# System drought indicator for the South Coast hydrologic region

## Water portfolio of the San Joaquin River hydrologic region

We use data from the California’s Department of Water Resources Water Data Portfolios (California Department of Water Resources, n.d.) to obtain the supply portfolio for the 2002-20 period.

Figure Water supply portfolio by supply provider for the South Coast hydrologic Region

As shown in Figure 1, the main sources of the water supply in southern California are:

* State Water Project (SWP): 24% of the supply
* Colorado: 22%
* Groundwater: 33%
* Los Angeles Aqueduct (Imports): 4%
* Local Supplies: 4%

These sources account for approximately 87% of the water supply for the region. From 2002 to 2020, a decline in total supply has been observed which can be largely attributed to conservation efforts, particularly during droughts 2007-2009 and 2014-2016 drought.

## Estimating supplies, demands and shortage

### Estimating supplies using drought indicators

#### State Water Project

SWDI of the delta exporting basins is expected to be a good indicator for predicting SWP deliveries to the South Coast. However, changes in regulations, introduced in 2007, to meet ecosystem objectives have decreased SWP deliveries (This meant that although the Delta was full, water intended for contractors was diverted to meet environmental needs). Consequently, Delta conditions before 2008 no longer reflect South Coast deliveries after 2008. As shown in the figure below, all SWP deliveries to the South Coast since 2007 have been lower compared to pre-2007 levels – a trend not observed in SWDI Delta. For example, in 2005, the SWDI Delta reached 0.9, and deliveries were around 1,500 MAF, whereas in 2011, the SWDI Delta was nearly the same, but deliveries were only 900 MAF.

Given the South Coast stores some of its imported water, relying solely on the SWDI of Delta exports is insufficient. As shown in the figures below, although the relationship between SWP deliveries and SWDI for South Coast and delt exporting basins are not clearly defined, a general trend is observable: higher SWP deliveries are typically associated with higher SWDI values for both the South Coast and Delta Exporting Basin.

Thus, we developed a linear regression model that incorporates both the SWDI of the South Coast and the Delta Exporting Basin and the logarithm of both SWDIs —that help fitting the non-linear relationship. To account for differences in deliveries, we divided the model into two segments: pre-2007 and post-2007. A regression model of four variables is used: SWDI of the Delta, SWDI of the South Coast, and logarithm of the SWDI of the Delta and South Coast – that help fitting the non-linear relationship. For the 2002-2007 and 2008-2020 periods, we obtain a coefficient of determination for the SWP deliveries, R2, of 0.87 and 0.88 respectively. Figure shows the result of the adjustment.

Figure Comparison of actual deliveries from SWP deliveries and estimated SWP deliveries

#### Los Angeles Aqueduct

Los Angeles Aqueduct imports water from Owens Valley, located in South Lahontan Hydrologic Region, so we correlate Los Angeles Aqueduct with the SWDI of South Lahontan. As shown in Figure below, the relationship is linear – the fuller the reservoirs, the higher the deliveries.

Figure Relationship between LA Aqueduct deliveries in the South Coast and the Surface Water Drought Indicator

A regression model using only SWDI of South Lahontan was utilized. For the 2002-19 period, we obtain a coefficient of determination for the local surface supplies, R2, of 0.86. Figure 5 shows the result of the adjustment.

Figure Comparison of actual deliveries from LA Aqueduct imports and estimated deliveries from LA Aqueduct imports

#### Groundwater

Groundwater is the most reliable and cost-effective water source, often supplemented during dry years when State Water Project allocations are low. However, due to the availability of Colorado River water, groundwater is managed sustainably, making it harder to observe a straightforward linear relationship with other sources.

Additionally, the groundwater pumping indicator—which reflects the annual change in groundwater levels and provides insight into the intensity of annual pumping— provides a better insight on groundwater deliveries (shows a better correlation than SWDI of Delta and SC).

A linear regression model with 5 variables is used to predict groundwater deliveries, incorporating SWDI Delta exports, SWDI South Coast, groundwater pumping indicator and the exponential of SWDI Delta and South Coast. With these variables, and for the 2002-20 period, we obtain a coefficient of determination for groundwater deliveries, R2, of 0.82. Figure below shows the result of the adjustment. More information on variable selection is found in the appendix.

#### Colorado River

Unlike the State Water Project, Colorado River deliveries are less impacted during drought years – serving as a backup to the State Water Project. As shown in the figure below, the non-linear relationship between SWDI Delta exporting basins and Colorado River deliveries is clear - When Delta water availability decreases, deliveries from the Colorado River tend to increase.

