The last two weeks we discussed wastewater and how the water we turn on in our faucets makes its way into the city sewer system, a regional wastewater treatment plant, and eventually into the Pacific Ocean (after being treated and discharged at a wastewater treatment plant).

This week we will discuss where we get our drinking water from – in other words, when you turn on your faucet to wash your hands or turn on your shower to bathe, where does this water come from?

First, I want to discuss a few global statistics on drinking water (potable water):

1) Today there are over 800 million people in the world who don't have access to clean drinking water (World Health Organization).

2) For every $1 spent on obtaining clean water, $5.50 is saved by preventing illness and disease (WHO).

3) At any given time, 50% of the developing world will suffer an illness directly attributed to unsafe or too little water.

4) In some developing countries, women/girls spend up to 4 hours a day fetching water!

Here are a few global statistics on wastewater:

1) Another huge global problem: where do you put all the human feces? 2.6 billion people lack any sanitation.

2) 200 million tons of sewage untreated every year.

3) 90% of developing world discharges raw sewage directly into soil, lakes, rivers, and oceans.

4) WHO estimates 1.4 million children die each year.

5) Every $1 invested returns over $8!

Clearly, these are sobering statistics. So, not only is having access to clean water (potable) a huge global problem – but so is handling the waste generated by the Earth's 7 Billion inhabitants. As I always stress during my lectures (when I teach on campus), Americans take a lot of things for granted, such as always having potable water within reach and advanced sewage collection systems. We are so spoiled that rarely do we even think about the source of water coming out of tap and/or where the water goes once we flush the toilet! Of course, there are rare exceptions such as the recent crisis in Flint, Michigan. But generally speaking, the United States has excellent water distribution systems as well as advanced sewage systems and treatment plants.

If you ever get a chance I strongly recommend traveling abroad to under-developed countries so you can get an idea how other people live. I guarantee you will come back home with a new appreciation of just how spoiled Americans are in regards to these two issues.

Here are some additional thoughts before we dive-in to the meat of this week's lecture: where does our water come from.

Handwashing: The simple act of washing one's hand can reduce diarrheal disease by 33%!

Global Water Supply: The world's total water supply can't be increased; It can only be better managed.

- What do I mean by this? Imagine being in space and you are looking down on planet earth (just like those pictures we see from the International Space Station); you see a lot of blue which reveals the majority of our planet's surface is covered by water. You also see a lot of white clouds, right? These clouds also hold a lot of water (in the form of water vapor)….so the total amount of water on earth (liquid, solid(ice), gas) cannot change. So, the next time you turn on your tap and drink a glass of water think about how that same water has been on this planet for thousands of years!

Of course, the amount of water in each state can change: for example, we might see a lot of glaciers melt over the next hundred years which would DECREASE the amount of solid water (ice) on earth, but it would INCREASE the amount of liquid and gaseous water on earth in exactly the same proportion.

Having said that, less than 3% of the Earth's water is fresh, and most of it is tied up in the polar ice caps or is too deep to access. So, again, all we can do is better manage the water that is on Earth.

I want to remind everyone of the 4 types of water conveyance systems we might see in a street in Los Angeles:

