Understanding and Saving the ‘Ewa Caprock Aquifer

A Picture Essay

by Dr. Kioni Dudley

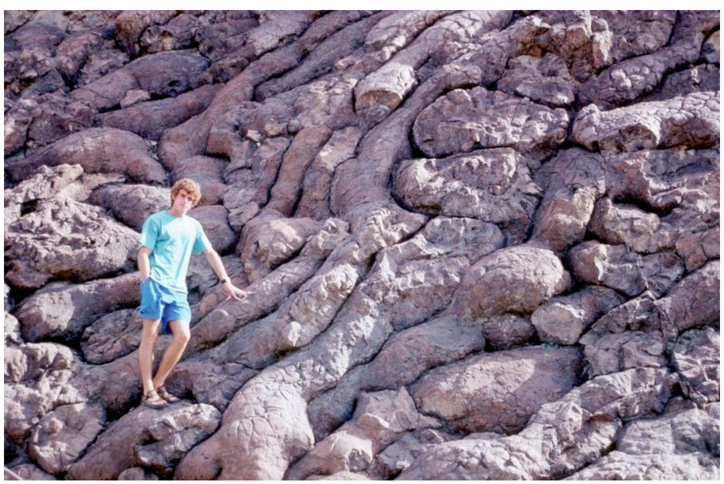
Geology reviewed by Charles Ice, a member of Hawaii's ground water regulatory community for nearly 30 years.

This essay has four parts. The first offers readers a clear understanding of the ‘Ewa caprock and its two important aquifers. The second addresses th dramatic decrease in rainfall we have experienced over the last 40 years and the drastic situation we face if the decrease continues at its current rate why it is happening, its effect on the ‘Ewa Caprock Aquifer, and the need to maximize fresh water recharge, especially by keeping the remaining land above it open and in farming so that it can be replenished by rainfall and irrigation. The third part puts together the facts learned earlier and shows how three major construction projects will end the last significant recharge of the aquifer from above. Part four briefly discusses the world-wide foo crisis anticipated by mid-century as an additional reason these lands must remain in farming.

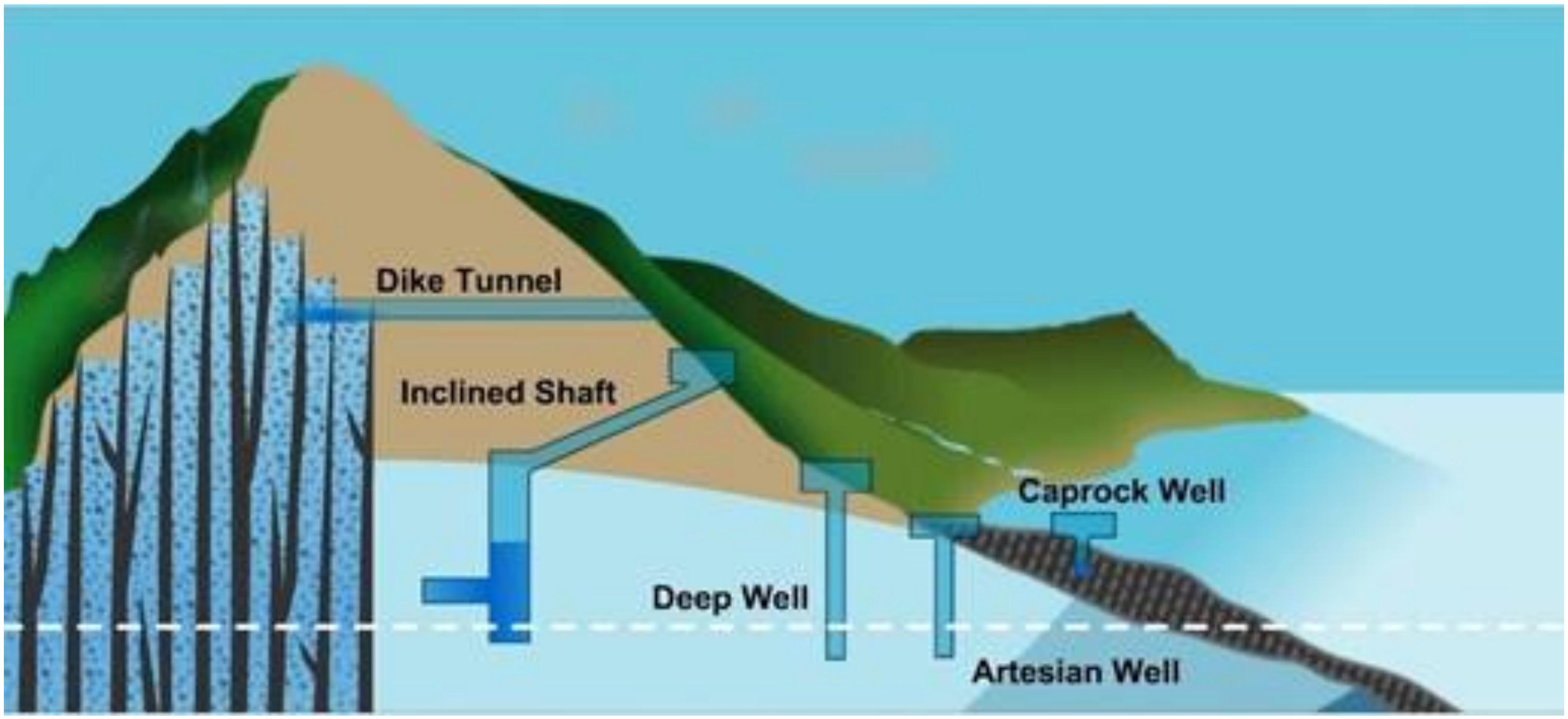
Part One
The ‘Ewa Caprock and Its Two Important Aquifers

Understanding the structure and substructure of the island

O’ahu was created by volcanic action. The whole island--Its mountains, everything beneath them, and the submerged foundation—are all volcanic lava. When lava flows above ground, it tends to flow in lines without any breaks, like long fingers or noodles. Layer flows over layer, and it is quite solid and stable. But when lava flows into water, it breaks up, forming pillows of lava as seen below. As the islands were being built, first as volcanoes under water, these pillows, sticky, and cooling from the outside in, piled up like rubble, subject to collapse in landslides. Because the pillow lava is not connected, there are considerable gaps in between the pillows allowing water to fill the open spaces between them.



The picture below might depict the south shore of O'ahu looking from Barber's Point towards Diamond Head. It shows a huge, light blue aquifer of fresh water beneath the island. The light blue fresh water floats on heavier and darker, blue green ocean water. This is not just a lens of water filling an open space under the island, however. Although not depicted, the lens is actually quite filled with pillow lava which provides the foundational structure for the island. The aquifer fills in the gaps between the pillows of lava.

