# California "Conservation-Consumption Score" analysis

By Ryan Menezes, Matt Stevens and Ben Welsh

A Los Angeles Times analysis published on Oct. 31, 2016 (http://www.latimes.com/local/lanow/la-me-In-water-conservation-backslide-20161018-snap-htmlstory.html), found that the overwhelming majority of California water districts increased their usage after the state eased its drought restrictions. Some of the most extreme increases were found in inland Northern California, led by the San Juan Water District near Folsom Lake.

How did The Times come to that conclusion? Using the computer code that follows.

#### Here's how it worked.

We started by downloading data from California's State Water Resources Control Board, which publishes a monthly accounting of each district's water usage on its website.

That data has been used by state regulators to monitor and enforce mandatory water-use reductions introduced as part of the state's emergency drought response. Regulators ended mandatory conservation for the vast majority of urban water suppliers this spring.

The state measures each district's water savings by comparing the number of gallons it supplies to homes, businesses and institutions each month versus the same month in 2013, a baseline that precedes Gov. Jerry Brown's proclamation of a drought State of Emergency.

The code below calculates that statistic for three months this summer after restrictions were eased, then compares it against the same months in 2015. In total, 93% of 387 districts increased water usage this year. Nineteen districts were excluded because they did not report enough data to the state.

California's water districts vary greatly in size, from large urban areas like Los Angeles to small districts in the rural north. To compare suppliers and identify areas where residents use large amounts of water at home, state officials also track the total amount of water used by each district's average resident each day.

This code combines that measure with each district's change in total summer water usage to create a ranking we're calling a Conservation-Consumption Score. By including both factors, this statistic -- sometimes known as a z-score -- better identifies areas where residents account for increases.

Some of the highest ranking districts by this score were found in Northern California and around Folsom Lake near Sacramento. The top score belonged to the San Juan Water District, the ultimate focus of our story.

#### Import and configure analysis tools.

```
In [1]: import os
   import pandas as pd
   import numpy as np
   import matplotlib.pyplot as plt
   from __future__ import division
   %matplotlib inline
In [2]: pd.set_option('display.float_format', lambda x: '%.2f' % x)
   pd.set_option("display.max_columns", 500)
```

#### Import raw water usage data from the state

```
In [3]: supplier_path = os.path.join(os.getcwd(), 'uw_supplier_data100516.xlsx')
In [4]: SUPPLIER_TABLE = pd.read_excel(supplier_path)
```

#### Keep the columns we want

#### Clean them up

```
In [7]: supplier_table['month'] = supplier_table['month'].astype(str)

/home/ben/.virtualenvs/ca-water-conservation-analysis/lib/python2.7/site-pack
ages/ipykernel/__main__.py:1: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: http://pandas.pydata.org/pandas-docs/st
able/indexing.html#indexing-view-versus-copy
   if __name__ == '__main__':
```

```
In [8]: supplier table.info()
          <class 'pandas.core.frame.DataFrame'>
          RangeIndex: 10936 entries, 0 to 10935
         Data columns (total 5 columns):
          supplier name
                                                       10936 non-null object
          month
                                                       10936 non-null object
          total_water_production_gallons
                                                       10936 non-null float64
          total water production gallons 2013
                                                       10936 non-null float64
          residential water usage
                                                       10936 non-null float64
          dtypes: float64(3), object(2)
         memory usage: 427.3+ KB
In [9]:
          supplier table.head()
Out[9]:
             supplier_name month total_water_production_gallons total_water_production_gallons_2013 re-
                   East Bay
                             2016-
                  Municipal
          0
                                                  6007500000.00
                                                                                     7172300000.00
                             08-15
              Utilities District
                   East Bay
                             2016-
                                                  6056600000.00
                                                                                     7452200000.00
          1
                  Municipal
                             07-15
              Utilities District
                   East Bay
                             2016-
          2
                  Municipal
                                                  5675900000.00
                                                                                     6927500000.00
                             06-15
              Utilities District
                   East Bay
                             2016-
          3
                                                  4959300000.00
                                                                                     6716500000.00
                  Municipal
                             05-15
              Utilities District
                   East Bay
                             2016-
                  Municipal
                                                                                     5417500000.00
                                                  4018800000.00
                             04-15
```

