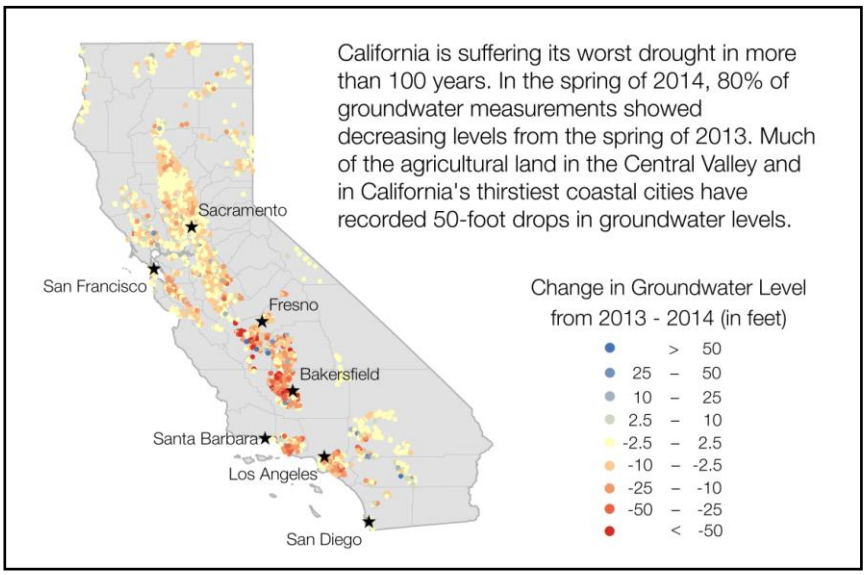


Figure 3: Depletion of Ground water Reserves in California from 2013-2014

Source: California Department of Water Resources

California Statewide Groundwater Elevation Monitoring Program

3. Causes:

3.1 Outdated system of Water Rights Laws- The outdated water laws in California include the **Water Rights Law** which is more in existence for more than 100 Years and Counting. The long and controversial history of water rights in California dates back to December, 1914. These rights, in spite of severe water crisis allow nearly 4,000 companies, farms and other water rights holders to use an unmonitored amount of water for free and in many cases, they can sell what they do not need. They have legal rights that allow them to use trillions of gallons of water each year. There are senior water rights and riparian water rights. A senior water right is one that was claimed before 1914. A riparian water right is one that may have been claimed after 1914 by an entity that owns land abutting a waterway. It states that those who hold water rights are required to report their diversions only every three years. Even in the reports there is no requirement of giving the details of how the water is used. It is based purely on estimation and not on actual flow measurements. Those with the most longstanding water rights and so called "riparian"

rights – don't have to report at all. Hence there is no accounting of the amount and use of water by the holders of water rights[4].

3.2 Minimal groundwater regulation- There has not been strict groundwater regulations which has encouraged over-pumping. It has largely been unregulated until recently and this lacuna in the water laws and regulatory gap has promoted unsustainable pumping or overdraft of water sources in many areas. Unregulated use also includes inappropriate '**Water Pricing'**, for example agricultural users get water at subsidized rates and them turning it around and selling it at a profit is indicative of an incredibly broken system.

3.3 Inappropriate 'Water Pricing'- As mentioned earlier and according to the leading expert, at the moment there is no existing shortage of water in the state but misallocation of water due to incorrect pricing. Appropriate pricing would allow judicious and cautious use of water by various users. It is only in 2015 Governor Jerry Brown ordered 400 local water-supply agencies, which serve 90% of residents, to deliver 25% less over the coming year. It however just targets the urban users and has no cap on the use by farmers for agriculture which sucks up about 80% of the state's water (excluding the half that is reserved for environmental uses)[5].

3.4 Management Fragmentation: There is difficulty in coordination because water reservoirs are owned by local agencies, state agencies, and federal agencies. This also has restricted the sharing of available data and information for conservation and better management. Fragmented and isolated work by different agencies has not yielded any fruitful results in water conservation.