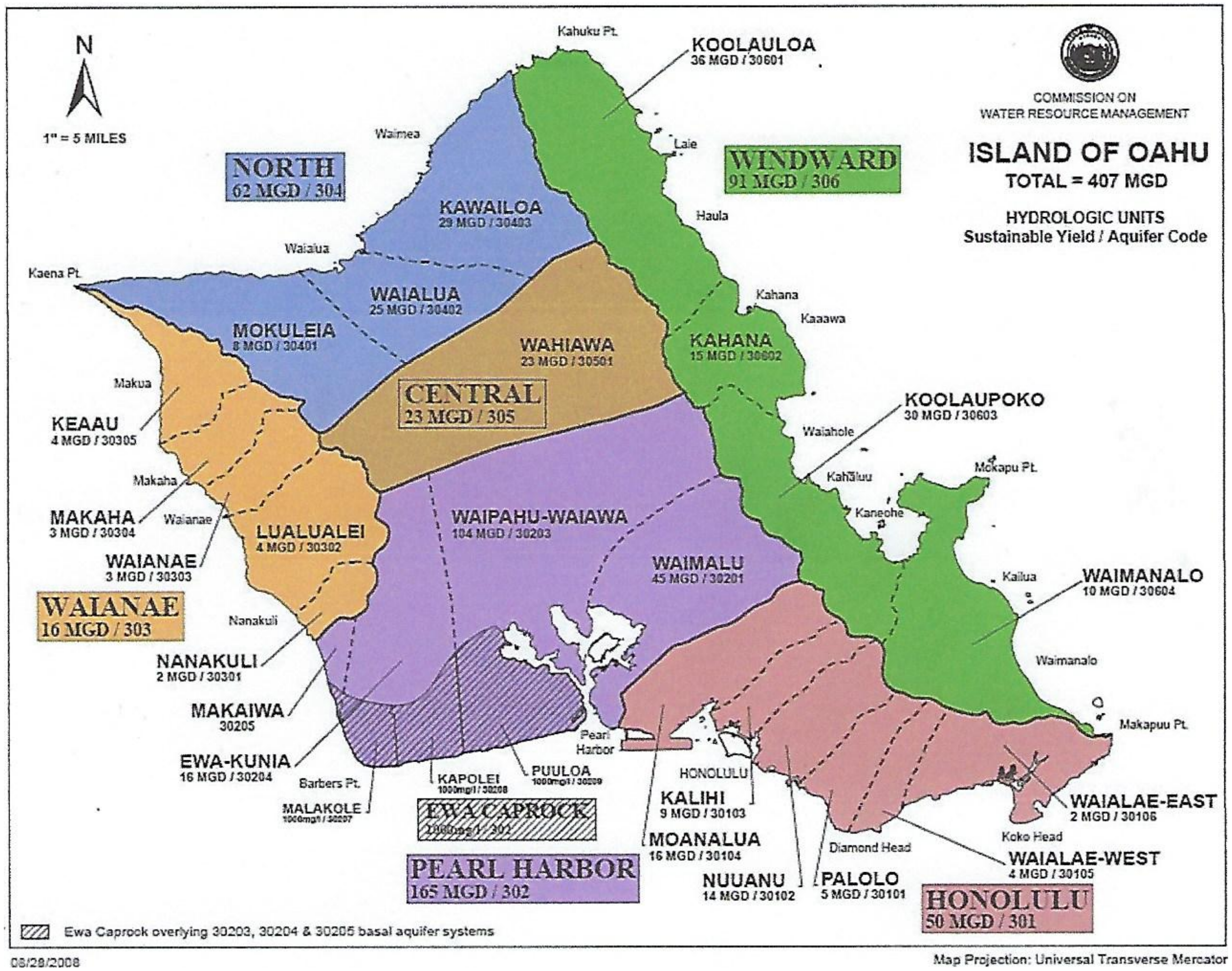


Notice also in the picture above, the thick, dark reef-caprock reaching down to the right into the ocean. This caprock holds the fresh water lens back under the island to its left, keeping it separated from the ocean. This caprock is actually a coral reef. Mark it well. This is the topic of this paper.

The bottommost layer of this reef which formed on and clings to the lava beneath it, became ever more compact and solid over the ages as it grew thicker and heavier. It is almost impervious. It is the bottommost layer that forms the shield or dam or cap that keeps the fresh water under the island, preventing it from flowing into the sea. Although not shown in this depiction, the caprock also extends onto the land.

Fresh Water Aquifers Beneath Oahu

This is a picture of the aquifers on O'ahu. Notice the large Pearl Harbor Aquifer in purple.



The Pearl Harbor Aquifer (in purple) is huge, covering the whole center section of O'ahu. Rain from the peaks of the Ko'olaus, from much of Central O'ahu, and from the whole southern section of the Waianae Mountains charge the aquifer. All of that fresh water is held back under the island and kept from running into the sea by the 'Ewa Caprock which is outlined in this drawing with ////. The caprock crosses the whole 'Ewa Plain.

Understanding the formation of reefs

Pictured below are various types of coral. The upper tips of each coral piece are coral polyps, living organisms. Eons ago, colonies of millions of coral polyps grounded themselves on the offshore lava. As they died, their shells along with the shells of oysters, clams, and mussels, filtered through the corals to their base, where they mixed with settling dirt from terrestrial runoff, forming a sediment that was compacted over millions of years, becoming limestone—limestone reefs.

Seen below as dark strips in the shallow water, the growing coral caused the reef to expand over the ages, eventually stretching the width of the entire ‘Ewa Plain, from the Barber’s Point to Pearl Harbor and beyond.

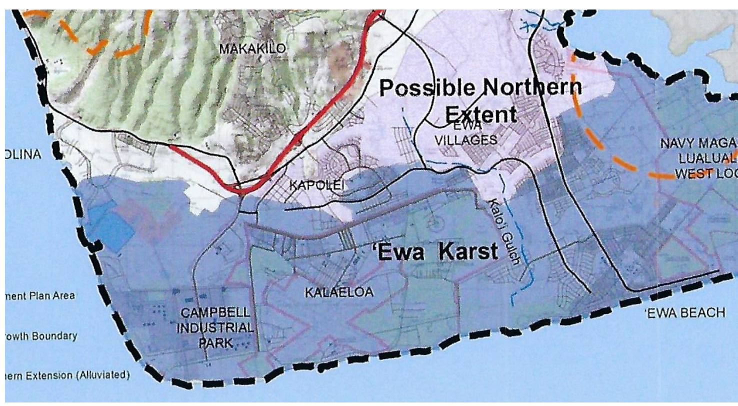
The reef also grew inland, aided by two different events in nature. Two or three million years ago, as the tectonic plate that O'ahu sits on moved, the island slowly settled into the sea, causing its surrounding shoreline to rise higher and to move inland towards the center of the island. The coral reef on the shoreline, needing shallow water and sunshine to survive, moved inward and higher with the shrinking seashore, growing over the newly exposed lava base of the island.

