BUT THE DROUGHT CAME BACK? THE VERY NEXT YEAR!

Harvard University | CS171 |Spring 2015 | Final Project | Process Book

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OVERVIEW AND MOTIVATION

In April 2015, California Governor, Jerry Brown, issued new directives which aim to reduce water consumption including an unprecedented mandatory 25% cut in urban water use. These measures were intended to address the growing concerns and threats of the sustained drought over the last couple of years.

As concerned Californians working for a renewable energy technology company, we are deeply engaged in promoting sustainable living practices which will impact our friends and family as well as our posterity. As a result, we are very passionate about gathering insights into this topic which may lead to some innovative solutions that could help address this pressing problem.

RELATED WORK

The following resources have inspired us and helped us drive forward a meaningful visualization for the purposes of conveying important insights into how the drought has affected California in the last few years.

1) ▶ MIT Residential Footprint - YouTube. (n.d.). Retrieved April 11, 2015, from https://www.youtube.com/watch?v=9-vl6AJ32fg
   a) We looked at some of the views presented in the MIT commute visualization and had considered a similar layout.

2) ▶ The Cat Came Back - Camp Songs - Kids Songs - Children's Songs by The Learning Station - YouTube. (n.d.). Retrieved April 11, 2015, from https://www.youtube.com/watch?v=LjMffHG1V_Q
   a) This song from our childhood helped inspired the title for our project.

3) California Drought Information | USGS California Water Science Center. (n.d.). Retrieved April 11, 2015, from http://ca.water.usgs.gov/data/drought/
   a) This website was referred to us by Eric Reichard (egreich@usgs.gov) who is our direct contact from USGS for any data questions that we may have.

4) California Land & Water Use. (n.d.). Retrieved April 11, 2015, from http://www.water.ca.gov/landwateruse/surveys.cfm
   a) Data on agriculture uses of water if we decide to incorporate California crops and how crop selection affects the severity of the drought.

5) CDFA > STATISTICS. (n.d.). Retrieved April 11, 2015, from http://www.cdfa.ca.gov/statistics/
   a) Agriculture production data could be located here.

6) cida.usgs.gov/ca_drought/. (n.d.). Retrieved April 11, 2015, from http://cida.usgs.gov/ca_drought/
   a) A self-reported data visualization of the drought was created using freely available USHS data.

7) CIDA-Viz/ca_reservoirs.json at master · USGS-CIDA/CIDA-Viz · GitHub. (n.d.). Retrieved April 11, 2015, from https://github.com/USGS-CIDA/CIDA-Viz/blob/master/ca_reservoirs/Data/ca_reservoirs.json
   a) This is the reservoir capacity and utilization data broken out by date and by reservoir name.

8) Crop_Coeffients.pdf. (n.d.). Retrieved from http://www.cimis.water.ca.gov/Content/PDF/Crop_Coeffients.pdf
   a) The crop coefficients rates are multiplied by then evaporation-transpiration of the reference group. We were interested in using the data as an additional point of reference.

9) How to Estimate Water Useage Required for an Irrigation System. (n.d.). Retrieved April 11, 2015, from http://www.irrigationtutorials.com/how-to-estimate-water-useage-required-for-an-irrigation-system/
   a) We were considering the use of the 'formula to calculate the gallons of irrigation water needed per day' to derive water usage where other more precise data was not available.

10) Mapping the Spread of Drought Across the U.S. - NYTimes.com. (n.d.). Retrieved April 11, 2015, from http://www.nytimes.com/interactive/2014/upshot/mapping-the-spread-of-drought-across-the-us.html
   a) This data vis was created by Mike Bostock and it shows how the drought has affected the US at large. We wanted to look at California in particular, but it was definitely interesting to see how the drought has affected many other parts of the country.

11) Microsoft PowerPoint - Blaine-Hanson Water Forum complete.ppt - blaine-hanson_water_forum_complete.pdf. (n.d.). Retrieved from http://www.pge.com/includes/docs/pdfs/shared/edusafety/training/pec/water/blaine-hanson_water_forum_complete.pdf
   a) General information from PGE on Evapotranspiration based on the crop type. It was a possibility to use the data presented in the slides to infer water usage for certain crops grown in California.

12) Streaming through 1Channel.ch. (n.d.). Retrieved April 11, 2015, from https://add2ac80562d5288b8b87115bba350a041fd1663.googledrive.com/host/0B2kv7wOF5KquclBsZXlUR1hCNms/index.html
   a) The list to scatter transition was of interest. It has no bearing on the California Drought, but the data vis involves a geospatial map, list, and scatter plot which we are considering to include in our final project.

13) USGS Release: Data-driven Insights on the California Drought (12/8/2014 8:33:13 AM). (n.d.). Retrieved April 11, 2015, from http://www.usgs.gov/newsroom/article.asp?ID=4069#.VSmUZZPK5aZ
   a) This is an example of a well-done data vis using D3 which focuses on the California Drought. It definitely a tremendous inspiration for us in our design process. We believe that our reservoir utilization vis could tell a similar story in a more compelling way.

14) Virtual Water - Discover how much WATER we EAT everyday. (n.d.). Retrieved April 11, 2015, from http://www.angelamorelli.com/water/
   a) This data vis was not only informative, but also, it contains a downwards scrolling transition between visualizations. It would certainly be a nice to have feature for our final project.

15) waterfootprint.org. (n.d.). Retrieved April 11, 2015, from http://waterfootprint.org/en/
   a) The various interactive tools are very inspiring for their application of geospatial mapping methods. The animation during the loading of data is done in good taste. It is definitely a welcome distraction of a transition as it fits the water theme nicely. It would be a nice to have feature between our transitions.

16) Start Using Landsat on AWS | AWS Official Blog. (n.d.). Retrieved April 11, 2015, from https://aws.amazon.com/blogs/aws/start-using-landsat-on-aws/
    a) 'Landsat on AWS' includes over 85,000 shots of the US West region. It is the first time that so much satellite imagery is made available to the public online via Amazon Web Services. We are considering using the images to correspond to the declining reservoir levels over time. Each selection would contain an actual satellite image corresponding to the time selection.

17) List of dams and reservoirs in California - Wikipedia, the free encyclopedia. (n.d.). Retrieved April 17, 2015, from http://en.wikipedia.org/wiki/List_of_dams_and_reservoirs_in_California
    a) This Wikipedia entry includes California dam trivia that could be of interest to the data visualization consumer. They have only tangential connections to the main topic, but they may provide the personal touch that could engage the viewers while they derive insights from our main visualizations.

18) Press, S. S. A. (n.d.). Drought forces California farms to stop pumping river water. Retrieved May 2, 2015, from http://www.sacbee.com/news/state/california/article20065272.html
    a) There is an update on the drought situation. It would be interesting to follow-up to see how much this would affect water withdrawal data.

19) Stockton, N. (2015, February 3). Lack of Rain Isn't the Only Story Behind the West's Brutal Drought. Retrieved May 4, 2015, from http://www.wired.com/2015/02/lack-rain-one-stories-behind-wests-inevitable-2015-drought/
    a) We used an image from this webpage for slide 1 which shows the lack of irrigation water in California.

20) California Drought Crisis Takes Toll On Lake Oroville. (2014, August 20). Retrieved May 4, 2015, from http://www.nbcnews.com/storyline/california-drought/california-drought-crisis-takes-toll-lake-oroville-n185001
    a) We used images from this webpage for slides 2 and 3 which shows before and after conditions in the second largest reservoir in California, Lake Oroville.

21) Before-and-afters of drought-riddled California's vanishing lakes. (n.d.). Retrieved May 4, 2015, from http://www.dailymail.co.uk/news/article-2731091/California-s-vanishing-lakes-Before-photos-reveal-shocking-shriveling-effect-state-s-devastating-drought-decades.html
    a) We used images from this webpage for slides 2 and 3 which shows before and after conditions in the second largest reservoir in California, Lake Oroville.

22) U.S. Drought Monitor Map Archive. (n.d.). Retrieved May 4, 2015, from http://droughtmonitor.unl.edu/MapsAndData/MapArchive.aspx
    a) We used the USDM map archive to create slide 4 with the (3) archived heat maps.

23) You Need To Know: About That Drought. (n.d.). Retrieved May 4, 2015, from http://social.huffingtonpost.com/eve-turow/you-need-to-know-about-th_2_b_6492904.html
    a) We pulled an image from this website for the parched land backdrop feautured in slide 4.

24) Did climate change cause California drought? - CNN.com. (n.d.). Retrieved May 4, 2015, from http://www.cnn.com/2015/04/08/opinions/sobel-california-drought/index.html

a) We used an image from this webpage which shows Governor Jerry Brown's announcement to reduce water usage for Commercial and Residential usage. The Governor used a data vis to make a point regarding how precipitation has dropped off significantly in the last few years.

25) Free Responsive HTML5 CSS Website Templates. (n.d.). Retrieved May 4, 2015, from http://www.templatemo.com
   a) We tried a number of their templates to see which one works the best with our visualizations. Ultimately, we ended up selecting template no. 401, 'Sprint'. It has been selected as a top template list titled: 'Best Free Responsive HTML5 CSS3'.

QUESTIONS

For our data visualization project, we began our journey by attempting to answer the following questions:

1) What is the state of California's water reservoirs in terms of utilization, location, and changes over time?

2) Where is California water being used and how can those use cases be categorized and broken out by volume?

3) Bonus: How do the types of agriculture in California affect water usage over time?

After mocking up our data using QlikView and Excel as well as doing more in-depth background research, we determined that it would be difficult to tie the agriculture data that we had obtained to our water reservoir utilization and water withdrawal data. As a result, we have decided to focus on addressing Questions (1) and (2) for our data vis project.

DATA

In general, data that comes from USGS have already been formatted in CSV and JSON which means that they will require minimal processing as they are structured.

For the purposes of achieving Objective #1, we would need to create two tables from raw files which are 'Daily Reservoir Utilization' and 'Reservoir Meta'. The fields required for 'Daily Reservoir Utilization' include <Reservoir ID>, <Storage Level>, <Date Recorded>. The fields required for 'Reservoir Meta' include <Reservoir ID>, <Storage Capacity>, <Longitude>, <Latitude>, and <Reservoir Name>. The tables will be aggregated on by <Year-Month> using the <Date Recorded> field. The <Average Storage> and <Capacity %> fields will be aggregated by <Year-Month>. The two tables will be joined on <Reservoir ID> as the key. Any reservoir outside of the top 10 capacity reservoirs will be grouped into an Others category. The raw files that enable the above operations are:

storage.json – Fields: 3, Records: 437,881

Reservoir ID	Date Recorded	Storage Level
SHA	1/1/2015	315,000
SHA	2/1/2015	285,000
SHA	3/1/2015	245,000

reservoir.json – Fields: 10, Records: 91

Reservoir ID	Storage Capacity	Longitude	Latitude	Reservoir Name
SHA	524,000	-23.212	27.7142	Shasta
ORO	324,000	-25.212	29.7142	Oroville

For the purposes of achieving Objective #2, we would need to create a '2010 CA Water Withdrawal Data' table. The fields that we would use are <Year>, <Usage>, <Ground or Surface>, <Saline or Fresh>,<Daily Volume>. The raw files that enable the above operations are:

usco2010.xlsx – Fields: 117, Records: 3,225

Year	Source	Usage	Saline or Fresh	Daily Volume
2010	Ground	Agriculture	Fresh	323,000
2010	Surface	Mining	Saline	28,000

Sankey Chart

We chose to use the Sankey chart to visualize the flow of water withdrawals in the state of California. This allowed us to visualize what areas the drought will affect the most.

The data structure for a Sankey Chart consists of Sources, Targets, Values and Nodes.

Sources, Targets and Values define where the water is coming from, where it's going and what volume of water. Water travels through different categories and levels.

1) Water Source:
   a) Surface Water (Reservoirs, Rivers, Creeks, Streams and Lakes)
   b) Ground Water (Pumps and Aquifers)

2) Water Type:
   a) Fresh (Water with a low concentration of dissolved salt and solids, potable water, and water that's not from the sea)
   b) Saline (Water containing salt and not potable)

3) Water Use:
   a) Public Supply
   b) Domestic
   c) Industrial
   d) Irrigation
   e) Irrigation Crop
   f) Irrigation Golf
   g) Livestock
   h) Aquaculture
   i) Mining
   j) Thermoelectric
   k) Thermoelectric once-through
   l) Thermoelectric recirculation

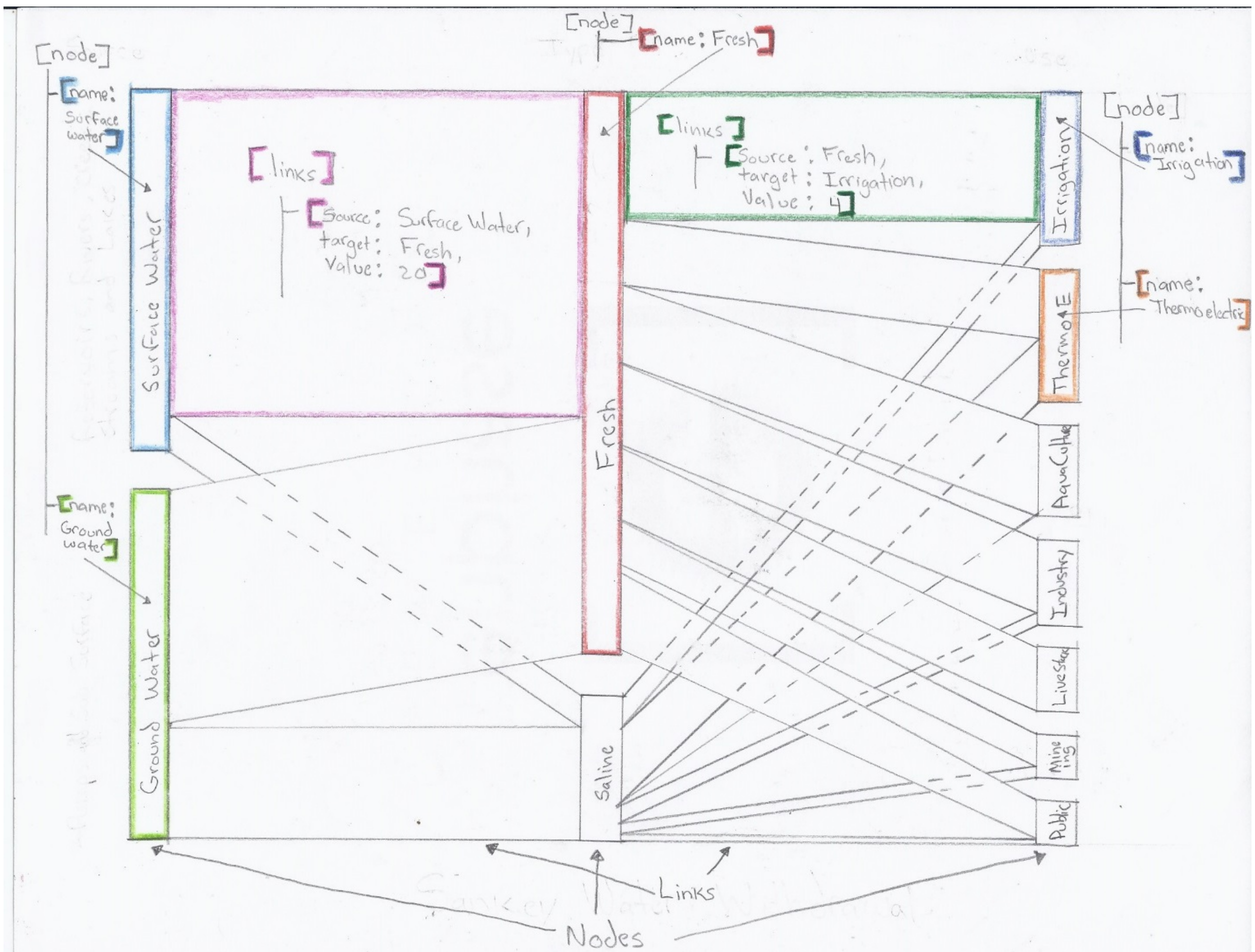
The quantity of water is measured in Millions of Gallons per Day (Mgal/d). By determining how many millions of gallons each reservoir holds you can easily calculate how much water every category is using.

Links are defined as the segments between the nodes, the width of each link is determined by the Value (Mgal/d). Attributes of a link are: Source, Target, and Value.

Nodes are defined as the labeled blocks that are connected by the links. The height of each node is determined by the sum of all the values linking to the node. Attributes of a node are: Name.

Data layout example for Sankey Chart:

```
{"links": [
{"source":"Surface Water","target":"Fresh","value":"20"},
{"source":"Fresh","target":"Irrigation","value":"4"},
] ,
"nodes": [
{"name":"Surface Water"},
{"name":"Fresh"},
] }
```



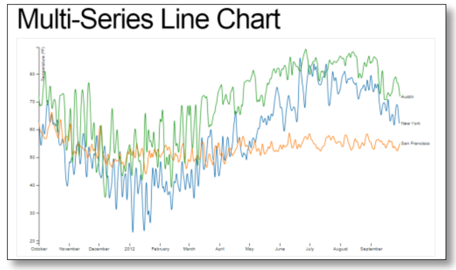
In order to visualize our data, we had to implement a large amount of data preparation, clean up, and wrangling. We began by looking for charts that would fit our models and designs. For the most intriguing charts, we would deconstructed them, and determine how data flows through from the raw to the visualization.

We came to the conclusion that preparing our data to fit the model of the chart would be more efficient and clean, rather than building visualizations from scratch around our source data structures.

1) Line Chart that displays reservoir capacity utilization over time

a) Reference -- http://bl.ocks.org/mbostock/3884955

```
Data Structure from the Example
  {
    name: name,
    values: {
          date: d.date,
          temperature: +d[name]
          }
  }
```



b) Raw Data from USGS

i) In our original data set, we contained dates that were nested alongside the storage level data. We also had multiple fields that were not relevant to our visualization.

```
Reservoir.json
[
        {
                "Station": "ANTELOPE LAKE",
                "ID": "ANT",
                "Elev": 4960,
                "Latitude": 40.18,
                "Longitude": -120.607,
                "County": "PLUMAS",
                "Nat_ID": "CA00037",
                "Year_Built": 1964,
                "Capacity": 22566,
                "Storage": {
                        "20000104": 15313.6428571429,
                        "20000111": 15240.7142857143,
                        "20000118": 15423,
                        "20000125": 15627.8571428571,
                        :
                        "20140826": 18292.1428571429,
                        "20140902": 17945.8571428571,
                        "20140909": 17598.4285714286,
                        "20140916": 17292.6666666667
                }
        },
        {
                "Station": "BEAR",
                "ID": "BAR",
                "Elev": 319,
                "Latitude": 37.367,
                "Longitude": -120.217,
                "County": "MARIPOSA",
```

Date was originally part of the storage label.

c) Processed Data

i) After processing the data and cleaning it up. Were able to parse out Date and Storage into separate fields. We also renamed fields and removed fields that were not needed.

```
Reservoir_processed.json
[
        {
                "name": "ANTELOPE LAKE",
                "capacity": 22566,
                "latitude": 40.18,
                "longitude": -120.607,
                "values": [
                        {
                                "date": "20000104",
                                "storage": 15313.6428571429
                        },
                        {
                                "date": "20000118",
                                "storage": 15423
                        },
                        {
                                "date": "20140916",
                                "storage": 17292.6666666667
                        }
                ]
        },
        {
                "name": "BEAR",
                "capacity": 7700
```

Fields now have their own labels, “date”, and “storage”.

d) Stacked Bar Charts displays reservoir utilization

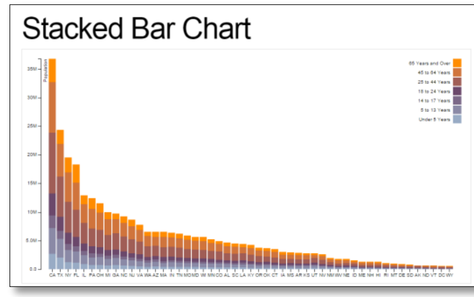
i) Reference -- http://bl.ocks.org/mbostock/3886208

Data Structure in Example

Each object in the data represents each bar.

Each object represents a segment (rectangle in graph).
"y0" represents "y" coordinate at the bottom of the segment.
"y1" represents "y" coordinate at the top of the segment.