3.5 Urban development- California is the most populated state in the US. It is also the state with the highest urban population density in the country: 95 percent of California's population lives in cities. City like Las Vegas has grown faster than any other city in the West, its footprint doubling in the past 25 years as more and more people have moved there. Denver's metro population hit 2.7 million in 2013, more than three times what it was in 1960[6]. More urbanization means more population, more use of water, more roads, more concretization, more suburbs, and more artificial conduits to divert and lead water to all the wrong places. All eventually lead to major cause of water runoff[7].

3.6 Climate change and Climate variability – As usual, there are mixed views on whether climate change can be blamed for California's water issues. It is true that the uncertainty in local weather and change in climate locally as well as globally is causing a significant change in fundamental water flow patterns and snowpack in the state. The system built for water management is based around snow accumulating and melting slowly and running off into our reservoirs. When that very basis is changing, it disturbs the whole system[8]. A recent National Oceanic and Atmospheric Administration (NOAA) report found climate change was not the cause for the water issues. It states that though global warming has caused excessive heat that may have worsened the drought's effects, but it isn't to blame for the lack of rain. Less rain and snow in recent years is more of a result of "natural variance" and it is also due to mismanagement of the water supply that has left the state more vulnerable to both short and long-term changes in climate[9].

3.7 Unsustainable use of groundwater basins

3.7.1 Agriculture- As per the data, agriculture is the main driver of water demand in the state. Agriculture is also major industry for the State. With 76,400 farms and ranches, California agriculture is a $54 billion dollar industry that generates at least $100 billion in related economic activity[10]. But in major agricultural regions like southern Central Valley and Central Coast, groundwater withdrawal exceeds the amount that can be replenished hence unsustainable. According to the state Department of Water Resources, in an average year, farmers use 80 percent of the water consumed by people and businesses — 34 million of 43 million acre-feet diverted from rivers, lakes and groundwater. On average, California's agricultural and urban sectors use about 42 million acre-feet of water per year, of which one to two million acre-feet comes from excess pumping of groundwater. There is still no limit on the use of water by farmers and on the changing the crops they plant. It is still the more water consuming crops such as almonds, walnuts, cotton and grapes being grown as major crops because many of the crops that use less water entitle farmers to fewer federal subsidies, and so farmers don't have much of an incentive to switch crops. For example cotton production has dropped steeply in California, since 1995, California farmers have gotten $3 billion in federal subsidies to grow it.

Clause like "Use it or Lose It" in state water laws also push farmers to flood their fields with much more water than they need lest they lose the right to that amount of water in the future[11].

3.7.2 Groundwater contamination- Human and Natural – Groundwater quality of available groundwater resources is a growing problem in some basins and closely related to agriculture. The contamination is both natural and human induced. In many rural areas, nitrate—produced by nitrogen fertilizer and manure—is polluting local drinking water supplies. Other sources of nitrate contamination include septic tanks and dairies. In some urban areas, industrial chemicals are the main source of contamination. This adds additional economic cost pressure for treatment to remove contaminants from drinking water, especially for small rural systems[12]. According to a study by USGS as part of the California State Water Board's Groundwater Ambient Monitoring and Assessment Program, there are natural contaminants like arsenic and uranium in 20 percent of the groundwater resources used for supply. Human-made contaminants occur in locations where large numbers of people rely upon groundwater like parts of the San Fernando, San Gabriel, and Santa Ana Basins, where millions of people depend on groundwater for part of their drinking supply. Efforts are needed to reduce future contamination by regulating and controlling industrial discharges and by changing farming practices. Efforts are also required to put in place in already-polluted basins need to be cleaned up.