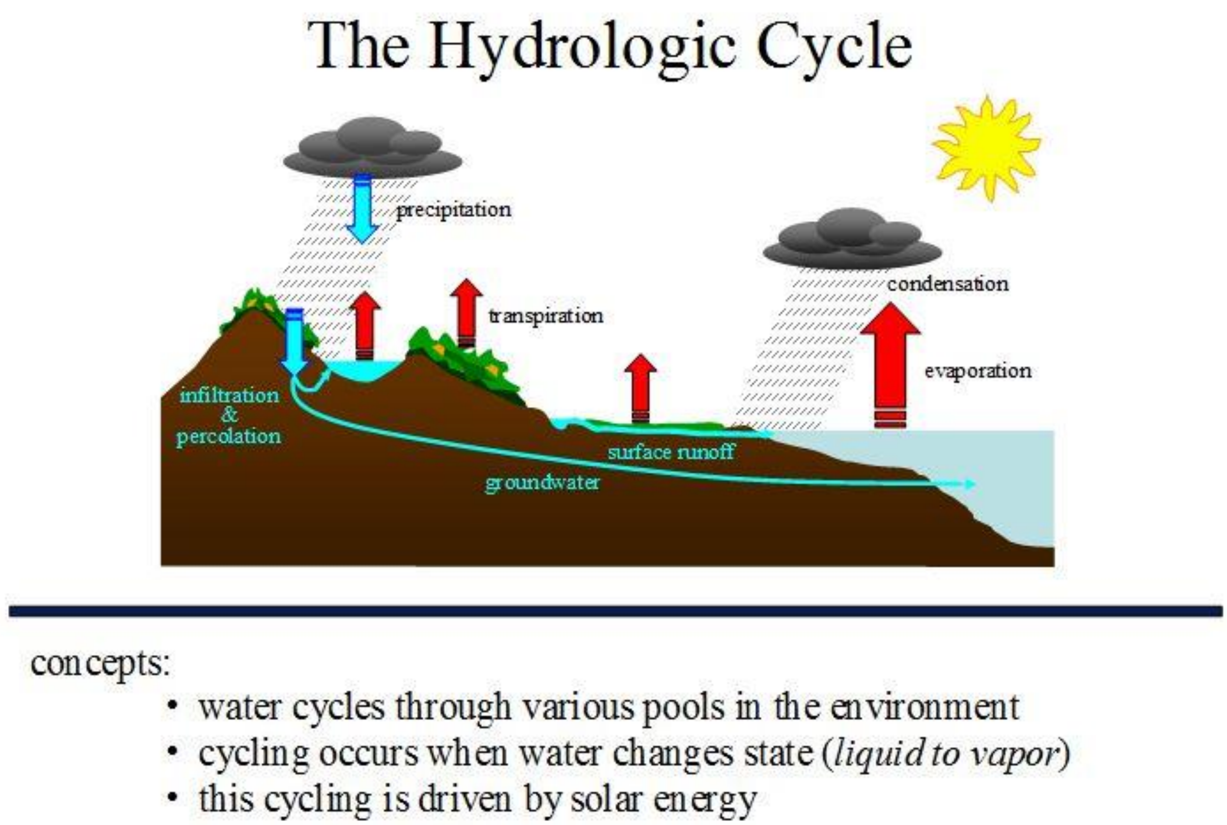
1) Drinking water
2) Sewer system
3) Reclaimed water
4) Storm drain (MS4)

This picture does not include the water main going down most streets (all you see are the fire hydrants and small water main access covers as you walk down the street). It also doesn’t include reclaimed pipes. While these were relatively rare in the past, today we are experiencing a large expansion of most reclaimed water systems in California due to the drought. What is reclaimed water? It is treated wastewater that is beneficially reused to mainly irrigate lawns. Reclaimed water can also be used for industrial cooling towers and even inside buildings for flushing toilets. Obviously, the more reclaimed water we use for these uses, the less drinking water (potable water) we “waste” on these activities. Have you ever seen a purple fire hydrant? If so, that hydrant is supplied with reclaimed water – not potable water (i.e., yellow fire hydrant). Also, sometimes you will see signs at parks/golf courses/cemeteries that state: “Do not drink – irrigated with reclaimed water”.

O.K., as I previously stated, water exists in 3 different states on Earth:

1) Solid (ice)
2) Liquid
3) Gas (water vapor)

The movement of water throughout our environment is known as the "Hydrologic Cycle" – remember the total amount of water does NOT change!



Starts with evaporation from ocean (water to gas)
- 80% of evaporation is from oceans
- 20% from inland water and vegetation
- Winds transport evaporated water around the globe

Relative Humidity is another important concept when we talk about water and its movement throughout our environment:

$$R.H. = \frac{\text{Actual Vapor Pressure}}{\text{Saturation Vapor Pressure}} \times 100$$

* Saturation VP is a unique function of TEMPERATURE *

There is a limit to how much water vapor air can hold and it is temperature dependent: colder air holds less water vapor than warmer air. For example, on a cold morning when you walk outside you can see your breath, right? The warm air in your lungs loses water as it hits the cold air outside your body and this is what you see. You all have watched the news and seen the weatherman (or woman) talk about the day's relative humidity percentage. Let's do a simple example of how this is calculated. Let's say it's 90 degrees Fahrenheit outside and I tell you that the Saturation Vapor Pressure (the maximum amount of water that the air can hold) is 48.1 millibars. Now, let's say I give you a machine that can measure the actual Vapor Pressure in the outside air and you find it is 10.2 millibars…..what is the Relative Humidity? It is 21%:

Ex: @ 90 F, Sat. VP = 48.1 mb
- What is R.H. if actual VP is 10.2 mb at 90 F?

