Appendix F

Sustainable Groundwater
Basin Yield

Antelope Valley Area of Adjudication

Appendix F

Sustainable Groundwater Basin Yield

F.1 Introduction

Part of the overall description of water resource and water supply conditions in the Antelope Valley Area of Adjudication (AVAA) includes derivation of the yield of the groundwater basin. For purposes of the overall Problem Statement, the amount of available groundwater supply is considered to be the sustainable yield of the basin which, as described in more detail in the rest of this appendix, is the rate of pumping that will result in no long-term depletion of groundwater storage. In other words, in this setting, the estimates of sustainable yield are based on the concept that groundwater levels, which are indicative of groundwater storage, are acceptable at some point in time; pumping rates are then estimated to maintain those groundwater levels, thus avoiding any chronic depletion of groundwater in basin storage (declining groundwater levels), but also not providing for any purposeful increase in storage (rising groundwater levels) that could occur if pumping were somehow controlled to a lower than sustainable rate.

This appendix describes the approach undertaken to estimate the sustainable yield of the AVAA. It also recognizes that the yield of any groundwater basin is dependent on land uses and other prevailing cultural conditions in the basin, including the use of multiple sources of water supply, which can change with time. In recognizing that cultural conditions have significantly changed in the AVAA over time, this appendix includes the derivation of estimated sustainable yield values under both native conditions (no supplemental water supplies) and supplemental conditions (utilization of imported and local surface waters to augment native water supply).

The sustainable yield of a groundwater basin is considered to be the amount of pumping that, for given land use conditions, produces return flows which, in combination with other recharge, result in no long-term depletion of groundwater storage. Fundamentally, for all cases where groundwater is used on lands overlying a basin and where such uses produce return flows that ultimately reach the underlying aquifer system, those return flows result in the aquifer's ability to sustainably support pumping at a rate that is higher than the rates of natural or other recharge to the aquifer. In a simple form, sustainable yield is conceptually illustrated as shown in Figure F.1-1. In that illustration, groundwater pumping is used to meet a combination of agricultural and municipal and industrial (M&I) water requirements. Each of those uses of groundwater produces a different amount of return flow to the basin. Collectively, those return flows add to natural recharge to produce a total quantity of water that can be pumped on a sustainable basis (no long-term depletion of groundwater storage).

In a more complex form, as is the currently prevailing case in the AVAA, sustainable yield is conceptually illustrated as shown in Figure F.1-2. In that illustration, sustainable yield is segregated into two components, a "native" component that derives solely from natural groundwater recharge in the basin, and a "supplemental" component that derives from recharge which results from the use of supplemental waters such as imported water from the State Water

Project (SWP). The native sustainable yield component is the same as the simple conceptual form of sustainable yield described and illustrated above (Figure F.1-1) where recharge is only natural recharge. The supplemental sustainable yield component, on the other hand, derives from the additional recharge to the groundwater basin as a result of utilizing supplemental waters. The subsequent pumping of that additional recharge produces the same kinds of return flows from the agricultural and M&I uses of that pumping. Collectively, those return flows add to the supplemental recharge to produce a quantity of water that can be pumped on a sustainable basis (no long-term depletion of groundwater storage).

Under both “native” and “supplemental” conditions, natural recharge is considered to be a constant average annual value that is representative of long-term average hydrologic conditions in the basin. Based on interpretation of historical hydrologic conditions, it can be expected that natural recharge will not actually be a constant average value every year; rather, there will be fluctuations in yearly hydrologic conditions, and fluctuations in resultant yearly amounts of natural recharge. Ultimately, however, the basin can be expected to receive average natural recharge over a long-term period; and that recharge, in combination with return flows deriving from sustainable pumping (plus recharge from use of supplemental water), will result in fluctuating but long-term stable groundwater storage. Thus, under sustainable pumping conditions, groundwater levels and storage can logically be expected to fluctuate through wet and dry hydrologic cycles, but to be generally stable and not tend toward depletion of the resource of a long-term basis.

F.2 Approach

To estimate sustainable yield under both native and supplemental conditions in the AVAA, each is expressed in equation form as follows.

$$\mathbf{NSY = NR + RF_{nag} + RF_{nmi} + RF_{mi}} \qquad \mathbf{(F1)}$$

where: $\mathbf{NSY}$ = native sustainable yield
$\mathbf{NR}$ = natural groundwater recharge
$\mathbf{RF_{nag}}$ = return flows from agricultural use of natural groundwater recharge
$\mathbf{RF_{nmi}}$ = return flow from municipal-type uses of natural groundwater recharge
$\mathbf{RF_{mi}}$ = return flows of recycled water

and

$$\mathbf{SSY = R_{sag} + R_{smi} + RF_{sag} + RF_{smi}} \qquad \mathbf{(F2)}$$

where: $\mathbf{SSY}$ = supplemental sustainable yield
$\mathbf{R_{sag}}$ = recharge from agricultural use of supplemental water
$\mathbf{R_{smi}}$ = recharge from municipal-type use of supplemental water
$\mathbf{RF_{sag}}$ = return flows from agricultural use of supplemental water
$\mathbf{RF_{smi}}$ = return flows from municipal-type use of supplemental recharge

For both of preceding expressions, sustainable conditions are governed by generally constant groundwater conditions, meaning that groundwater storage fluctuates with varying hydrologic or other conditions but remains within a generally constant long-term range, i.e. trending neither up or down.