3.7.3 Industrial/Commercial use of water: Water-bottling plant in California – The state does not have a permit process for regulation of ground water use. In most areas of California, overlying land owners may extract percolating ground water and put it to any beneficial use without any approval from the State Board or a court. There is, thus no regulation on the bottling plants too. It is shocking that a state with a 100 years history of drought encourages bottled water companies in the name of job creation and economy boost. This continues to pressure an already burdened water system[13]. Most of the bottling pants lie in Northern California like the Crystal Geyser's plant near the city of Mount Shasta. The plant faces no cap on what it can pump. Before this the shallower sources of water were used by Dannon and Coca-Cola for their bottling operation. Other bottling brands in operation include Nestle Arrowhead and Pure Life, Walmart through DS Services, Dasani, Aqufina**,** Niagara Bottling LLC etc. Strangely there is no

environmental impact assessment done by any of the companies and the County and city officials declare that have no legal authority to require any such report because the site was zoned for heavy industry when it was a lumber mill, and water bottling is a prior and permitted use[14]. The impact is greater because the pressure on upper water resources compromises the water availability in the lower regions of the state[15].

4 Effects:

4.1 Overdraft Basin- Overdraft occurs in parts all over California. Unsustainable groundwater extraction and decrease in its recharge has led to a decline in groundwater level. This condition is increasing in number throughout California, and is impacting the state in many ways.

4.2 Saltwater Intrusion- This is a major long-term groundwater quality challenge. Excessive pumping of ground-water reduces freshwater flow toward coastal discharge areas and cause saltwater to be drawn toward the freshwater zones of the coastal aquifer. Saltwater intrusion decreases freshwater storage in the aquifers, and, in extreme cases, can result in the abandonment of supply wells. Salts in irrigation water and wastewater applied to crops or urban landscapes are concentrated by evapo-transpiration from plants, leaving salts behind[16]. Imported or pumped water for domestic needs and economic activity also brings along salts that stay in the soil to eventually reach the groundwater. Salinity from other sources like local soils, aquifers, water from irrigation, animal farming and municipal and industrial wastes is a major threat to agriculture as well as drinking water[17].

4.3 Land Subsidence-Land subsidence is one of the most diverse forms of ground failure, ranging from small or local collapses to broad regional lowering of the earth's surface. Excessive groundwater pumping is the single largest cause of subsidence because it causes compaction of already susceptible aquifer systems and in fact the 5,200 mi^2 affected by subsidence in the San Joaquin Valley has been identified as the largest human alteration of the Earth's surface topography. The second largest cause of subsidence in California is the oxidation (decomposition) of organic soils. Effects of land subsidence include damage to buildings and infrastructure such as roads and canals, increased flood risk in low-lying areas, and lasting damage to groundwater aquifers and aquatic ecosystems[18].

4.4 Decreased stream flows- Due to the increased diversion of water from streams and rivers and excessive ground water pumping for agricultural and domestic uses, the amount of water that remains in natural watercourses has decreased. Full stream flow helps in maintaining water quality. With decreased stream floe the concentration of pollutants in the water also increases. Lowered groundwater levels drain water from rivers, stressing ecosystems during low-flow times [19&20].

4.5 Impact on flora and fauna- In addition to the economic cost, the water crisis have direct as well as indirect effects on flora and fauna throughout the region. Reports and research state that the current conditions may be contributing to the spread of the West Nile virus, and its threatening populations of geese, ducks and Joshua trees. Dry, hot periods can exacerbate wildfires which again has other cascading effect on ecology[21].

5 Solutions-

5.1 Steps taken by State Authorities

a) Water Legislation, 2009- Implemented in year 2009 it aimed at sustainable water use and demand reduction in the state. This law made the Department of Water Resources to convene an independent technical panel for providing information on new demand management measures, technologies, and approaches to department and the legislature. These measures include all water conservation measures, programs and incentives that prevent the wastage of water and promote the efficient use and reuse of available resource. It ultimately aims at reduction in urban per capita water use in California by 20% by December 31, 2020. It requires each urban retail water supplier to develop urban water use targets and an interim urban water use target, in accordance with specified requirements. It also targeted agricultural water suppliers to implement efficient water management practices. A single standardized water use reporting form was also to be prepared by the department, in consultation with other state agencies. It also will make urban retail water suppliers and agricultural water suppliers (under conditions) ineligible for state water grants or loans unless they comply with the water conservation requirements as established by the bill[22].