10.2mb/48.1mb x 100 = 21%

Another important concept important in our discussion of how air moves through our environment is the **Adiabatic Lapse Rate:** Air cools 3.5 degrees F per 1,000 foot elevation gain. This is one of the driving forces for the Hydrologic Cycle. So, let's say it's 77 degrees where I am standing and you walk up a 2,000 foot ladder and stop directly above me……what would be the air temperature up where you are, looking directly down at me 2,000 feet below? It would be 70 degrees because of the adiabatic lapse rate.

Problem: We climb Mt. Whitney (15,000') – how cold is it at the summit if it is 70 F in Lone Pine (3,000')?

The answer is 28 F, right?

Water Chemistry

Water has some strange properties due to the hydrogen bonding between the water molecules:

1) Expansion upon freezing (forms a crystalline structure)
2) Higher boiling temperature (vs. other Group 6A Hydrides)
3) Higher melting point (32 Degrees)
4) Higher cohesion (sticks together – i.e., straw)
5) Higher Specific Heat (Resists changes in temp.)
6) High Heat of Vaporization (Resists evaporating)
7) Maximum Density occurs at 4 degrees Celsius

In other words, the hydrogen bonding gives water some unique properties and if it wasn't for the hydrogen bonding we probably wouldn't be able to survive on earth. Can you imagine how fast water would evaporate from the oceans/lakes/etc. if water had a much lower heat of vaporization?

It's important to stress that in the middle of winter, ice on a lake floats on top of water and the deepest water (at the bottom) would have a temperature of 4 degrees Celsius (around 39 degrees F.).

3 Imported Sources of Water: City of Los Angeles

1) Colorado River

The Colorado River is the most legislated, debated, and litigated river in the world. It is the main water source for the Southwestern United States. Due to various lawsuits and the inability to come to an agreement, the 7 States (Wyoming, Colorado, Utah, New Mexico, Arizona, Nevada, and California) continue to challenge each other's rights to the Colorado River's water. Various interstate compacts, federal and state laws, water contracts, and treaties are now known as "The Law of the River." However, I want to stress that even today there is no consensus among all the parties involved, including Mexico!