#### Filter the data to only the three summer months in 2015 and 2016

**Utilities District** 

/home/ben/.virtualenvs/ca-water-conservation-analysis/local/lib/python2.7/sit e-packages/pandas/util/decorators.py:91: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: http://pandas.pydata.org/pandas-docs/st able/indexing.html#indexing-view-versus-copy return func(\*args, \*\*kwargs)

```
In [12]: "Total records: {}".format(len(supplier_table))
Out[12]: 'Total records: 10936'

In [13]: "Month records: {}".format(len(month_table))
Out[13]: 'Month records: 2425'
```

### Eliminate any suppliers who have fewer or greater than six months of data with those labels

```
In [14]:
            supplier_counts = month_table.groupby("supplier_name")['supplier_name'].count
            ().to_frame("count").reset_index()
In [15]:
            incomplete_month_table = supplier_counts[supplier_counts['count'] <> 6]
In [16]:
            incomplete month table
Out[16]:
                                        supplier_name
                                                        count
               7
                                                            5
                                      Anderson, City of
                                        Calexico City of
              34
                                                            5
             118
                                      Escondido City of
                                                            5
             167
                                 Hi-Desert Water District
                                                            5
             195
                                        Lemoore City of
                                                            4
             200
                                       Livingston City of
                                                            5
             210
                                        Lynwood City of
                                                            5
             225
                           Mission Springs Water District
                                                            5
             227
                                       Monrovia City of
                                                            4
             280
                                       Porterville City of
                                                            4
             311
                                      San Bruno City of
                                                            5
             322
                                       San Jose City of
                                                            5
             349
                  South Feather Water and Power Agency
                                                            5
                                        Stockton City of
             353
                                                            5
                                       Susanville City of
             360
                                                            5
                                                            5
             366
                                        Torrance City of
             375
                         Twentynine Palms Water District
                                                            5
             376
                                           Ukiah City of
                                                            4
             385
                         Valley of the Moon Water District
                                                            5
```

In [17]: complete\_month\_table = month\_table[~month\_table['supplier\_name'].isin(incomple
 te\_month\_table['supplier\_name'])]

```
In [18]: "Complete month records: {}".format(len(complete_month_table))
Out[18]: 'Complete month records: 2334'
```

#### Group and sum the total water production for each summer

```
summer_16_table = complete_month_table[complete_month_table['month'].isin(['20
In [19]:
          16-08-15', '2016-07-15', '2016-06-15',])]
          summer 16 totals = summer 16 table.groupby("supplier name")['total water produ
In [20]:
          ction gallons'].sum().to frame("total water production 16").reset index()
In [21]:
          summer 16 totals.head(5)
Out[21]:
                         supplier_name
                                      total_water_production_16
           0
                         Adelanto City of
                                                 434024228.54
             Alameda County Water District
                                                3937000000.00
           2
                      Alco Water Service
                                                 344299000.00
           3
                        Alhambra City of
                                                 775637185.75
                    Amador Water Agency
                                                 350910000.00
In [22]:
          "Summer 16 records: {}".format(len(summer_16_totals))
Out[22]: 'Summer 16 records: 389'
In [23]:
          summer_15_table = complete_month_table[complete_month_table['month'].isin(['20
          15-08-15', '2015-07-15', '2015-06-15',])]
In [24]:
          summer 15 totals = summer 15 table.groupby("supplier name")['total water produ
          ction_gallons'].sum().to_frame("total_water_production_15").reset_index()
In [25]:
          summer_15_totals.head(5)
Out[25]:
                                      total_water_production_15
                         supplier_name
           0
                         Adelanto City of
                                                 387316100.00
             Alameda County Water District
                                                3374000000.00
                      Alco Water Service
                                                 350899000.00
           3
                        Alhambra City of
                                                 777996350.08
                    Amador Water Agency
                                                 287480000.00
          "Summer 15 records: {}".format(len(summer 15 totals))
In [26]:
Out[26]: 'Summer 15 records: 389'
```

```
summer_13_totals = summer_16_table.groupby("supplier_name")['total_water_produ
          ction_gallons_2013'].sum().to_frame("total_water_production_13").reset_index()
In [28]:
          summer_13_totals.head()
Out[28]:
                          supplier_name total_water_production_13
           0
                         Adelanto City of
                                                   393342171.40
              Alameda County Water District
                                                 5273000000.00
                       Alco Water Service
                                                  447983000.00
           2
           3
                         Alhambra City of
                                                  1060724599.23
                    Amador Water Agency
                                                   431220000.00
          "Summer 13 records: {}".format(len(summer_13_totals))
In [29]:
Out[29]: 'Summer 13 records: 389'
```