To solve the preceding equations, water requirements and sources, as well as the source, location, and rates of return flow, in the basin were first identified. Mathematical relationships were then developed between water requirements and return flows in order to substitute terms in and simplify solution of the equations for yield. Four assumptions were made in order to facilitate calculations of yield: 1) there are no delays between utilization of water and its recharge; 2) an average return flow rate was developed and utilized herein for agricultural irrigation; 3) return flow rates were developed and utilized for M&I water usage from the detailed analysis of M&I water requirements and supplies as described in Appendix D; and 4) recycled water was considered to be discharged via evaporation, irrigation at or below agronomic rates, or other means.

The long-term average annual natural recharge used for estimation of sustainable groundwater basin yield was derived from the results of the two independent analyses of natural groundwater recharge as described in Appendices C and E. Those analyses reached independent estimates of long-term natural recharge of about 56,000 afy and about 55,000-57,000 afy, respectively. In light of the nature of the respective methods, those results were interpreted to reflect an average long-term natural recharge of about 60,000 afy. Sustainable groundwater basin yield was then estimated by adding components of recharge and return flow that derive from the various uses of water in the AVAA, and thus contribute to sustainable groundwater yield.

Land uses in the basin include agricultural and several municipal-type uses, and the rates of return flow from municipal areas differ depending on the form and location of water use. The land use and associated return flow locations and rates are summarized and then individually discussed below, with return flow rates expressed as percentages of the agricultural and municipal water requirements, Q_{ag} and Q_{mi}, respectively, where Q_{ag} and Q_{mi} are in units of acre-feet per year.

Land Use	**Return Flow Location**	**Return Flow Rate***
Agricultural	agricultural lands	25% $\mathbf{Q_{ag}}$
M&I (urban, sewered)	on property	6.8% $\mathbf{Q_{mi}}$
	Lancaster WRP - Paiute Ponds	C_1 = 20 afy
	Lancaster WRP - treatment ponds	C_2 = 200 afy
	Lancaster WRP area - agric. irrigation	25% applied
	Palmdale WRP - treatment ponds	C_3 = 235 afy
	Palmdale WRP - land application	80% applied
	Palmdale WRP area – agric. irrigation	25% applied
M&I (unsewered**)	on property	21.3% $\mathbf{Q_{mi}}$

* *C is a constant recharge.*

** *includes portions of urban areas, and all mutual and small water company and rural residential areas on septic tanks.*

Agricultural Return Flow - The average agricultural return flow rate used for estimating native and supplemental sustainable yield was 25% of $\mathbf{Q_{ag}}$. That fraction was based on: 1) average and median rates for the historical period 1929-2005 (27% and 25%, respectively) and 2) average rate for the recent period 1986-2005 (23%).

Municipal Return Flow - The municipal return flow rates described as percentages of the total M&I water requirement in the basin were developed as follows.

$$\mathbf{Q_{mi} = Q_{urb} + Q_{mwc} + Q_{rr}}$$

where: $\mathbf{Q_{mi}}$ = total M&I water requirement

$\mathbf{Q_{urb}}$ = water requirement for the urban areas

$\mathbf{Q_{mwc}}$ = water requirement for the mutual and small water company areas = 5% $\mathbf{Q_{urb}}$

$\mathbf{Q_{rr}}$ = water requirement for the rural residential areas = 8% $\mathbf{Q_{urb}}$

then: $\mathbf{Q_{mi}} = 100\%\mathbf{Q_{urb}} + 5\%\mathbf{Q_{urb}} + 8\%\mathbf{Q_{urb}}$

or: $\mathbf{Q_{mi}} = 113\%\mathbf{Q_{urb}}$

and: $\mathbf{Q_{urb}} = 100/113\ \mathbf{Q_{mi}} = 88.5\%\ \mathbf{Q_{mi}}$

$\mathbf{Q_{mwc}} = 5/113\ \mathbf{Q_{mi}} = 4.4\%\ \mathbf{Q_{mi}}$

$\mathbf{Q_{rr}} = 8/113\ \mathbf{Q_{mi}} = 7.1\%\ \mathbf{Q_{mi}}$

The $\mathbf{Q_{urb}}$ term was further refined to accommodate different return flow rates from sewered and unsewered portions of the urban areas. It is estimated that, of the water utilized in sewered areas, 44% is consumptively used and 11% becomes return flow through outside irrigation, while the remaining 45% is utilized indoors and ultimately conveyed to WRPs. For water utilized in unsewered areas (urban, MWC, and RR), consumptive use is estimated to remain the same but the fraction that would be routed to WRPs in sewered areas is assumed to become return flow through on-site waste disposal; thus 44% is estimated to be consumptively used and 56% is estimated to be return flow in unsewered areas.