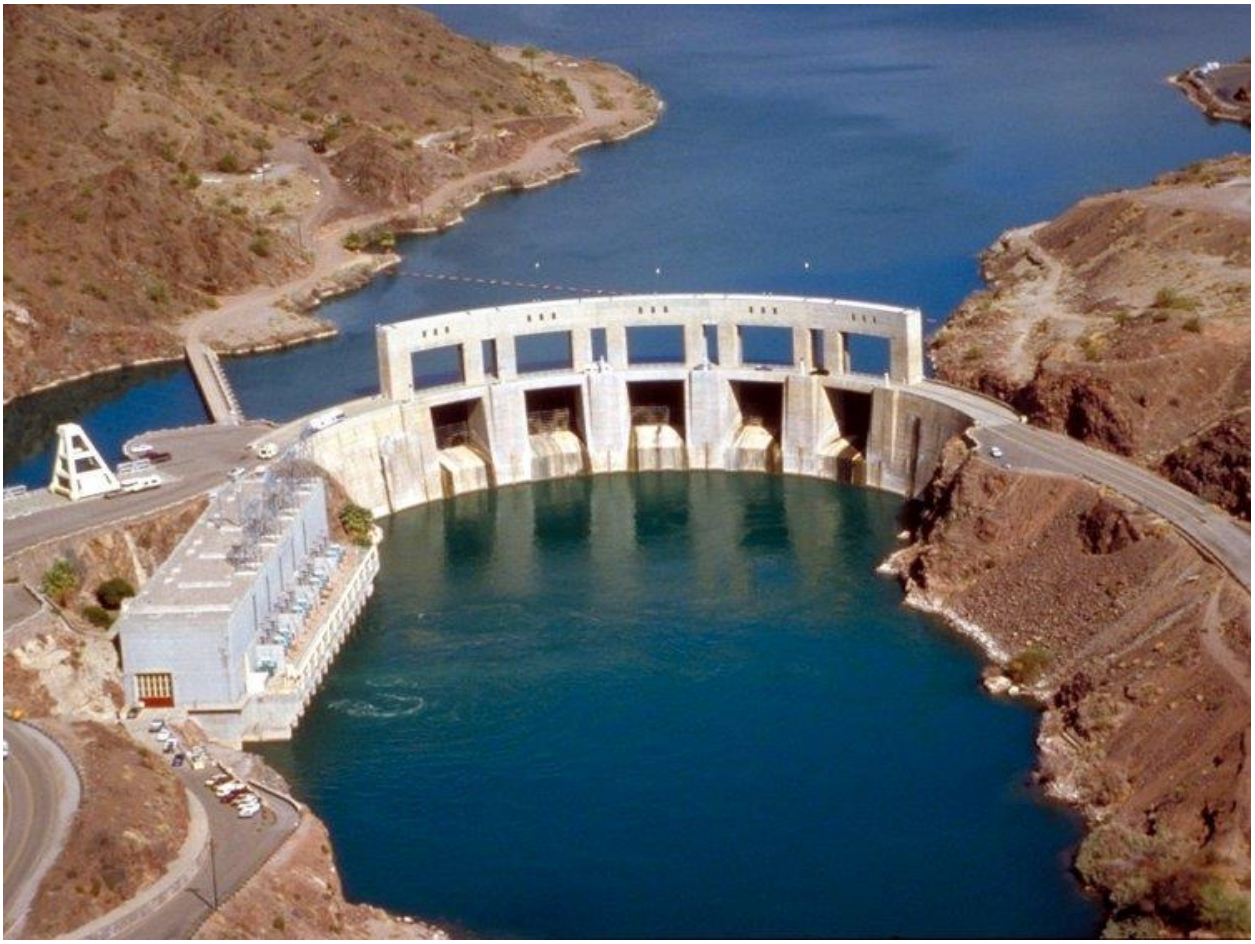
To make matters even more complicated, the Metropolitan Water District was formed in 1928 and several cities joined forces to construct the Colorado River Aqueduct. The aqueduct was completed in 1941 and delivers about 1.2 million acre-feet of water to Southern California (about 1 billion gallons of water a day!). The aqueduct is over 240 miles long and is quite an engineering feat. The start of the aqueduct is Lake Havasu – Parker Dam created Lake Havasu specifically for the aqueduct.

In the map below, you can see the Colorado River Aqueduct towards the bottom left. We will talk about the other 2 aqueducts shortly (California and Los Angeles Aqueducts).

Exhibit 3A
Major Sources of Water Supply for Los Angeles

Parker Dam

- Created Lake Havasu (648,000 af)
- Deepest dam in the world (320 feet), but 73% is underground
- During construction: excavated 235 feet below the river bed
- Dam was completed in 1938



The photo above is misleading since the majority of the dam can't be seen because it is below the water level. Needless to say, it is extremely deep!

O.K., now let's talk about the California Aqueduct or "State Water Project" as it is also known as:

Facts about the SWP

- 580 miles of aqueducts (444 = California Aqueduct)
- 15 pumping plants along 444 miles lifts water a total of 3,500 feet
- Edmonston Pumping Plant lifts water almost 2,000 feet (record)
- Two branches: East (Lake Perris) and West (Castaic Lake)
- Completed in 1972

This aqueduct was also a major engineering feat. The sources of water come from all the way above Sacramento since the Feather and Sacramento Rivers contribute to the water flows into the Aqueduct. The aqueduct itself starts in the Sacramento Delta at the Banks Pumping Plant. The Edmonston Pumping Plant, at the base of the Tehachapi Mountains, lifts the water almost 2,000 feet over the mountains and into Pyramid Lake and Castaic Lake, which is the terminus of the Western Branch.