## Join those summer production totals into a combined table

In [30]:	<pre>summer_table = summer_16_totals.merge(summer_15_totals, on="supplier_name") summer_table = summer_table.merge(summer_13_totals, on="supplier_name")</pre>							
In [31]:	<pre>"Total summer records: {}".format(len(summer_table))</pre>							
Out[31]:	'Total summer records: 389'							
In [32]:	summer_table.head(5)							
Out[32]:	supplier_name total_water_production_16 total_water_productio				total_water_production_13			
	0	Adelanto City of	434024228.54	387316100.00	393342171.40			
	1	Alameda County Water District	3937000000.00	3374000000.00	5273000000.00			
	2	Alco Water Service	344299000.00	350899000.00	447983000.00			
	3	Alhambra City of	775637185.75	777996350.08	1060724599.23			
	4	Amador Water Agency	350910000.00	287480000.00	431220000.00			
	4	<b>←</b>						

Calculate the percentage change of summers 15 and 16 versus the baseline of summer 2013

```
In [33]:
          summer table['savings 16'] = summer table.apply(
               lambda x: (x['total_water_production_16']-x['total_water_production_13'])/
          float(x['total water production 13']),
               axis=1
          )
In [34]:
          summer_table['savings_15'] = summer_table.apply(
               lambda x: (x['total_water_production_15']-x['total_water_production_13'])/
          float(x['total_water_production 13']),
               axis=1
          )
In [35]:
          summer table.sort values('savings 16', ascending=False).head()
Out[35]:
                supplier_name total_water_production_16 total_water_production_15 total_water_production_
             0 Adelanto City of
                                          434024228.54
                                                                  387316100.00
                                                                                           393342171.
                   North Marin
                                         1134200000.00
                                                                  715000000.00
                                                                                          1102000000.
           236
                  Water District
                 Humboldt Bay
           166
                     Municipal
                                           50810000.00
                                                                   53060000.00
                                                                                            49765000.
                  Water District
            10
                  Arcata City of
                                          180277000.00
                                                                  177507000.00
                                                                                           178787000.
           124
                 Fortuna City of
                                          125000000.00
                                                                  119100000.00
                                                                                           127100000.
```

#### Calculate the difference between in that statistic between 15 and 16

```
In [36]:
           summer_table['savings_change'] = summer_table.apply(
                lambda x: x['savings_16']-x['savings_15'],
                axis=1
           summer table.head(5)
In [37]:
Out[37]:
               supplier_name total_water_production_16 total_water_production_15 total_water_production_13
            0 Adelanto City of
                                                                                             393342171.40
                                          434024228.54
                                                                   387316100.00
                     Alameda
                 County Water
                                                                  3374000000.00
                                         3937000000.00
                                                                                            5273000000.00
                      District
                   Alco Water
            2
                                          344299000.00
                                                                   350899000.00
                                                                                             447983000.00
                      Service
                Alhambra City
            3
                                          775637185.75
                                                                   777996350.08
                                                                                            1060724599.23
                          οf
                Amador Water
                                          350910000.00
                                                                   287480000.00
                                                                                             431220000.00
                      Agency
```