If there are 2 segments, with a values of 50 and 40.
The first segment will have a "y0"=0, and "y1"=50.
Then second segment will add the prior segment and have values of "y0"=50, and "y1"=90

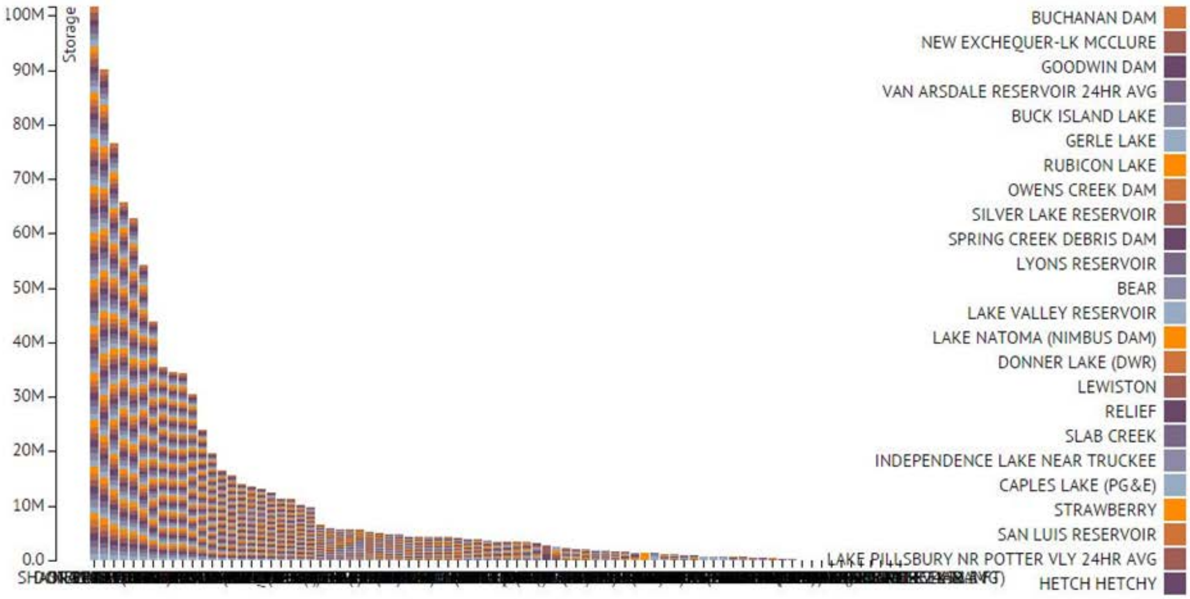


ii) Original Data (From file 1.Line Chart)

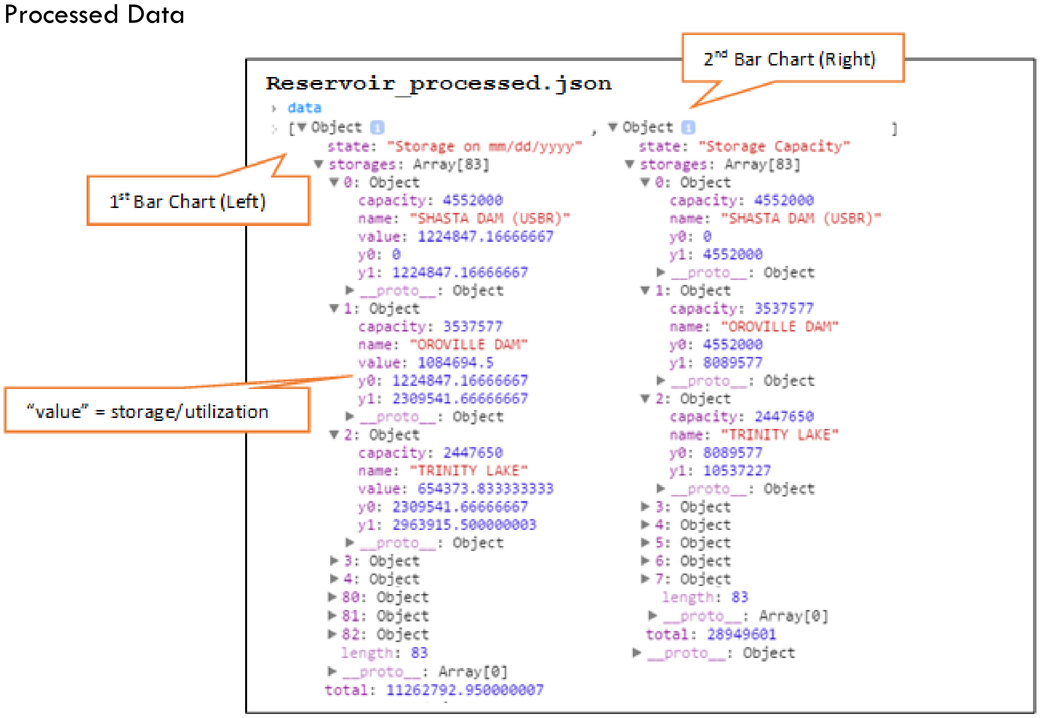
Reservoir_processed.json

```
[
        {
                "name": "ANTELOPE LAKE",
                "capacity": 22566,
                "latitude": 40.18,
                "longitude": -120.607,
                "values": [
                        {
                                "date": "20000104",
                                "storage": 15313.6428571429
                        },
                        {
                                "date": "20000118",
                                "storage": 15423
                        }
```

iii) When loading our unprocessed data into the bar chart, we received some un-expected results and proceeded to clean the data further and prepare it for the bar chart.



e) Processed Data

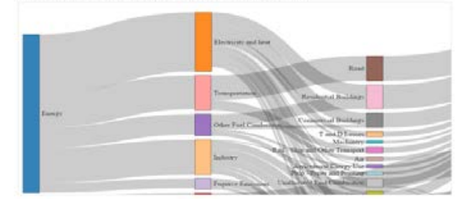


f) Water Withdrawal Sankey Chart

i) Reference -- http://bl.ocks.org/d3noob/5028304

(1) Future Enhancement: Display a drop down or Bar Chart (Bar Chart would be sorted by water usage by state) to allow users to select a state to view the water withdrawals for the selected state and compare it with California's water withdrawals.

Sankey diagram with horizontal and vertical node movement



```
Data Structure in Example
```

```
{
"links": [
{"source":"Agricultural Energy Use","target":"Carbon Dioxide","value":"1.4"},
{"source":"Agriculture","target":"Agriculture Soils","value":"5.2"},
{"source":"Agriculture","target":"Livestock and Manure","value":"5.4"},
{"source":"Agriculture","target":"Other Agriculture","value":"1.7"},

{"source":"Waste","target":"Waste water - Other Waste","value":"1.5"},
{"source":"Waste water - Other Waste","target":"Methane","value":"1.2"},
{"source":"Waste water - Other Waste","target":"Nitrous Oxide","value":"0.3"}
] ,
"nodes": [
{"name":"Energy"},
{"name":"Industrial Processes"},
{"name":"Electricity and heat"},
{"name":"Industry"},
```

ii) Original Raw Data

(1) Usco2010.xlsx, "CountyData" saved as a CSV file

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	STATE	STATEFIPS	COUNTY	COUNTYFIP	FIPS	YEAR	TP-TotPop	PS-GWPop	PS-SWPop	PS-TOPop	PS-WGWFr	PS-WGWSa	PS-WGWTo	PS-WSWFr	PS-WSWSa	PS-WSWTo	PS-WFrTo
2	AL	01	Autauga County	001	01001	2010	54.571			48.222	5.09	0.00	5.09	0.00	0.00	0.00	5.09
3	AL	01	Baldwin County	003	01003	2010	182.265			153.463	22.97	0.00	22.97	0.00	0.00	0.00	22.97
4	AL	01	Barbour County	005	01005	2010	27.457			25.555	4.15	0.00	4.15	0.00	0.00	0.00	4.15
5	AL	01	Bibb County	007	01007	2010	22.915			21.279	4.89	0.00	4.89	0.00	0.00	0.00	4.89
6	AL	01	Blount County	009	01009	2010	57.322			44.464	2.44	0.00	2.44	52.17	0.00	52.17	54.61
7	AL	01	Bullock County	011	01011	2010	10.914			10.176	2.30	0.00	2.30	0.00	0.00	0.00	2.30
8	AL	01	Butler County	013	01013	2010	20.947			17.599	2.70	0.00	2.70	0.00	0.00	0.00	2.70
9	AL	01	Calhoun County	015	01015	2010	118.572			112.390	20.83	0.00	20.83	2.47	0.00	2.47	23.30
10	AL	01	Chambers County	017	01017	2010	34.215			25.875	0.00	0.00	0.00	4.31	0.00	4.31	4.31
11	AL	01	Cherokee County	019	01019	2010	25.989			17.876	2.53	0.00	2.53	0.96	0.00	0.96	3.49

(2) Usco2010.xlsx, "DataDictionary" saved as a CSV file

	A	B	C	D	E
1	Column Tag	Data Element	Source	Type	Use
2	STATE	State postal abbreviation			
3	STATEFIPS	State FIPS code			
4	COUNTY	County name			
5	COUNTYFIPS	County FIPS code			
6	FIPS	Concatenated State-county FIPS code			
7	YEAR	Year of data=2010			
8	TP-TotPop	Total population of county, in thousands			
9	PS-GWPop	Public Supply, population served by groundwater, in thousands			
10	PS-SWPop	Public Supply, population served by surface water, in thousands			
11	PS-TOPop	Public Supply, total population served, in thousands			
12	PS-WGWFr	Public Supply, groundwater withdrawals, fresh, in Mgal/d	Ground	Fresh	Public Supply
13	PS-WGWSa	Public Supply, groundwater withdrawals, saline, in Mgal/d	Ground	Saline	Public Supply
14	PS-WGWTo	Public Supply, groundwater withdrawals, total, in Mgal/d			
15	PS-WSWFr	Public Supply, surface-water withdrawals, fresh, in Mgal/d	Surface	Fresh	Public Supply
16	PS-WSWSa	Public Supply, surface-water withdrawals, saline, in Mgal/d	Surface	Saline	Public Supply
17	PS-WSWTo	Public Supply, surface-water withdrawals, total, in Mgal/d			
18	PS-WFrTo	Public Supply, total withdrawals, fresh, in Mgal/d			
19	PS-WSaTo	Public Supply, total withdrawals, saline, in Mgal/d			

We added Source, Type, and Use. Based on "Data Element" column.

iii) Processed Data (Step 1)

```
aggregatedUsageData_processed.json
  {
        "PS-WGWFr": 2742.200000000001,
        "PS-WGWSa": 84.29,
        "PS-WSWFr": 3472.2299999999996,
        "PS-WSWSa": 0,
        "DO-WGWFr": 142.47000000000003,
        "DO-WSWFr": 29.449999999999999,
        "IN-WGWFr": 399.2699999999999,
        "IN-WGWSa": 0,
        "IN-WSWFr": 1.1300000000000001,
        "IN-WSWSa": 0,
        "IR-WGWFr": 8685.98,
        "IR-WSWFr": 14370.509999999995,
        "IR-IrSpr": 1792.5000000000005,
        "IR-IrMic": 2892.8500000000004,
        "IR-IrSur": 5665.98,
        "IC-WGWFr": 8553.369999999999,
        "IC-WSWFr": 14290.059999999992,
        "IC-IrSpr": 1701.2500000000002,
        "IC-IrMic": 2892.8500000000004,
```

<Process>
1. Removed unused columns.
2. Filter to California (STATE="CA")
3. Aggregated all County rows together.

```
dictionaryData_processed.json
[
        {
                "ColumnTag": "PS-WGWFr",
                "Data Element": "Public Supply,  groundwater withdrawals, fresh, in Mgal/d",
                "Source": "Ground",
                "Type": "Fresh",
                "Use": "Public Supply",
                "Lvl4": ""
        },
        {
                "ColumnTag": "PS-WGWSa",
                "Data Element": "Public Supply, groundwater withdrawals, saline, in Mgal/d",
                "Source": "Ground",
                "Type": "Saline",
                "Use": "Public Supply",
                "Lvl4": ""
        },
```

<Process>
Removed all unused columns.

iv) Processed Data (Step 2)

```
sankeyData_processed.json
{
        "nodes": [
                {
                        "name": "Ground"
                },
                {
                        "name": "Fresh"
                },
                {
                        "name": "Public Supply"
                },
                {
                        "name": "Saline"
                },
                {
                        "name": "Thermoelectric reci
                }
        ],
        "links": [
                {
                        "source": "Ground",
                        "target": "Fresh",
                        "value": 2742.200000000001
                },
                {
                        "source": "Fresh",
                        "target": "Public Supply",
                        "value": 2742.200000000001
                },
                {
                        "source": "Ground",
                        "target": "Saline",
                        "value": 84.29
                },
                {
                        "source": "Saline",
                        "target": "Public Supply",
                        "value": 84.29
                }]
}
```

<Process>
Nodes
1. Gathered all words to be used as nodes from "Source", "Type" and "Use" in dictionary Data_processed.json, such as "Ground", "Fresh".
2. Removed duplicate nodes.
3. Output nodes with the label, "name".

<Process>
Links
1. Paired source and target from "Source" and "Type", "Type" and "Use" columns in dictionaryData_processed.json.
2. Joined the values from aggregatedUsageData_processed.json.

EXPLORATORY DATA ANALYSIS

Figures 1-10 were created using screenshots of data visualizations created on the QlikView platform.

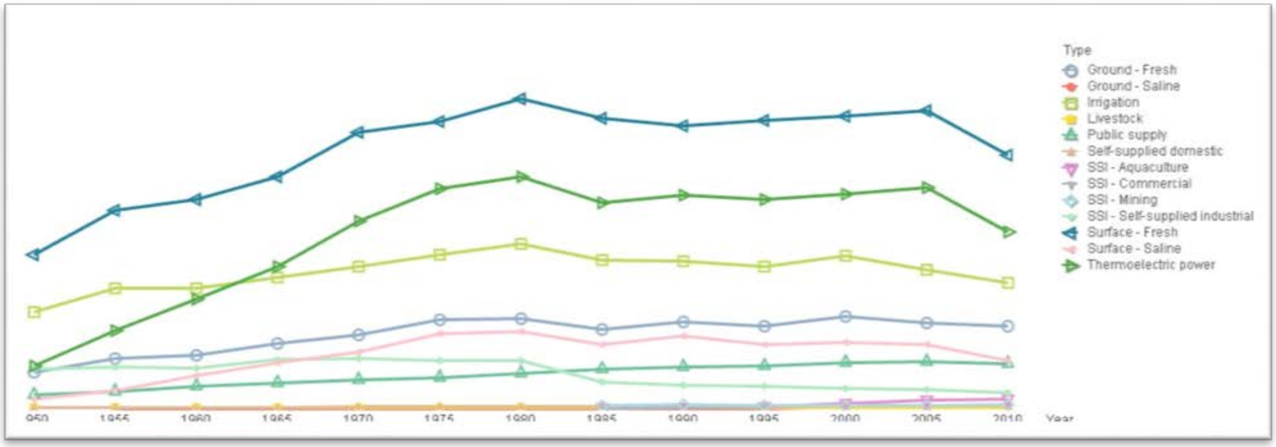


Figure 1

In Figure 1, we wanted to see how water withdrawal categories changed over time. The data was provided by USGS and was recorded every five years. It was interesting to see the rise of Thermoelectric power from the 1950's and plateauing in the 1970's.

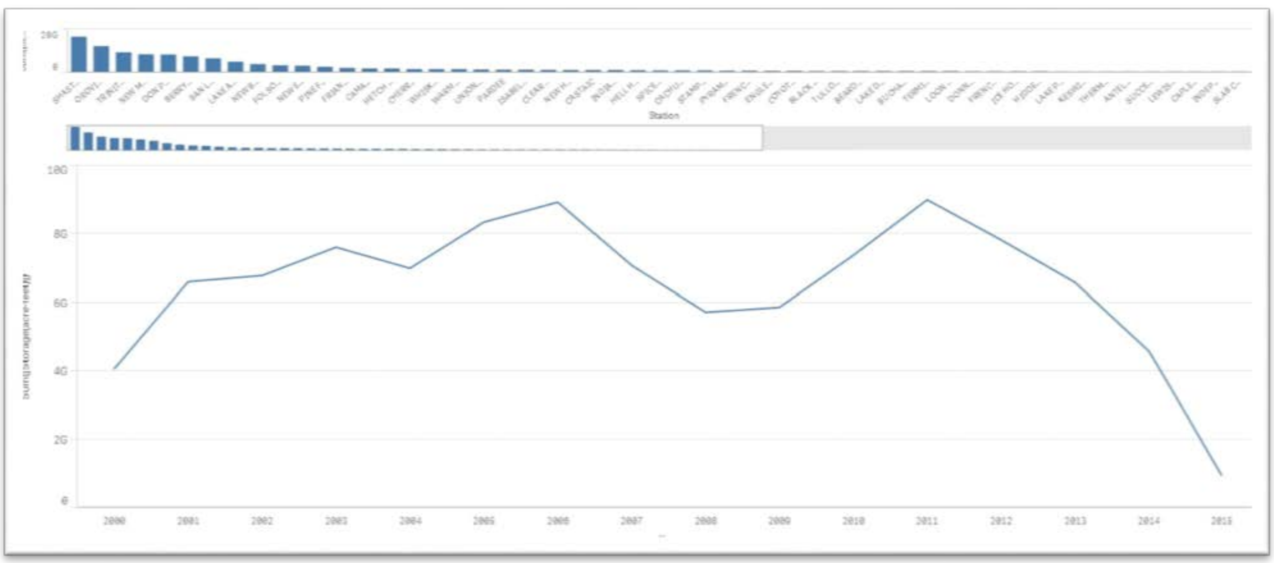


Figure 2

In Figure 2, we are looking at reservoir level data over time. Each reservoir in California is broken out in the bar chart while the line chart shows aggregate reservoir level using the brushing tool in between the two graphs. It is quite apparent that since 2011, the reservoir levels have dropped off dramatically to levels not seen since the early 2000's.

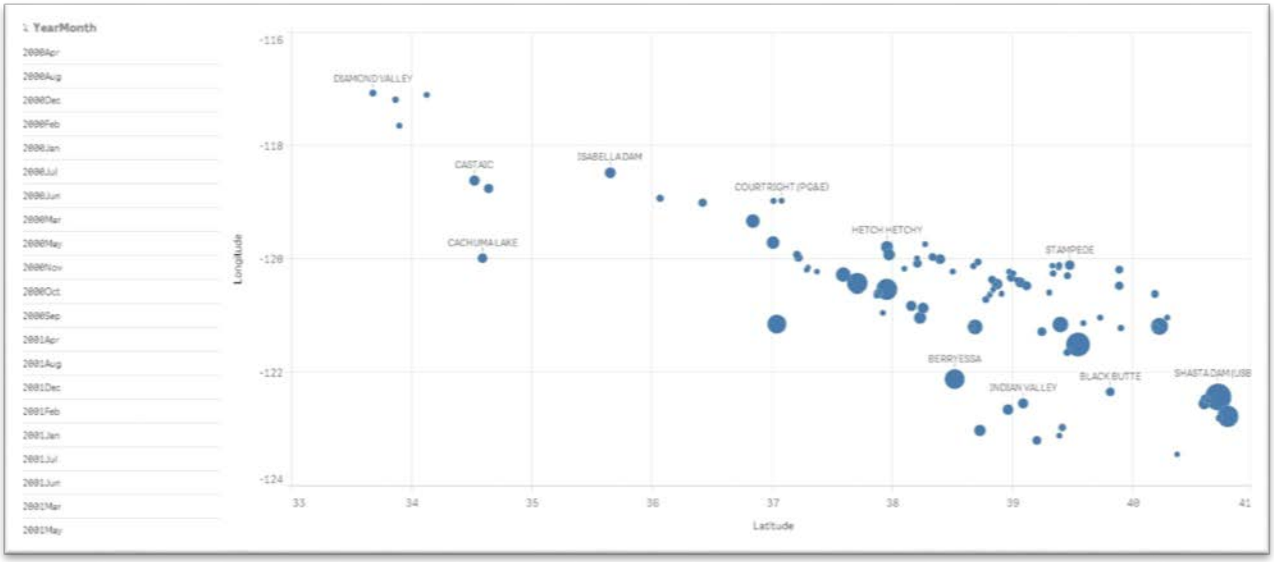


Figure 3

In Figure 3, a bubble chart is created to visualize relative locations based on geographical coordinates on a Cartesian plane of the reservoirs and their capacities. Shasta is the largest of the California reservoirs by volume.

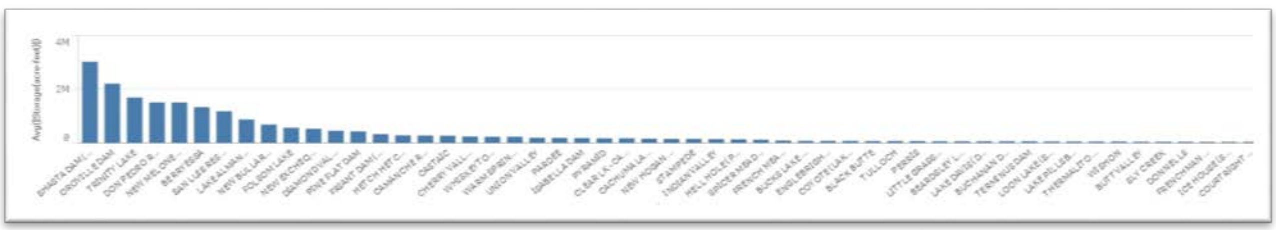


Figure 4

In Figure 4, we graphed the California reservoirs by name using the average water level over time as the dependent variable.

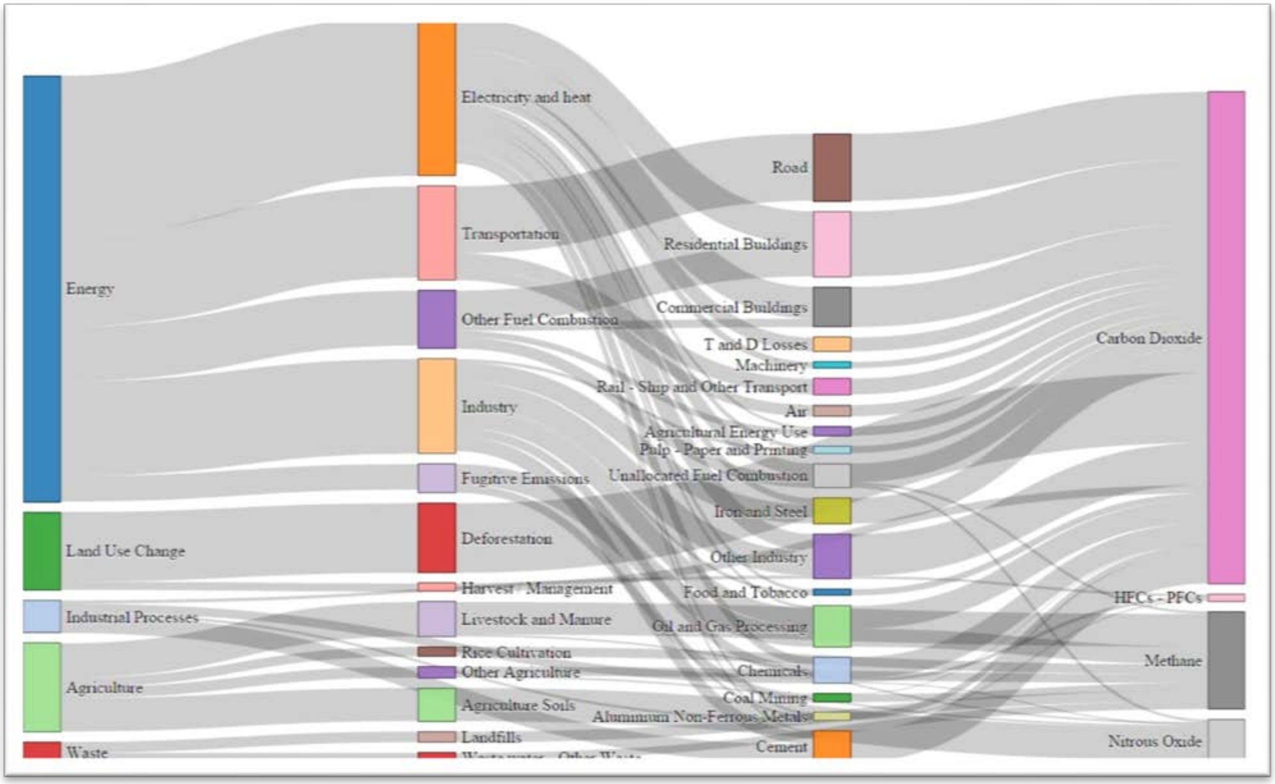


Figure 5

In Figure 5, we used a Sankey Graph representation of the water withdrawal category data.