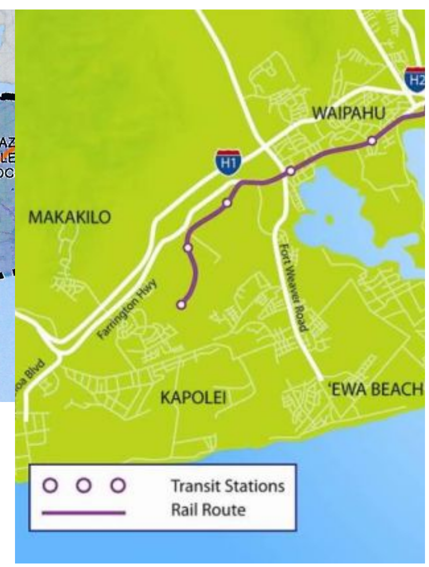
A second repetitive series of events in nature, "Little Ice Ages" that occur about every 100,000 years, would add many layers of coral reef above this. In the warm periods (interglacial periods) between the "Little Ice Ages," the seas rose as much as 150 feet higher than they are today. As it rose, the shoreline and its accompanying reef moved to higher elevations, farther inland, eventually as much as three or four miles inland on the 'Ewa plain. Then, as each Ice Age approached, the shoreline and its accompanying living reef moved outward and downward. These movements gave the coral opportunities to add new layers of limestone to each elevation of the existing reef as the shoreline crossed over it.

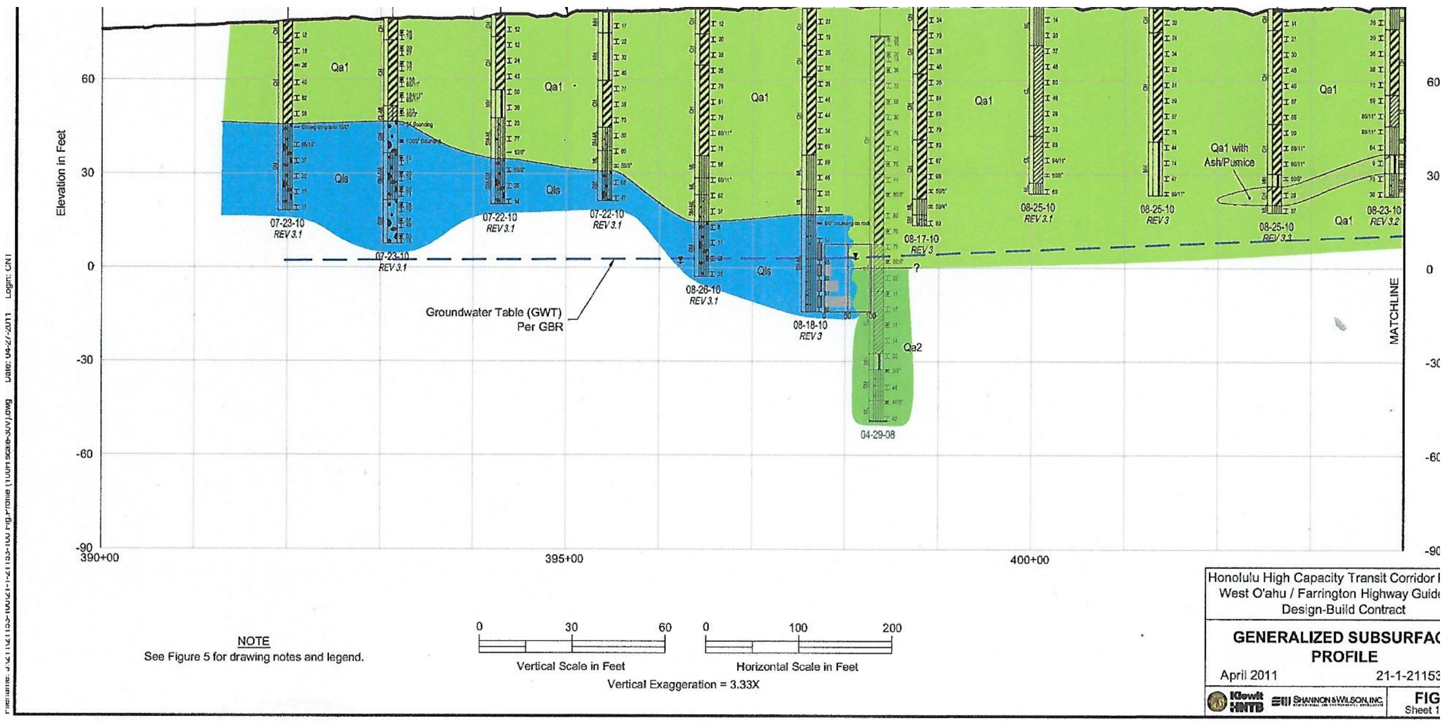
At the shoreline, the caprock is 1,000 feet thick. It thins out as it reaches higher elevations. Nearer to the mountains, the coral reef caprock is covered by many feet of alluvium (dirt that has washed down from the mountain.) Closer to the beach, the caprock is exposed in many areas.

The coral caprock's inland extent

It is *not* currently known how far inland the reef extends. Some experts have believed that it comes up as far as the H-1 freeway, which is shown as the red line in the map on the left, and as the top yellow line in the map on the right. The map from the 'Ewa Watershed Management Plan is more conservative. It refers to the caprock as the "Eva Karst"karst." Karst is an irregular limestone region with sinks, underground streams, and caverns. This map shows the Possible Northern Extent of the caprock in light purple. The top edge of this Possible Extent is well below the freeway and pretty much follows the path of the rail across the plain. The rail is the red line in the map to the right. It starts at Kroc Center.







This picture shows the first twelve drillings done by HART for the Rail. It is a view facing roughly west, with the first hole to the south (left).

The borings for the Rail brought surprising news. As the drawing above shows, at that eighty-foot elevation, near Kroc Center, the drillings for the first seven pilings of the rail line found the top of the caprock (in blue) roughly thirty feet below the surface, at fifty feet above current sea level. At that point it was roughly 30 feet thick. This all was completely as expected. But within roughly the next 400 feet northward, the top of the caprock strangely took a dip to roughly sixty feet below the surface where, at a thickness of roughly 40 feet, it abruptly ended. In the picture above, the green color is alluvium (soil washed down over the eons from the Wai'anae mountains). The blue below that is the coral caprock. HART describes the blue is "Fossil fragments of coral-algai reef and related detrital deposits cemented together in medium to very dense consistency." This matches the description for the extremely dense lowest layers of the caprock which form a dam holding back the fresh water beneath the island from flowing into the sea.

