The exhibits in this section characterize the hydrologic setting of the Chino Basin and its importance to water supply and groundwater management within the Basin.

The Chino Basin covers about 240 square miles and is located centrally within the Santa Ana River Watershed. Exhibit 3 shows the location of the Chino Basin within the context of the upper Santa Ana River Watershed. The Santa Ana River flows southwest through the Chino Basin from the Riverside Narrows to Prado Dam. Downstream of Prado Dam, the Santa Ana River flows through the Orange County Basin and out to the ocean. In total, the drainage area of the Santa Ana River Watershed at Prado Dam is about 1,490 square miles. The following streams are tributary to the Santa Ana River within the Chino Basin: San Sevaine Creek, Day Creek, Deer Creek, Cucamonga Creek, and San Antonio/Chino Creek. These tributaries generally flow from north to south. The time of concentration[1] to Prado Dam for the Santa Ana River is estimated to be between one to two days. By contrast the time of concentration to Prado Dam for tributaries of the Santa Ana River that flow from north to south in the Chino Basin is a few hours.

Exhibit 3 shows the locations of three San Bernardino County Flood Control District (SBCFCD) precipitation stations: the San Bernardino Hospital station, located centrally in the Santa Ana River Watershed tributary to the Chino Basin; an Ontario hybrid station (combined records of SBCFCD 1017 and 1075), located in the central Chino Basin; and the Montclair station, located in the northwestern portion of the Basin. Exhibit 3 also shows the U.S. Geological Survey's stream-gaging stations on the Santa Ana River at Riverside Narrows (*SAR at MWD Xing*) and below Prado Dam (*SAR at Below Prado Dam).*

Precipitation is a major source of recharge to the Chino Basin; thus, the magnitude and temporal pattern of this recharge can be understood by analyzing long-term precipitation records. In Exhibit 4, annual precipitation totals are plotted from the Ontario (1915 to 2014) and San Bernardino Hospital stations (1901 to 2014). Exhibit 4 characterizes long-term precipitation trends within and upstream of the Chino Basin. The mean annual precipitation totals at the Ontario and San Bernardino Hospital stations are 15.28 inches and 16.22 inches, respectfully. Exhibit 4 also includes a plot of the cumulative departure from mean precipitation (CDFM), which is used to characterize the occurrence and magnitude of the wet and dry periods. Positive sloping segments of the CDFM plot (trending upward to the right) indicate wet periods, and negative sloping segments of the CDFM plot (trending downward to the right) indicate dry periods. The longest dry period for the 1900 to 2014 record is from 1945 to 1976—a 32 year period.