# Rank the cities that have regressed the most towards their 2013 baseline

In [38]:	<pre>summer_table.sort_values("savings_change", ascending=False).head()</pre>					
Out[38]:	supplier_name		total_water_production_16	total_water_production_15	total_water_production_	
	236	North Marin Water District	1134200000.00	715000000.00	1102000000.	
	313	San Juan Water District	1783309914.14	1204845426.88	2045265134.	
	314	San Lorenzo Valley Water District	206498200.00	138808800.00	243345319.	
	123	Folsom City of	2425963874.01	1835195236.86	2725421335.	
	321	Santa Fe Irrigation District	1035523249.86	763209212.32	1257134805.	
	4				<b>&gt;</b>	

# Calculate the average monthly water usage per person (R-GPCD) in each district for the summer of 2016

In [39]:		<pre>summer_16_means = summer_16_table.groupby('supplier_name')['residential_water_ usage'].mean().to_frame("residential_water_usage_mean_16").reset_index()</pre>				
In [40]:	su	mmer_16_means.head(5)				
Out[40]:		supplier_name	residential_water_usage_mean_16			
	0	Adelanto City of	117.48			
	1	Alameda County Water District	84.23			
	2	Alco Water Service	103.25			
	3	Alhambra City of	89.18			
	4	Amador Water Agency	102.61			

# Join those water usage average to our combined table

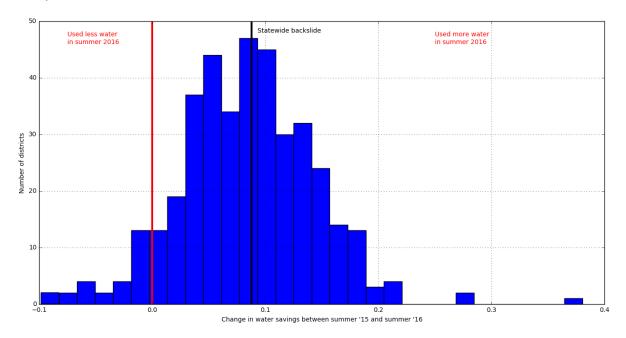
```
In [41]: summer_table = summer_table.merge(summer_16_means, on="supplier_name")
```

In [42]:	<pre>summer_table.head(5)</pre>					
Out[42]:	supplier_name		total_water_production_16	total_water_production_15	total_water_production_13	
	0	Adelanto City of	434024228.54	387316100.00	393342171.40	
	1	Alameda County Water District	3937000000.00	3374000000.00	5273000000.00	
	2	Alco Water Service	344299000.00	350899000.00	447983000.00	
	3 Alhambra City of		775637185.75	777996350.08	1060724599.23	
	4	Amador Water Agency	350910000.00	287480000.00	431220000.00	
	4				<b>&gt;</b>	

#### Calculate summary statistics to judge how many districts regressed in summer 2016

```
In [47]: plt.figure(figsize=(16,8))
    summer_table.savings_change.hist(bins=30)
    plt.axvline(0, linewidth=3, c='red')
    plt.axvline(savings_16 - savings_15, c='black', linewidth=3)
    plt.annotate("Statewide backslide", (0.093, 48))
    plt.annotate("Used less water\nin summer 2016", (-0.075, 46), color='red')
    plt.annotate("Used more water\nin summer 2016", (0.25, 46), color='red')
    plt.ylabel("Number of districts")
    plt.xlabel("Change in water savings between summer '15 and summer '16")
```

Out[47]: <matplotlib.text.Text at 0x7f03fbf01c90>



Calculate a "Conservation-Consumption Score" that adjusts the savings change by the amount of water usage to surface the high-usage districts that regressed the most