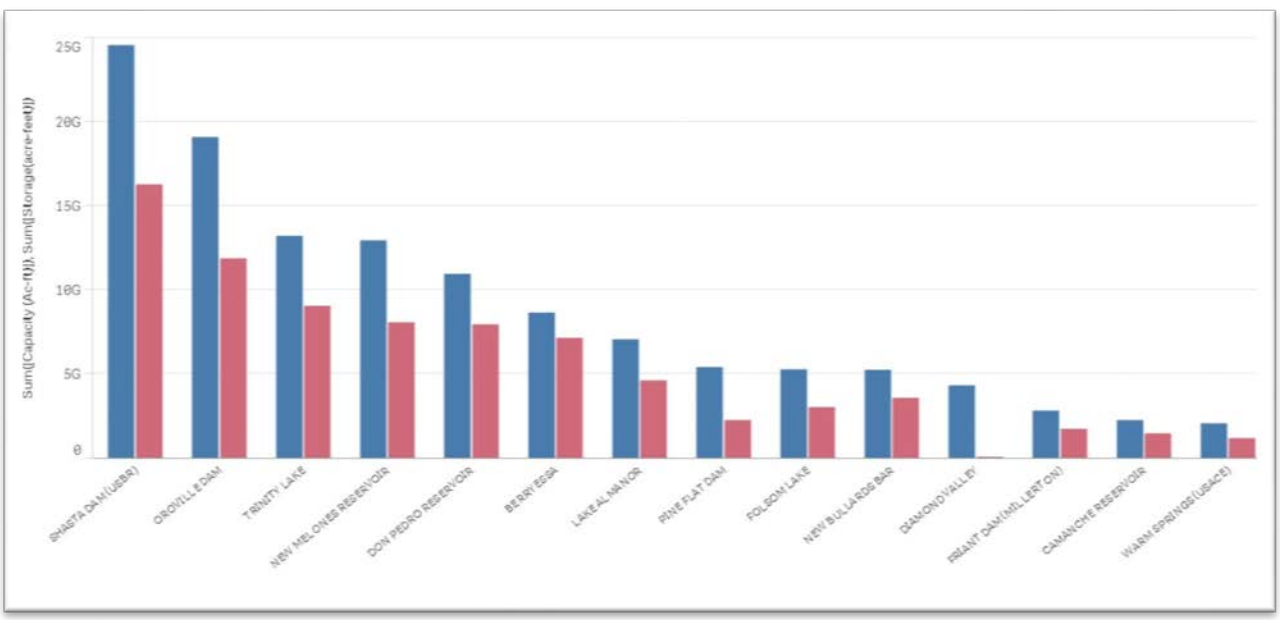


Figure 6

In Figure 6, we sought to show the total storage capacity versus total water levels. In retrospect, it may have made more sense to use an average as opposed to the sum because the capacity remains constant for each reservoir. Summing the capacities may be confusing for the end users.

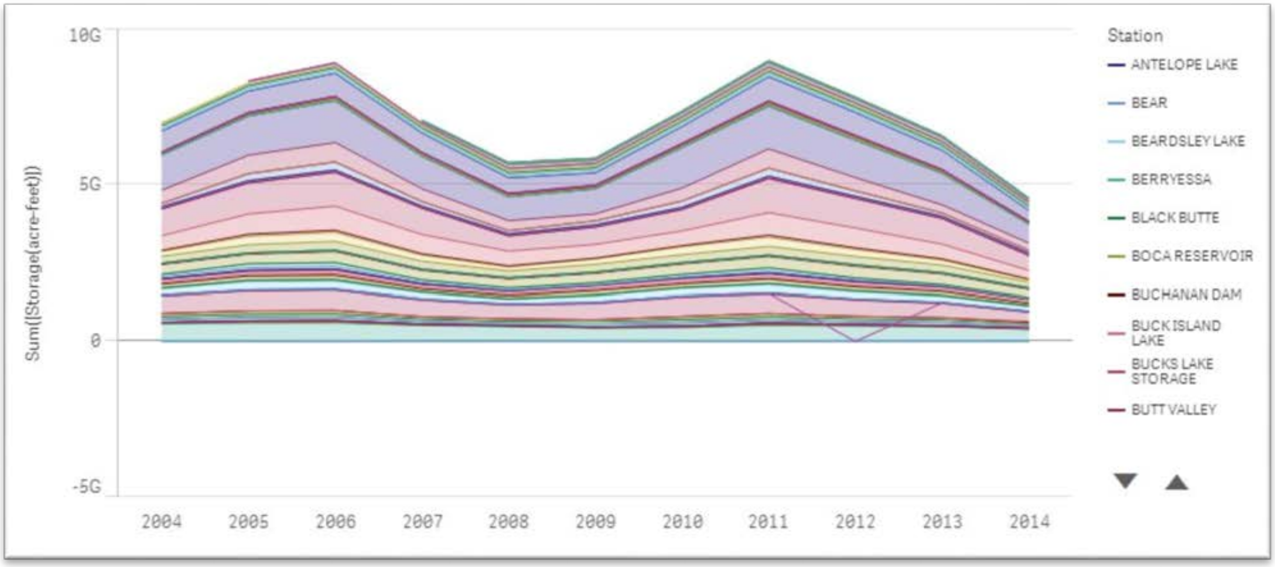


Figure 7

Figure 7 is a visualization of a stacked area chart displaying the contributions of each reservoir level over time.

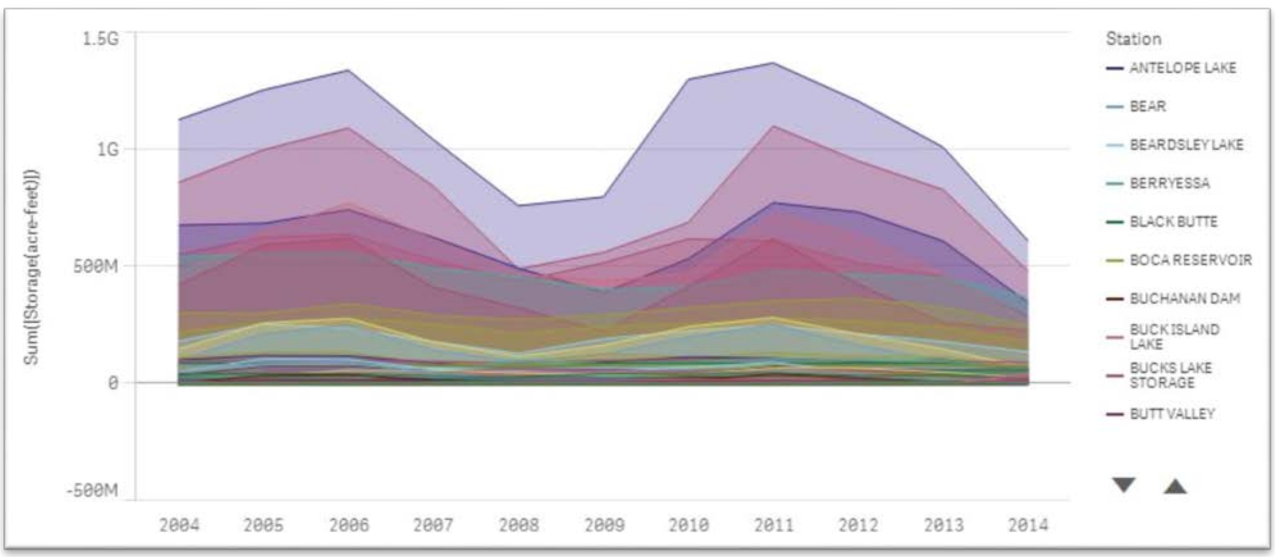


Figure 8

Figure 8 is an overlay of stacked area charts for each reservoir level over time.

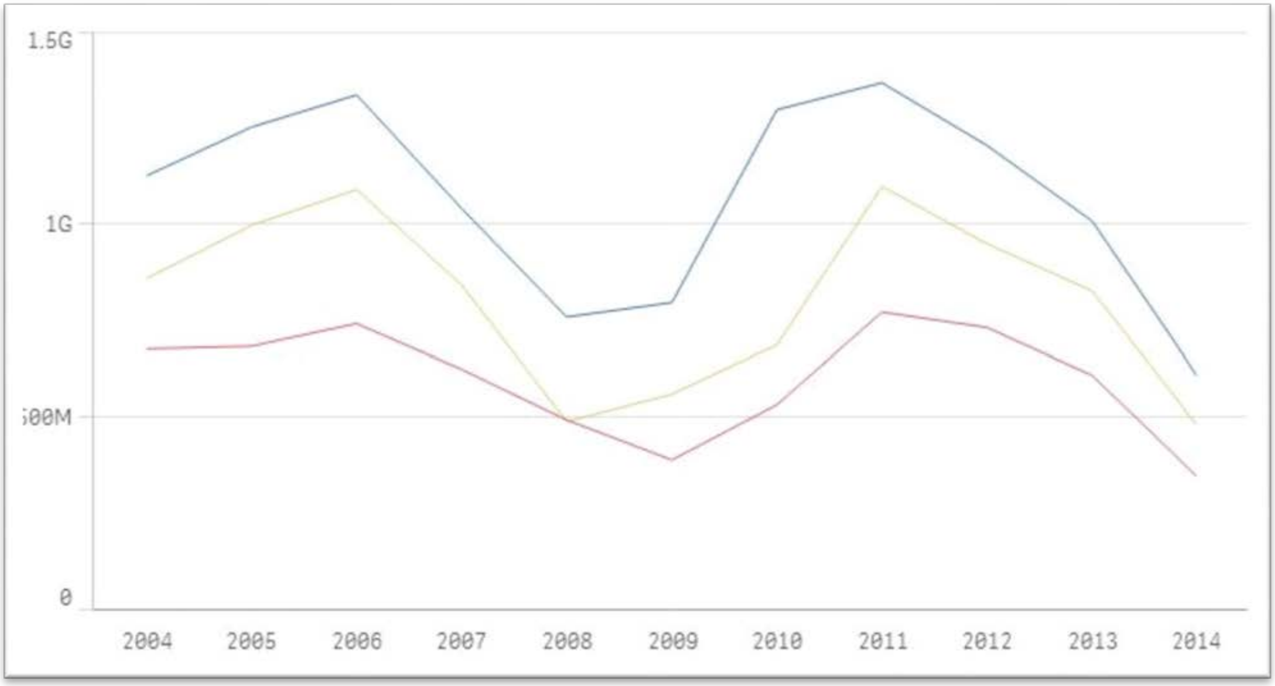


Figure 9

Figure 9 is an unshaded area chart of the top 3 reservoirs by sorted by greatest volume over time in descending order. It was an experiment to see if this would be a less cluttered view as opposed to a shaded area graph for every reservoir water level over time.

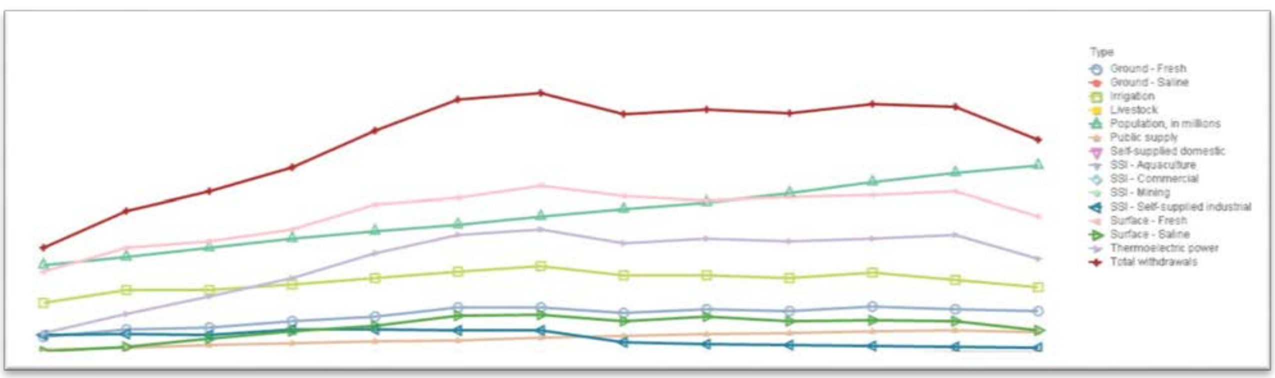


Figure 10

Figure 10 is a simple line graph that shows the trending of water withdrawal categories over time.

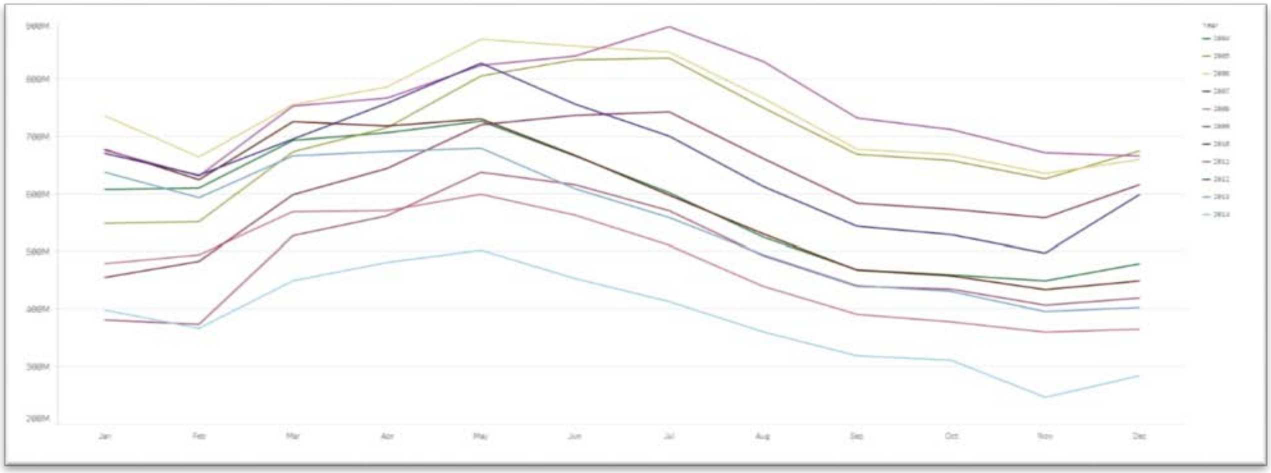


Figure 11

Figure 11 is a line chart comparing all reservoir capacities YoY for the past 10 years. The independent variable is Month while the dependent variable is Year.

DESIGN EVOLUTION

Our initial reasons for pursuing the California Drought as the subject matter and focus of our final project were delineated along with our initial designs and project component scheduling. This formed the majority of our content for the Project Proposal which is duplicated in Figures 11 and 12:

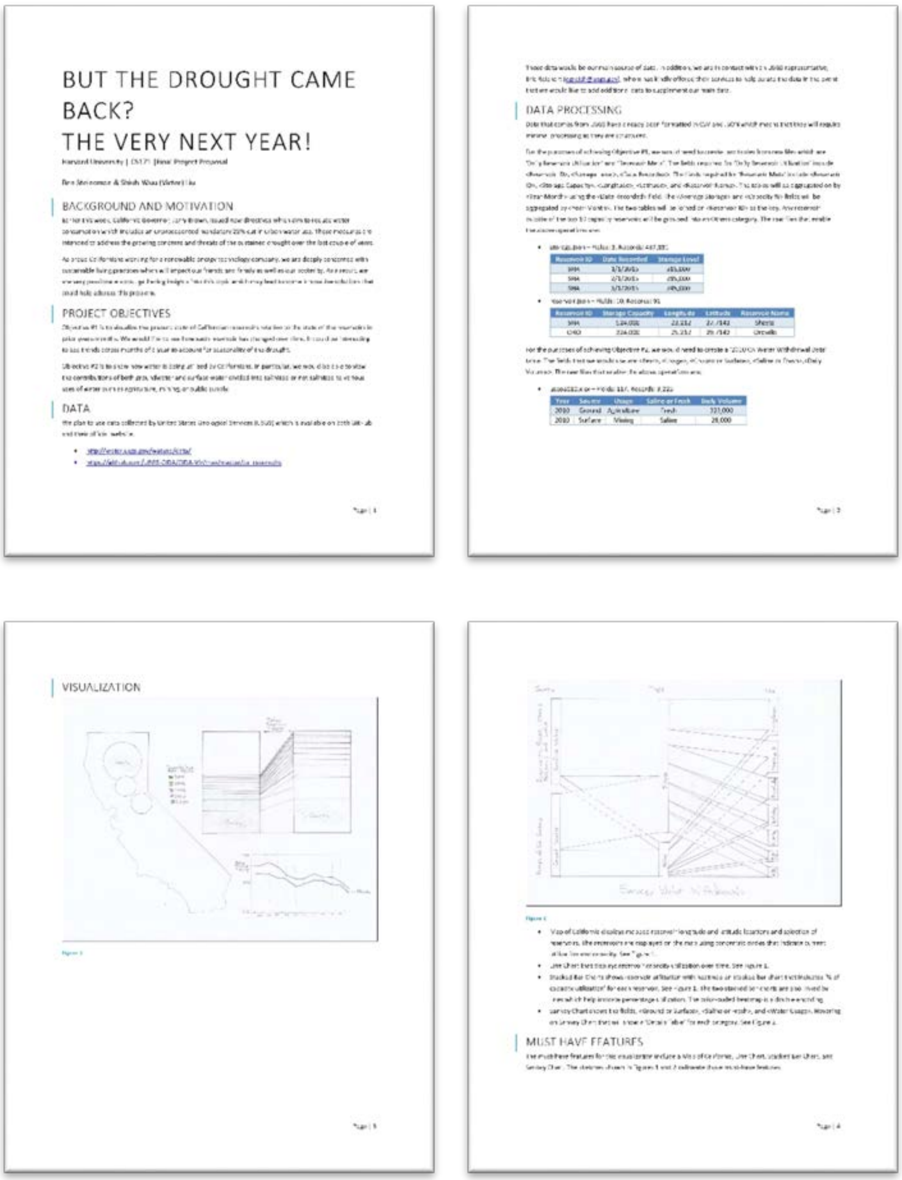

BUT THE DROUGHT CAME BACK?
THE VERY NEXT YEAR!
BACKGROUND AND MOTIVATION
PROJECT OBJECTIVES
DATA
DATA PROCESSING
VISUALIZATION
MUST HAVE FEATURES

Figure 11

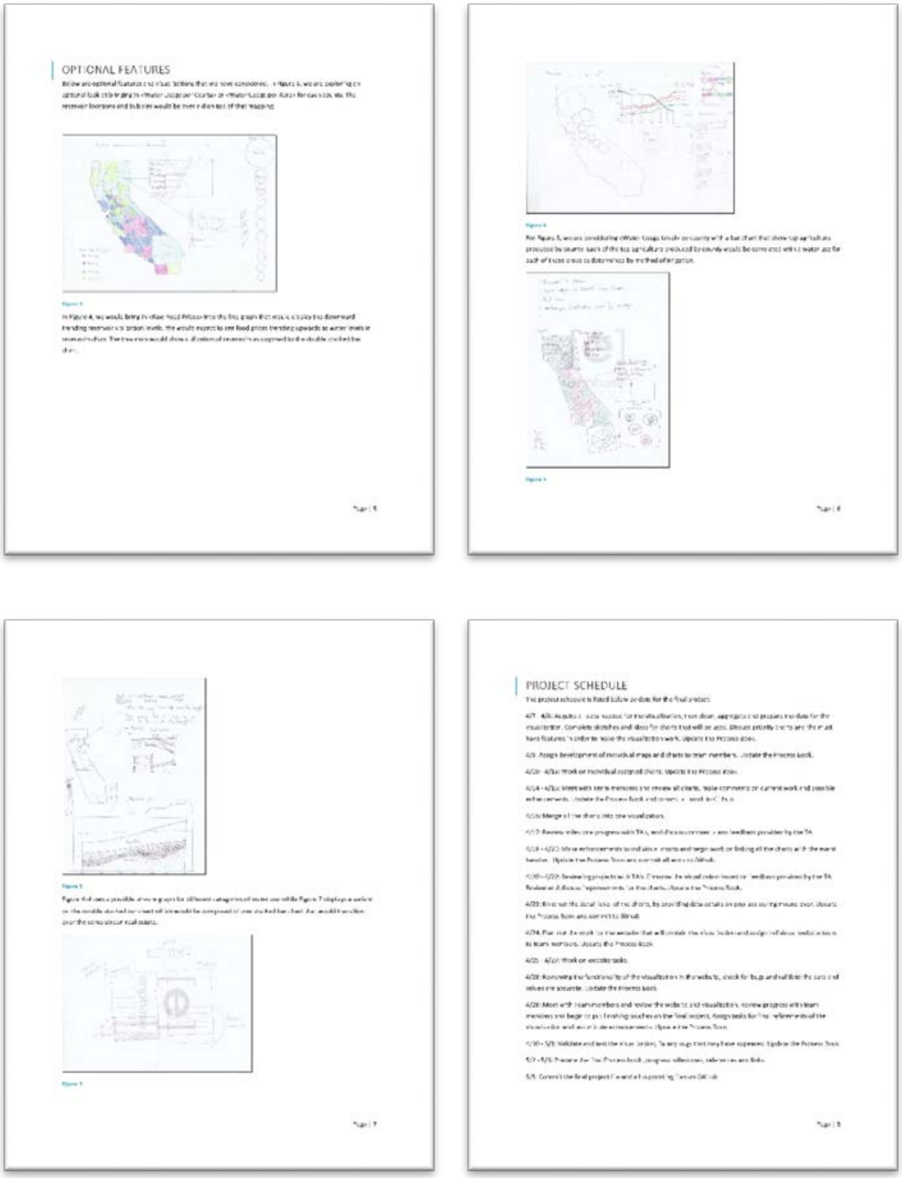


Figure 12

Our Final Project Proposal original design drawings are expanded below in Figures 14 and 15.

