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-ln-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

In [5]:
```
supplier_table = SUPPLIER_TABLE.iloc[:,[0,3,18,19,21]]
```

In [6]:
```
supplier_table.columns = [
    'supplier_name',
    'month',
    'total_water_production_gallons',
    'total_water_production_gallons_2013',
    'residential_water_usage'
]
```

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
0	East Bay Municipal Utilities District	2016-08-15	6007500000.00	7172300000.00	
1	East Bay Municipal Utilities District	2016-07-15	6056600000.00	7452200000.00	
2	East Bay Municipal Utilities District	2016-06-15	5675900000.00	6927500000.00	
3	East Bay Municipal Utilities District	2016-05-15	4959300000.00	6716500000.00	
4	East Bay Municipal Utilities District	2016-04-15	4018800000.00	5417500000.00	

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

In [10]:
```
target_months = ['2016-08-15', '2016-07-15', '2016-06-15', '2015-08-15', '2015-07-15', '2015-06-15',]
month_table = supplier_table[supplier_table['month'].isin(target_months)]
```

In [11]:
```
month_table.drop_duplicates(inplace=True)
```

```
/home/ben/.virtualenvs/ca-water-conservation-analysis/local/lib/python2.7/site-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/stable/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	Anderson, City of	5
34	Calexico City of	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
353	Stockton City of	5
360	Susanville City of	5
366	Torrance City of	5
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

In [19]:
```
summer_16_table = complete_month_table[complete_month_table['month'].isin(['2016-08-15', '2016-07-15', '2016-06-15',])]
```

In [20]:
```
summer_16_totals = summer_16_table.groupby("supplier_name")['total_water_production_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
1	Alameda County Water District	3937000000.00
2	Alco Water Service	344299000.00
3	Alhambra City of	775637185.75
4	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(['2015-08-15', '2015-07-15', '2015-06-15',])]
```

In [24]:
```
summer_15_totals = summer_15_table.groupby("supplier_name")['total_water_production_gallons'].sum().to_frame("total_water_production_15").reset_index()
```

In [25]:
```
summer_15_totals.head(5)
```

Out[25]:

	supplier_name	total_water_production_15
0	Adelanto City of	387316100.00
1	Alameda County Water District	3374000000.00
2	Alco Water Service	350899000.00
3	Alhambra City of	777996350.08
4	Amador Water Agency	287480000.00

In [26]:
```
"Summer 15 records: {}".format(len(summer_15_totals))
```

Out[26]:
```
'Summer 15 records: 389'
```

In [27]:
```
summer_13_totals = summer_16_table.groupby("supplier_name")['total_water_production_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
1	Alameda County Water District	5273000000.00
2	Alco Water Service	447983000.00
3	Alhambra City of	1060724599.23
4	Amador Water Agency	431220000.00

In [29]:
```
"Summer 13 records: {}".format(len(summer_13_totals))
```

Out[29]:
```
'Summer 13 records: 389'
```

Join those summer production totals into a combined table

In [30]:
```
summer_table = summer_16_totals.merge(summer_15_totals, on="supplier_name")
summer_table = summer_table.merge(summer_13_totals, on="supplier_name")
```

In [31]:
```
"Total summer records: {}".format(len(summer_table))
```

Out[31]:
```
'Total summer records: 389'
```

In [32]:
```
summer_table.head(5)
```

Out[32]:

	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

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.
236	North Marin Water District	1134200000.00	715000000.00	1102000000.
166	Humboldt Bay Municipal Water District	50810000.00	53060000.00	49765000.
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
)
```

In [37]:
```
summer_table.head(5)
```

Out[37]:

	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

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

In [38]:
```
summer_table.sort_values("savings_change", ascending=False).head()
```

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.

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

In [39]:
```
summer_16_means = summer_16_table.groupby('supplier_name')['residential_water_
usage'].mean().to_frame("residential_water_usage_mean_16").reset_index()
```

In [40]:
```
summer_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]:
```
summer_table.head(5)
```

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

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

In [43]:
```
savings_16 = (summer_table.total_water_production_16.sum() - summer_table.tota
l_water_production_13.sum()) / (summer_table.total_water_production_13.sum())
savings_15 = (summer_table.total_water_production_15.sum() - summer_table.tota
l_water_production_13.sum()) / (summer_table.total_water_production_13.sum())
```

In [44]:
```
"State water use overall backslid {} percentage points".format((savings_16 - s
avings_15)*100)
```

Out[44]:
```
'State water use overall backslid 8.80388151728 percentage points'
```