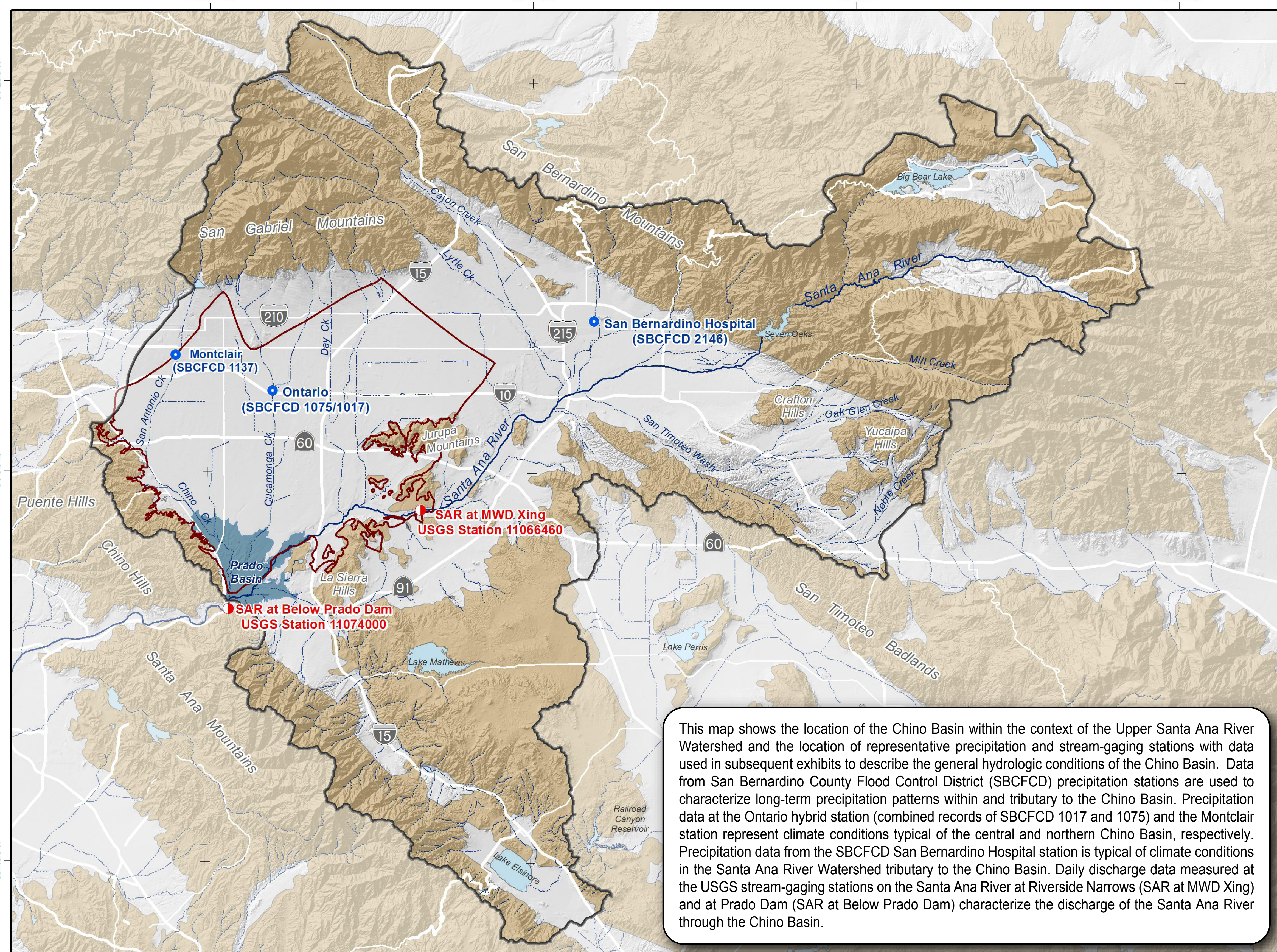
The Safe Yield of the Chino Basin was computed using a base period of 1965 through 1974, a period of ten years. This base period had two years of above average precipitation, eight years of below average precipitation, and falls within the 1945 through 1976 dry period. The average annual precipitation for the base period was 14.64 inches, or 0.77 inches less than the long-term annual average. The post-Peace-Agreement period runs from July 2000 to present, a fourteen-year period. The post-Peace-Agreement period contains four years of above average precipitation and ten years below average precipitation. The average annual precipitation during the post-Peace-Agreement period is 13.71 inches, or 1.57 inches less than the long-term annual average, which is comparable to the 1945 through 1976 dry period. Precipitation during the base period in which the Safe Yield was initially estimated, and the post-Peace-Agreement period, is less than average; thus, the yield developed during these periods is likely less than the yield that would be developed from a longer, more hydrologically representative period.

Exhibit 5 shows the historical relationship between precipitation and storm water discharge in the Chino Basin and uses a double-mass curve analysis to illustrate the change in the precipitation-discharge relationship. A double-mass analysis is an arithmetic plot of the accumulated values of observations for two related variables that are paired in time and thought to be related. As long as the relationship between those two variables remains constant, the double-mass curve will appear as a straight line (constant slope). A change in slope indicates that the relationship has changed; the break in slope denotes the timing of that change.

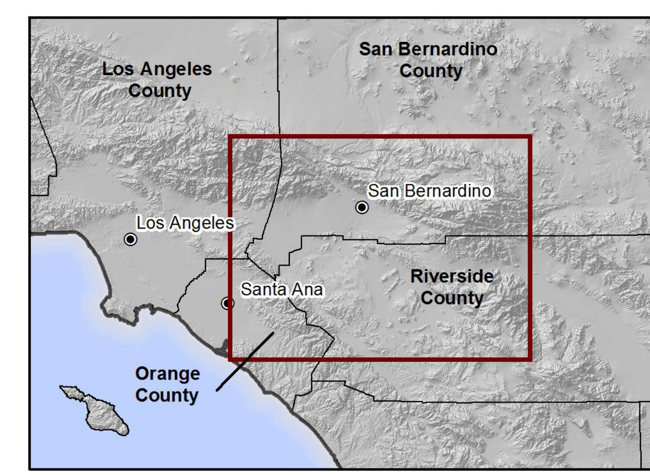
Specifically, in Exhibit 5, the double-mass curve analysis was used to look at precipitation versus storm water discharge reckoned at Prado Dam (*SAR at Below Prado Dam*) and precipitation versus storm water discharge generated between Riverside Narrows and Prado Dam (storm water reckoned at *SAR at Below Prado Dam* minus storm water reckoned at *SAR at MWD Xing*). In each plot, the slope of the double-mass curve after water year 1976/77 is much steeper than prior years. The change in curvature suggests that a significant change occurred in the precipitation-discharge relationship: there is an increase in the magnitude of storm water discharge starting in the late 1970s. This increase in storm water discharge is due to land surface modifications caused by the conversion from agricultural to urban uses, the rapid post-1969 lining of stream channels in the Chino Basin and elsewhere in the upper Santa Ana Watershed, and other associated drainage system modifications. The hydrologic effects of land use changes and channel lining were apparently masked by the below average precipitation years that preceded the 1978 through 1983 wet period. These charts indicate that natural storm water recharge in the Chino Basin declined as the stream channels were lined and that the storm water available for diversion to recharge basins has increased significantly with urbanization. In fact, the average annual decrease in natural storm water recharge due to the lining of stream channels in the Chino Basin was recently estimated to be about 13,000 acre-ft/yr (WEI, 2014).