b) Bills and a bond proposal under Water Legislation, 2009- California state Legislature passed an historic package of bills and a bond proposal that are designed to ensure a reliable and clean water supply for future generations. The bills also created a Delta Council, a Delta Plan, stricter groundwater monitoring targeting illegal diversions, water conservation policy with water recycling and conservation programs. It also aims at enforcement of It has a long term goal of restoring most ecologically sensitive areas like the Sacramento-San Joaquin Delta[22].

c) The Soil and Water Resources Conservation Act of 1977 (RCA) – It provides the United States Department of Agriculture (USDA) with a planning and strategic assessment for the conservation, protection soil, water, and other related natural resources. Through RCA, USDA performs the assessment of the status and trends of soil, water, and related resources on non-Federal land and their capability to meet present and future demands. It also looks into programs and policies for soil and water conservation. For example the recent appraisal in 2011 examines interrelated issues like climate change, increased bio-fuels production, the quality and availability of water that have serious implications for U.S. agriculture and forestry[23].

d) Sustainable Groundwater Management Act, 2014- In 2014 the state adopted the Sustainable Groundwater Management Act**.** It will ensure to regulate extraction for the first time. It is expected to eventually bring about some integration of groundwater and surface water management because it will make regulators and water users to realize that they depend on surface water to recharge aquifers. It defines sustainability as the avoidance of six undesirable results: lowering of groundwater levels, reductions in groundwater storage, impacts on water quality, saltwater intrusion from seawater, subsidence of the land surface and impacts on interconnected surface waters[24.] It has the potential to transform the state from having a deficient system of groundwater management to having a set of locally inclusive governance systems that will achieve long-term groundwater sustainability.

e) Monitoring Critically Overdraft Basins- Defined in the Sustainable Groundwater Management Act (SGMA), 2014, a basin is critically overdraft when the continuation of present water management practices will eventually result in overdraft-related environmental, social, or economic impacts. SGMA directs the Department of Water Resources (DWR) to identify

groundwater basins and sub-basins in conditions of critical overdraft. Conditions of critical overdraft result from undesirable impacts which can include seawater intrusion, land subsidence, groundwater depletion, and/or chronic lowering of groundwater levels. DWR has identified 21 such basins[25].

f) Final 2016 Drought Contingency Plan - California Department of Water Resources and the U.S. Bureau of Reclamation finalized the 2016 Drought Contingency Plan that outlined the operations of the State Water Project and Central Valley Project operations for February-November 2016. It was developed in coordination with State and federal agencies like U.S. Fish and Wildlife Service, National Marine Fisheries Service, California Department of Fish and Wildlife, and the State Water Resources Control Board (SWB). It focuses the potential modification requests needed to balance the competing needs and benefits of the limited water supplies in the context of consecutive dry years[26].

g) Frost Protection Regulation 862 – Russian River Watershed by State Water Resources Control Board- It regulates all water use for frost protection, surface or groundwater. It pertains to people who divert under pre-1914 right, appropriative, riparian, and interconnected groundwater through w**a**ter demand management program or plan. This plan has an inventory of the frost diversion system, stream monitoring, frost protection diversions, identification and timelines for implementation of any necessary corrective actions, and annual reporting. The regulation shifted the burden of proof from the challenger to the user to demonstrate that there's no impact on flow[27].

h) Recharge Net Metering policy- In Pajaro Valley the groundwater agency put in place a mechanism to incentivize innovative projects like greater storm water recharge through **Recharge Net Metering policy** . As per this policy all groundwater users in the basin will be refunded the pumping fee if they put projects in place that return excess storm water into the basin during the winter[28]. This is an excellent example of putting in efforts to bring a groundwater basin's water budget into balance either by pumping less groundwater or by bringing other sources of water into the basin to help recharge aquifers directly or to use in place of water demands that were otherwise satisfied by groundwater.

