# 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 drough periods 2007-2009 and 2014-2016.

## 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 1,600 MAF, whereas in 2011, the SWDI Delta was nearly the same, but deliveries were below 1000 MAF.

As shown in the figure below, the relationship between SWP deliveries and SWDI for the delta exporting basins is not clearly defined, but a general trend is observable: higher SWP deliveries are typically associated with higher SWDI values for the Delta Exporting Basin.

A linear regression model with 2 variables is used to predict state water project deliveries: Categorical variable (also known as ‘dummy variables’) — used to differentiate between pre and post 2007 periods — and logarithm of SWDI delta exporting basins— that help fitting the non-linear relationship. Additionally, the deliveries variable has been log-transformed for similarly help better fit the non-linear relationship. For the 2002-20 period, we obtain a coefficient of determination for groundwater deliveries, R2, of 0.77. Figure below 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 linear 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 a consistent 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, groundwater is managed sustainably, making it harder to observe a straightforward relationship with SWDI delta exporting basins as shown in figure below.

Additionally, the groundwater pumping indicator—which represents the annual change in groundwater level, informing about the intensity of annual pumping— provides a better insight on groundwater deliveries.

A linear regression model with logarithm of groundwater pumping intensity indicator is used to predict groundwater deliveries. For the 2002-20 period, we obtain a coefficient of determination for groundwater deliveries, R2, of 0.58. Figure below shows the result of the adjustment.

#### 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. The plateau after the median (percentile = 0.5) could be due to infrastructure constraints to how much water can be imported from the Colorado River

Thus, a linear regression model with logarithm of the SWDI of the exporting basins was utilized to predict Colorado deliveries. For the 2002-20 period, we obtain a coefficient of determination for the deliveries from Delta imports, R2, of 0.74. Figure below shows the result of the adjustment.

### Combined supplies from different sources

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Supply | Number of Variables | Variables | r2 | Adjusted r2 | Note |
| SWP | 2 | dummy variable | 0.77 | 0.74 | Log of deliveries used |
| log (SWDI exporting basins) |
| LA Aqueduct | 1 | SWDI of South Lahontan | 0.86 | 0.85 |  |
| Groundwater | 1 | log (GWPII) | 0.58 | 0.55 |  |
| Colorado | 1 | log (SWDI exporting basins) | 0.73 | 0.72 |  |

Please check out appendix as well since I have included alternatives that provide better estimates for each supply.

# Appendix

SWP

Instead of this (which yields r2=0.77):

Y: log SWP

X: dummy variable, log (SWDI delta)

We use:  
Y: SWP

X: dummy variable, log (SWDI delta)

Which yields slightly better performance (0.82)

The following figures were not included since the sample size is very small (2002-2007) and might distort the analysis. 2008-2020 shows the general trend of increasing swp deliveries as SWDI delta increases, the plateau and the decrease could be due to infrastructure constraints.

Groundwater

We can get a decent estimate of groundwater deliveries (r2 = 0.73) by using the following variables:  
log (SWDI delta), (log SWDI SC), log (GWPII)

A screenshot of a computer

Description automatically generated

Physical interpretation:

A table with numbers and letters

Description automatically generated

Groundwater deliveries are relatively consistent as shown in the table above (where the intercept has p-value <0.005). The SWDI delta and pctl\_gwchange is negative which means:

As SWDI delta is higher, more swp deliveries thus less gw deliveries. (as also seen in figure above)

As pclt\_gwchange is lower, more pumping thus more gw deliveries. (as also seen in figure above)

SWDI SC is positive, not sure if we can interpret it correctly. Could it be that more groundwater deliveries mean reservoirs are more filled (SWDI SC is higher). P-value

Colorado

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.

As shown in the figures above the relationship between Colorado deliveries and SWDI delta and GWPII is logarithmic.

By utilizing logarithmic of both SWDI delta and GWPII, we obtain the following results.

A table with numbers and a black text

Description automatically generated

A white rectangular table with black text

Description automatically generated with medium confidence

These results validate our reasoning with high r2 and p-value less than 0.05 for both and negative coefficients for both variables.

Estimating Colorado river using sum of estimated deliveries of SWP, GW and LAA does not yield good performance (r2=0.27 using polynomial 2nd order trendline).

|  |  |
| --- | --- |
| Estimated GW+LAA+SWP imports | Actual Colorado River imports |
| 3481 | 1309 |
| 3341 | 757 |
| 3384 | 1099 |
| 3371 | 772 |
| 3453 | 807 |
| 3608 | 1079 |
| 2586 | 1254 |
| 2648 | 1216 |
| 2673 | 988 |
| 2820 | 956 |
| 2754 | 902 |
| 2916 | 1304 |
| 2706 | 1730 |
| 2342 | 1573 |
| 2614 | 1187 |
| 2774 | 917 |
| 2759 | 775 |
| 2641 | 835 |