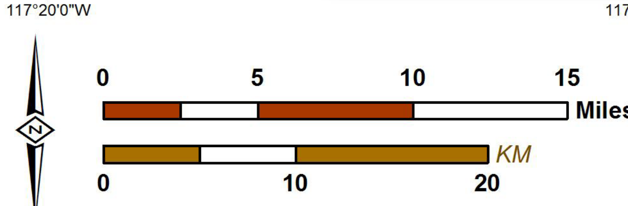
Exhibit 5 also shows what the relationship would be if no storm water were recharged for the Chino Basin Groundwater Recharge program, starting in fiscal year 2005. The plots of the relationship without storm water recharge to recharge basins show that the Chino Basin Groundwater Recharge Program has offset Chino Basin recharge losses due to the historical lining of the channels and urbanization and that there is potential to increase this recharge in the future.

[1] The time of concentration is the time it takes for runoff from the most distant upstream part of the watershed to reach a specified point of interest.



This map shows the location of the Chino Basin within the context of the Upper Santa Ana River Watershed and the location of representative precipitation and stream-gaging stations with data used in subsequent exhibits to describe the general hydrologic conditions of the Chino Basin. Data from San Bernardino County Flood Control District (SBCFCD) precipitation stations are used to characterize long-term precipitation patterns within and tributary to the Chino Basin. Precipitation data at the Ontario hybrid station (combined records of SBCFCD 1017 and 1075) and the Montclair station represent climate conditions typical of the central and northern Chino Basin, respectively. Precipitation data from the SBCFCD San Bernardino Hospital station is typical of climate conditions in the Santa Ana River Watershed tributary to the Chino Basin. Daily discharge data measured at the USGS stream-gaging stations on the Santa Ana River at Riverside Narrows (SAR at MWD Xing) and at Prado Dam (SAR at Below Prado Dam) characterize the discharge of the Santa Ana River through the Chino Basin.