In order to estimate the respective fractions of sewered and unsewered municipal-type land uses, influent volumes at WRPs were compared to urban water requirements, and the service areas of sanitation districts were compared to the service areas of municipal water purveyors. Based on those comparisons, approximately 70% of the urban area is estimated to be currently sewered and the remainder is estimated to be served by individual on-site waste disposal systems (septic tanks and leach fields).

then: **$\mathbf{Q_{urb}}$ (sewered)** = 70% x 88.5% $\mathbf{Q_{mi}}$ = 62% $\mathbf{Q_{mi}}$
$\mathbf{Q_{urb}}$ (unsewered) = 30% x 88.5% $\mathbf{Q_{mi}}$ = 26.5% $\mathbf{Q_{mi}}$

All municipal-type water use in the basin can then be grouped in categories of sewered or unsewered areas, with the corresponding rates of return flow, consumptive use, and conveyance to the WRPs expressed as percentages of the total M&I water requirement $\mathbf{Q_{mi}}$ as follows:

Municipal-type water use in sewered areas	**Municipal-type water use in unsewered areas***
11% as return flow = 6.8% $\mathbf{Q_{mi}}$	56% as return flow = 21.3% $\mathbf{Q_{mi}}$
44% consumpt. use = 27.3% $\mathbf{Q_{mi}}$	44% consumpt. use = 16.7% $\mathbf{Q_{mi}}$
45% to WRP = 27.9% $\mathbf{Q_{mi}}$	**Total = 38%** $\mathbf{Q_{mi}}$
Total = 62% $\mathbf{Q_{mi}}$	

* sum of 26.5% urban + 4.4% MWC + 7.1% RR from above

As a result, for all urban, MWC, and RR areas, the disposition of water utilized is at the following rates:

Return Flow: (6.8% + 21.3%)$\mathbf{Q_{mi}}$ = 28.1% $\mathbf{Q_{mi}}$
Consumptive Use: (27.3% + 16.7%)$\mathbf{Q_{mi}}$ = 44% $\mathbf{Q_{mi}}$
Conveyance to WRP: 27.9% $\mathbf{Q_{mi}}$

WRP Return Flows - Of the water conveyed to the WRPs, approximately 25% of the influent is lost during treatment at both the Lancaster and Palmdale plants with the remaining 75% available for reuse. Of the 25% lost, return flows to the basin result from treatment pond percolation, estimated previously as 200 afy from Lancaster WRP, 235 afy from Palmdale WRP, and minimal amounts from the Rosamond Community Services District and Edwards AFB WRPs (Appendix G) for a combined estimated return flow of approximately 500 afy.

Then, of the total water estimated to be conveyed to the WRPs (27.9% $\mathbf{Q_{mi}}$):

Losses (including 500 afy return flow) = 27.9% $\mathbf{Q_{mi}}$ x 25% = 7% $\mathbf{Q_{mi}}$
Recycled water available for reuse = 27.9% $\mathbf{Q_{mi}}$ x 75% = 20.9% $\mathbf{Q_{mi}}$

Return Flow Summary - In summary, the municipal and agricultural return flows can be expressed as the following percentages of municipal and agricultural water requirements $\mathbf{Q_{mi}}$ and $\mathbf{Q_{ag}}$:

Agricultural return flow rate, $\mathbf{RF_{ag}}$ **=** 25% $\mathbf{Q_{ag}}$

Municipal return flow rate, $\mathbf{RF_{mi}}$ **=** 28.1% $\mathbf{Q_{mi}}$ **+ 500 afy**
(with 20.9% $\mathbf{Q_{mi}}$ available for reuse)

F.3 Scenarios

Recognizing that agricultural and municipal-type land uses contribute different return flow fractions that, in turn, contribute to the sustainable yield of the groundwater basin, it is evident that sustainable yield is not a constant and is, on the other hand, a variable that is dependent on prevailing land use in the basin. Recognizing also that groundwater recharge primarily derives from both natural supplies (i.e. local precipitation and runoff) and supplemental supplies (e.g. local surface water and imported water), it is further evident that sustainable yield is not a constant and is, on the other hand, a variable that is also dependent on prevailing water supplies and utilization of water supplies to meet water requirements and/or to otherwise manage water resources.

To capture the variations in the preceding factors, which are commonly described as part of cultural conditions in a given basin, two sets of sustainable yields were prepared for the AVAA: one set for different mixes of land use under "native" conditions, where only natural recharge is the primary source of sustainable groundwater supply in the basin; and a second set, also for different mixes of land use but under "supplemental" conditions, where natural recharge is augmented by recharge from the use of supplemental water supplies such as has occurred with the importation of SWP water since the 1970's. In both sets of estimated sustainable yield, land use mixes were based on actual conditions as have occurred in recent times: an average for the five year period (1995-1999) immediately preceding the filing of the current adjudication; an average for the last ten years (1996-2005); and in a single recent year (2005). The two sets of sustainable yield estimates are comprised of seven scenarios, four for native conditions and three for supplemental conditions, each of which is described and detailed as follows.