i) Water curtailments- In 2015 State Water Board (**SWB),** for the first time restricted diversion and pumping. They reached out to several watersheds – the Sacramento-San Joaquin watershed, the Russian River, the Scott River, parts of the Eel and the whole Delta area was told not to divert water[29].

j) Habitat Conservation through Fish and Game Code 1602: Lake and Streambed Alteration Agreement- Fish and Game Code section 1602 requires a person or an to notify California Department of Fish and Wildlife (CDFW) before starting any activity that may divert or obstruct the natural flow of any water body (river, stream or lake) or use or change any material from the bed, channel or bank of any river, stream, or lake; or deposit debris, waste or other materials that could pass into any river, stream or lake. It includes any episodic or perennial river, stream or lake as well as ephemeral streams, desert washes, and watercourses with a sub- surface flow or any work undertaken within the flood plain of water body[30.]

k) Governor's Executive order for mandatory water use reductions, 2015- State Water Resources Control Board adopted it with the aim of cutting urban water use by 25 percent in a year. There are 411 urban water districts in the California, and the 25 percent reduction will be drawn from all of them combined. All 411 urban water districts will be broken out into "buckets." Those with higher per-capita water use and few or no conservation programs will be put together with higher reduction goal buckets. Those with lower per-capita use and robust conservation initiatives will be put into buckets with lower goals. It also required better drought planning from cities and farmers. The state is also required to prepare emergency water restrictions for 2017 in case the five-year drought persists[31].

l) Better water storage in California under Proposition 1 (Water Quality, Supply, and Infrastructure Improvement Act of 2014) - It focuses on Water Storage Investment program by funding the Public Benefits of Water Storage Projects. It allocated $2.7 billion to pay for public benefits of water storage projects that improve the operation of the state water system with focus on net improvement in ecosystem or water quality conditions and cost effectiveness. A variety of storage projects qualify under the measure, not just surface storage, but also

groundwater storage and contamination projects. As per the bond, public benefits that can be funded through it can include ecosystem improvements, water quality improvements, flood control, emergency response, and recreation benefits. All such projects have to give measurable improvements in the Delta ecosystem or its tributaries. It designated the California Water Commission as the agency responsible for appropriately allocating these funds. The program will support the California Water Action Plan and its call for a safe and reliable supply of water to support the state's economy, environment, and quality of life[32].

m) Water Use Restrictions by City of Livermore and Norwalk - Livermore City Council and Norwalk city council has enacted a new water conservation ordinance which applies to every resident, including Cal Water customers. The ordinance includes the following water use restrictions; Limited lawn watering and landscape irrigation and it must not result in run-off to paved areas. Vehicles may be washed at home no more than once per month, and only with a bucket and hose equipped with a shut-off nozzle. Swimming pools must not leak, be over-filled, or be left uncovered when not in use. Fire hydrants to be used exclusively for fire-fighting or other public safety activities. Drinking water may not be used for compacting or dust control. Hosing of paved areas is not allowed. Restaurants may serve water upon request only, and must use low-flow rinse nozzles.

n) Conservation pricing- Directive 8 of Governor's Executive Order B-29-15 in year 2015 promotes water conservation pricing mechanisms as an effective tool to prevent wasteful water use. It enables local water agencies to put in efforts to conserve water in the short as well as long term. It incentivizes consumers who conserve water thereby reducing water demand. There are also rate structures put in place by water suppliers to promote water conservation through economic incentives consistent with statewide water use restrictions. Rate-setting is a complex undertaking AS it involves numerous local determinations but the specific form of the direction is left to the discretion of the State Water Board. It continuously engages with other state agencies, suppliers, and other stakeholders to address the financial, technical, political, and legal challenges associated with changing rates, surcharges, and other fees. It aims at finalizing water rate structures that encourage efficient water use[33 &34].