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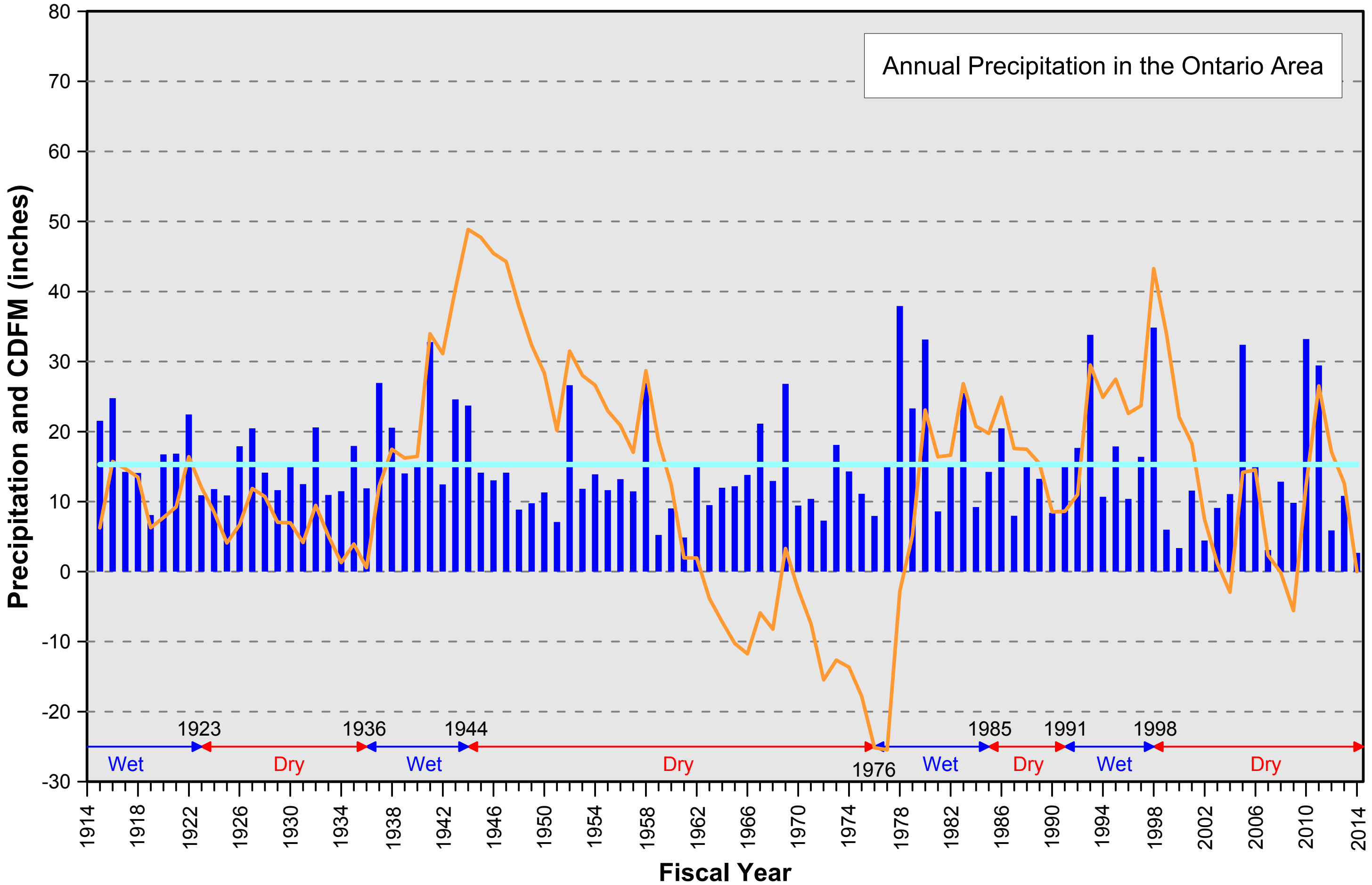
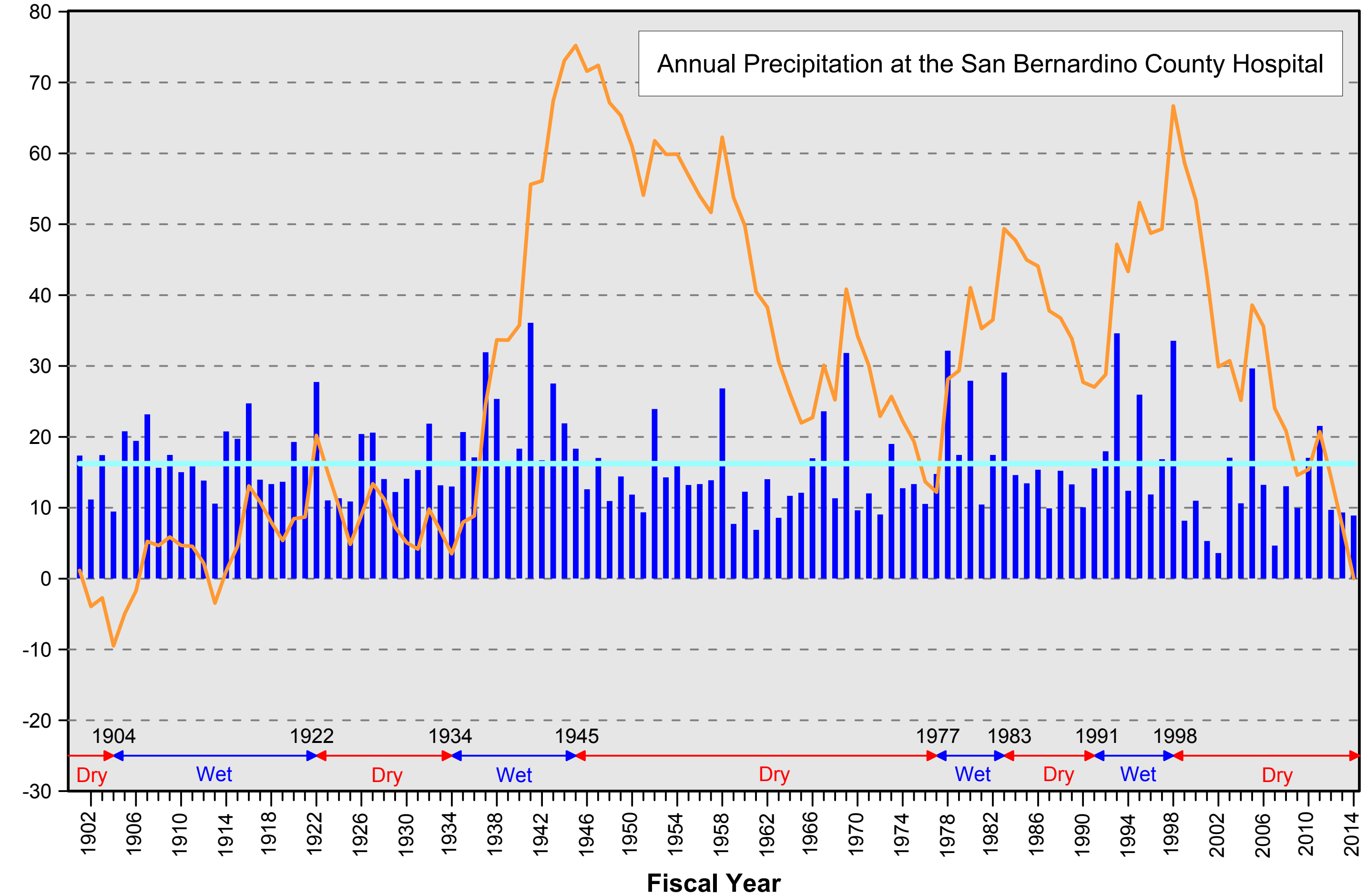
2014 State of the Basin
General Hydrologic Conditions