F.3.1 Native Sustainable Yield

As introduced above, native sustainable groundwater yield is the amount of pumping which, under a given set of cultural conditions (e.g. land use), generates return flows that, when combined with only natural recharge, result in no change in groundwater storage. As also introduced above, native sustainable yield is not a constant in that it can vary as a function of differing mixes of land use. Recognizing the evolution of land use practices in the basin over the last several decades, estimates of native sustainable yield are derived as follows for four sets of land use conditions: Scenario 1 - early historical conditions when essentially all land use devoted to agriculture; Scenario 2a - mixed agricultural and municipal-type land use as existed, on average, over the five-year period immediately prior to the filing of the present adjudication, 1995-1999; Scenario 2b - mixed agricultural and municipal-type land use as existed, on average, over the ten-year period 1996-2005; and Scenario 2c - mixed agricultural and municipal-type land use as was present in 2005.

Scenario 1 – Estimated Native Sustainable Yield for Historical (primarily agricultural) Cultural Conditions

For this scenario, prepared to illustrate the approximate sustainable yield when the AVAA was developing and dominated by agricultural land use, the basic equation (F1) can be simplified to

$$\mathbf{NSY_{ag} = NR + RF_{ag}}$$

where: $\mathbf{NSY_{ag}}$ = native sustainable yield for ag-only land use
$\mathbf{NR}$ = natural recharge, as above
$\mathbf{RF_{ag}}$ = return flows from agricultural irrigation

Substituting terms from the Approach above and recognizing that, in this scenario $\mathbf{NSY_{ag}}$ would be just agricultural pumping ($\mathbf{Q_{ag}}$) that would be sustainable,

$$\mathbf{NSY_{ag}} = \mathbf{Q_{ag}} = \mathbf{NR + RF_{ag}}$$

or: $\mathbf{NSY_{ag}} = \mathbf{Q_{ag}} = 60{,}000 + 25\%\ \mathbf{Q_{ag}}$

then: $\mathbf{NSY_{ag}} = \mathbf{Q_{ag}} = 60{,}000/0.75 =$ **80,000 afy**

Scenario 2 – Estimated Native Sustainable Yield for Mixed Agricultural and M&I Cultural Conditions

For this scenario, prepared to illustrate the approximate sustainable yield when the Valley had developed into land-use mixes that were present in the periods described above, the basic equation (F1) can be expressed as

$$\mathbf{NSY_{mix} = NR + RF_{ag} + RF_{mi}}$$

where: $\mathbf{NSY_{mix}}$ = native sustainable yield for mixed ag and municipal land uses
$\mathbf{NR}$ = natural recharge, as above
$\mathbf{RF_{ag}}$ = return flows from agricultural irrigation
$\mathbf{RF_{mi}}$ = return flows from municipal-type land uses

Substituting terms from the Approach above and recognizing that, in this scenario, $\mathbf{NSY_{mix}}$ would be a combination of agricultural pumping ($\mathbf{Q_{ag}}$) and municipal-type pumping ($\mathbf{Q_{mi}}$) that would be sustainable,

$$\mathbf{NSY_{mix} = Q_{ag} + Q_{mi} = NR + RF_{ag} + RF_{mi}}$$

or: $\mathbf{NSY_{mix} = Q_{ag} + Q_{mi}} = 60{,}000 + 25\%\ \mathbf{Q_{ag}} + (28.1\%\ \mathbf{Q_{mi}} + 500)$

simplifying: $75\%\ \mathbf{Q_{ag}} + 71.9\%\ \mathbf{Q_{mi}} = 60{,}500$ afy

In order to solve the preceding equation, the agricultural and municipal water requirement percentages were combined into a "weighted" total pumping, denoted as the simplified term **Q** below. The weighting was necessary because the fractions of agricultural and municipal land use vary annually, and the return flow rates associated with each use vary as outlined above. Scenarios 2a, 2b, and 2c were then developed to reflect the prevailing land use (cultural) conditions in the three periods described above: 1995-1999 (Scenario 2a), 1996-2005 (Scenario 2b), and 2005 (Scenario 2c). Each is summarized as follows.

<u>Scenario 2a -1995 - 1999 (land use = 51.9% Ag and 48.1% M&I)</u>

from above, 75% $\mathbf{Q_{ag}}$ + 71.9% $\mathbf{Q_{mi}}$ = 60,500

for this scenario, $\mathbf{Q_{ag}}$ = 51.9% **Q**
$\mathbf{Q_{mi}}$ = 48.1% **Q**

so: (75% x 51.9%) **Q** + (71.9% x 48.1%) **Q** = 60,500 afy

then: 38.9% **Q** + 34.6 **Q** = 60,500 afy

or: 73.5% **Q** = 60,500 afy

then: **Q** = 60,500/0.735 = **82,300 afy**

<u>Scenario 2b -1996 - 2005 (land use = 53.2% Ag and 46.8% M&I)</u>

from above, 75% $\mathbf{Q_{ag}}$ + 71.9% $\mathbf{Q_{mi}}$ = 60,500

for this scenario, $\mathbf{Q_{ag}}$ = 53.2% **Q**
$\mathbf{Q_{mi}}$ = 46.8% **Q**