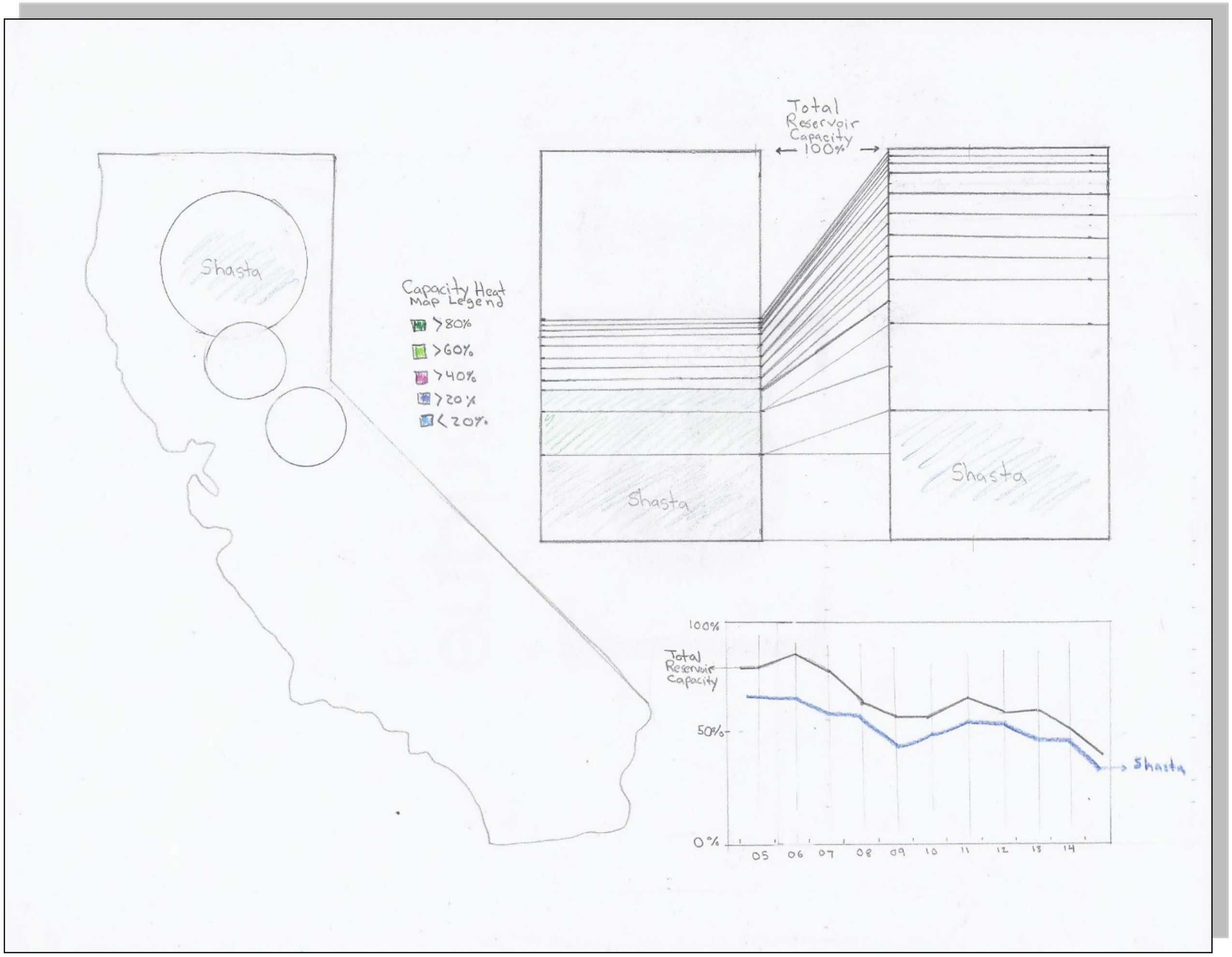


Figure 13

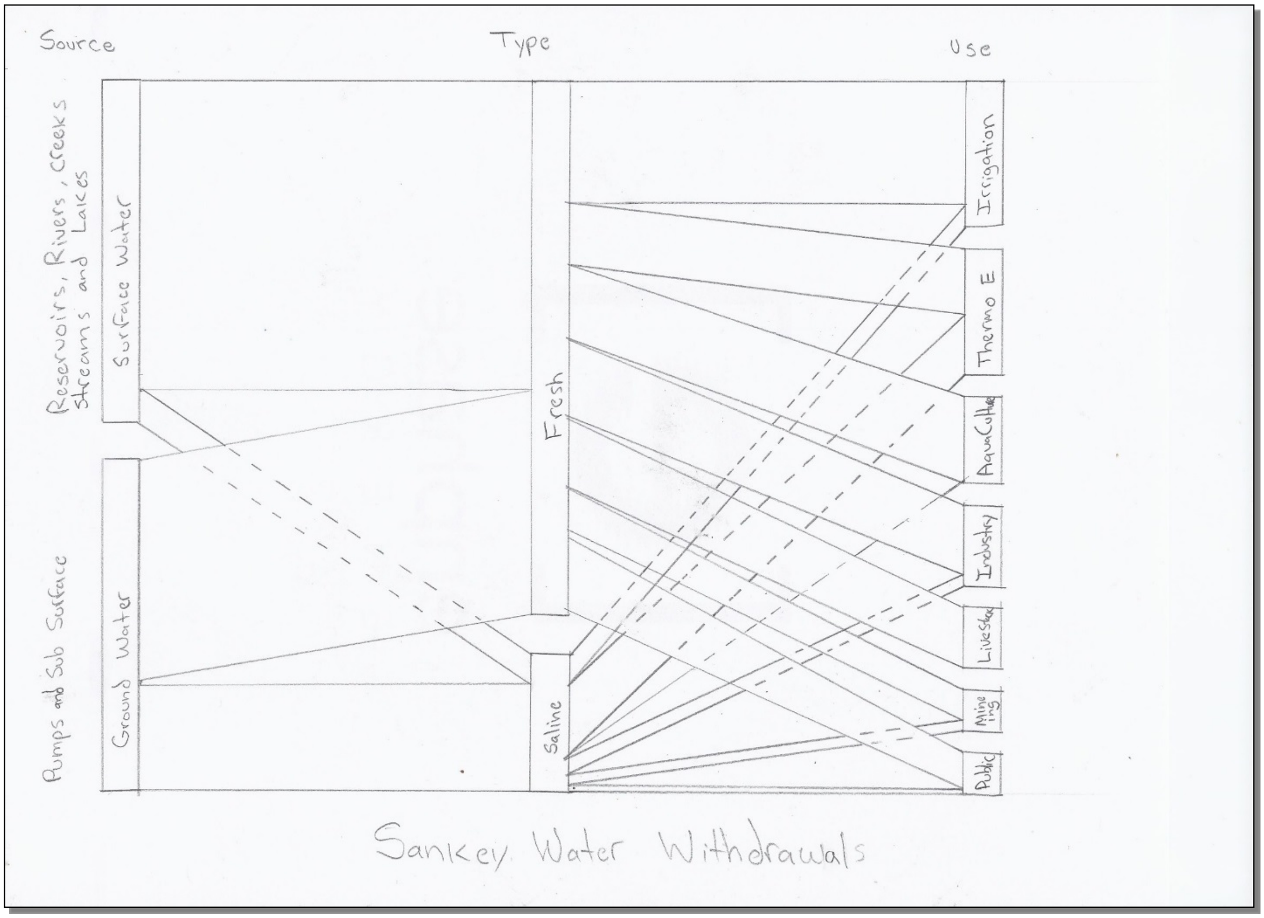
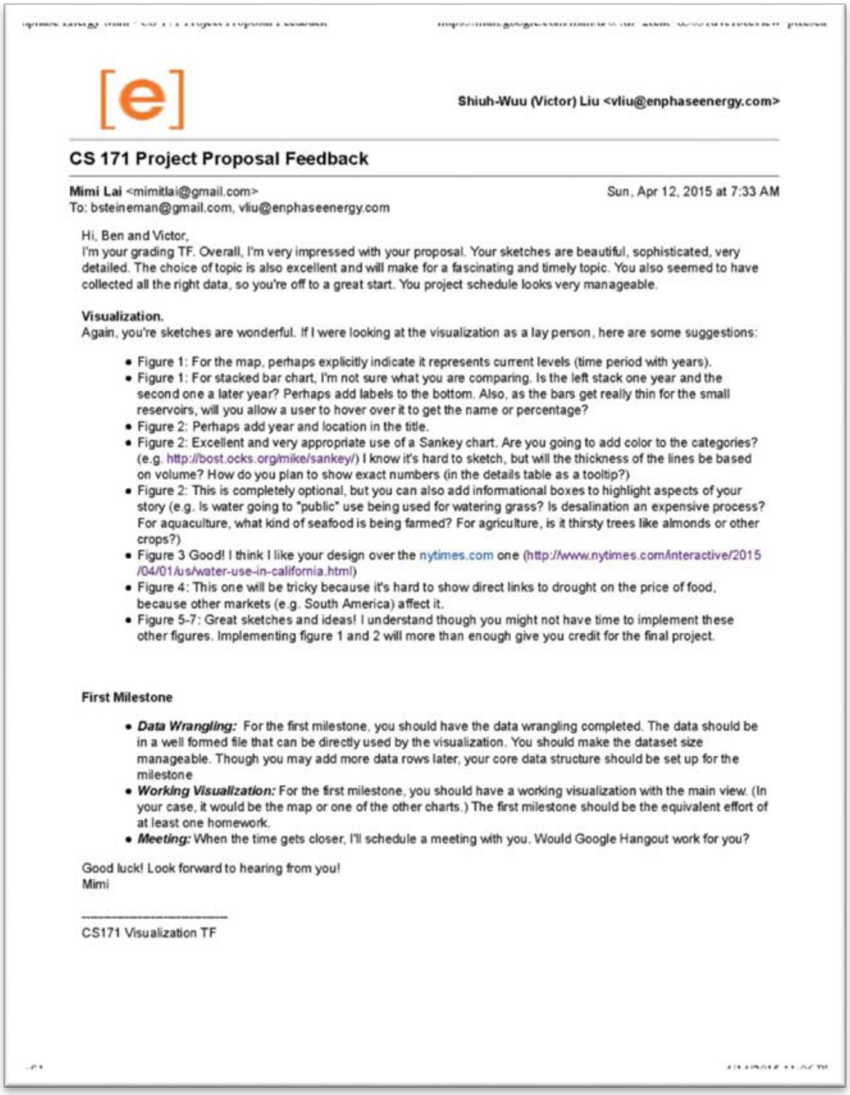


Figure 14

1) Map of California displays mapped reservoir longitude and latitude locations and selection of reservoirs. The reservoirs are displayed on the map using concentric circles that indicate current utilization and capacity. See Figure 13.
2) Line Chart that displays reservoir capacity utilization over time. See Figure 13.
3) Stacked Bar Charts shows reservoir utilization with heatmap on stacked bar chart that indicates '% of capacity utilization' for each reservoir. See Figure 13. The two stacked bar charts are also linked by lines which help indicate percentage utilization. The color-coded heatmap is a double encoding.
4) Sankey Chart shows the fields, <Ground or Surface>, <Saline or Fresh>, and <Water Usage>. Hovering on Sankey Chart that will show a 'Details Table' for each category. See Figure 14.

One of the TF's, Mimi Lai, reviewed our Project Proposal and gave us the following feedback as shown in Figure 15.



Shiuh-Wuu (Victor) Liu <vliu@enphaseenergy.com>

CS 171 Project Proposal Feedback

Mimi Lai <mimitlai@gmail.com> Sun, Apr 12, 2015 at 7:33 AM
To: bsteineman@gmail.com, vliu@enphaseenergy.com

Hi, Ben and Victor,
I'm your grading TF. Overall, I'm very impressed with your proposal. Your sketches are beautiful, sophisticated, very detailed. The choice of topic is also excellent and will make for a fascinating and timely topic. You also seemed to have collected all the right data, so you're off to a great start. You project schedule looks very manageable.

Visualization.
Again, you're sketches are wonderful. If I were looking at the visualization as a lay person, here are some suggestions:

- Figure 1: For the map, perhaps explicitly indicate it represents current levels (time period with years).
- Figure 1: For stacked bar chart, I'm not sure what you are comparing. Is the left stack one year and the second one a later year? Perhaps add labels to the bottom. Also, as the bars get really thin for the small reservoirs, will you allow a user to hover over it to get the name or percentage?
- Figure 2: Perhaps add year and location in the title.
- Figure 2: Excellent and very appropriate use of a Sankey chart. Are you going to add color to the categories? (e.g. http://bost.ocks.org/mike/sankey/) I know it's hard to sketch, but will the thickness of the lines be based on volume? How do you plan to show exact numbers (in the details table as a tooltip?)
- Figure 2: This is completely optional, but you can also add informational boxes to highlight aspects of your story (e.g. Is water going to "public" use being used for watering grass? Is desalination an expensive process? For aquaculture, what kind of seafood is being farmed? For agriculture, is it thirsty trees like almonds or other crops?)
- Figure 3 Good! I think I like your design over the nytimes.com one (http://www.nytimes.com/interactive/2015/04/01/us/water-use-in-california.html)
- Figure 4: This one will be tricky because it's hard to show direct links to drought on the price of food, because other markets (e.g. South America) affect it.
- Figure 5-7: Great sketches and ideas! I understand though you might not have time to implement these other figures. Implementing figure 1 and 2 will more than enough give you credit for the final project.

First Milestone

- ***Data Wrangling:*** For the first milestone, you should have the data wrangling completed. The data should be in a well formed file that can be directly used by the visualization. You should make the dataset size manageable. Though you may add more data rows later, your core data structure should be set up for the milestone
- ***Working Visualization:*** For the first milestone, you should have a working visualization with the main view. (In your case, it would be the map or one of the other charts.) The first milestone should be the equivalent effort of at least one homework.
- ***Meeting:*** When the time gets closer, I'll schedule a meeting with you. Would Google Hangout work for you?

Good luck! Look forward to hearing from you!
Mimi

\-
CS171 Visualization TF

Figure 15

Additionally, we met with a representative, Joshua Darlington, from another CS 171 project group to exchange feedback on our projects. Joshua was interested in our topic and, in fact, during our conversations, it quickly became evident that he was fairly well read up on the latest happenings in the California drought. As a result of his domain knowledge, he had some reservations in showing the declining reservoir levels as he believes that they are fairly self-evident.

We respectfully disagree with his assessment because reservoir levels are directly related to how much water is available for usage which is exactly what our two selected data visualizations hone in on and form a clear, logical progression. As a result, we have decided to go ahead with our design as the intended audience is the general public whom may or may not be knowledgeable as he is regarding this popular topic.

Joshua also mentioned that the drought is not only going to affect California, but also this will impact the entire country. Per his suggestion we thought it would be of interest to our end users if we gave the option to show water usage filtered by all US states instead of only California. This would allow users to interact with our Sankey visualization and give some context on a national level by enabling the comparisons of water withdrawals trends in California to water withdrawal trends in other US states.

Our initial stab at the designs included all of the basic forms of our visualizations including the double stacked bar chart, line chart, and Sankey Diagram as shown in Figure 16.

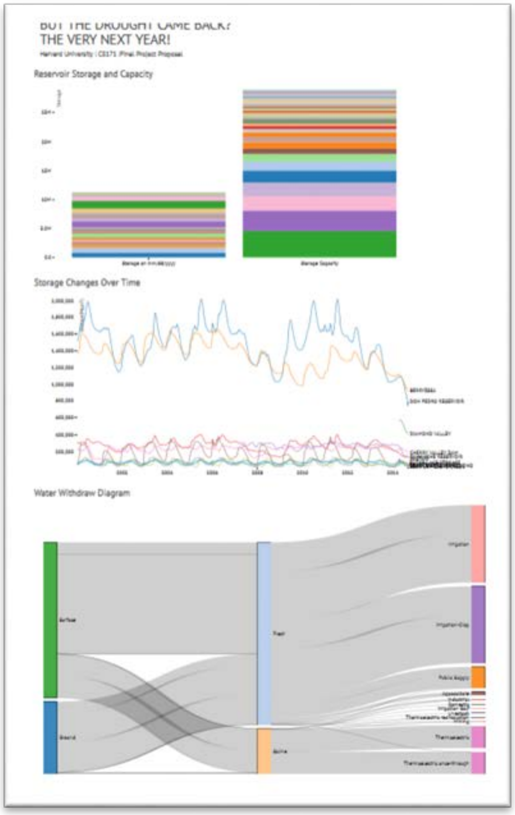


Figure 16

In Figure 17, we wanted to present a more high resolution view of the stacked bar graphs in order to highlight the large number of reservoirs in California. We had considered displaying top 10 reservoirs by capacity and then grouping the remainder reservoirs into an 'Other' category, but after spending some time weighing the pros and cons, we have determined that showing all of the reservoirs with the given color selections is the best course of action.

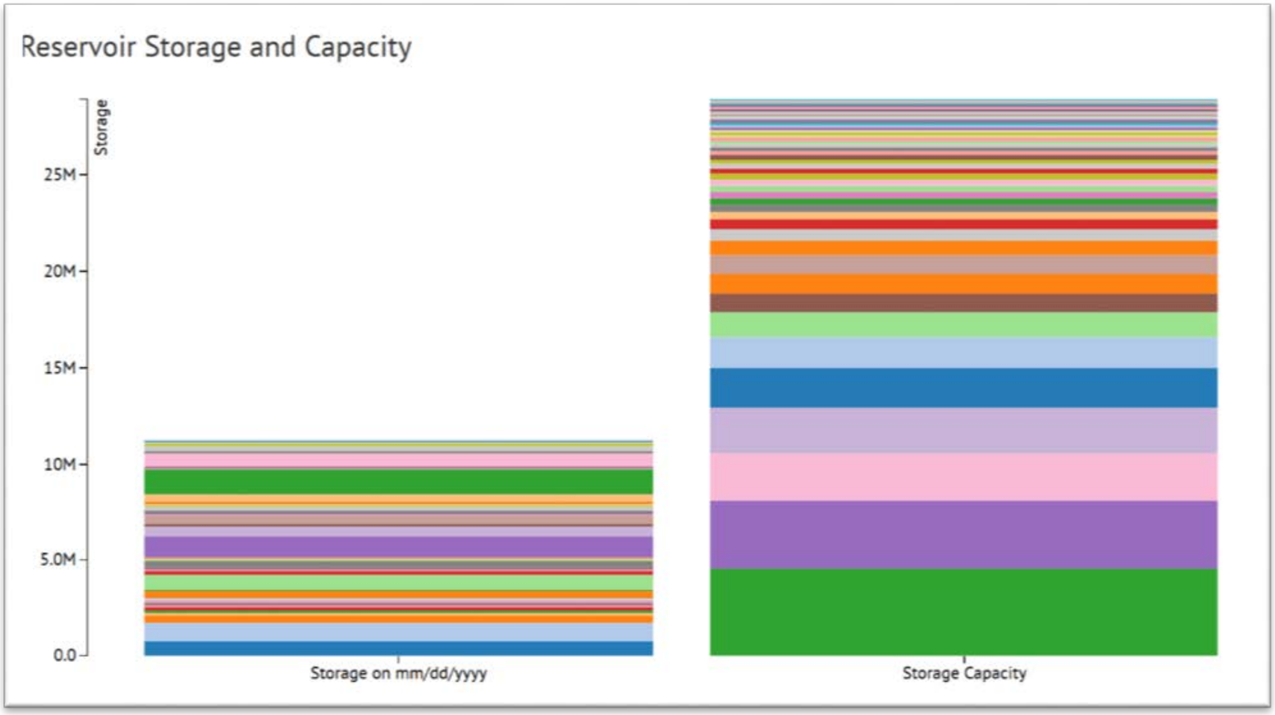


Figure 17

In Figure 18, we are showing the top 10 reservoirs by capacity. It is with the intention of reducing clutter in our visualization. In this particular version, we are experimenting with the omission of the aforementioned long tail reservoirs that are outside of the top 10. It makes more sense in this case as opposed to the stacked bar charts in Figure 17 because the reservoir capacities are superimposed on top of each other. In other words, the total reservoir capacities in California are not meant to be inferred from this chart.

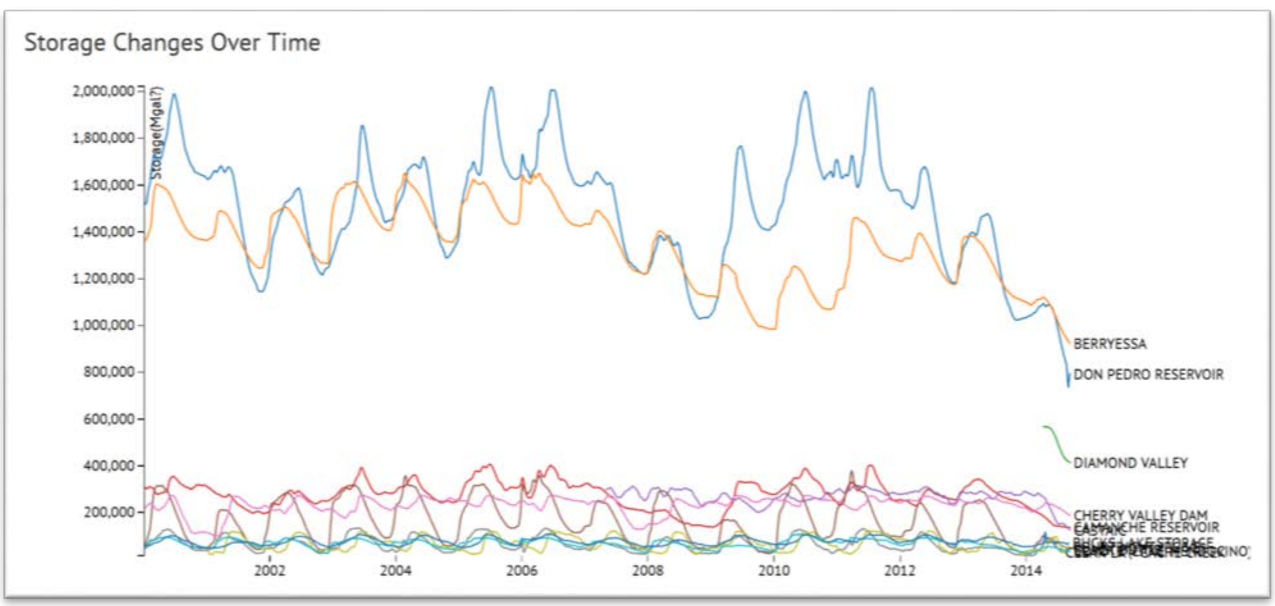


Figure 18

Figure 19, is shows how the Sankey chart could be manipulated to clear up relationships through the feature that allows for the rearrangement of each set of data hierarchy.