Additionally, groundwater is often preferred over Colorado because it is a more affordable alternative than imported water. However, the figure below also shows that increased groundwater pumping is associated with higher Colorado River deliveries. This could suggest that both groundwater and Colorado River water are being utilized to compensate for reduced SWP deliveries.

Thus, a linear regression model with four variables was utilized: SWDI of the exporting basins, groundwater pumping intensity indicator and logarithm of both SWDI of the exporting basins and the groundwater indicator. For the 2002-20 period, we obtain a coefficient of determination for the deliveries from Delta imports, R2, of 0.90. Figure below shows the result of the adjustment. More information on variable selection is found in the appendix.

### Combined supplies from different sources

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Supply | number of variables | Variables | Derived | Performance (r2) |
| SWP | 4 | SWDI exporting basins | log (SWDI exporting basins) | 0.87 |
| SWDI of South Coast | log (SWDI of the South Coast) | 0.88 |
| LA Aqueduct | 1 | SWDI of South Lahontan |  | 0.86 |
| Groundwater | 5 | SWDI exporting basins | exp (SWDI exporting basins) | 0.82 |
| SWDI of South Coast | exp (SWDI of the South Coast) |
| GW Pumping Intensity Ind |  |
| Colorado | 4 | SWDI exporting basins | exp (SWDI exporting basins) | 0.9 |
| GW Pumping Intensity Ind | exp (GW Pumping Intensity Ind) |

# Appendix

State Water Project

I experimented with different configurations. Some less-successful trials:

* Removal of log SWDI SC yields:  
  R²: 0.83 Adjusted R²: 0.59
* Removal of log SWDI SC yields:  
  R²: 0.71 Adjusted R²: 0.29

Interestingly usage exponential instead of logarithmic of the 2 variables yields a much lower performance (r2=0.71)

Groundwater

I experimented with different configurations. I began with a large configuration (15 variables): the SWDI of the Delta, South Coast, Colorado, and two groundwater indicators, along with the exponential and logarithm of each This model yielded a coefficient of determination (R²) of 0.96 and an adjusted R² of 0.68. When the logarithmic transformations were removed, R² dropped to 0.85, and adjusted R² decreased to 0.65.

Afterwards consequent removal of the variables yielded the following results:

* Trial 3: Removal of SWDI Colorado (and its exponential).

R²: 0.85 Adjusted R²: 0.72

* Trial 4: Removal of gw\_elev (and its exponential).

R²: 0.82 Adjusted R²: 0.72

* Trial 5: Removal of the exponential of gw\_change.

R² and Adjusted R² remained unchanged at 0.82 and 0.74, respectively.

Further removal of variables significantly reduced model performance.

Extra:

Instead of using exp, using logarithm will yield similar results.

2 variable linear regression using GW pumping intensity indicator and SWP deliveries yields only 0.51. usage of logarithm of the variables will improve r2 to 0.61.

Colorado River

The relationship becomes less clear when comparing the deliveries. Since 2007, SWP deliveries have decreased, making it harder to establish a correlation between SWP and Colorado River deliveries. Similarly, when comparing the Colorado River with groundwater, both have shown a general trend of increasing, suggesting that they may both be conjunctively dependent on SWP.

I experimented with different configurations. I began with a large configuration (15 variables): the SWDI of the Delta, South Coast, Colorado, and two groundwater indicators, along with the exponential and logarithm of each This model yielded a coefficient of determination (R²) of 0.95 and an adjusted R² of 0.9. When the logarithmic transformations were removed, R² dropped to 0.93, and adjusted R² decreased to 0.83.

Afterwards the trials yielded the following results:

* Trial 3: Removal of SWDI Colorado (and its exponential).

R²: 0.92 Adjusted R²: 0.85

* Trial 4: Removal of gw\_elev (and its exponential).

R²: 0.917 Adjusted R²: 0.87

* Trial 4: Removal of swdi SC (and its exponential).

R²: 0.90 Adjusted R²: 0.87

* Trial 4: Removal of exp GW

R²: 0.856 Adjusted R²: 0.82

* Trial 5: Removal of exp SWDI delta.

R²: 0.74 Adjusted R²: 0.706

Extra:

Train model till 2013 using SWDI delta and GW pumping Ind (exp of each) and test 2014 to 2020.

Train r2: 0.76

Test r2: 0.98