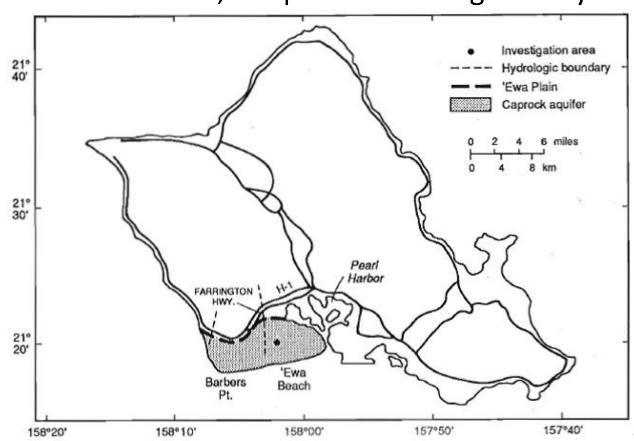
If caprock was only encountered in the first seven HART drillings, reaching to only about 400 feet north of the first hole, and was not found any farther north, was this then the end of the of northern extent of the caprock? Continuation of caprock northward on either side of the rail holes cannot be definitively ruled out. Coral is dissolved by fresh water, and heavy rainwater runoff from nearby mountains in the Wai'anae range has run through this area for eons. It is possible that the rail line runs through a valley in the coral karst that was caused by this fresh water runoff.

Another stunning discovery by HART was that the rail borings that run across the 'Ewa Plain from UH West O'ahu to Ft. Weaver Rd. also showed no evidence of a coral reef beneath. It must be noted, however, that the rail crosses the 'Ewa Plain at a level seventy feet higher (150' elevation) than the Kroc Center borings (80' elevation). Most of the HART borings going across the plain only went down to the 90' elevation, which was ten feet above the ground surface at Kroc Center. And at the Kroc Center, the top of the caprock was another 40 feet down. The borings crossing the 'Ewa Plain also only encountered alluvium (dirt washed down from the mountains). They did not reach lava. The foundation of the caprock would be expected to cling to the lava beneath it, as it does elsewhere. Since no lava was encountered either, it is possible that the caprock does exist below the rail pilings, but just further down. Thus, the caprock could extend as far north as the rail crossing the plain, and it could extend even farther northward. Future deeper drillings are necessary to determine how far inland it truly reaches.

This inland extent of the caprock is a great concern because there is an aquifer *within* the 'Ewa Caprock which relies partly on rainwater and irrigation for its recharge. If the caprock doesn't extend up to the rail line and Farrington Hwy., a far greater percentage of the aquifer has been covered over by housing than has previously been thought. We may be in crisis mode to save that aquifer.

The TWO Separate Aquifers Lying Beneath the Whole 'Ewa Plain!

We have seen a picture above (pg.2) of the various aquifers on O'ahu, including the huge Pearl Harbor aquifer, and another picture (pg.3) showing its fresh water held back and separated from the sea by the dense, nearly impervious bottommost layer of the 'Ewa caprock. What has not been discussed is that this great fresh-water Pearl Harbor aquifer is *beneath* the caprock, while there is another aquifer *within* the caprock, the 'Ewa Caprock Aquifer. Though the caprock's inland extent is unknown, the picture below generally shows the size of this 'Ewa Caprock Aquifer.



SOURCE: Lau et al. (1986).

Discussing the Nature of the Caprock

Let us begin our discussion of the ‘Ewa Caprock Aquifer with a look at coral and coral reef.   The caprock is actually coral reef, limestone. Below are pictures of limestone. Notice how porous it can be. Also notice also that shells and sediment have compacted to form it.

Below is a cliff of limestone reef, once under water. Limestone is formed in layers - called bedding planes. These bedding planes contain vertical cracks called joints.   Joints and bedding planes allow rain and irrigation to seep down, and ocean water to flow inland through the reef cracks.

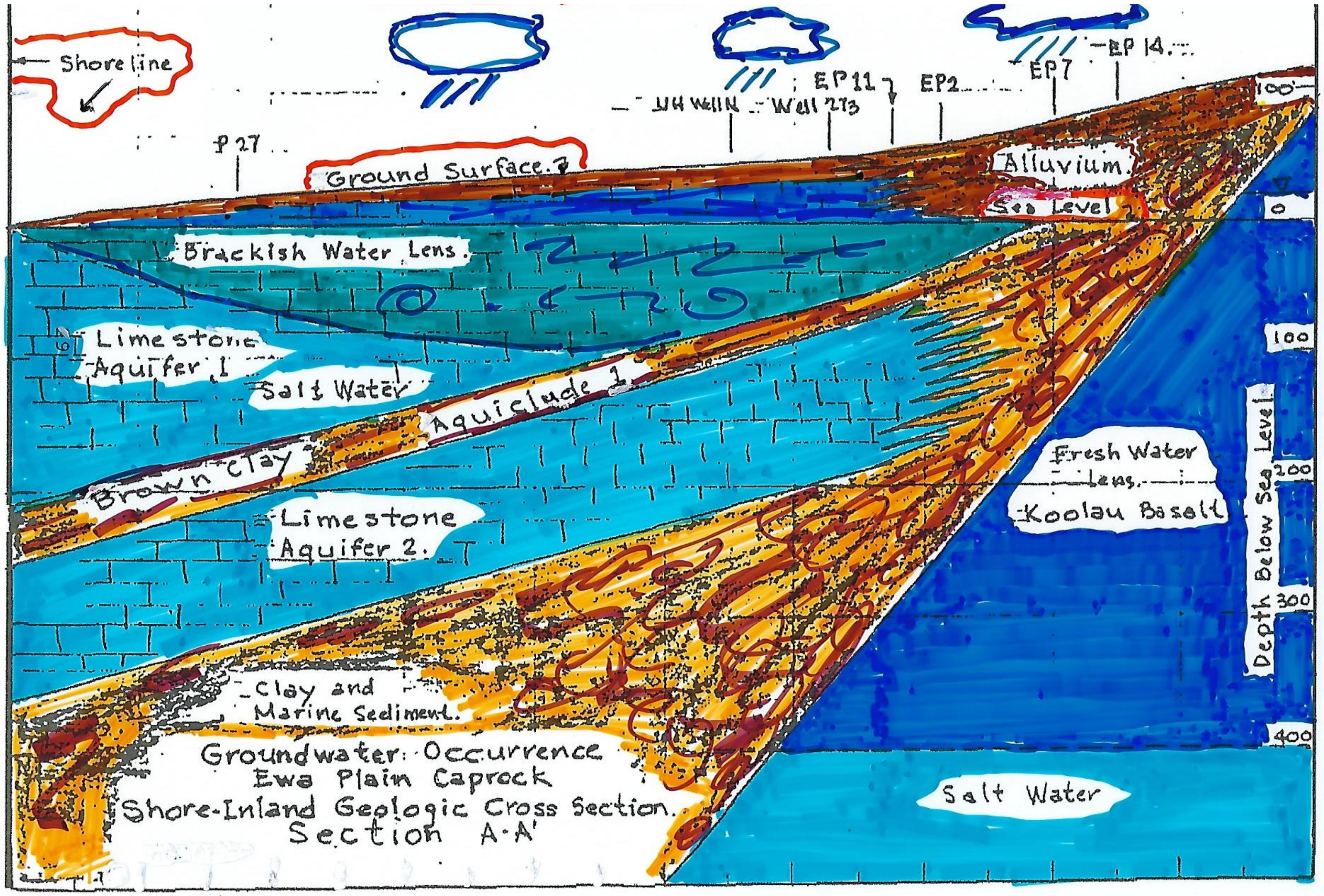
The image below shows more massive joints and bedding planes in limestone which, again was formerly under water.