Santa Ana River Watershed Tributary to Prado Dam

Exhibit 3





Annual Statistics of Long-Term Precipitation Records
(inches)

Statistics	Ontario Area*	San Bernardino Hospital
Period of Record (Fiscal Year)	1915 to 2014	1901 to 2014
Mean	15.28	16.22
Minimum	2.67	3.61
Maximum	37.92	36.10
Standard Deviation	7.72	6.69
Mean + 1 Standard Deviation	23.00	22.91
Coefficient of Variation	50%	41%

* Two precipitation stations in the Ontario Area (SBCFCD 1075 and 1017) were combined to create a long-term record. These two precipitation stations are in close proximity to each other and their overlapping records are highly correlated. Recent data is from SBCFCD Station 1017.

The Chino Basin has a semi-arid Mediterranean climate. Precipitation is a major source of groundwater recharge for the Basin; thus, the magnitude and temporal pattern of this recharge can be understood by analyzing long-term precipitation records. Shown here are the long-term precipitation records for the Ontario Area (located centrally within the Chino Basin) and the San Bernardino County Hospital (located within the Santa Ana River Watershed, upstream of the Chino Basin). These figures show the fiscal year annual precipitation totals, long-term average annual precipitation, and the cumulative departure from mean precipitation (CDFM). The CDFM plot is a useful way to characterize the occurrence and magnitude of wet and dry periods: positive sloping segments (trending upward to the right) indicate wet periods, and negative sloping segments (trending downward to the right) indicate dry periods. In the Ontario area, four series of wet-dry cycles are apparent: prior to 1914 through 1936, 1937 through 1976, 1977 through 1991, and 1992 through 2014. The record of the San Bernardino County Hospital station shows the same pattern of wet-dry cycles. The ratio of dry years to wet years is about three to two. That is, for every ten years, about six years will have below average precipitation and four years will have greater than average precipitation. That said, the 1945 through 1976 dry period is 32 years long. During this dry period, for the Ontario station, there were 27 dry years to 5 wet years, averaging about 2.31 inches per year below the average annual precipitation, and for the San Bernardino County Hospital station, there were 23 dry years to 9 wet years, averaging about 1.86 inches per year below the average annual precipitation.

The base period used to compute the Safe Yield of the Chino Basin in the 1978 Judgment was 1965 through 1974, a period of ten years. This base period had three years of above-average precipitation and seven years of below-average precipitation and falls within the 1945 through 1976 dry period. The average annual precipitation for the base period was 14.64 inches, or 0.64 inches less than the long-term annual average. The post-Peace-Agreement period is from July 2000 to present, a fourteen-year period. The post-Peace-Agreement period contains four above-average precipitation years: 2005, 2006, 2010, and 2011; the remaining years had below average precipitation. In the Chino Basin, the four driest years in the 100 period for which data are available at the Ontario station occurred since 1999 and include in order of the driest to less dry: 2014 (2.67 inches), 2007 (3.09 inches), 2000 (3.37 inches), and 2002 (4.43 inches). The average annual precipitation during the post-Peace Agreement period is 13.71 inches, or 1.57 inches less than the long-term annual average. One of the takeaways from these charts is that the recharge from precipitation during the base period, in which the Safe Yield was initially estimated, and the post-Peace-Agreement period should be less than average; thus, the yield developed during these periods is likely less than the yield that would be developed from a longer, more hydrologically-representative period.