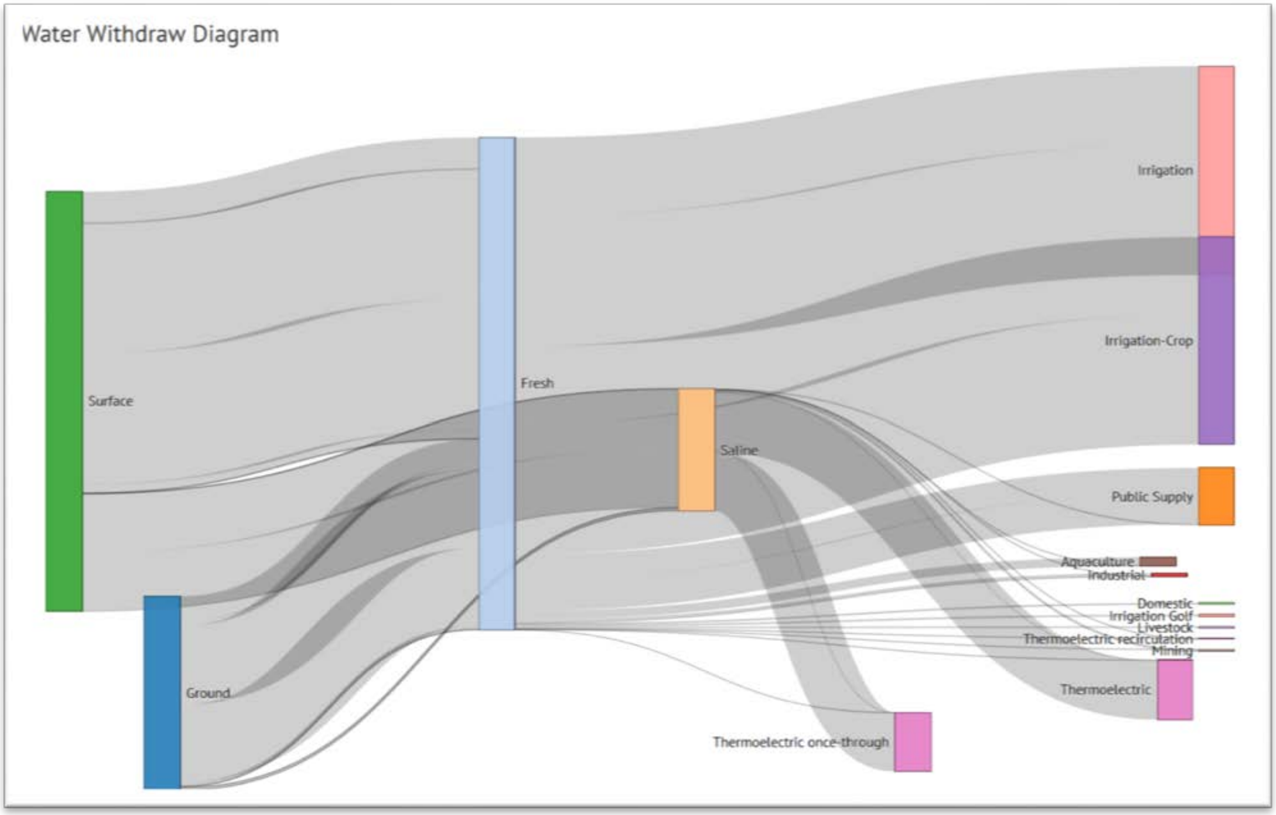


Figure 19

Beginning with Figure 20, we want to show our final design implementations after our Google Hangout meeting with our TF, Mimi Lai. The general feedback from our TF was that she was interested in our project and our progress had been above her expectations. Given the choice between implementing a geospatial map versus more features to existing graphs, our TF was unequivocally supportive of the more features focus as a priority option.

In addition, our TF suggested that we add features such as a selection tool, more story, text descriptions on the website, and tool tip elements. If there is more time for the geospatial mapping, then we could consider using Leaflet.js for the underlying maps.

In Figure 20, we decided to attempt to visualize all of the reservoirs on the same multi-line chart. This was certainly a hairball of data vis which rendered it unreadable and useless. It is interesting to note that there is a great difference in capacity between the top reservoirs and the rest of the reservoirs.

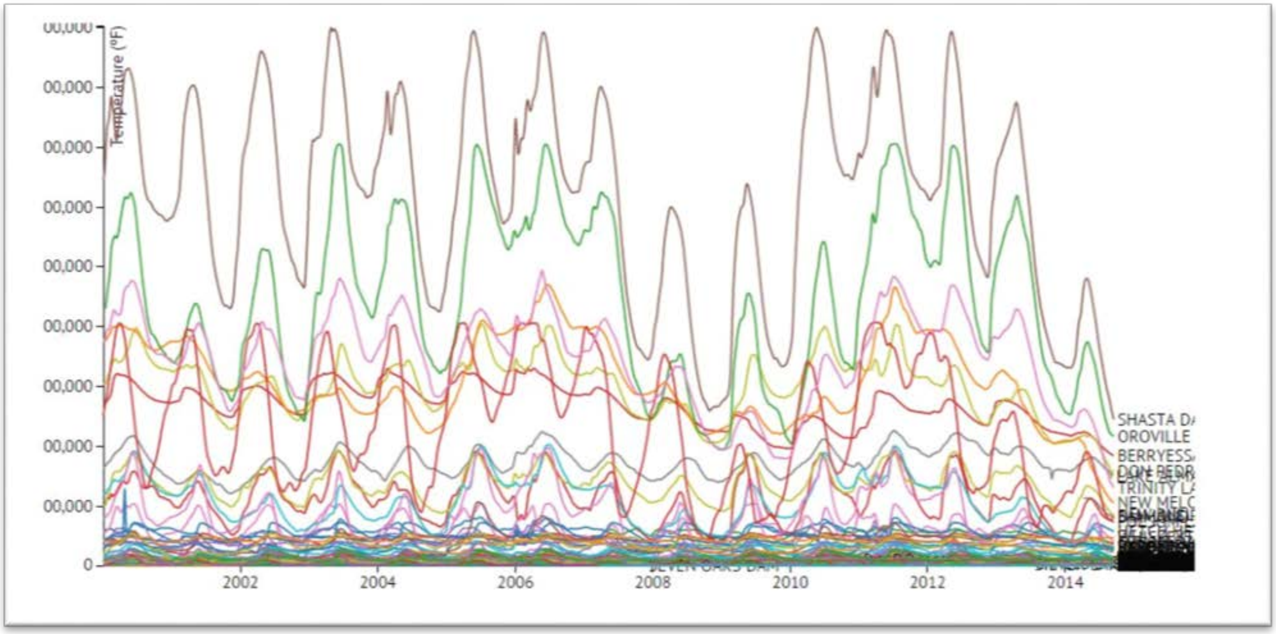


Figure 20

In Figure 21, we attempt to visualize only the top 10 reservoirs by capacity on our multiline graph. It is quite obvious that even just the top 10 reservoirs was starting to look like a hairball of data vis. This is when we decided to look into displaying only one set of data from a selected reservoir. The selections could occur at the stacked bar chart or at the geospatial map with a simple mouse over or click selection.

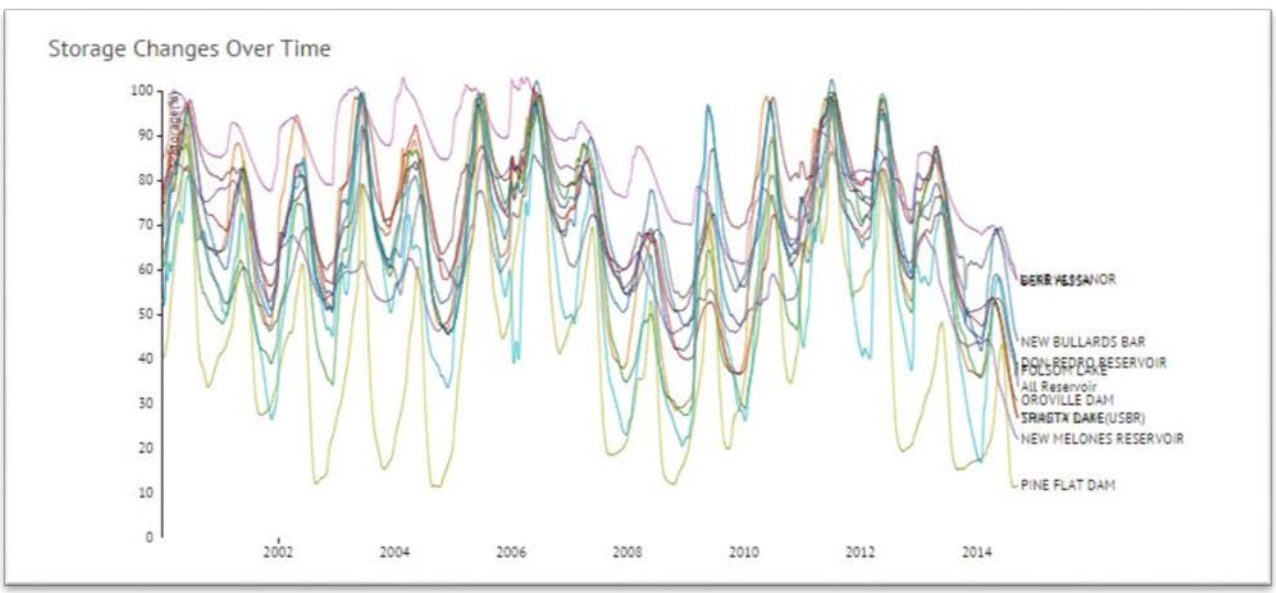


Figure 21

In Figure 22, we attempted to display the reservoirs by storage % of capacity and then aggregate the reservoir capacities over time into a single line that displayed the overall (All Reservoirs) % of capacity. The overall capacity allowed us to see how low California reservoirs actually are relative to an aggregation.

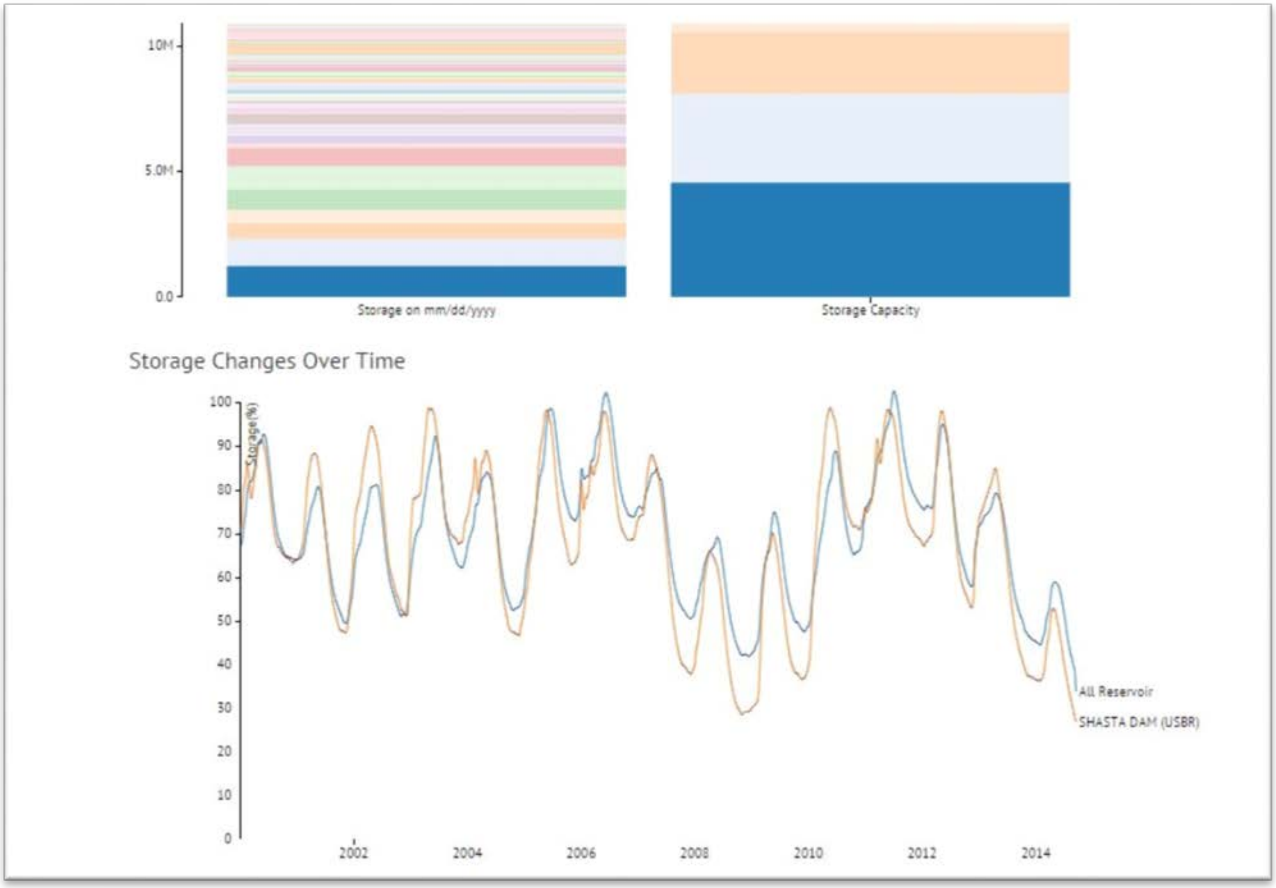


Figure 22

The next step was to setup the bar charts so that rollovers on a single stacked bar displays a single reservoir % of capacity compared to the overall all reservoir % of capacity. This worked quite well and allowed us to compare the overall capacity to a single reservoir relatively by comparing % of capacity. The results are shown in Figure 23.

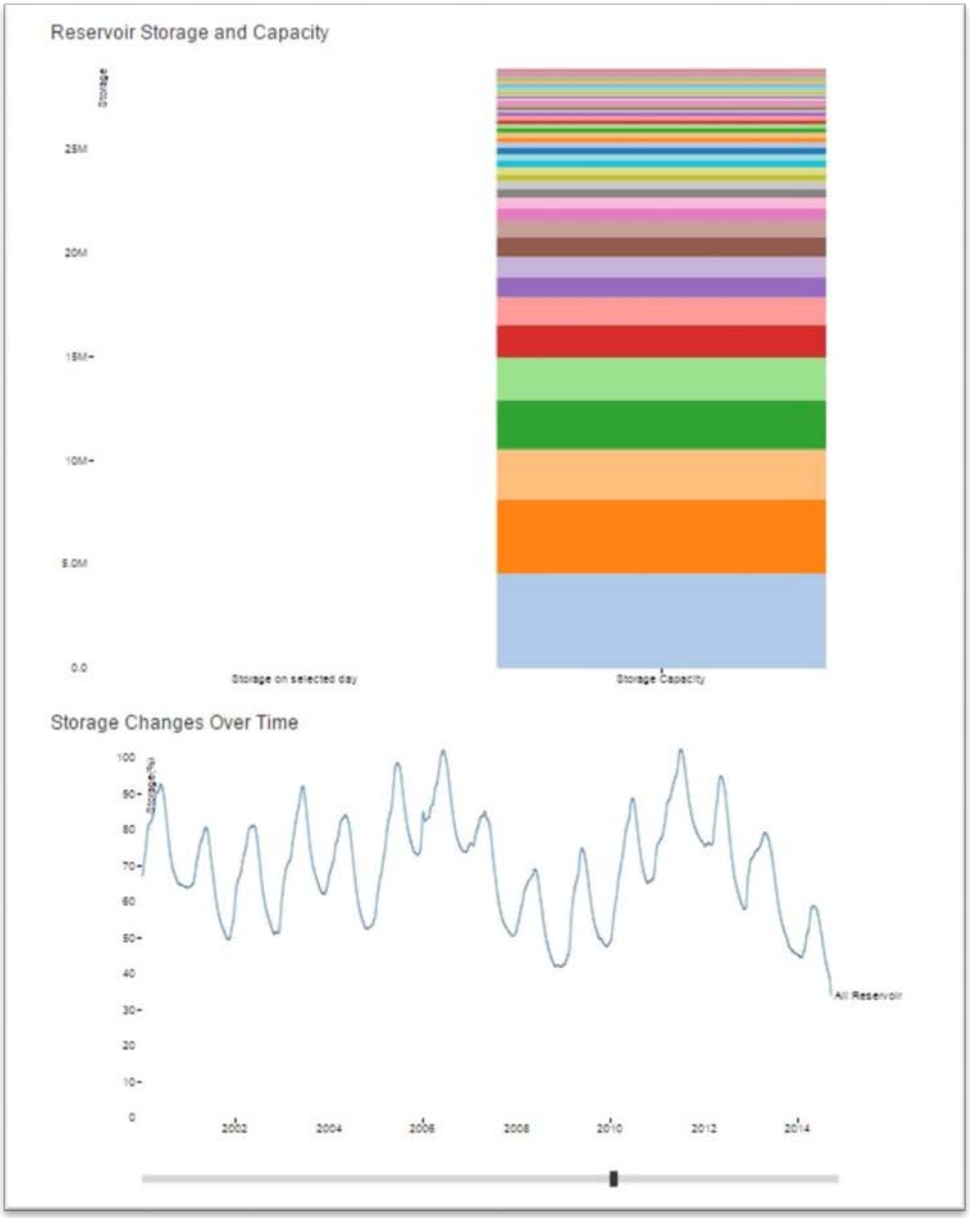


Figure 23

In Figure 24, we wanted the bar chart to be affected by a slider below the line chart. Depending on the time period set by the slider, this would display the reservoir storage on the top left chart. The issue that we encountered was that since our data was aggregated at the week level, the slider would allow for selections of days in between week end dates. This resulted in the creation of null data elements.

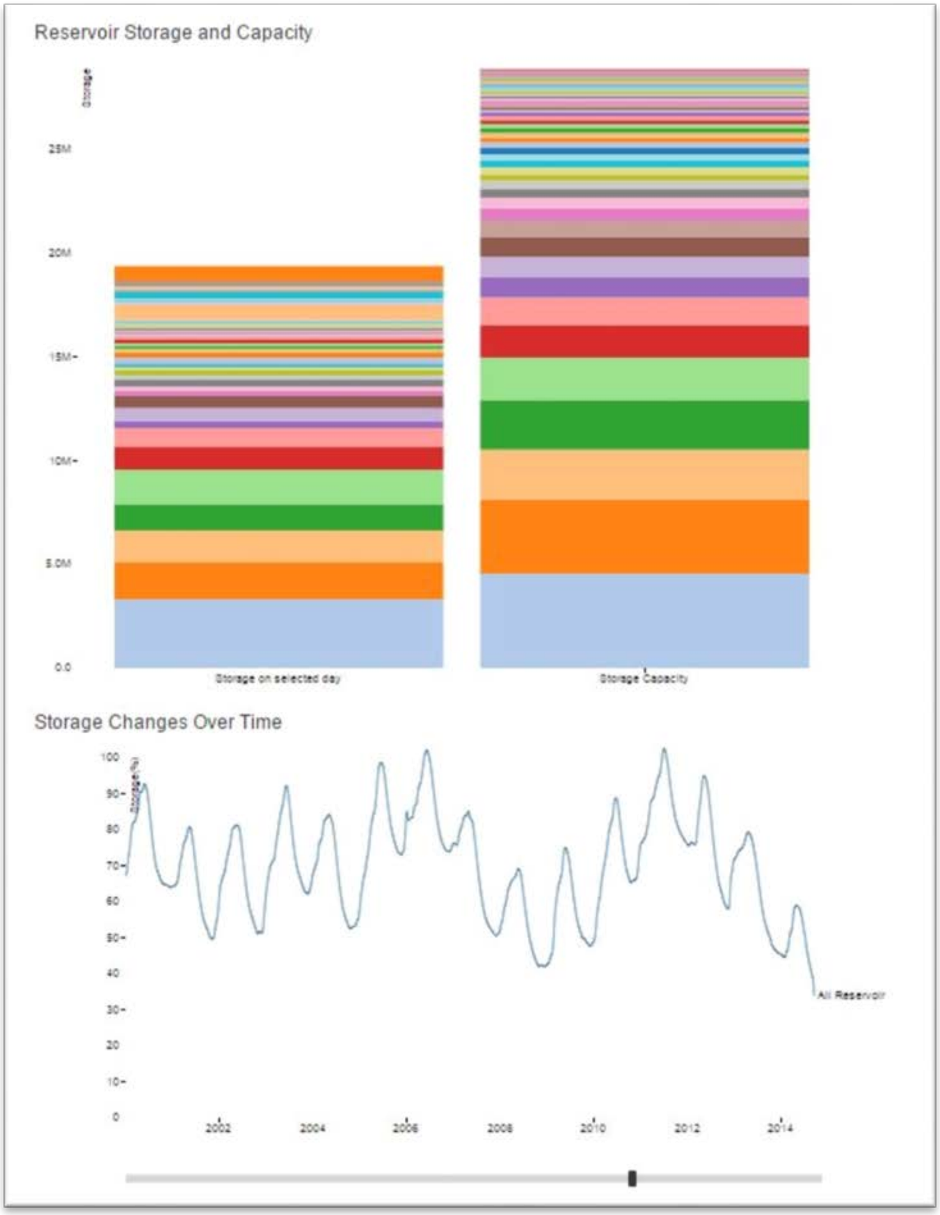


Figure 24

In Figure 25, as a possible solution we moved the slider into the bar chart so that users would only be able to select valid Year-Weeks on the Line Chart. The selector was quite plain and was deemed to require some additional aesthetic considerations and attention. A viable option would be to add a date to the selector that updates based on the selected date. There could also be a corresponding date that displays on bottom of the stacked bar chart and changes displayed dates accordingly with the movement of the data selector.

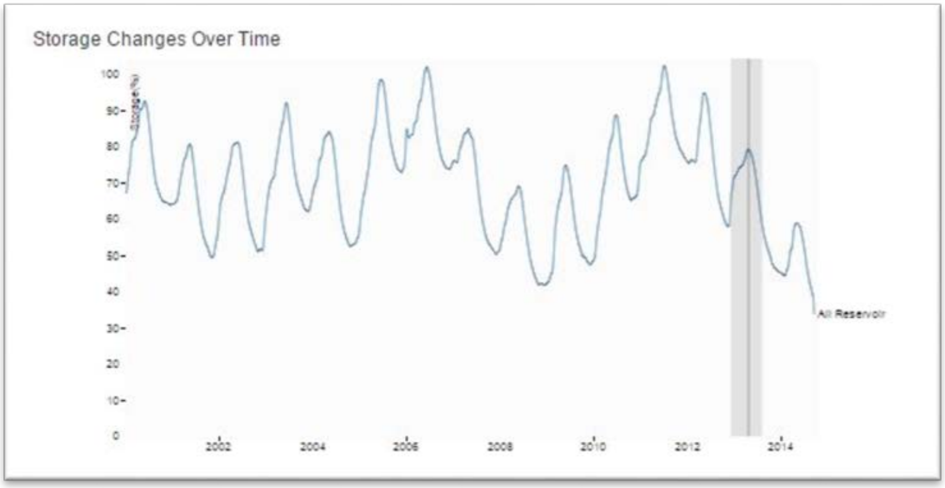


Figure 25

In Figure 26, we attempted once again to load all of the reservoir utilization data. It resulted in a severe performance decrease due to the number of points and attached data. In the future, it may be worth exploring ways to reduce the performance issues such as flattening raw data and unloading irrelevant data, but for the purposes of our project, we are electing to show less line graphs at the same point in time.