Underground, the ‘Ewa Caprock looks like these pictures, with water, the ‘Ewa Caprock Aquifer, flowing through the cracks. Water from rainfall and irrigation flows down and mixes with sea water flowing in from the ocean. Because fresh water is lighter than sea water, the sea water holds the fresh water above it, also pushing it landward. In doing so, it forms a water lens within which the fresh and salt water mix, forming brackish water, with the least saline water rising to the top.

A classic drawing done by John Mink in 1989 (on the next page) depicts a cross section of the structure of the ‘Ewa caprock. Before turning to it, please note that while previous pictures in this essay have looked eastward from Barber’s Point, this drawing is focused westward, looking from the Pearl Harbor area towards Barber’s Point. It is also important to note that everything that is portrayed is onshore. Mink’s drawing of the caprock begins at the shoreline to the left, and stretches inland about 20,000 feet, or roughly four miles, depicting what is below the surface.

Note the Pearl Harbor Aquifer which is seen in deep blue on the right side of the picture. The water of this aquifer flows between and around the volcanic pillow lava rocks in the substructure of the island. Lava is basalt. Mink thus calls this the Ko’olau Basalt Aquifer. The caprock can be seen holding back the Ko’olau Basalt (Pearl Harbor) Aquifer with its dense bottommost level. This rock shield is not completely impenetrable, however. It is estimated that between 3 and 6 million gallons flows from the basalt aquifer into the top caprock aquifer each day.

Below is the famous 1989 drawing by eminent hydrologist John Mink, husband of U.S. Rep. Patsy Mink. His map was in black and white. Color was added by Dr. Kioni Dudley. The brick-like marks in the limestone depict bedding planes and vertical joints. The drawing merits careful study. Please spend some time with it.



Let us now turn our attention to the aquifer within the upper caprock, the ‘Ewa Caprock Aquifer. Starting with the surface and working our way down, we find that, as the caprock stretches inland, it is covered with ever-deeper alluvium (soil that has washed down from the mountains over the eons). Beneath the alluvium, notice the dark blue fresh water from rainfall and irrigation which seeps down from the surface through the soil and then through the joints and bedding planes. As this water moves down through the caprock, it eventually reaches Aquiclude I, a nearly impervious “water excluder” composed of highly compacted brown clay. The aquiclude holds the fresh water back from descending father. In that place, it mixes with salt water which has worked its way inland through the limestone cracks. The mixture of fresh water and salt water is lighter than the salt water alone, so it floats on top of it. In the picture, notice the brackish water lens which the mixture of fresh water and salt water have created, and how that brackish water lens is buoyed up against the aquiclude by the heavier salt water beneath it. This brackish water lens *is* the ‘Ewa Caprock Aquifer.

Below the brown-clay Aquiclude 1 is another area of salt water coming in from the sea. Then there is a very dense and quite impervious level of Clay and Marine Sediment. It is this bottom layer of the caprock which does the job of separating the ocean water from the Pearl Harbor fresh water lens which has percolated down from the mountains and highlands.

There are, then, two completely different aquifers beneath the whole of the ‘Ewa Plain – the great Pearl Harbor Aquifer beneath the deepest, impervious level of the caprock, which provides us our drinking water. And in the higher levels of the caprock, there is a great brackish water ‘Ewa Caprock Aquifer.

It is extremely important to know that this higher ‘Ewa Caprock Aquifer depends on the land directly above it for recharge. The three major sources for recharge are rain and and large-winter-storm water flow, lateral and upward inflow from the basal aquifer, and the irrigation of farms, golf courses and public areas directly above it. Aloun Farms (Ho’opili/UHWO) irrigates with fresh water from the deep basal aquifer. This is an additional source of “new” water for the aquifer.

The brackish water of the Caprock Aquifer is too saline to drink, but during sugar times this brackish water from the higher caprock aquifer was used to irrigate a great part of the sugar lands on the ‘Ewa plain. Today, the City of Kapolei and Gentry Development use it for their irrigation of public places. The Honouliuli Sewer treatment plant draws from it. And many industrial users in Campbell Industrial Park also use its water.