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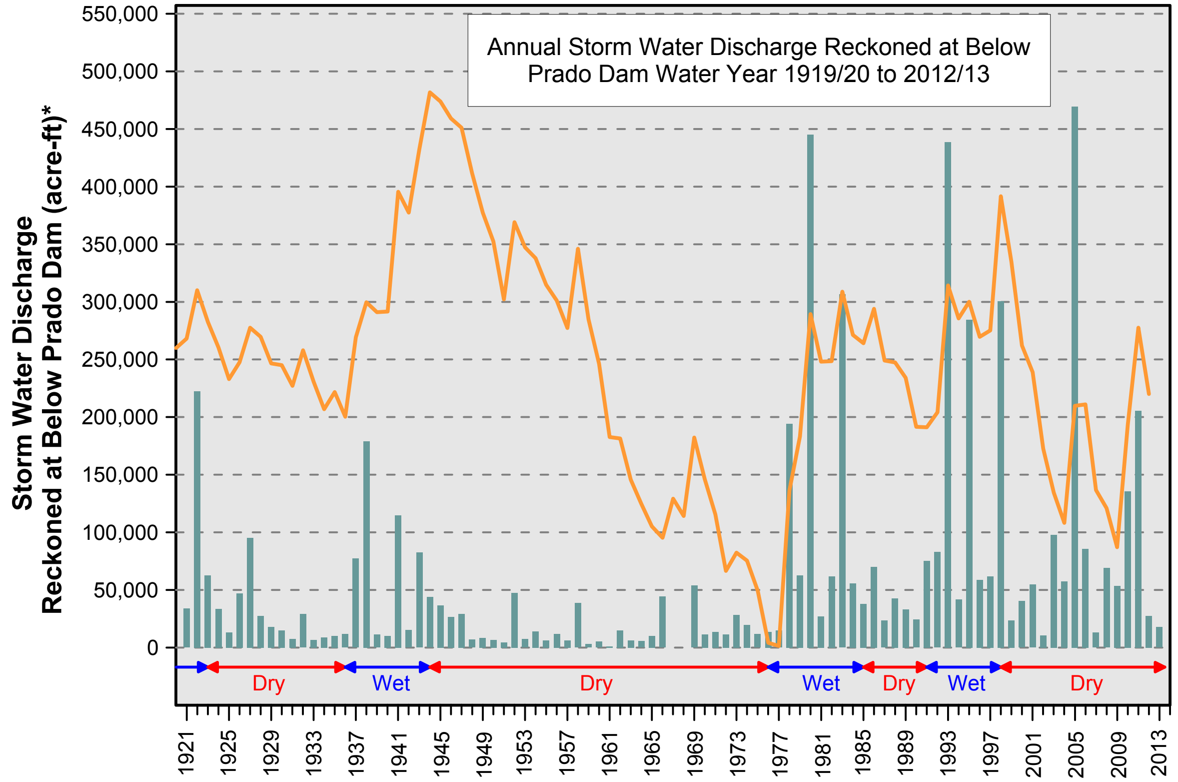
Annual Precipitation (inches)
Cumulative Departure from Mean Precipitation
Long-Term Average Annual Precipitation (inches)