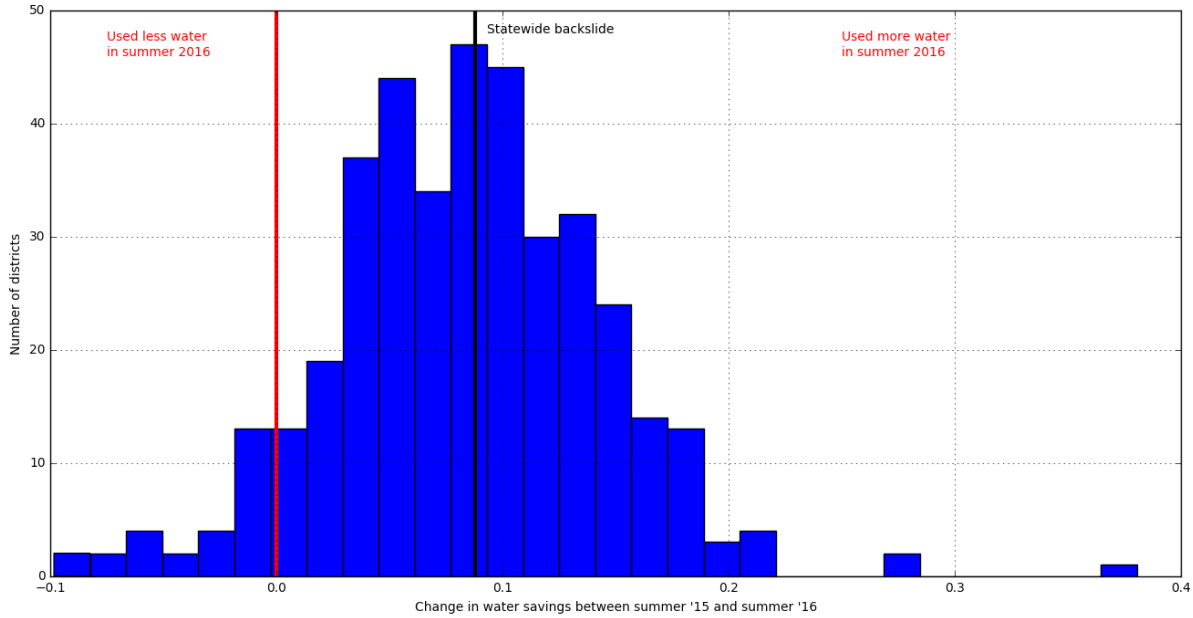
In [45]:
```
pct_backslid = len(summer_table[summer_table['savings_change'] > 0]) / len(sum
mer_table)
```

In [46]:
```
"{}% of urban districts in the state backslid".format(pct_backslid*100)
```

Out[46]:
```
'92.8020565553% of urban districts in the state backslid'
```

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)

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

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)
```

Out[54]:

	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.

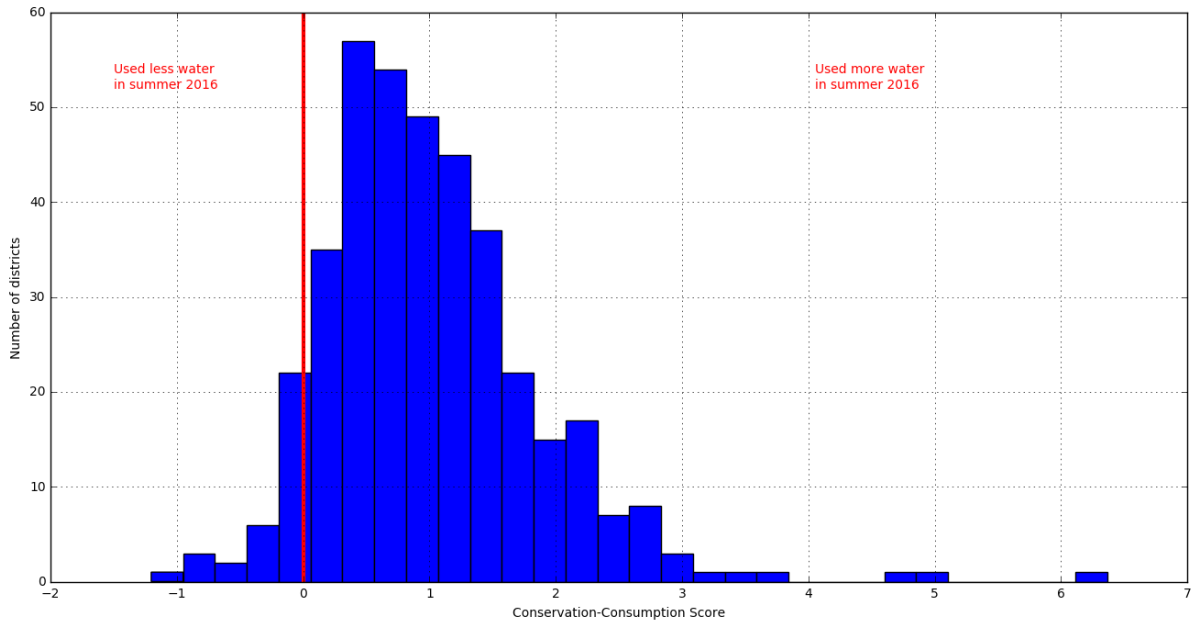
In [50]:
```
summer_table.sort_values("cc_score").head(10)
```

Out[50]:

	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.

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", index=False)
```