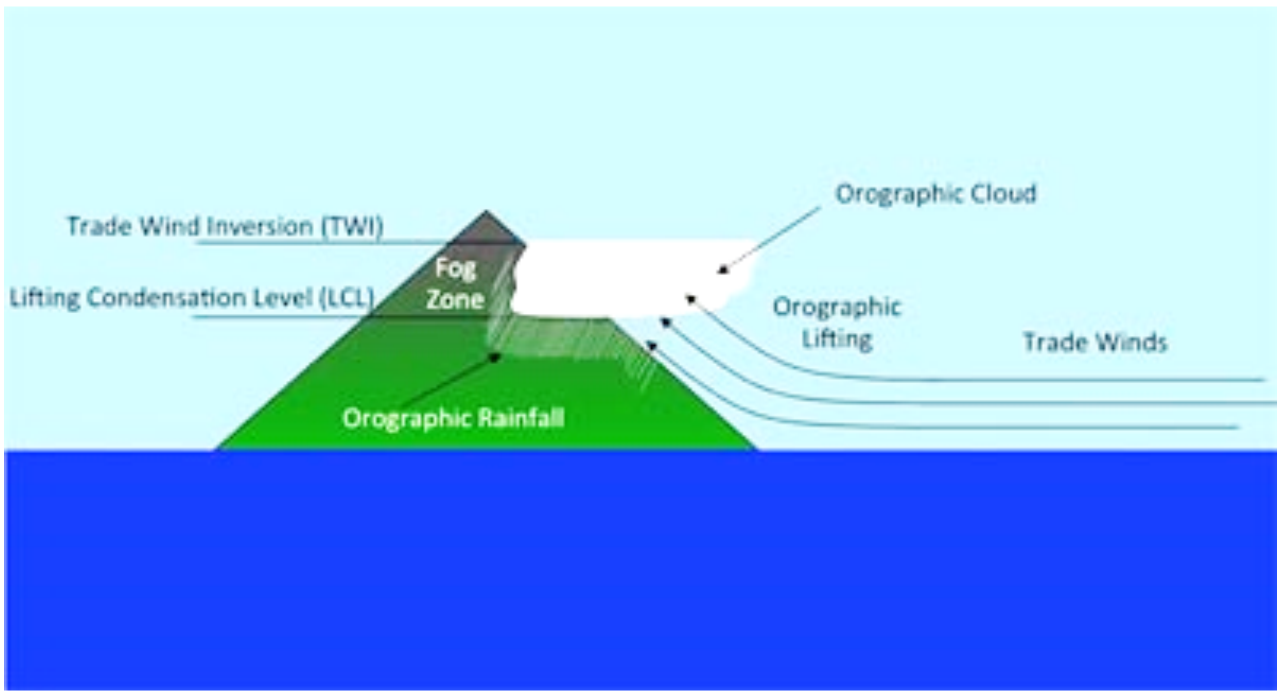
If we cover over Ho'opili and UHWO, we lose all of the recharge for the aquifer from rainfall and irrigation from the Ho’opili and UHWO farmlands.

Part Two
Drastic Decrease in Rainfall to Impact all Hawai'i Aquifers

In the last forty years, Hawai'i has lost 20% of its annual rainfall. What climate change will bring in the future is very uncertain. There are many contradictory projections. However, forecasts produced by the University of Hawaii do predict that, *if this decrease continues at its current rate*, by the last quarter of this century, the leeward sides of most Hawaiian Islands will have 70% to 90% less rainfall than today.

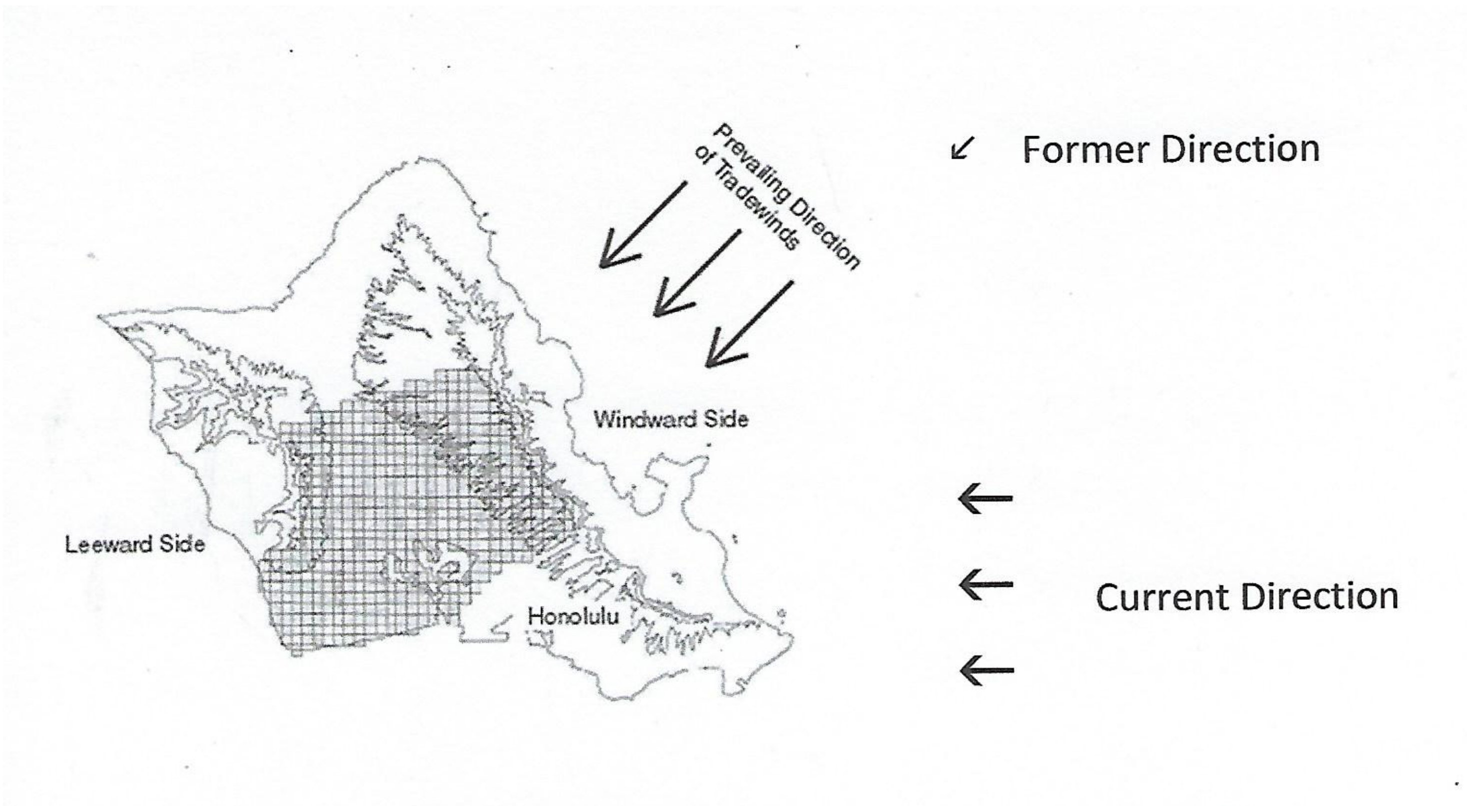
Why is the cause of this? Historically, the leeward sides of the islands seldom get tradewind rains, and depend on the great storms of winter—cold fronts dipping down from the north, and Kona Storms coming from the west—for their rainfall. Warming seas have caused these storms to migrate north, and storm after storm is passing the islands by.

But the windward side is also in trouble. As the seas have warmed, the path of the tradewinds coming across the Pacific has moved to the south. Historically, the trades have reached the islands from the East North East, hitting the Ko'olaus head-on, with the mountains forcing their warm, moisture-laden air to rise, where it cooled and condensed, creating rainfall that provided 65% of our water.