2014 State of the Basin
General Hydrologic Conditions

Long-Term Precipitation Within and Upstream of the Chino Basin

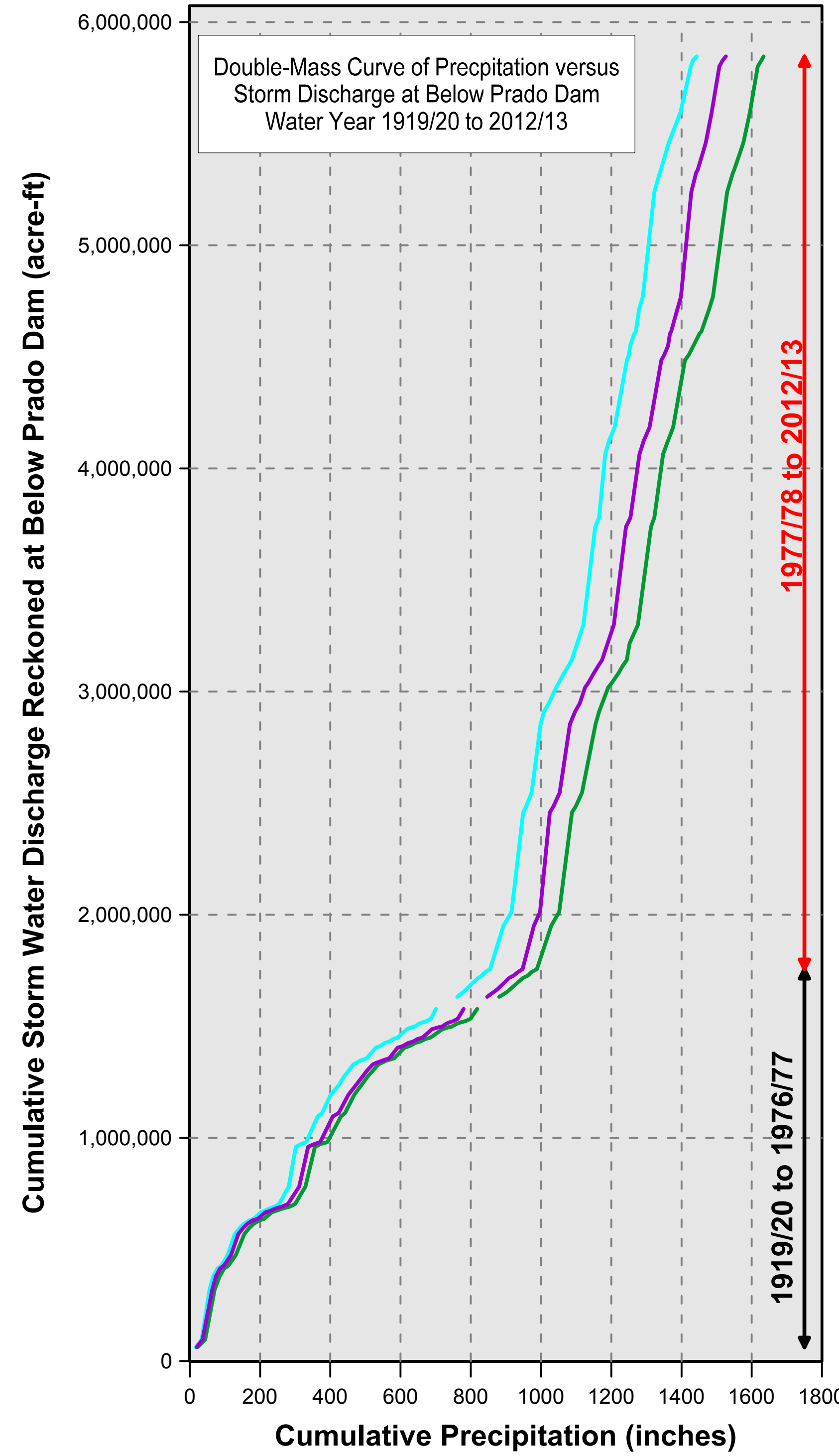
Exhibit 4

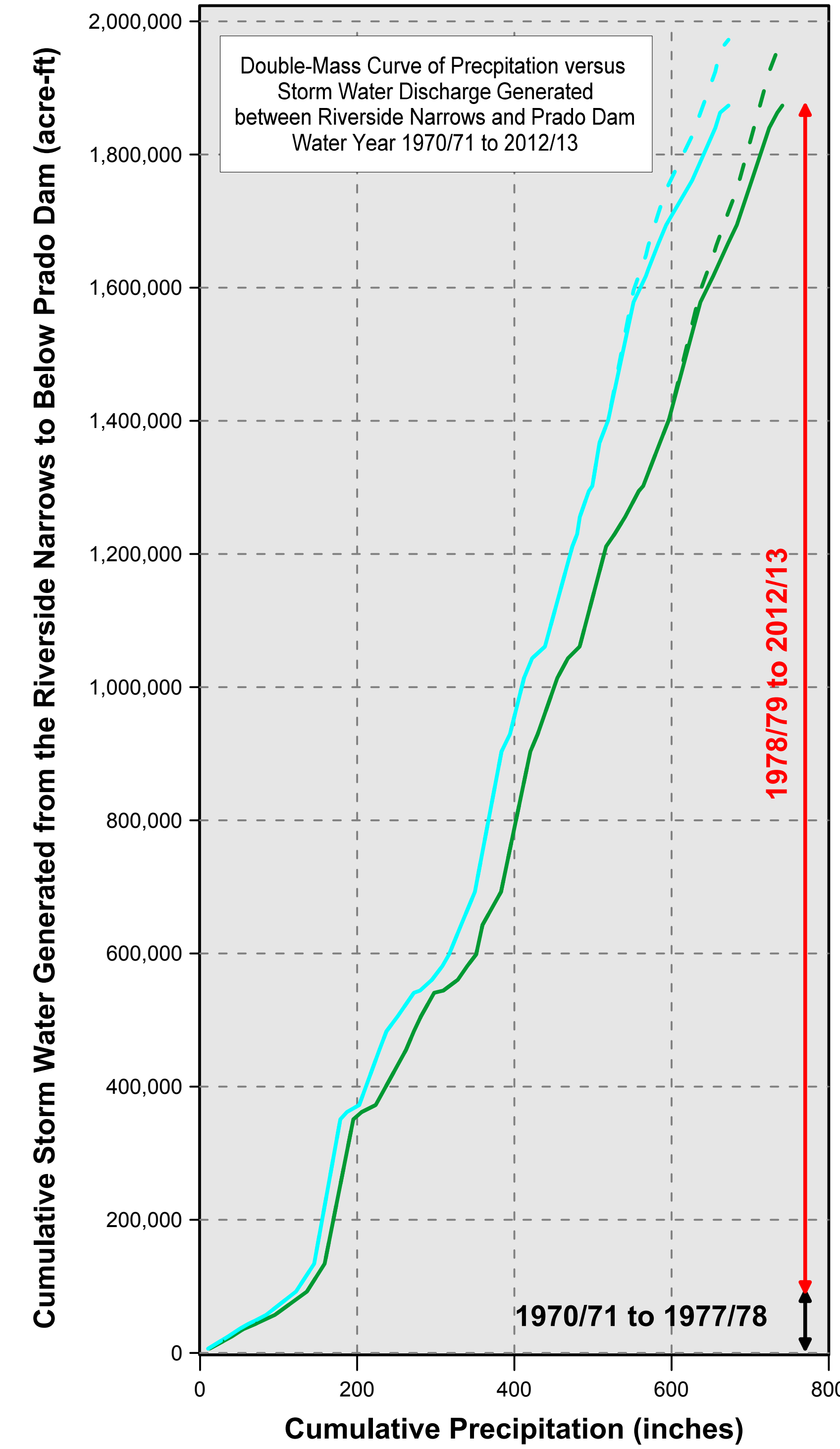


*Storm water discharge data at below Prado Dam is not available for 1967 and 1968.

As seen in the graph entitled Annual Storm Water Discharge Reckoned at Below Prado Dam, around water year 1976/1977, the relationship of precipitation to storm water discharge appears to change significantly such that there was more discharge per unit of precipitation produced after this time (compare the amount of storm water runoff for the 1936 to 1944 wet period with the 1977 to 1983 wet period).

A double-mass curve analysis can illustrate the change in the precipitation-runoff relationship. A double-mass curve analysis is an arithmetic plot of the accumulated values of observations for two related variables that are paired in time and thought to be related. As long as the relationship between those two variables remains constant, the double-mass curve will appear as a straight line (constant slope). A change in slope indicates that the relationship has changed; the break in slope denotes the timing of that change. Shown here are double-mass curves of precipitation at stations in and around the Chino Basin versus Santa Ana River storm water discharge reckoned at Below Prado Dam and Santa Ana River storm water discharge generated between Riverside Narrows and Prado Dam (storm water discharge reckoned at SAR at Below Prado Dam minus storm water discharge reckoned at SAR at MWD Xing). Note that in each plot, the slope of the double-mass curve after water year 1976/1977 is much steeper than prior years. The change in curvature suggests that a significant change occurred in the precipitation-discharge relationship: there is an increase in the magnitude of storm water discharge starting in the late 1970s. This increase in storm water discharge is due to land surface modifications caused by the conversion from agricultural to urban uses, the