o) Other noticeable Senate bills that affects water directly or indirectly

i. **Senate Bill 20,2015-** It requires public access to the groundwater information that well drillers file with the Department of Water Resources after completing a well. Between 1977 and 2010, some 432,469 water wells were drilled in California, according to the Department of Water Resources. The state knows the numbers with precision where these wells supply and for what purpose because every driller is required to file a detailed well completion report, which is a one-page document asks for information on the depth of the well, underground geology, location, and depth to water[35]. The data on geologic layers, sediments, and well locations though these logs can help researchers map aquifer boundaries, estimate how much water they hold, and trace the movement of contaminants.

ii. **Senate Bill 88, 2015-** This bill requires anyone who diverts more than 10 acre-feet (12,334 cubic meters) of water per year from a stream to precisely measure and report their water usage including old water rights. Beginning 2017, this will eliminate the practice of merely estimating water use. From 2020, all these diverters will be required to report all their water diversions in real time using telemetry devices. The good news is that the fifth year of drought offers the chance to reinvest in effective water solutions by expanding innovating landscaping, encourage water reuse and recovery , improve agricultural irrigation practices, price water properly etc[36].

iii. **Senate Bill (SB) 859**, **2016-** It establishes a Healthy Soils Program which helps in building quality agricultural soil to increase carbon sequestration. Healthy soils directly help retain more water[37].

iv. **Senate Bill 1414, 2016-** It aims to help increase energy efficiency, which can also help save water[38].

v. **Senate Bill 552, 2016-** It allows the State Water Resources Control Board to bring in an outside contractor to help struggling water agencies meet water standards and implement a number of measures to help ratepayers, and also to create a long-term sustainability plan[39].

vi. **Senate Bill 1263, 2016-** It aims to guarantee the safety and reliability of drinking water by tying with existing water districts rather than creating their own It is because smaller water agencies tend to be more likely, because of limited resources, not to meet reliability or quality regulations[40].

vii. **Senate Bill 814, 2016-** It would require urban water agencies to define and discourage excessive water use during state announced drought emergencies that need strict water restrictions. Agencies are free to use a rate structure or an excessive-use ordinance that would come with fines and possible drought-shaming. This legislation ensures that every urban retail water supplier has a mechanism to curtail excessive water use by users[41].

viii. **Assembly Bill 1755, 2016-** It focus on better collection and sharing of water data by creating a statewide integrated water data platform that, among other things, would integrate existing water and ecological data information from multiple databases and provide data on completed water transfers and exchanges[42].

ix. **Assembly Bill 935, 2016**- It may help move 15,000–30,000 acre-feet (18.5–37 million cubic meters) of water a year to nine irrigation districts that compose the South Valley Water Association in the San Joaquin Valley. It authorizes $7 million in state for pumping water out of the lower San Joaquin River and into the California Aqueduct on the west side of the San Joaquin Valley, transported south to the Cross Valley Canal, then east to the Friant-Kern Canal[43].

x. **Assembly Bill 2594, 2016-** It helps move storm water from nuisance to resource. The new law lets water agencies collect storm water and then make the most of it – including reusing it, recharging groundwater with it, selling it or using it to boost water quality[44].