so: (75% x 53.2%) **Q** + (71.9% x 46.8%) **Q** = 60,500 afy

then: 39.9% **Q** + 33.6% **Q** = 60,500 afy

or: 73.5% **Q** = 60,500 afy

then: **Q** = 60,500/0.735 = **82,300 afy**

Scenario 2c -Year 2005 (land use = 51.5% Ag and 48.5% M&I)

from above, 75% $\mathbf{Q}_{\mathbf{ag}}$ + 71.9% $\mathbf{Q}_{\mathbf{mi}}$ = 60,500

for this scenario, $\mathbf{Q}_{\mathbf{ag}}$ = 51.5% **Q**
$\mathbf{Q}_{\mathbf{mi}}$ = 48.5% **Q**

so: (75% x 51.5%) **Q** + (71.9% x 48.5%) **Q** = 60,500 af

then: 38.6% **Q** + 34.9% **Q** = 60,500 af

or: 73.5% **Q** = 60,500 af

then: **Q** = 60,500/0.735 = **82,300 afy**

F.3.2 Sustainable Yield with Native and Supplemental Waters

As introduced above, total sustainable groundwater yield is the amount of pumping which, under a given set of cultural conditions (e.g. land use, water supply, etc.) generates return flows that, when combined with natural recharge plus other recharge that derives from the use of supplemental water, result in no change in groundwater storage. As with the estimates of native sustainable yield above, estimates of sustainable yield for a combination of native and supplemental conditions need to recognize that they are similarly dependent on land and water use practices, including prevailing practices related to how supplemental waters are used in the AVAA and how they thus add groundwater recharge to that which occurs naturally. In this case, of course, sustainable yield estimates are also dependent on the amounts of supplemental water that are used to produce additional groundwater recharge that, in turn, supports additional sustainable yield. Recognizing those factors, estimates of total sustainable yield, and the supplemental sustainable yield attributable to utilization of supplemental waters, were derived for three sets of land use conditions that coincide with those used for native yield estimates above, but when supplemental water was also being used: Scenario 3a - mixed agricultural and municipal-type land use as existed, on average, over the five-year period immediately prior to the filing of the present adjudication, 1995-1999; Scenario 3b - mixed agricultural and municipal-type land use as existed, on average, over the ten-year period 1996-2005; and Scenario 3c - mixed agricultural and municipal-type land use as was present in 2005.

Scenario 3 – Estimated Supplemental Sustainable Yield for Mixed Agriculture and M&I Cultural Conditions

For this scenario, prepared to illustrate the approximate sustainable yield that resulted from the augmentation of native water supplies with supplemental water in the AVAA, and also prepared to illustrate the respective contributions to increased yield by agricultural and municipal-type importations of supplemental water, the basic equations (F1 and F2) can be combined as

$$\mathbf{TSY_{mix} = NSY_{mix} + SSY_{mix}}$$

where: $\mathbf{TSY_{mix}}$ = total sustainable yield from native plus supplemental waters for mixed ag. and municipal-type land uses
$\mathbf{NSY_{mix}}$ = native sustainable yield as derived in Scenario 2 above
$\mathbf{SSY_{mix}}$ = supplemental sustainable yield derived from use of imported and other supplemental waters for mixed ag and municipal-type land uses

Then inserting components of supplemental sustainable yield into Equation F2 above,

$$\mathbf{SSY_{mix} = R_{sag} + R_{smi} + RF_{sag} + RF_{smi}}$$

where: $\mathbf{R_{sag}}$ = recharge from agricultural use of supplemental water (25% of agricultural supplemental water use, $\mathbf{SW_{ag}}$)
$\mathbf{R_{smi}}$ = recharge from municipal-type uses of supplemental water (28.1% of municipal-type supplemental water use; $\mathbf{SW_{mi}}$)
$\mathbf{RF_{sag}}$ = return flows from agricultural irrigation using recharge from ag use of supplemental water (25% of $\mathbf{Q_{sag}}$)
$\mathbf{RF_{smi}}$ = return flows from municipal-type uses of recharge from M&I-type use of supplemental water (28.1% of $\mathbf{Q_{smi}}$)

Recognizing that $\mathbf{SSY_{mix}}$ would be a combination of agricultural pumping ($\mathbf{Q_{sag}}$) and municipal-type pumping ($\mathbf{Q_{mi}}$) that would both derive from the use of supplemental water and be sustainable, and further recognizing that supplemental yield is allocated to the user-types who utilized the imported or other supplemental water,

$$\mathbf{SSY_{mix} = Q_{sag} + Q_{smi} = R_{sag} + R_{smi} + RF_{sag} + RF_{smi}}$$

where: $\mathbf{Q_{sag}}$ = agricultural share of supplemental sustainable yield
$\mathbf{Q_{smi}}$ = municipal-type share of supplemental sustainable yield

and: $\mathbf{Q_{sag} = R_{sag} + RF_{sag}}$
$\mathbf{Q_{smi} = R_{smi} + RF_{smi}}$

or: $\mathbf{Q_{sag} = R_{sag} + 25\%\ Q_{sag}}$
$\mathbf{Q_{smi} = R_{smi} + 28.1\%\ Q_{smi}}$

simplifying: $\mathbf{Q_{sag} = R_{sag}}/0.75$
$\mathbf{Q_{smi} = R_{smi}}/0.719$

and: $\mathbf{SSY_{mix} = Q_{sag} + Q_{smi} = (R_{sag}}/0.75\mathbf{)} + \mathbf{(R_{smi}}/0.719)$