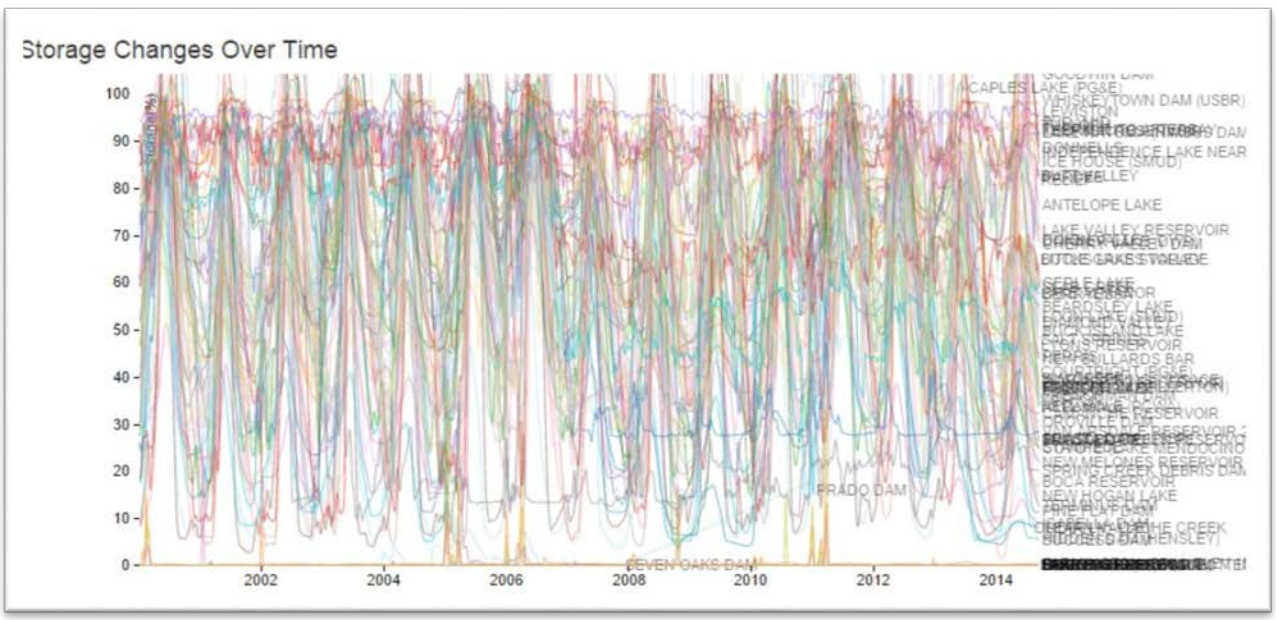


Figure 26

After feeling more comfortable with our data visualizations, we set forth to find a suitable webpage template to house our visualizations. We were especially interested in 'responsive' webpage designs because they involve the use of other JS libraries which would allow all of the data vis to load within a single webpage. Ultimately, we settled on the layout that is shown in Figure 27 and 28. The built-in slide show functionality allows us to upload images and short text descriptions that are best able to set the stage prior to introducing our D3 data visualizations.

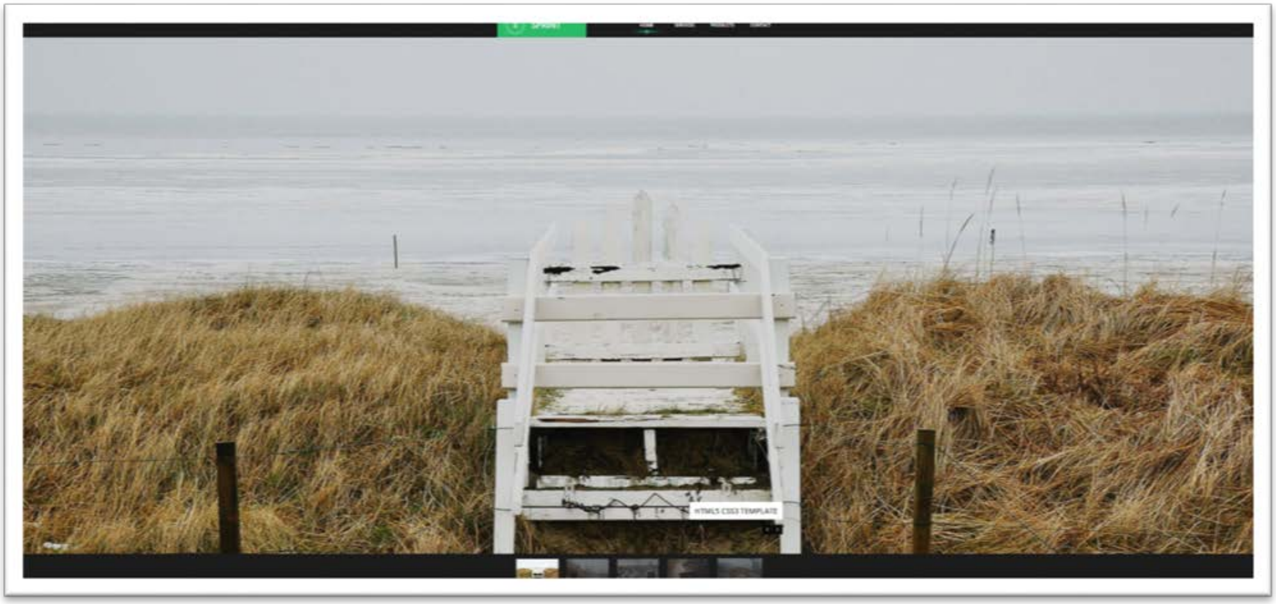


Figure 27

It should be noted that this layout has the additional benefit of being mobile-friendly. If the available screen real estate were decreased to a certain point in the horizontal, then the floating menu bar at the top of the screen would switch to a more compact drop down menu.

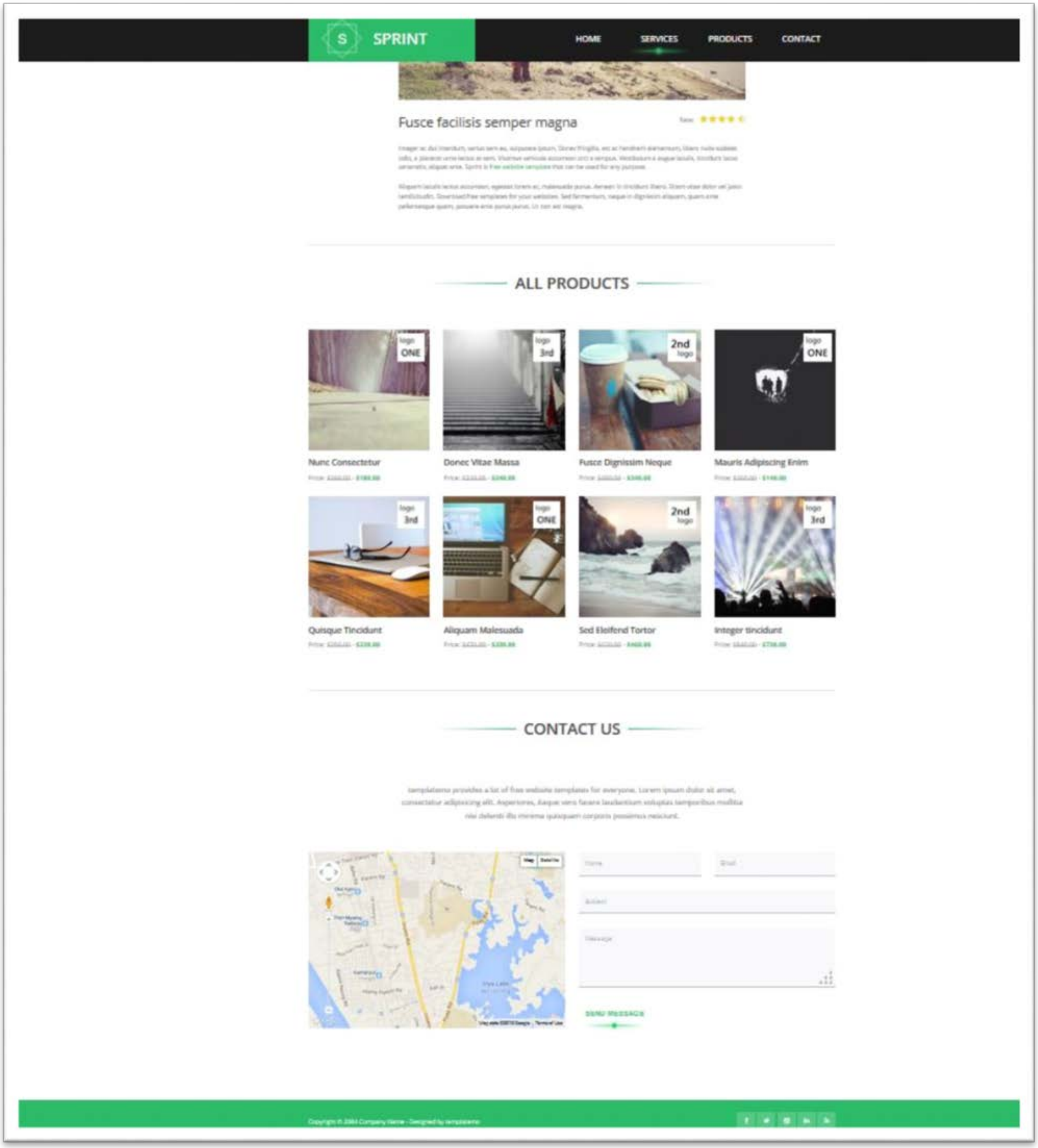


Figure 28

Figure 29 is a composite image of raw images from news outlets around the world. We selected photos that are highly relevant to our topic and tell a strong story of an effect of the drought. In addition, an important selection criteria was the resolution of the raw photo. This is important to consider because in our chosen base layout, the slides are expanded automatically to fill the extant of a browser display.

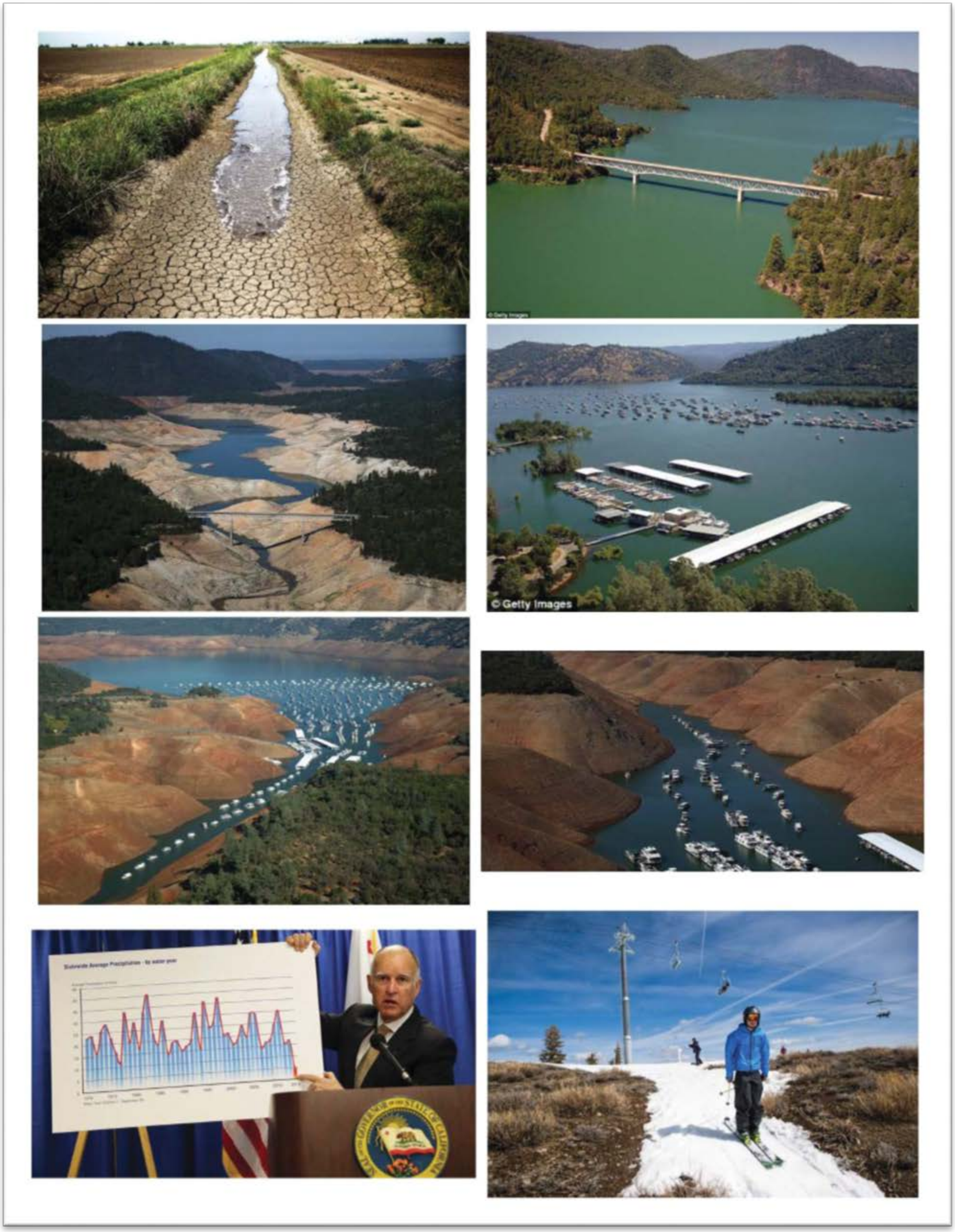


Figure 29

For slide 4, we used US Drought Monitor archived maps to create affected drought maps in California. Figure 30 is a screenshot of the US Drought Monitor access portal. Part of the reason for the inclusion of these maps was because we elected to not create maps in D3 due to time constraints and with the blessing of our TF. While having D3 maps would be visually appealing, they do not add significant functional value to our final visualization as we are no longer following through with our original vision of tying water withdrawal data at a California county level to decreasing reservoir capacity utilization.

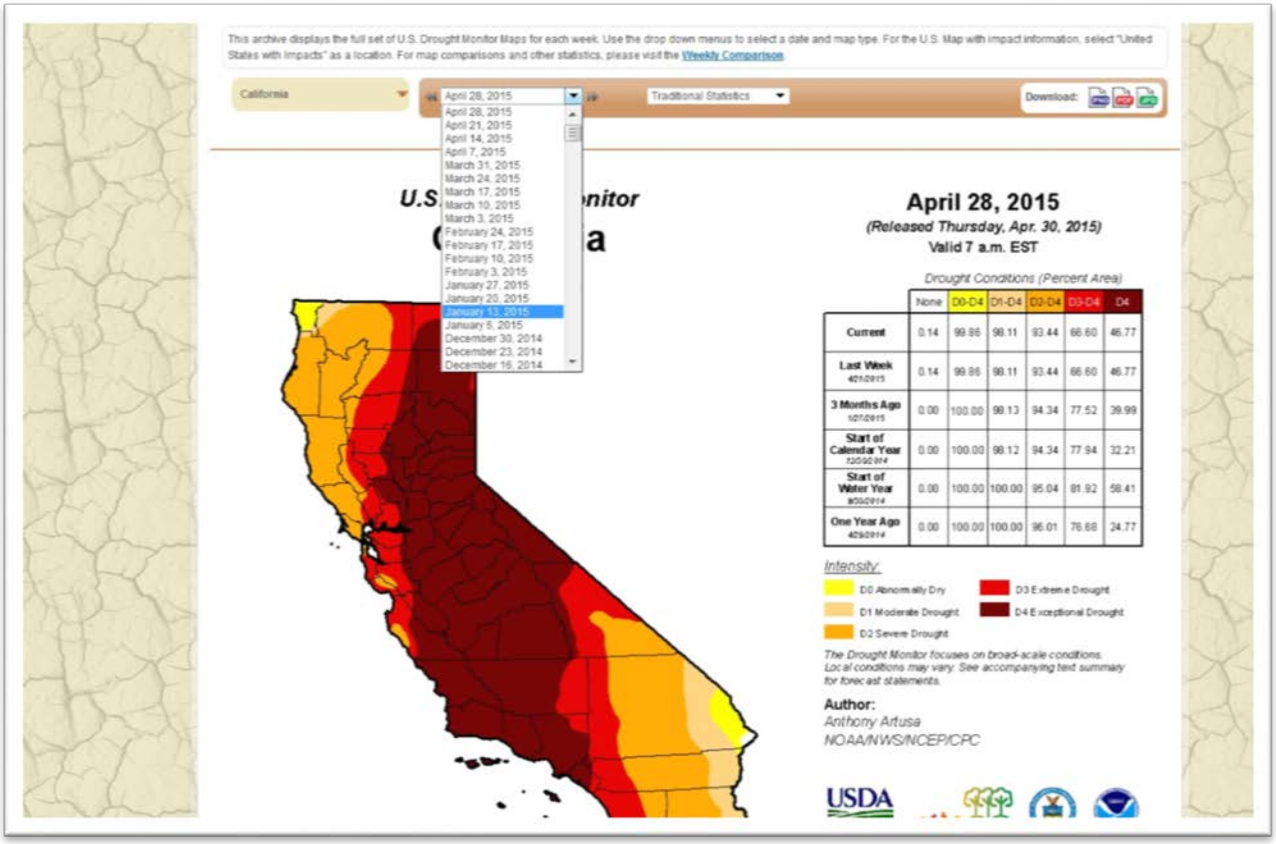


Figure 30

After many iterations, we are finally ready to pull all of our pieces together into the final output. The final design considerations are delineated in the following section, 'Implementation'.

IMPLEMENTATION

Our implementation involves two distinct data vis on a single 'responsive'-style webpage utilizing modern web framework such as HTML5, CSS, D3, and JS. Figure 31 shows a zoomed out view of our final design.

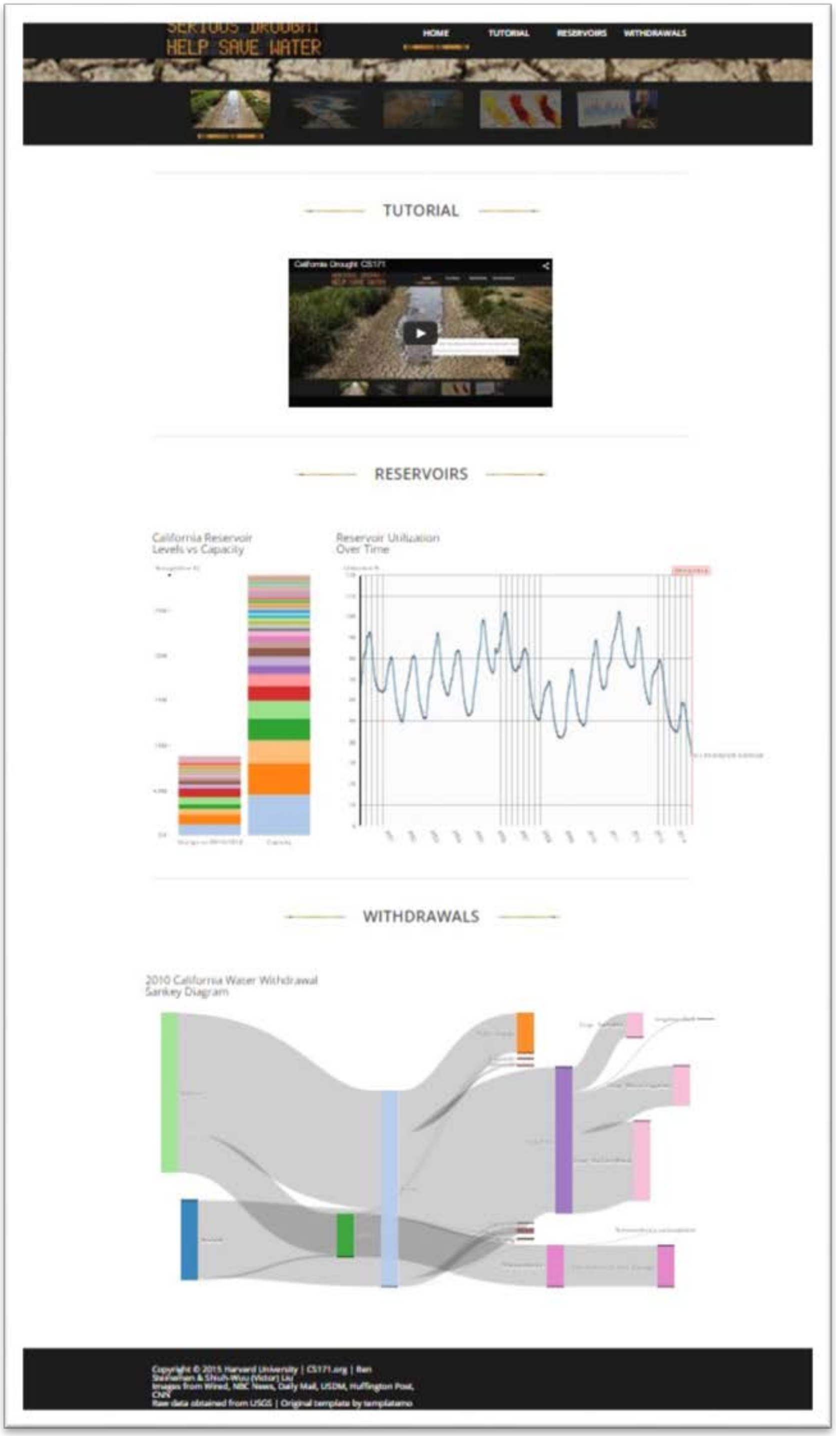


Figure 31

Figure 32 is our landing page which allows the user to cycle through (5) static images that set the mood for the data vis to come further down the page. The white arrows in black boxes allow the user to move, laterally, to the next picture.

Figure 32

Figure 33 is the second image which shows before and after photos of the second largest reservoir in California. The (5) thumbnails below the main picture allows the user to jump to any image at any time. By default, the main image expands and contracts according to the browser's total calculated viewable area at all times.