Orographic means "caused by a mountain."

Now that tradewinds are arriving more from the East, rather than from the East North East, they are glancing by the Ko'olaus, rather than hitting them straight-on, producing considerably less rising action and considerably less rainfall. If warming seas cause the tradewind direction to continue shifting southward, this could become much more of a problem.



But the story gets worse. The warming seas have killed the winds altogether on many days. Forty years ago, we had tradewinds on 291 days a year. We currently have trades 210 days. That's a drop of 81 days, a quarter of the days in a year. And with temperatures continuing to rise, we can expect to lose more tradewind days. No trades, no rain on the Ko'olau side.

The University of Hawaii Department of Geography has been studying all of this, producing conflicting predictions.. The maps on the next page Statistical Downscaling Studies. They show what the wet season and dry season will bring if the decrease in rainfall cointinues at its current rater.

It is clear that the Leeward and Leeward Coast areas will be hardest hit.

If the maps below showed today's conditions, they would be entirely white. The colors show the differences from today.

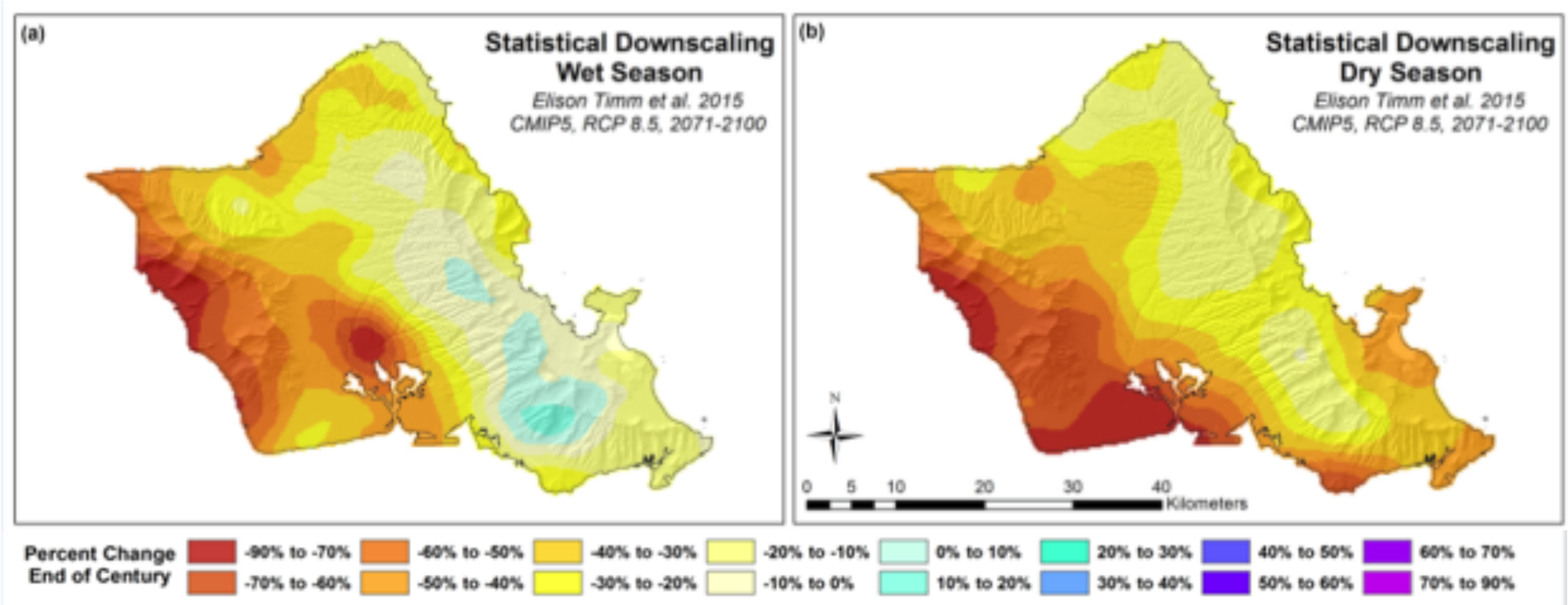


Figure developed by Abby Frazier, Univ. of Hawaii. Modified from data presented in Helweg et al. 2016

Part Three
Impact on 'Ewa Caprock Aquifer
The Need to Reverse Plans to Build

What will this ever-further-decreasing rainfall do to our aquifers? As the decades progress, year after year, aquifers will become further and furthe shrunken. In the drawing above, the reddest area is right over the 'Ewa Caprock Aquifer.

Today, houses and streets cover most of the Ewa Plain. Rainwater hits their hard surfaces and is directed into storm drains which lead to the ocean. Given the terrible and ever-increasing shortage of rainfall expected over the next fifty years, and the fact that the open farmland of UHWO and Ho'opili are major sources for rainfall and irrigation replenishing that caprock aquifer, and the fact that if it is not replenished, the water will eventually become so saline that it cannot be used, it is clear that we must stop building over the aquifer and preserve the farmland that is left.

Three Things that Must Be Reversed to Save the Aquifer

1. Placement of the new farm at UHWO

UHWest O'ahu, outlined in red, occupies a major part of the last open land above the 'Ewa Caprock Aquifer. Most of the property is currently in farming. But residential and commercial development is planned for the section marked in yellow in the map below.