Scenario 3a - 1995 - 1999 (land use = 51.9% Ag and 48.1% M&I; average supplemental water deliveries = 19,550 afy Ag and 48,100 afy M&I)

for this scenario:
$\mathbf{NSY}$ = 82,300 afy (from Scenario 2a)
$\mathbf{SW_{ag}}$ = 19,550 afy
$\mathbf{SW_{mi}}$ = 48,100 afy
$\mathbf{R_{sag}} = 0.25\ \mathbf{SW_{ag}} = 0.25 \times 19{,}550$ afy = 4,890 afy
$\mathbf{R_{smi}} = 0.281\ \mathbf{SW_{mi}} = 0.281 \times 48{,}100$ afy = 13,515 afy

then:
$\mathbf{Q_{sag}} = \mathbf{R_{sag}}/0.75$
$\mathbf{Q_{sag}}$ = 4,890/0.75 = **6,500 afy**

and:
$\mathbf{Q_{smi}} = \mathbf{R_{smi}}/0.719$
$\mathbf{Q_{smi}}$ = 13,515/0.719 = **18,800 afy**

then:
$\mathbf{SSY_{mix} = Q_{sag} + Q_{smi}}$

= 6,500 afy + 18,800 afy
$\mathbf{SSY_{mix}}$ **= 25,300 afy**

and:
$\mathbf{TSY_{mix} = NSY_{mix} + SSY_{mix}}$

= 82,300 afy + 25,300 afy
$\mathbf{TSY_{mix}}$ **= 107,600 afy**

Scenario 3b - 1996 - 2005 (land use = 53.2% Ag and 46.8% M&I; average supplemental water deliveries = 16,625 afy Ag and 56,320 afy M&I)

for this scenario:
$\mathbf{NSY}$ = 82,300 afy (from Scenario 2b)
$\mathbf{SW_{ag}}$ = 16,625 afy
$\mathbf{SW_{mi}}$ = 56,320 afy
$\mathbf{R_{sag}} = 0.25\ \mathbf{SW_{ag}} = 0.25 \times 16{,}625$ afy = 4,155 afy
$\mathbf{R_{smi}} = 0.281\ \mathbf{SW_{mi}} = 0.281 \times 56{,}320$ afy = 15,825 afy

then:
$\mathbf{Q_{sag}} = \mathbf{R_{sag}}/0.75$
$\mathbf{Q_{sag}}$ = 4,155/0.75 = **5,500 afy**

and:
$\mathbf{Q_{smi}} = \mathbf{R_{smi}}/0.719$
$\mathbf{Q_{smi}}$ = 15,825/0.719 = **22,000 afy**

then:
$\mathbf{SSY_{mix} = Q_{sag} + Q_{smi}}$

$= 5{,}500 \text{ afy} + 22{,}000 \text{ afy}$

$\mathbf{SSY_{mix} = 27{,}500\ afy}$

and: $\mathbf{TSY_{mix} = NSY_{mix} + SSY_{mix}}$

$= 82{,}300 \text{ afy} + 27{,}500 \text{ afy}$

$\mathbf{TSY_{mix} = 109{,}800\ afy}$

Scenario 3c - Year 2005 (land use = 51.5% Ag and 48.5% M&I; supplemental water deliveries = 9,500 af Ag and 64,000 af M&I)

for this scenario: $\mathbf{NSY}$ = 82,300 afy (from Scenario 2c)

$\mathbf{SW_{ag}} = 9{,}500$ afy

$\mathbf{SW_{mi}} = 64{,}000$ afy

$\mathbf{R_{sag}} = 0.25\ \mathbf{SW_{ag}} = 0.25 \times 9{,}500 \text{ afy} = 2{,}375 \text{ afy}$

$\mathbf{R_{smi}} = 0.281\ \mathbf{SW_{mi}} = 0.281 \times 64{,}000 \text{ afy} = 17{,}985 \text{ afy}$