This indexed score:

- 1. Accounts for how much a district's savings changed between the summers of 2015 and 2016 (in the numerator)
- 2. Gives greater weight to districts with high residential water use (RGPCD). Positive scores indicate districts that backslid (in the denominator)

$$CCS = rac{SavingsChange}{rac{1}{\sqrt{RGPCD16}}}$$

```
In [48]: summer_table['cc_score'] = (summer_table['savings_change']) / np.sqrt(1/summer_table['residential_water_usage_mean_16'])
```

In [54]: summer\_table.sort\_values("cc\_score", ascending=False).head(10)

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$\mathbf{\circ}$	uс		٠.

	supplier_name	total_water_production_16	total_water_production_15	total_water_production_
313	San Juan Water District	1783309914.14	1204845426.88	2045265134.
236	North Marin Water District	1134200000.00	715000000.00	1102000000.
321	Santa Fe Irrigation District	1035523249.86	763209212.32	1257134805.
20	Bella Vista Water District	1352609273.48	954418829.68	2133349292.
123	Folsom City of	2425963874.01	1835195236.86	2725421335.
366	Valley Water Company	353353287.44	283979518.63	410344702.
314	San Lorenzo Valley Water District	206498200.00	138808800.00	243345319.
119	Fair Oaks Water District	1240415368.65	967123776.82	1586443516.
367	Vaughn Water Company	1330959198.00	1112734671.00	1596587387.
388	Yucaipa Valley Water District	1266950000.00	1029590000.00	1363260000.
4				<b>&gt;</b>

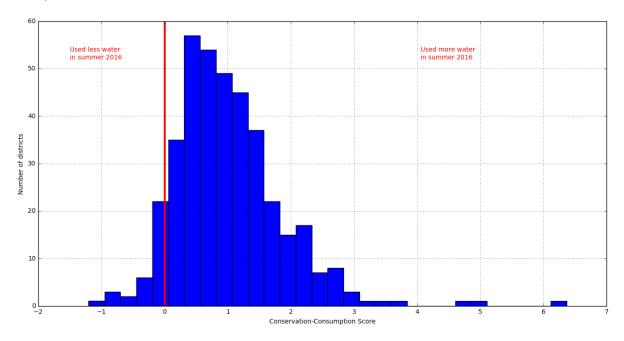
In [50]: summer\_table.sort\_values("cc\_score").head(10)

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v	u			•	

	supplier_name	total_water_production_16	total_water_production_15	total_water_production_
157	Hanford City of	1320227298.00	1478892470.00	1638207120.
374	Wasco City of	340340000.00	383540000.00	537330000.
278	Redlands City of	2373827645.69	2534733080.35	2977565169.
258	Patterson City of	299352884.00	331531760.00	472549824.
43	California Water Service Company King City	117795290.86	134772150.21	172538330.
25	Blythe City of	289600000.00	309500000.00	364000000.
210	Martinez City of	261478566.22	281485963.62	324474264.
166	Humboldt Bay Municipal Water District	50810000.00	53060000.00	49765000.
235	North Coast County Water District	214788155.83	232613485.70	345158649.
224	Morro Bay City of	92005424.00	97087596.00	119120801.
4				<b>&gt;</b>

```
In [51]: plt.figure(figsize=(16,8))
    summer_table.cc_score.hist(bins=30)
    plt.axvline(0, linewidth=3, c='red')
    plt.annotate("Used less water\nin summer 2016", (-1.5,52), color='red')
    plt.annotate("Used more water\nin summer 2016", (4.05,52), color='red')
    plt.ylabel("Number of districts")
    plt.xlabel("Conservation-Consumption Score")
```

Out[51]: <matplotlib.text.Text at 0x7f03fbe81650>



# Write the combined table out to a CSV

```
In [52]: summer_table.sort_values("cc_score", ascending=False).to_csv("analysis.csv", i
ndex=False)
```