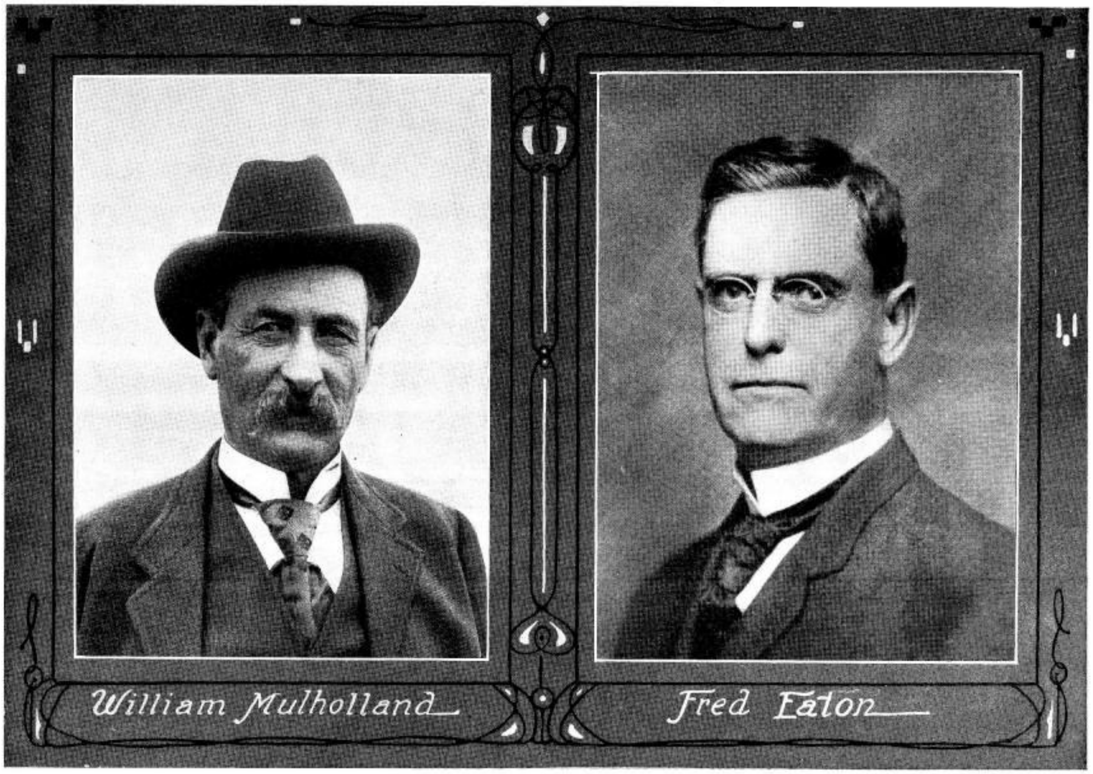
The 15 pumping plants use a tremendous amount of energy (just like the 6 pumping plants along the Colorado River Aqueduct). In fact, the State Water Project is the single biggest electricity user in the State of California! Also, evaporation causes significant amounts of water to be lost before the terminus of the Eastern and Western branches. Clearly, the future of water security in Los Angeles is going to have to be based on local supplies of water. How can we increase the amount of local water? One big potential source is Stormwater. As most of you know or have seen with your own two eyes, almost all of the rain water that falls on Los Angeles goes straight out to the Los Angeles River and makes its way to the ocean. There is a huge movement in Los Angeles to start capturing this rain water – either through direct means (i.e., cisterns) or indirect means (i.e., infiltrating the water into the groundwater table). In my opinion, the use of stormwater, in conjunction with expanding reclaimed water use, will account for a tremendous increase in the amount of local water supplies which will eventually decrease our reliance on imported water.

O.K., now let's turn our attention to my favorite source of imported water into Los Angles: Los Angeles Aqueduct

- 1908-1913
- Total construction cost approx. $23 million (bond)
- Eastern side of Sierra Nevada
- Entirely by gravity

Yes, you read the last bullet point correctly: ENTIRELY BY GRAVITY. So, unlike the Colorado River and California Aqueducts which use TREMENDOUS amounts of energy, the L.A. Aqueduct uses no energy whatsoever. The water flows entirely by gravity all the way from the Owens Valley to Los Angeles (over 200 miles). So, now you know why this aqueduct continues to amaze me even today…..imagine the engineering feat, especially considering it was built between 1908 and 1913. There weren't a whole lot of machines available at that time; the majority of the aqueduct was built by mules and manual labor – not withstanding all the dynamite used for the tunnels!