then: $\mathbf{Q_{sag}} = \mathbf{R_{sag}}/0.75$

$\mathbf{Q_{sag}} = 2{,}375/0.75 = \mathbf{3{,}200\ afy}$

and: $\mathbf{Q_{smi}} = \mathbf{R_{smi}}/0.719$

$\mathbf{Q_{smi}} = 17{,}985/0.719 = \mathbf{25{,}000\ afy}$

then: $\mathbf{SSY_{mix} = Q_{sag} + Q_{smi}}$

$= 3{,}200 \text{ afy} + 25{,}000 \text{ afy}$

$\mathbf{SSY_{mix} = 28{,}200\ afy}$

and: $\mathbf{TSY_{mix} = NSY_{mix} + SSY_{mix}}$

$= 82{,}300 \text{ afy} + 28{,}200 \text{ afy}$

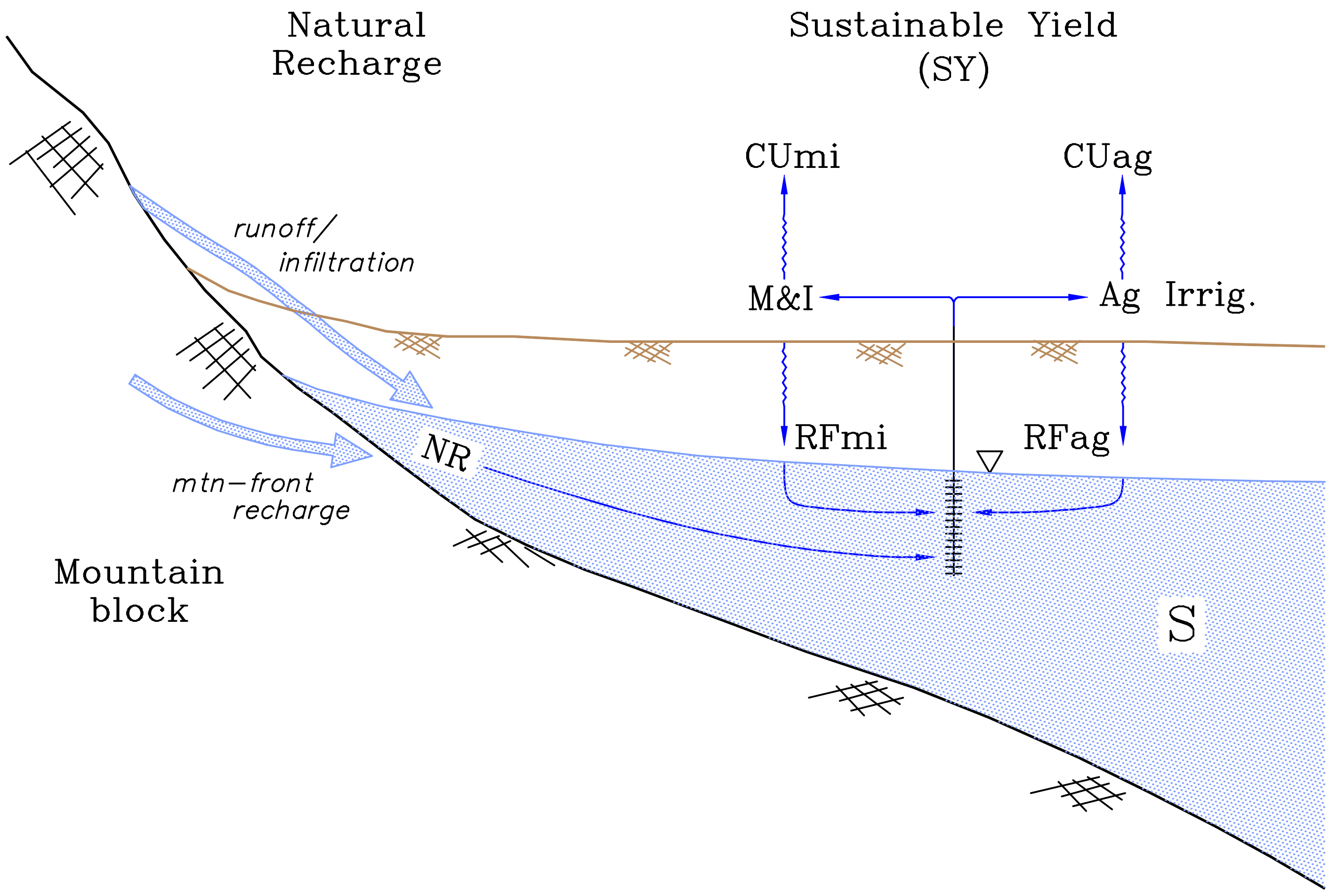
$\mathbf{TSY_{mix} = 110{,}500\ afy}$

F.4 Summary

As would logically be expected, with the return flow contributions that have derived from the importation of supplemental water, the sustainable yield of the groundwater basin has been increased above native conditions. For the mixes of land use that have occurred since the mid-1990’s, native sustainable yield has been about 82,300 afy. Depending on what time period is selected to be representative (recognizing the wide variations in imported water supply and utilization in the three scenarios described above), total sustainable yield has increased to as much as about 110,000 afy as a result of supplemental water use. Of that increase, again depending on what time period is considered representative, the respective contributions to the increase vary as a result of the respective agricultural and municipal-type uses of supplemental water. For the time periods represented by the scenarios herein, the native and supplemental sustainable yield values are summarized in Table F.4-1; included in the table are the contributions to increased sustainable yield by agriculture and by municipal-type uses as a result of their respective uses of imported water.