rapid post-1969 lining of stream channels in the Chino Basin and elsewhere in the upper Santa Ana Watershed, and other associated drainage system improvements. These charts indicate that natural storm water recharge in the Chino Basin declined as the channels were lined and that the storm water component of the Santa Ana River at Prado Dam has increased significantly with urbanization. The average annual decrease in storm water recharge due to the lining of stream channels in the Chino Basin was estimated to be about 13,000 acre-ft/yr (WEI, 2014).





Watermaster and the IEUA initiated the Chino Basin Groundwater Recharge Program in 2005 in part to increase storm water recharge in the Chino Basin. Shown above, are double-mass curves for the Ontario and Montclair precipitation stations versus the storm water discharge generated between Riverside Narrows and Prado Dam. Also shown are what these curves would have looked like had the Chino Basin Groundwater Recharge Program not been implemented (dashed lines starting in 2005). The shifting of the actual double-mass curves to the right caused by the recharge program is evidence that the recharge program has begun to offset recharge losses due to past channel lining and land use decisions and that there is additional opportunity to increase recharge in the future.

Cumulative Departure from Mean Precipitation (Ontario Station)

Storm Water at Prado Dam (acre-ft)

Cumulative Precipitation at San Bernardino County Hospital vs. Storm Water Flow

Cumulative Precipitation at Montclair vs. Storm Water Flow

Cumulative Precipitation at Montclair vs. Storm Water Flow (Without Storm Water Recharge in the Chino Basin)

Cumulative Precipitation at Ontario vs. Storm Water Flow

Cumulative Precipitation at Ontario vs. Storm Water Flow (Without Storm Water Recharge in the Chino Basin)

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2014 State of the Basin
General Hydrologic Conditions

Relationship of Precipitation and Storm Water Discharge in the Chino Basin

Water Year 1919/20 to 2012/13

Exhibit 5