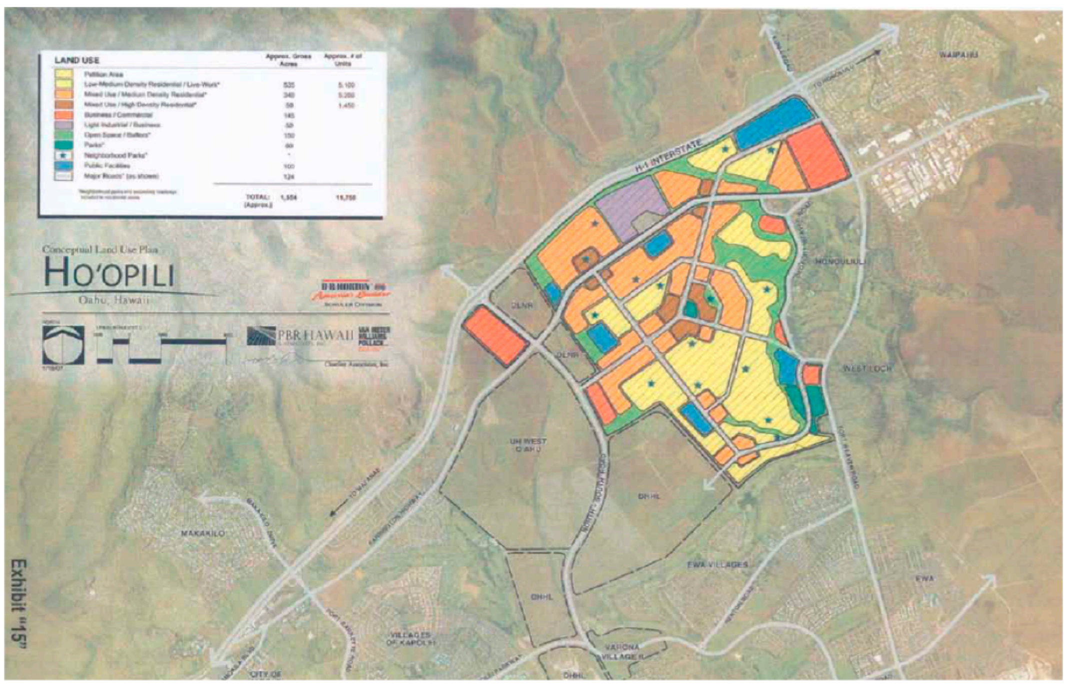
UHWO has a marvelous "Sustainable Community Food Systems" program to educate farmers and move Hawai'i towards self-sustainability. This program has received a large grant and will work with Ma'o Farms to develop a 200 acre farm, currently planned for property above the freeway.

There is a serious problem in placing the farm above the freeway, however. The upper edge of the 'Ewa Caprock does not stretch that far inland. If UHWO puts the new 200 acre farm *north of* the freeway, the farm's irrigation and the rainfall it receives will seep down into the ground *north of* the freeway, eventually making its way to the lower 'Ewa or Pearl Harbor aquifer beneath the caprock, with very little, or none of it, reaching the Caprock Aquifer, *south of* the freeway.

The 'Ewa Caprock Aquifer depends on the lands directly above it for recharge from the irrigation, rainfall, and storm inflow. To help save the aquifer, the farm must be put on the property below the freeway.

The UHWO property north of the freeway includes both flatland and hillside. The residential and commercial development now slated for the flatland of the lower campus must be moved to the hillside above the freeway where its view lots can command higher prices. And the new farm must be moved to the lower campus to help maintain recharge of the 'Ewa Caprock Aquifer.

2. Ho'opili



The Ho'opili development is just across the road from UHWO, to the East. They are fast building their planned 12,000 houses. Ho'opili and UHWO cover the highest portion of the caprock aquifer, the area also farthest from the sea, where the aquifer water is least saline. As open, irrigated lands, they provide the fresh water to this high end of the brackish water lens. We will lose this all-important recharge when they are covered.

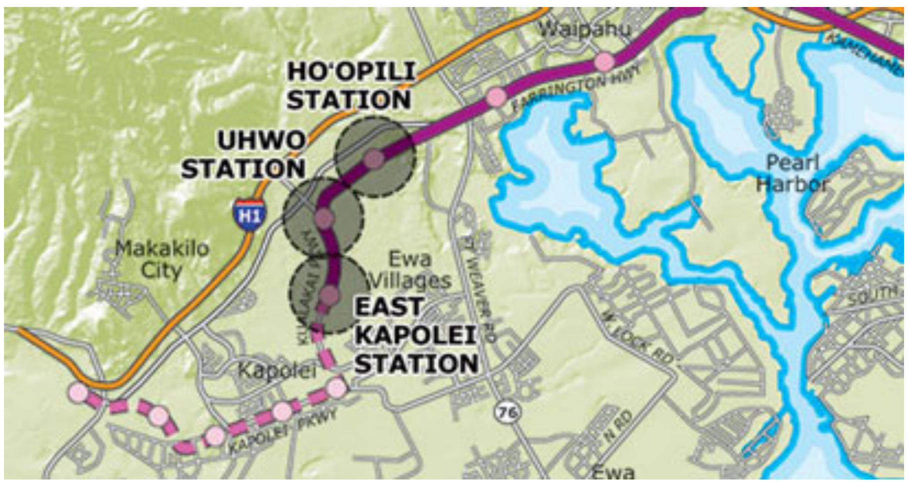
As the largest of the remaining open places above the Caprock Aquifer, these farmlands are the last hope of recharging the aquifer from above. When they are covered with hard surfaces, we will lose an aquifer, an aquifer that now provides water for public spaces and industrial businesses on the ‘Ewa plain.   As we face the unknowns of decades of drastically reduced rainfall, continuing to build on those lands is simply wrong.

It must be kept in mind that none of the information in these pages was on anybody’s radar when the Ho’opili project was approved.

3. Transit Oriented Development

There has been a bill before the legislature this year which would create a new HCDA East Kapolei, specifically to push forward intense Transit Oriented Development (TOD) surrounding three Rail stations over the Caprock Aquifer. There are people in high places pushing this effort. Transit Oriented Development means high rises and other dense development in the mile surrounding the site.   This, of course, is exactly the opposite of what we need to happen.

Multi-level parking structures for West-side drivers using the Rail are needed at the stations, and should be allowed. But TOD development must be put in the Primary Urban Center, between Waipahu and the downtown.   The Caprock Aquifer must be given every chance to survive.



Part Four
Food Crisis by Mid-century
Need for a Farming Renaissance

While local government and the news media are ignoring it, the world is experiencing a population explosion. In 1940, the world had 2 billion people. Just forty years later, in 1980, the world had 4 billion people. In 2020, it will have nearly 8 billion people. This exponential explosion will continue. To feed everyone, in just thirty years, we will need to double world food production. For every bite of food on earth today, we will need two by 2050. The United Nations predicts that we will have 371 million people without food, equal to the entire population of the United States.

Today, Hawai'i imports 90% of our food. In 2050 the price of the little food available will be too high to bring in. We need to become 100% food-self-sustaining on just 30 years. Further, recently the state predicted an increase of 220,000 *new* people in Hawaii by 2045. We will need to increase our food production by 12 times if we are to feed everyone in 2050. To accomplish this, we must start NOW. Ho'opili and UHWO lands and the Koa Ridge lands MUST be kept in agriculture. We must open up thousands more acres. We also need more cattle ranges, dairies, chicken and egg farms, and piggeries. We need all of the businesses that will provide machines and supplies for farming, and businesses to prepare the foods for sale. We need schools to prepare our students for all of the jobs in a full-blown agricultural renaissnce. We need so much.

Read more about this at www.2050Hawaii.gov. Protect the 'Ewa Caprock Aquifer! Spark an agriculture revolution! Let our people survive!

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Change will not come if we wait for some other person or if we wait for some other time.
We are the ones we have been waiting for. We are the change that we seek. (Barack Obama, 2008)