5.2 Other possible interventions that can be implemented:

a) Better groundwater management- California's groundwater basins can store large volumes of water, which is especially valuable during lean season or droughts. Better management would ensure limited pumping in normal and wet years so that groundwater levels can recover. Groundwater storage can be increased by aiding percolation through the soil. As a solution, some urban areas—including much of Southern California and Silicon Valley—have created local authorities that can charge fees to fund recharge programs and regulate pumping.

b) Better Water Accounting- Accounting for water is a new concept for California but this tool will track inflows and withdrawals carefully. Precise accounting would help the state to ease the pain of water shortages during drought and prevent environmental disasters[45].

c) Desalination and recycling of waste water - Water from desalination plants costs roughly five times more than urban Californians pay for water now. San Diego County has

constructed the largest desalination plant in the western hemisphere, at a cost of $1 billion at Carlsbad in 2015. It is estimated to provide safe water to approximately 300,000 people apart from serving as a major test of the feasibility and expense of utility-scale desalination technology[46]. California-based start-up WaterFX has also developed their own homegrown solar-powered desalination system. If desalination projects are not feasible then other options like recycled wastewater and conservation should be promoted.

d) Education- Educating the public and policymakers on subject of water is important for overcoming challenges facing water policy. Public in general is often poorly informed about where their water comes from, where wastewater goes, the value of water, the importance of sustainable funding for water management and regulation, and how declining water quality affects their lives. Better education and information about water problems could drive more informed policymaking. It also important to make efforts to inform politicians and decision makers on such issues important public issues[47].

e) Urban water use control- There has however been a control on urban water use which has been held relatively steady over the past two decades, despite massive population growth due to smart pricing and low-flow toilets. Per-capita water use in California has declined from 232 gallons a day in 1990 to 178 gallons a day in 2010 [48]. But there needs more efforts on the public as well as policy makers part. This could include water conservation rebates for use of more efficient products like High Efficiency Clothes Washers, Premium High Efficiency Toilets (HETs), Weather Based Irrigation Controllers (WBICs) , Rotating Sprinkler Nozzles, Rain Barrels and Cisterns for collection and reuse rainwater for irrigation etc.

f) Efficient Landscaping - More efficient and strict city regulations for landscape regulations will also curb the unnecessary use and mis-use of precious resource like water. More cities need to replicate the examples of city like Norwalk which adopted the Water Efficient Landscape Ordinance on January 5, 2016. This included balance between for artificial turf, hardscapes such as concrete, pavers, stones, etc. and open ground along with approved water efficient landscape designs within front yards and parkways etc[49.]

g) Water harvesting through perma-culture- Water harvesting is about more than just capturing water; it also calls for working and designing the land in a way that reintroduces water into a holistic, integrated system. We can turn parched land into forest and drought-proof farms

by capturing runoff and allowing it to sink in to the soil. A regenerative ecological design studies and practices mimicking the beneficial relationships of nature in designing communities and environments in which humans live and work. It also includes designing homes, environments and communities in the most comfortable, ecological, and sustainable ways possible[50].

h) **Change in choice of crops and irrigation strategies-** There should be plan to adapt to shifting yield and productivity patterns associated with current and future changes in temperature and precipitation. This would also require the adaptive responses for crop production and land use, crop markets, returns to producers, and water quality measures. There should be serious discussion on plan to substitute water thirsty crops with drought tolerant varieties in the state.

6. Conclusion

The capitalist development model, industrial agriculture, and urban and industrial growth have altered the natural reserves and have disturbed water's natural cycles and leading severe water crisis. Outdated laws and unregulated groundwater use has all led to the current crisis. Water has been and will be the key to all life. If no concrete and long term plan is made and implemented, cities would suffer as cheap water would not be available. Farmers and food production would take the biggest hit. Farmers would fallow millions of acres, letting row crops die first. They would pump massive amounts of groundwater to keep orchards alive eventually leading to dry wells would go dry. The cost of digging deeper wells for agriculture would exceed the value of their crops. Banks would refuse to loan the farmers money. Regulators and consumers need to rethink the value of water. At the crux of the issue—we don't value water, or at least there is a disconnect between its price and value. Managing water is only going to get more complex, in large part because of the impact of extreme weather. The rights of individuals to pump groundwater should be subject to responsible management regulations by groundwater management agencies. A few good years of rain and snow is not going help if there is no management on the ground and long term water conservation programs are implemented by authority. It is equally important for public to understand the issue and work hand in hand with the local authorities.

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