Contrary to popular belief, the original idea for the aqueduct came from Fred Eaton, not William Mulholland. Mr. Eaton was the former L.A. City Engineer and Mayor. He spent $30,000 of his own money in the late 1890's to investigate this idea. He approached Mulholland and City Leaders in 1904 with a Private/Public partnership idea. After Mulholland himself surveyed several possible routes, the idea gained traction. Mulholland stated that not only could he build the aqueduct entirely for gravity flow, but the aqueduct would generate lots of money by the sale of electricity from hydroelectric plants.



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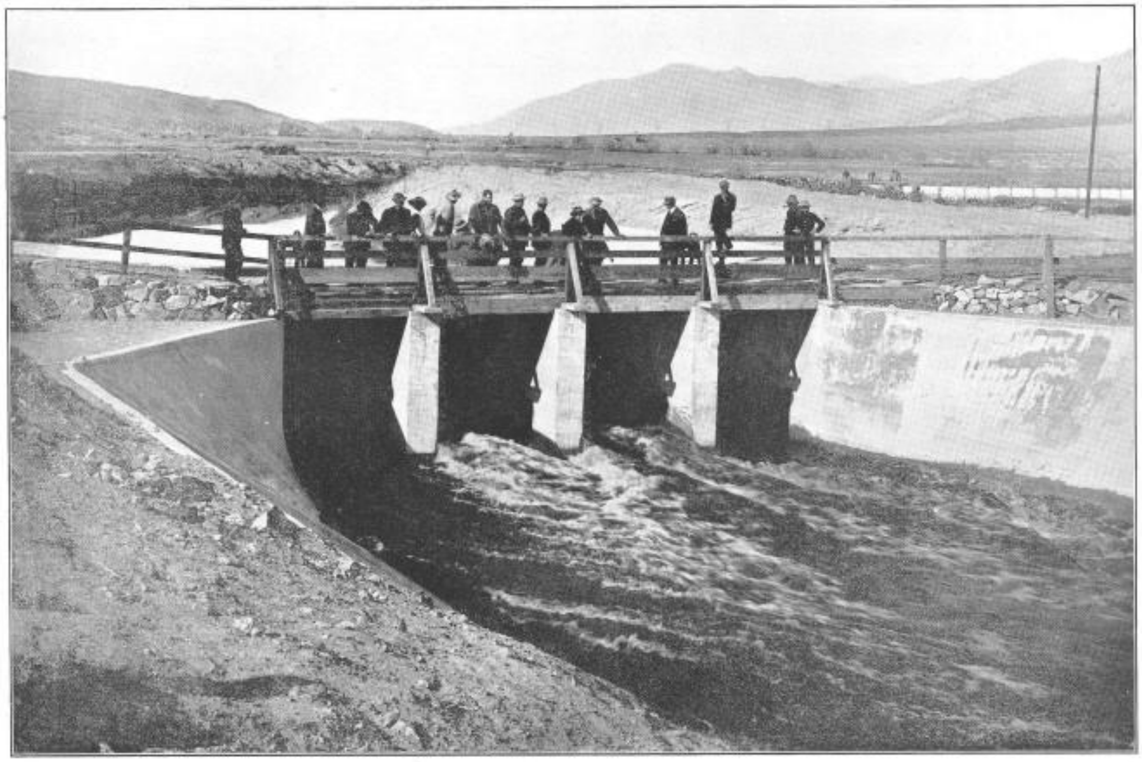
Two bond measures were brought before the voters of Los Angeles in 1905 and 1907. Both of them passed by an overwhelming majority. The aqueduct was built on time and under budget – a rarity for a government project!

Here is a picture of the opening gates when the aqueduct first began operation in 1913. I recently took a tour of the aqueduct and the original structure remains unchanged over 100 years later!



OPENING THE AQUEDUCT HEADGATES, FEBRUARY 13, 1913

And here is a photo of the terminus of the original aqueduct and the second aqueduct (built in the 1970s). The original aqueduct is off to the left and can be seen discharging water through the mountain (Mulholland used dynamite to tunnel through the mountain). The newer aqueduct can be seen descending down the mountain through the cascades. Both aqueducts bring water to Los Angeles and the pipes seen in the photos generate electricity. So you only usually see the water flowing down the cascades (and the original open conduit) when L.A. is not generating electricity.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