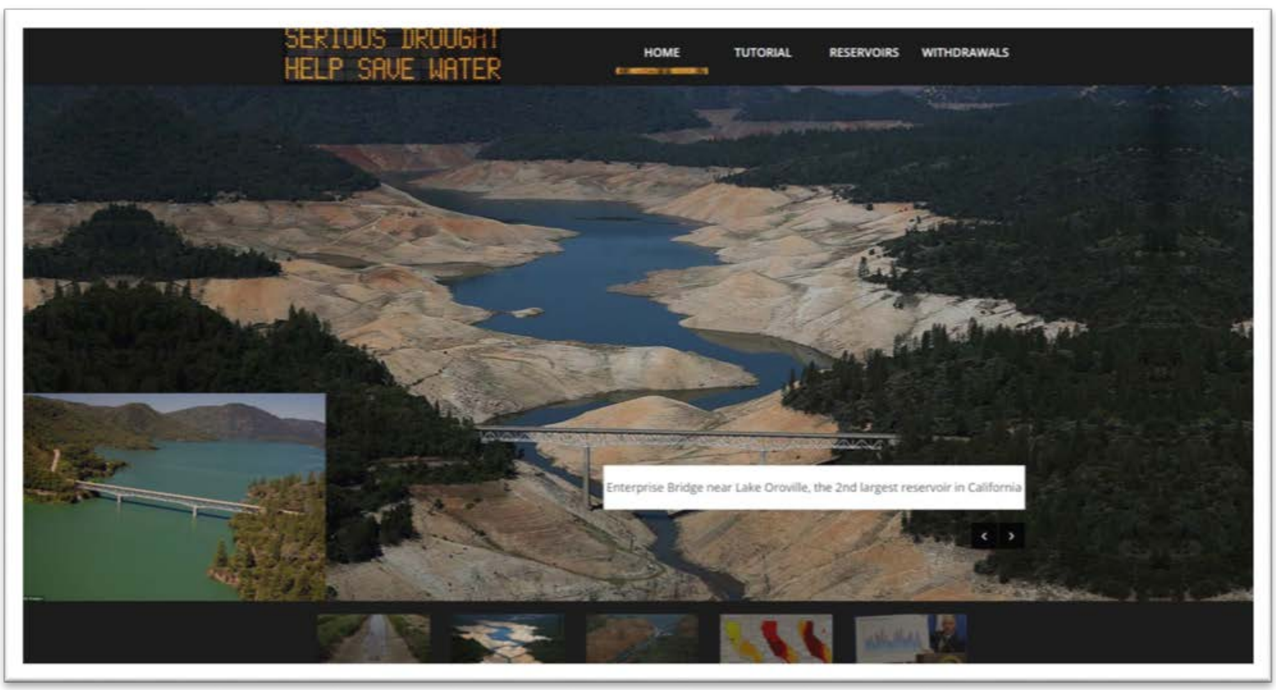


Figure 33

Figure 34 is similar to Figure 33 in that it sets the tone for the severity of the California drought as captured in all of its visceral dismality. The California Department of Transportation (CalTrans) sign was duplicated as a part of the header because the ominous orange glow is a perfect pairing with its equally ominous message imploring water conservation for the masses. The rainstick, of Aztec origins, under the 'HOME' button in the header serves as a digital lucky charm as its physical counterparts have been designated by the supernatural powers that be to herald the formation of rain clouds upon a healthy shaking of its form.

Figure 34

Figure 35 was created using maps pulled from the US Drought Monitor map archives. It helps highlight how the drought has affected the most populous parts as well as the coveted farm lands of California.

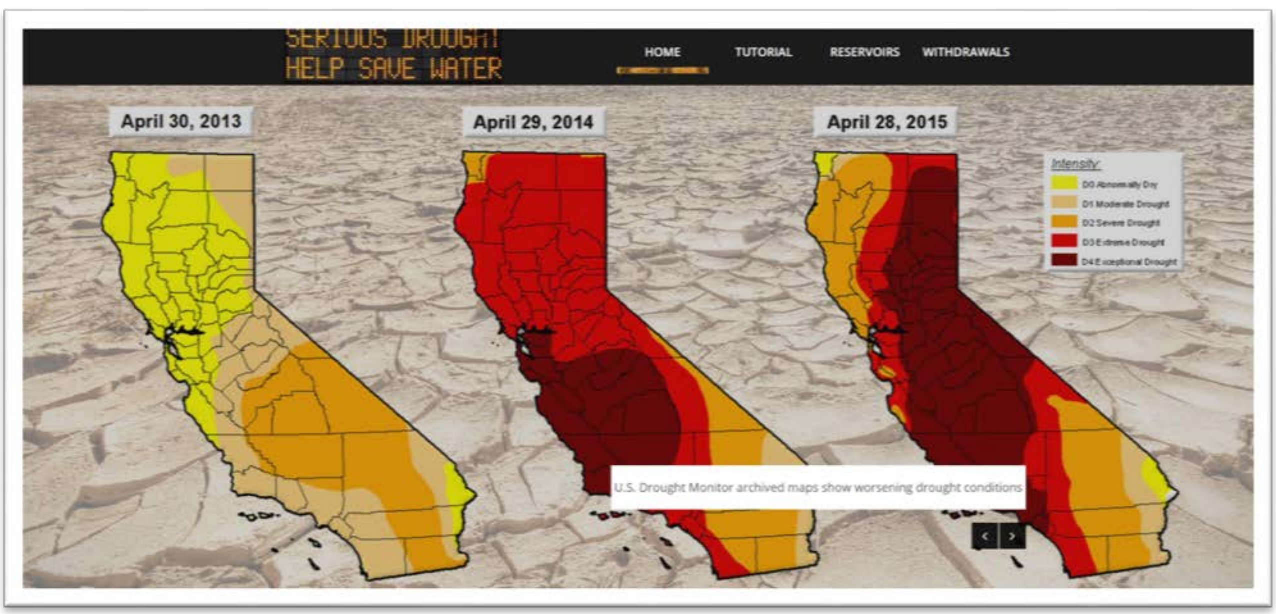


Figure 35

Figure 36 was included to show California Governor Jerry Brown making an important point regarding drought severity using a static piece of data visualization. This is the perfect end of our image slides and a fitting segue to our own D3 visualizations.

Figure 36

Figure 37 shows our Tutorial page which allows for the end users to watch a YouTube video featuring a personal walkthrough of our webpage as narrated by Ben Steineman. For the sake of brevity, we have omitted a large collection of outtakes and bloopers videos in which not much ego was left unscathed.

Figure 37

The 'RESERVOIRS' button leads users to our first visualization which is composed of two stacked bar charts and a multiline chart as shown in Figure 38.

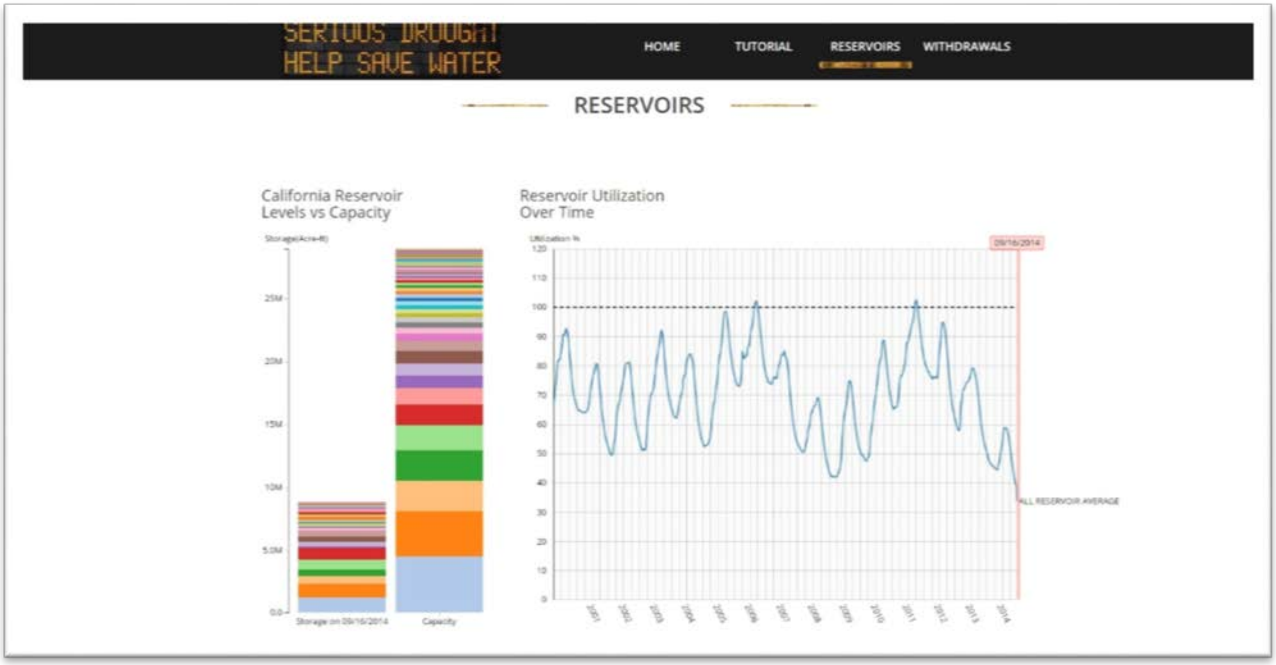


Figure 38

The 'ALL RESERVOIR AVERAGE' line is displayed by default on the multiline graph which reveals reservoir utilization rates over time. The left stacked bar chart shows reservoir water levels for each of the reservoirs in California while the right stacked bar chart shows reservoir capacity for each of the reservoirs in California. A mouseover on any of those stacked bars would trigger a display of the reservoir utilization rate line on the multiline graph as shown in Figure 39.

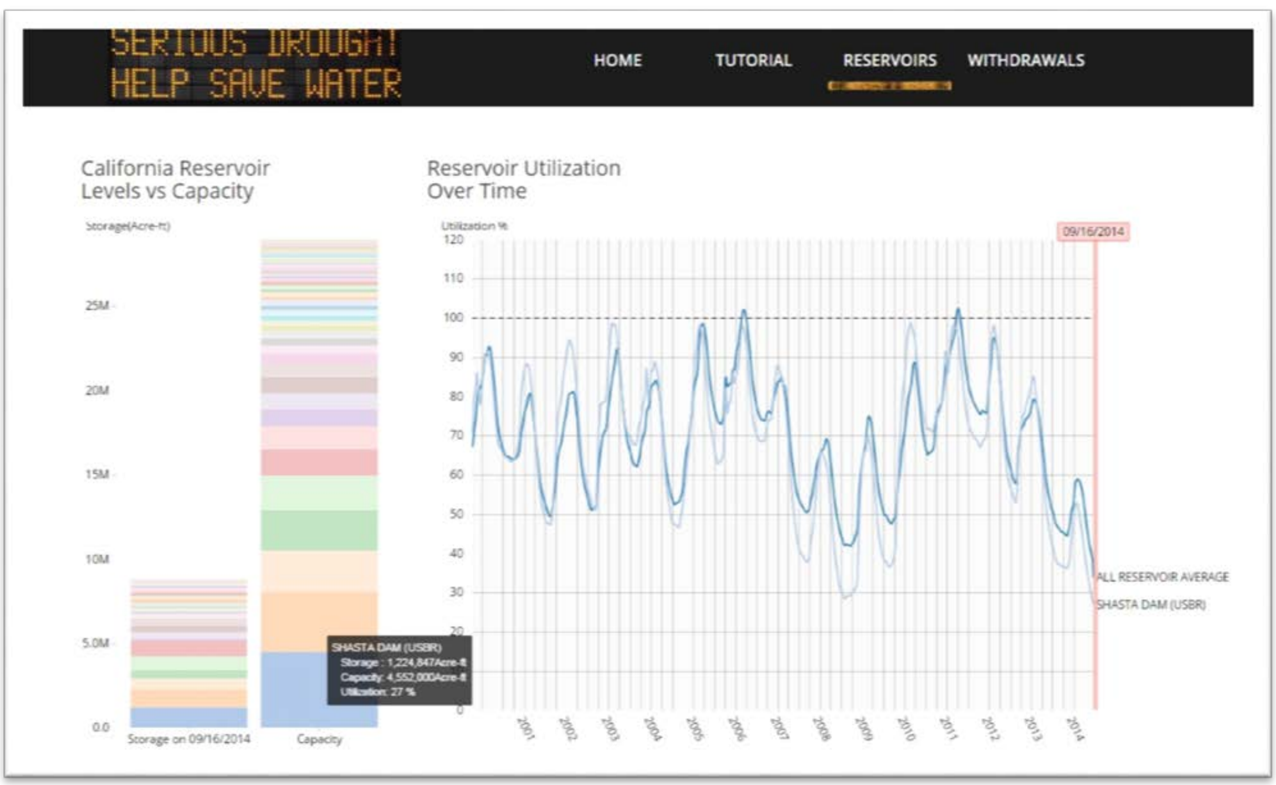


Figure 39

Additionally, if you click on any stacked bar, then the reservoir-specific utilization line is locked on the multiline graph. Clicking an empty space on the stacked bar chart reverts the multiline graph back to its default single line form with mouseover individual reservoir line selections available, once again, as seen in Figure 40.

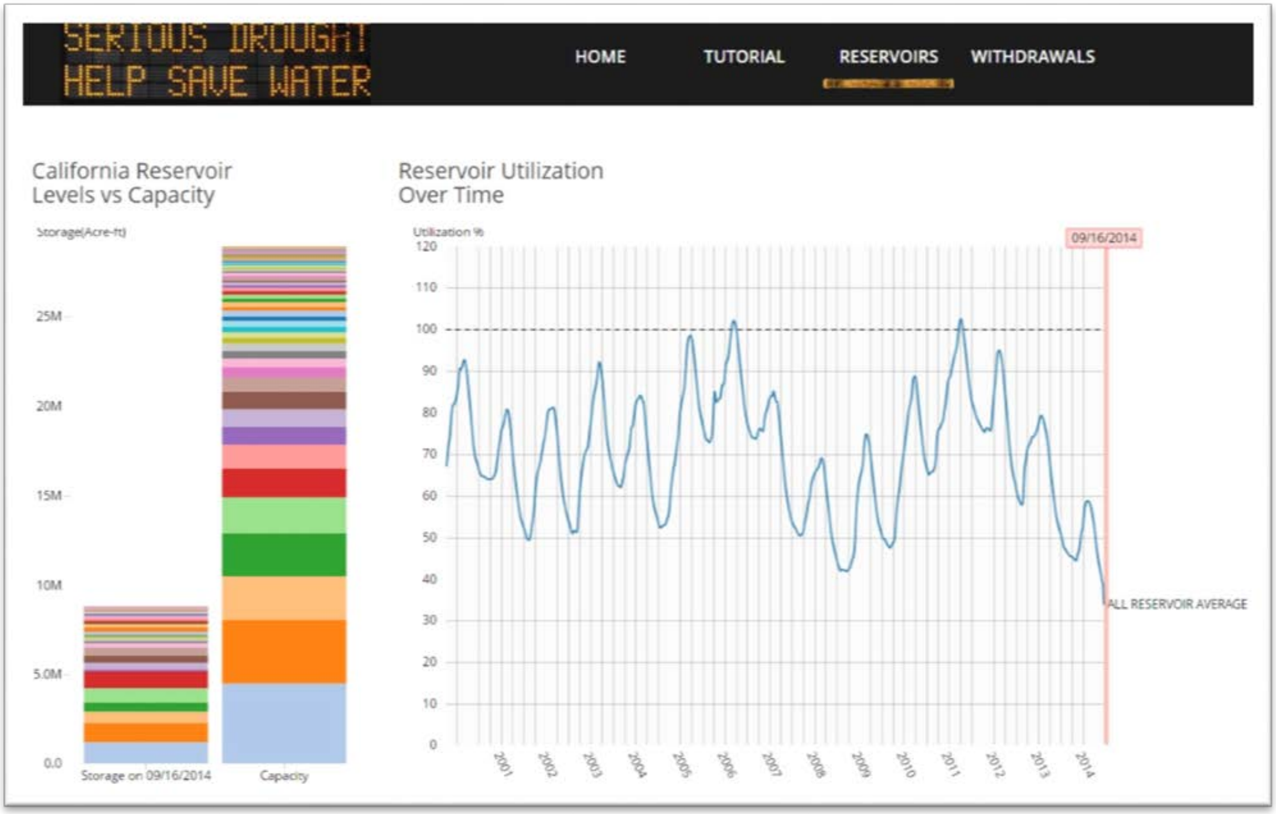


Figure 40

Figure 41 shows another clicked and locked reservoir-specific line. It is very easy to spot utilization profile variations between a single reservoir and the average.

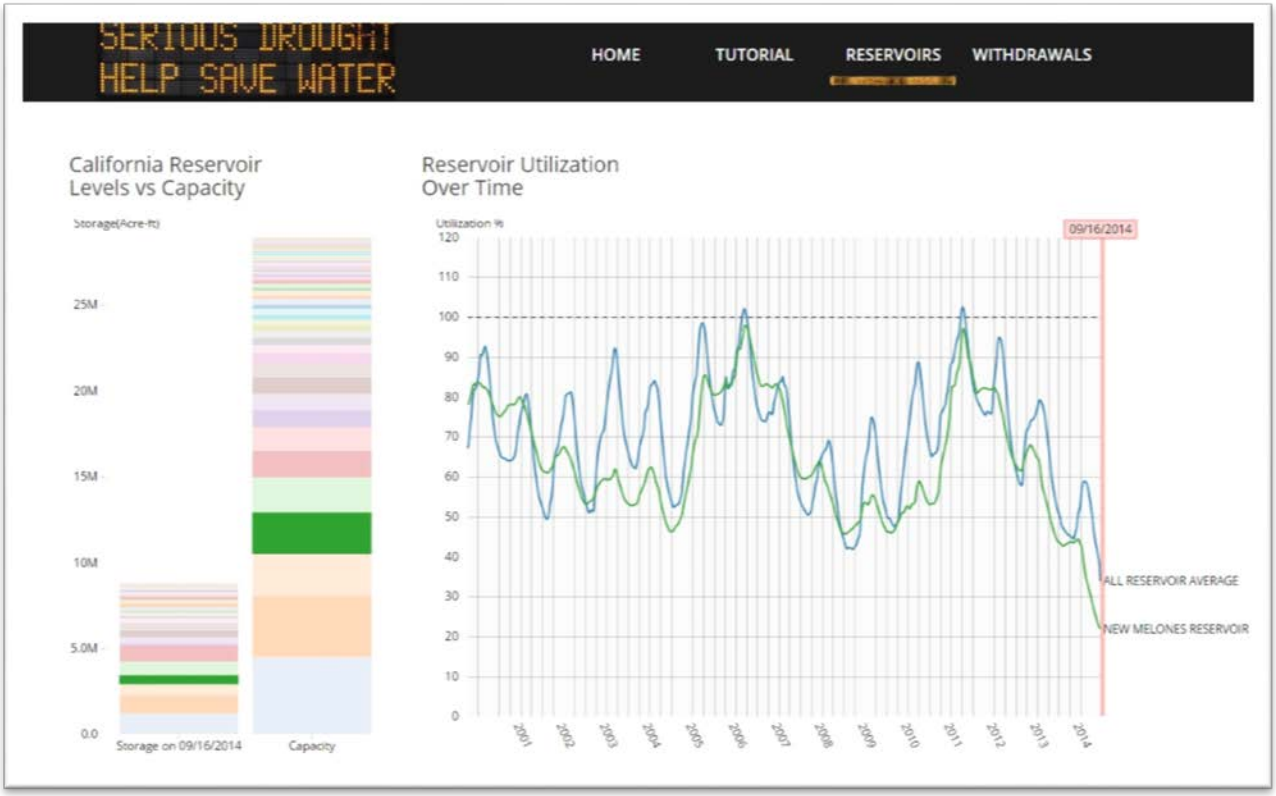


Figure 41

Another interactive feature on this data vis is the date selector on the multiline graph. It defaults on the latest available data point, but as you change the date, then the reservoir level stacked bar chart transitions to show varying reservoir levels for each reservoir. Figure 42 shows a date selection other than the default date selection.

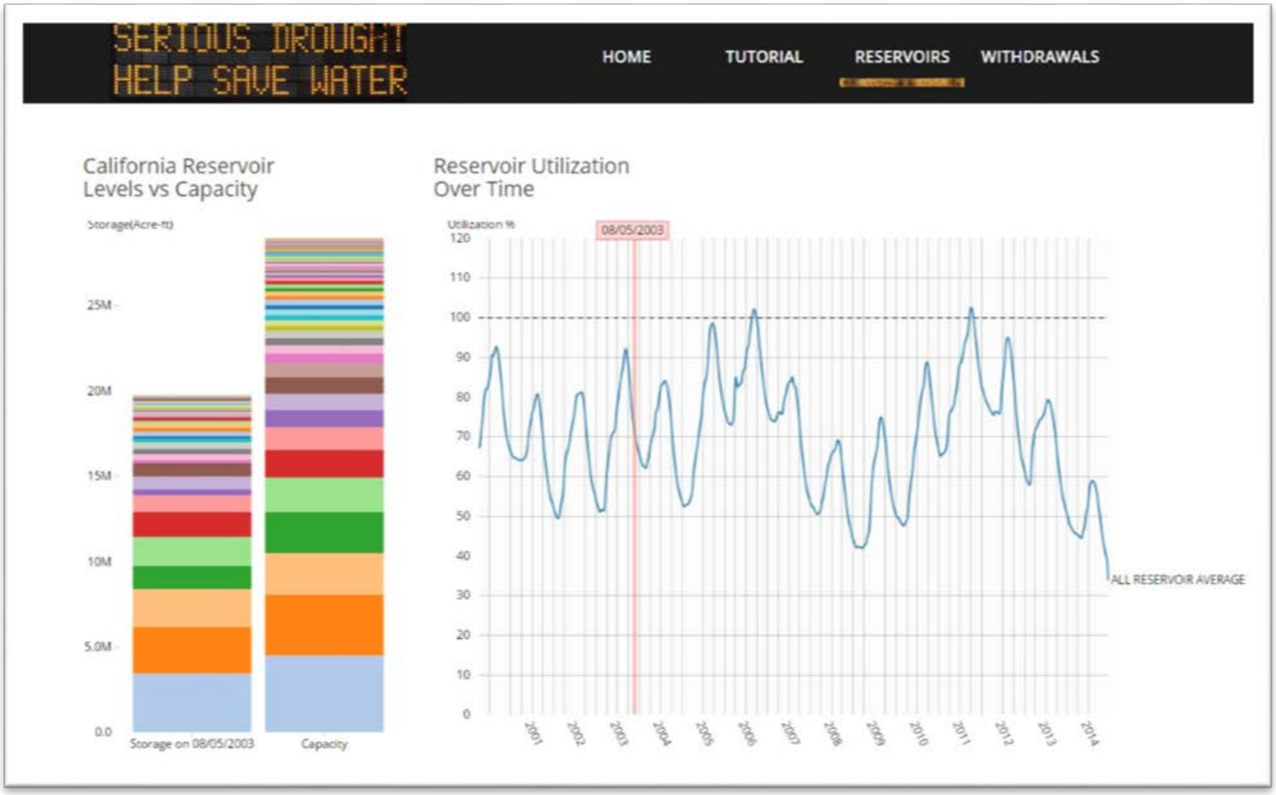


Figure 42

Figure 43 shows yet another alternative date selection which triggers the reservoir level stacked bar chart to move in accordance and tandem with the selected date.