Table F.4-1
Sustainable AVAA Groundwater Yield Summary

Scenario	Land Use Period	Native Sustainable Yield (afy)	Supplemental Sustainable Yield (afy)	Total Sustainable Yield (afy)	Contribution to Yield Increase (afy)	
					Ag.	**M&I**
1	All ag.	80,000	---	---	---	---
2a/3a	1995-1999	82,300	25,300	107,600	6,500	18,800
2b/3b	1996-2005	82,300	27,500	109,800	5,500	22,000
2c/3c	2005	82,300	28,200	110,500	3,200	25,000



Sustainable Yield (SY) = Natural Recharge (NR) + Ag Return Flows (RFag) + M&I Return Flows (RFmi)
(when S = constant over time)

Ag = agricultural irrigation

M&I = municipal and industrial use

CU = consumptive use

S = groundwater storage

CAD FILE: G:/Projects/Antelope Valley/06-6-075/AV Sustainable Yield Diagram.dwg

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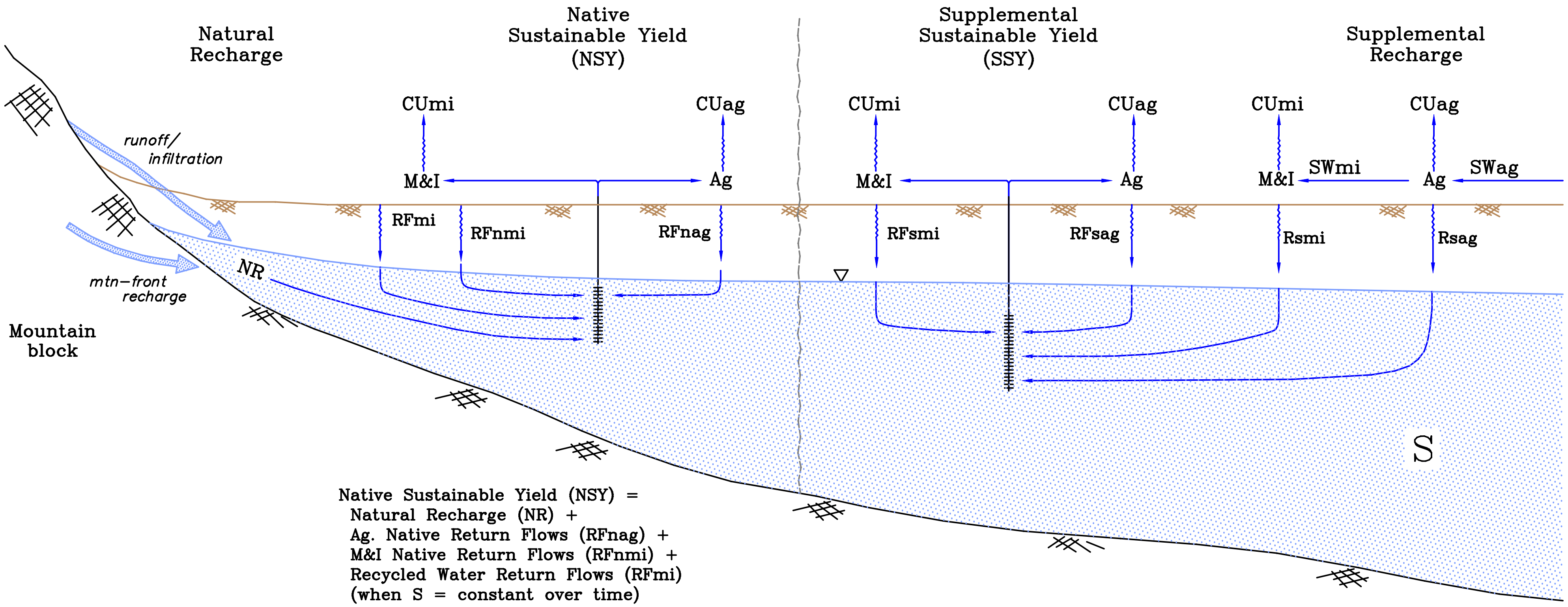
Figure F.1-1
Schematic Illustration of Sustainable Yield
Antelope Valley Area of Adjudication



Native Sustainable Yield (NSY) =
Natural Recharge (NR) +
Ag. Native Return Flows (RFnag) +
M&I Native Return Flows (RFnmi) +
Recycled Water Return Flows (RFmi)
(when S = constant over time)

Supplemental Sustainable Yield (SSY) =
Recharge from Ag. Use of Supp. Water (Rsag) +
Recharge from M&I Use of Supp. Water (Rsmi) +
Ag. Supp. Return Flows (RFsag) +
M&I Supp. Return Flows (RFsmi)
(when S = constant over time)

Ag = agricultural irrigation
M&I = municipal and industrial use
CU = consumptive use
SW = supplemental water
S = groundwater storage

CAD FILE: G:/Projects/Antelope Valley/06-6-075/AV NST Sustainable Yield Diagram.dwg

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Figure F.1-2
Schematic Illustration of Native, Supplemental, and Total Sustainable Yield
Antelope Valley Area of Adjudication