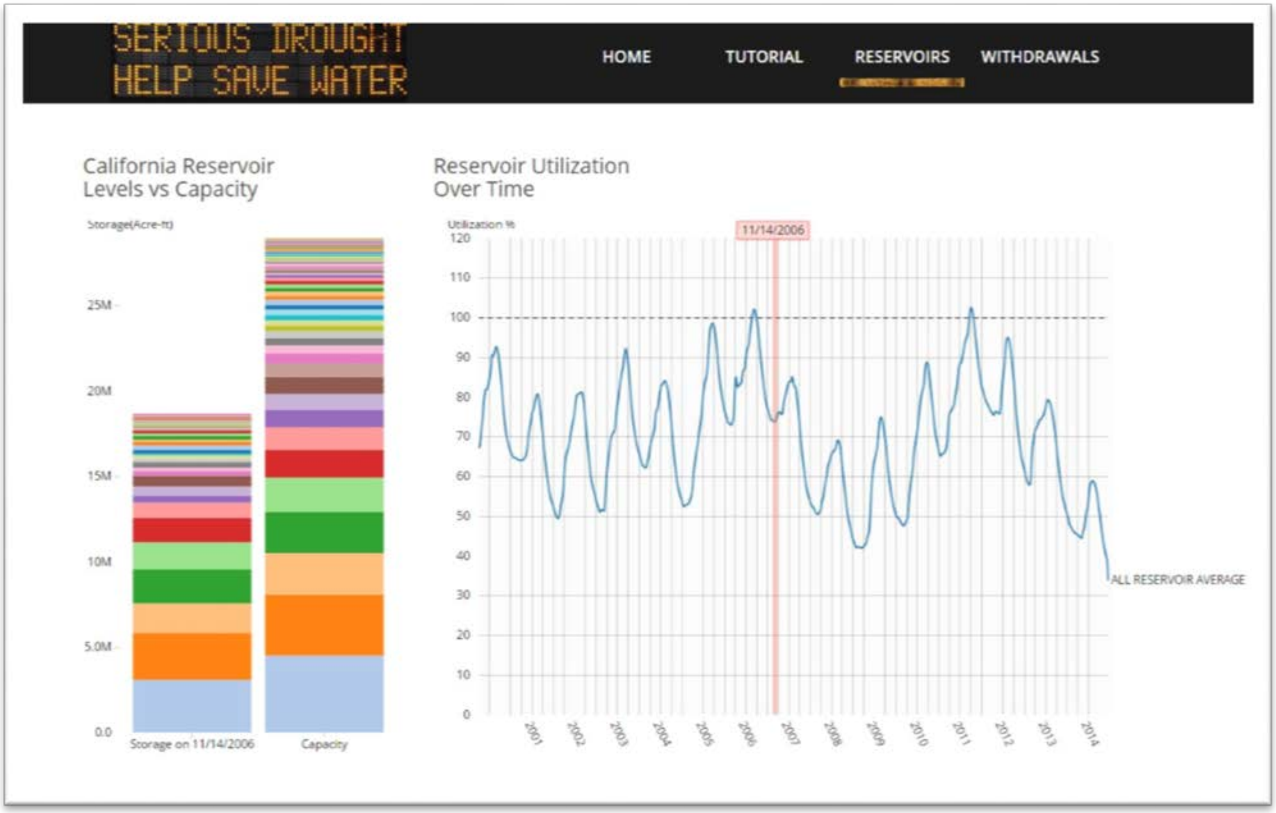


Figure 43

Figure 44 shows that the mouseover and click selection options on the stacked bar chart are still available given any date selection on the multiline graph.

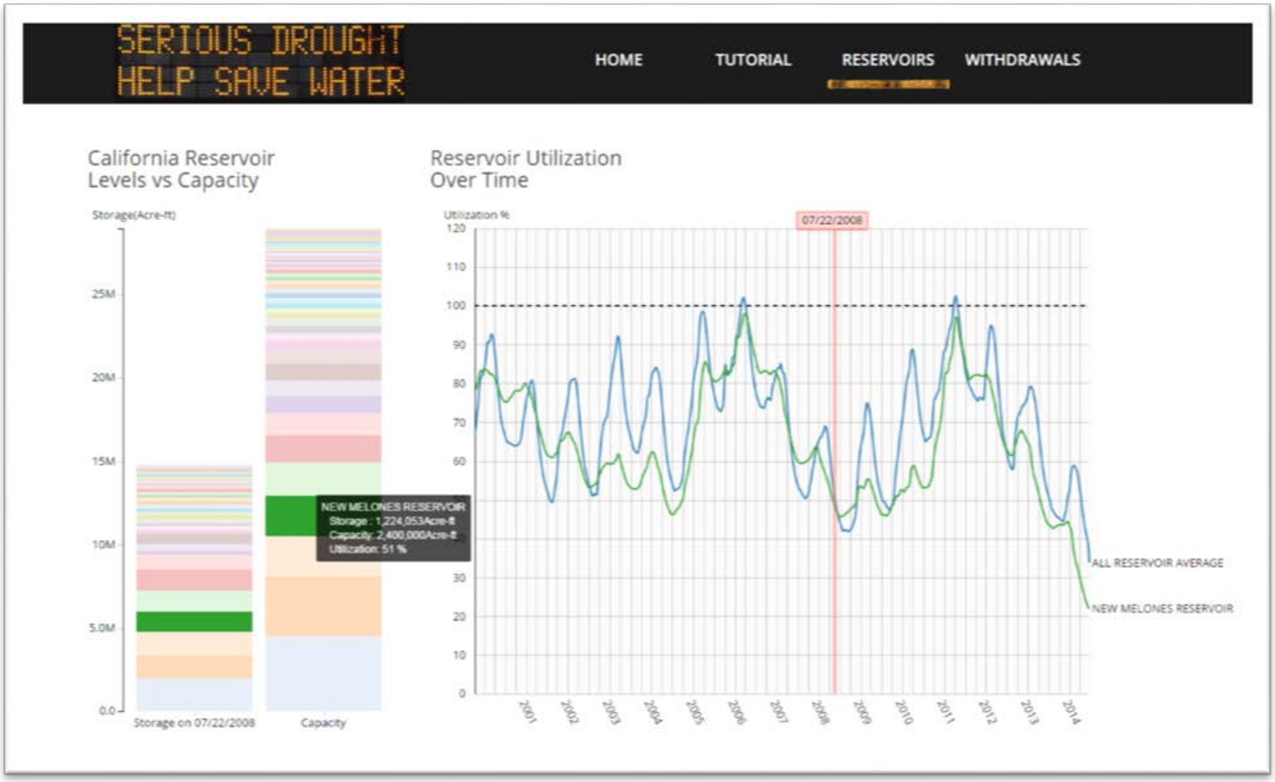


Figure 44

Figure 45 is the default view of our Sankey Diagram which shows the 2010 water withdrawals in California.

Figure 45

Each rectangular node could be dragged and repositioned as shown in Figure 46 at the end user's discretion.

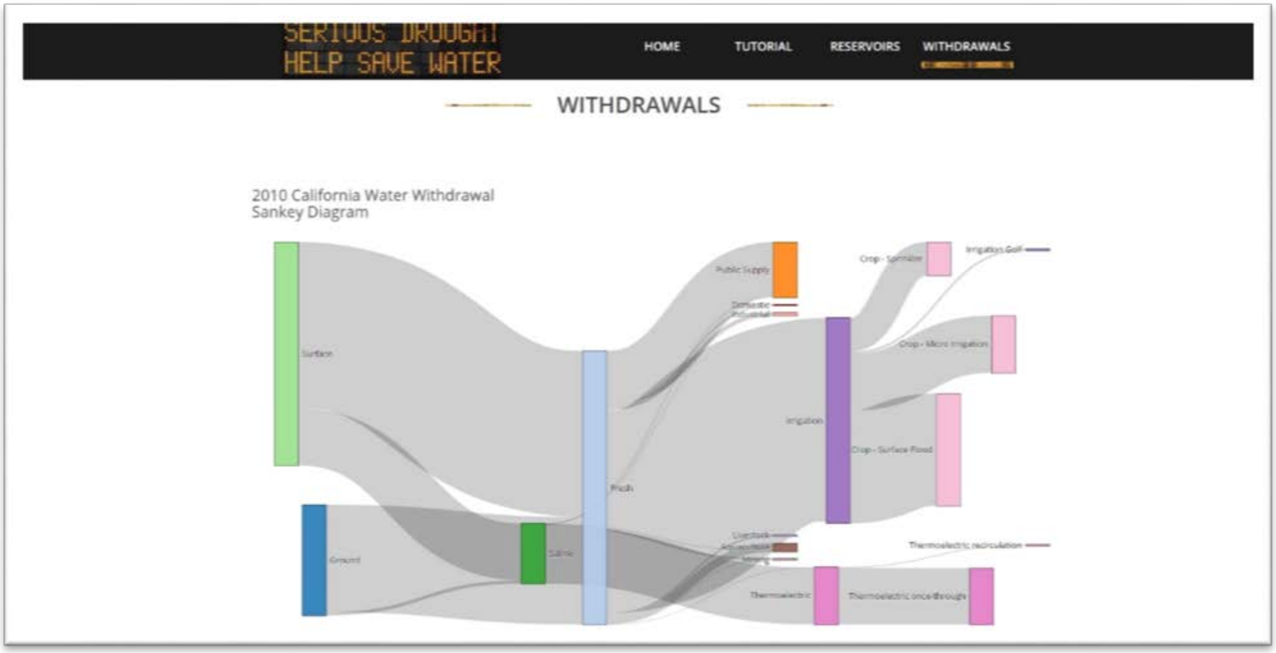


Figure 46

Figure 47 shows a perhaps less practical, but interesting view of an alternate user defined state. A mouseover reveals the numerical value and unit of measure for every Sankey Diagram link.

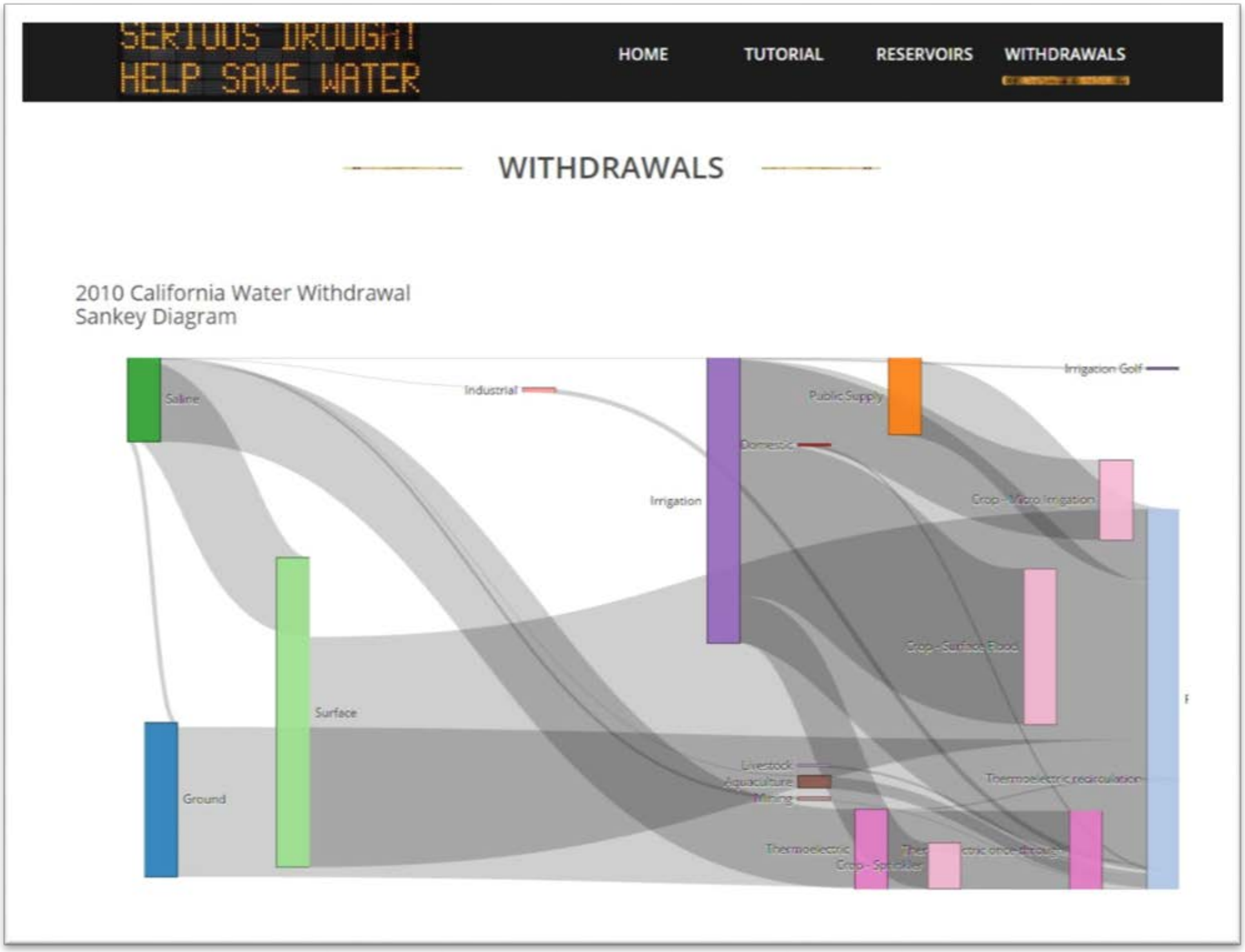


Figure 47

Figure 48 is located at the bottom of our webpage. It shows acknowledgements for images used in the creation of our slide show, raw data obtained from USGS, and the free webpage template obtained from templatemo. Most importantly, we wanted to prominently highlight Harvard University and the CS 171 teaching staff for taking us this far in our data vis journey. Each of the names are linked to an appropriately relevant webpage.

Additionally, both Process Book and Proposal is available for download for interested parties.

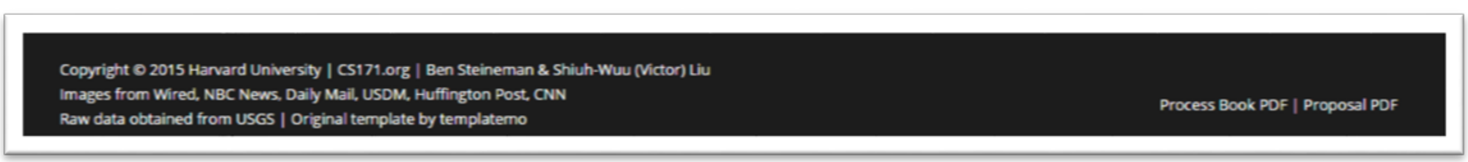


Figure 48

Figure 49 shows a view of our site on a tablet which shrinks the top floating menu into a drop down menu bar.

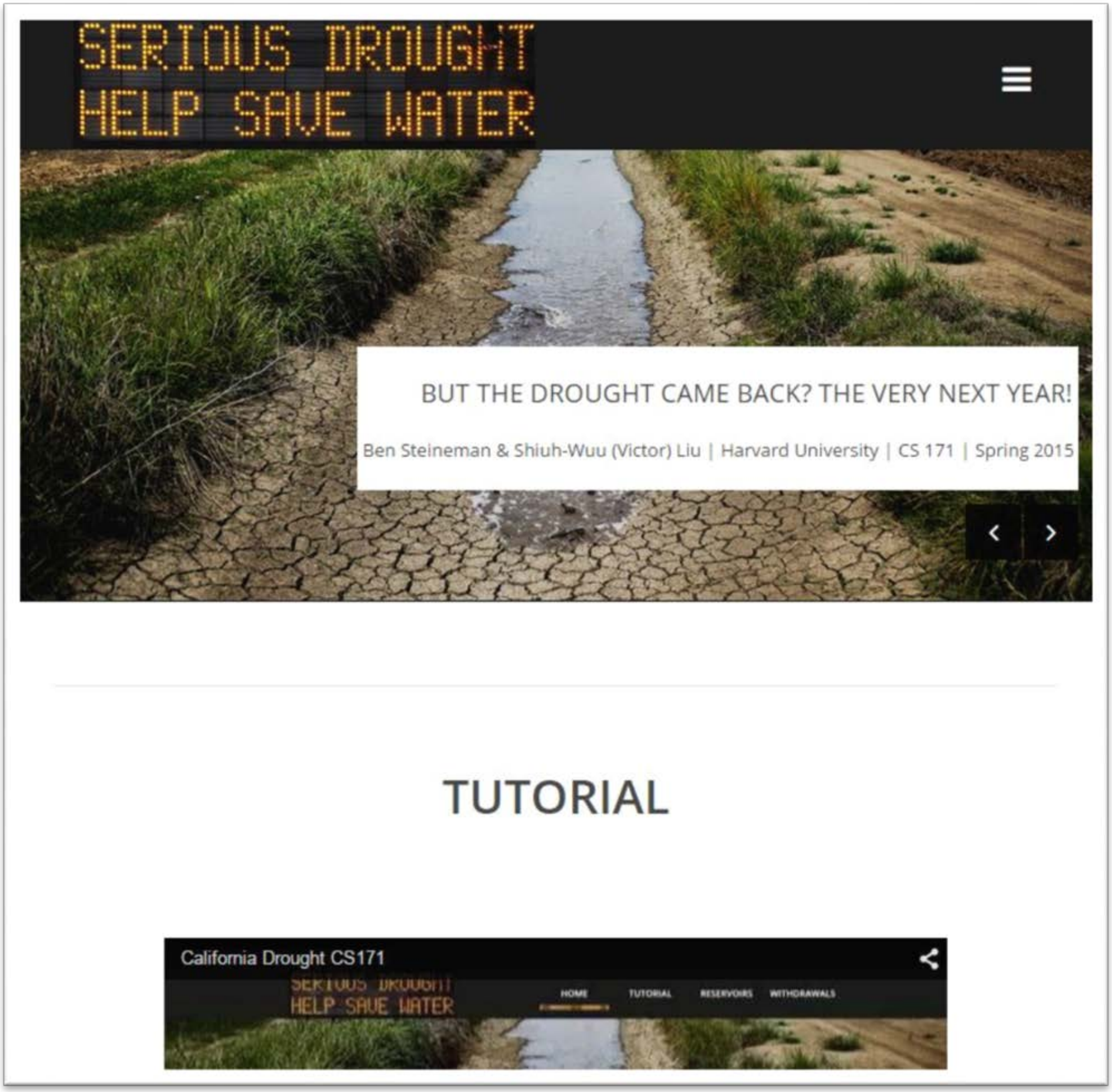


Figure 49

Figure 50 shows how our webpage would be displayed on a mobile device. Again, the top menu bar selected yields a drop down menu which allows for navigation in a constrained screen environment.

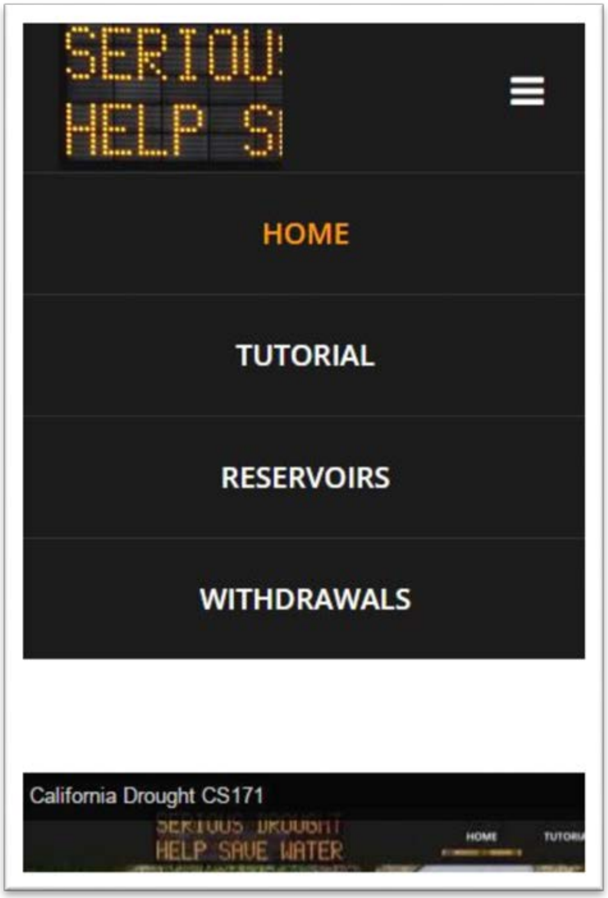


Figure 50

EVALUATION

Through our visualizations, we are able to see that the reservoir utilization rates in California have been dropping significantly from 2000-2014. On the other hand, we are also able to see that 'Irrigation' is the largest use of fresh water in 2010. We feel confident that our data visualizations address the critical parts of our main research questions which are duplicated below:

1. What is the state of California's water reservoirs in terms of utilization, location, and changes over time?

2. Where is California water being used and how can those use cases be categorized and broken out by volume?

As an aside, since our calculated utilization rates are exceeding 100% which is theoretically impossible, we are forced to conclude that the USGS data contains dirty or missing data elements. Without calculating rates, then we would have had no way to assess if the reported data contained ambiguities. The expected seasonality effects on each of the plotted reservoir curves matches our intuition of peaks in the late spring and troughs in the late fall of each year. Even though there are some dirty or missing data elements, observing the seasonality of water utilization makes us more comfortable with serving this dataset to our end users.

Our final project could be improved the most if we were able to secure time to implement a geospatial mapping of the reservoirs which are linked to the stacked bar charts and the multiline graphs. Consequently, county level water withdrawal data could have been used to provide another class of map elements on the same geospatial map related to reservoir utilization and location.

Another opportunity would be to link the date selections from the reservoir utilization data with the water withdrawal data. Since the water withdrawal data is collected every (5) years, we would need to interpolate or project based on past data. We can perform a simple linear interpolation for data in between two known data points, but for projecting a future data point for the purposes of interpolation, then we could look towards reservoir utilization trends to make an educated guess as to what the projected ending future 5-year data point would be.

A more light-hearted approach which will have an infographic-esque flavor to the data vis, would be stacked bar charts denominated in almonds or other agricultural products that consume large amounts of water. This could be tied to rising food prices subtracting inflation and freight costs. Freight costs may be approximated by crude oil prices given a temporal correction for the lag in rising freight costs.

Beyond the California drought, we could extend our data vis to include data from other US states or move beyond our country's borders to other countries sharing in the unfortunate circumstance of being afflicted by severe drought.

Suffice to say, there are many ways to slice the data in order to help end users draw meaningful conclusions from derived insights from our California drought data vis. It is our hope that with decision makers using those insights as a springboard for formulating actionable plans, the drought will NOT be coming back the very next year.