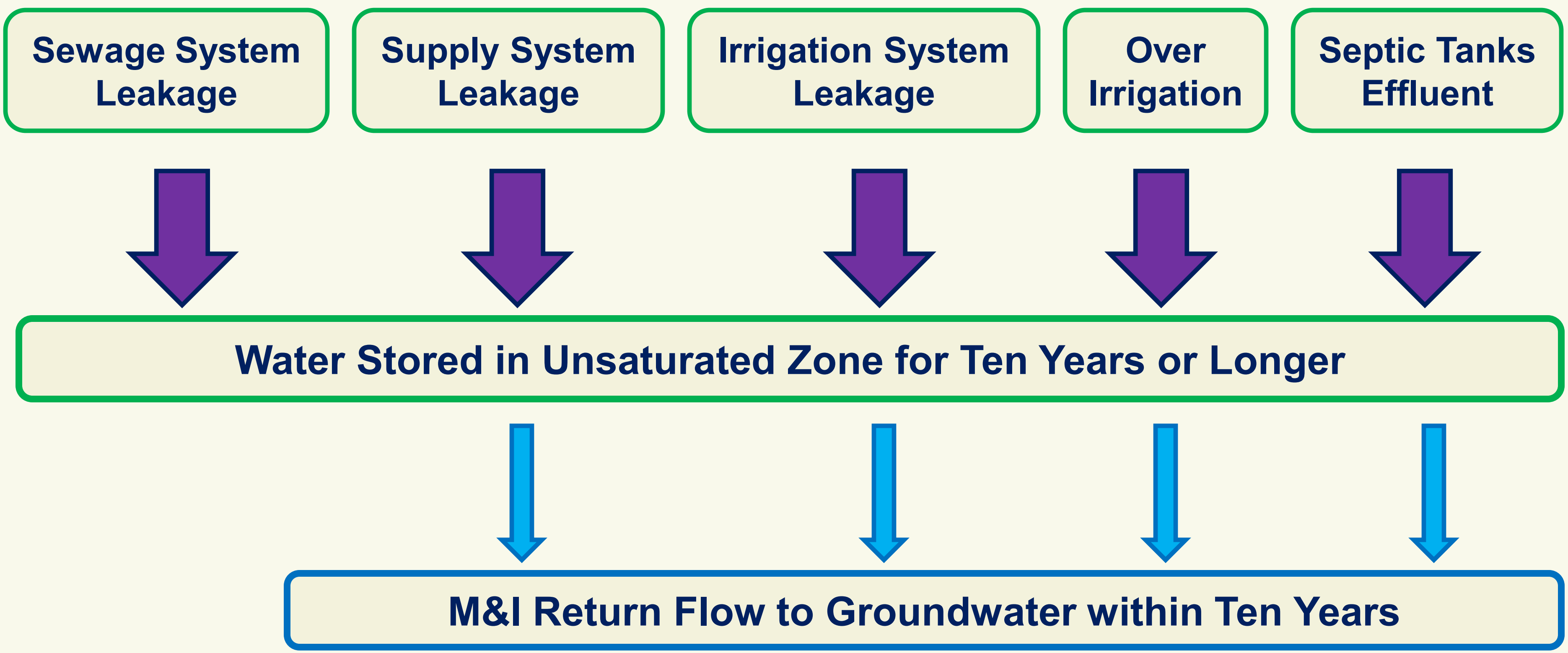
5-AGWA-1

On-Site M&I Return Flow in Antelope Valley is the part of the water withdrawn or imported for M&I purposes that will return to the groundwater within ten years and can be used again.

Components of M&I Return Flow



On-Site M&I Return Flow

as percentage of total volume of water entering the supply system

Component	Technical Report	Current Analysis
	1946 -2006 On-site Return Flow	2005 - 2010 On-site Return Flow
Sewage System Leakage	NA	0.0
Supply System Leakage	NA	0.7
Irrigation System Leakage	NA	1.0
Over-irrigation	11.0	0.3
Septic Tank Effluents from UnSewered Houses	17.1	3.7
TOTAL	28.1	5.7
Total Compounded	39.1	

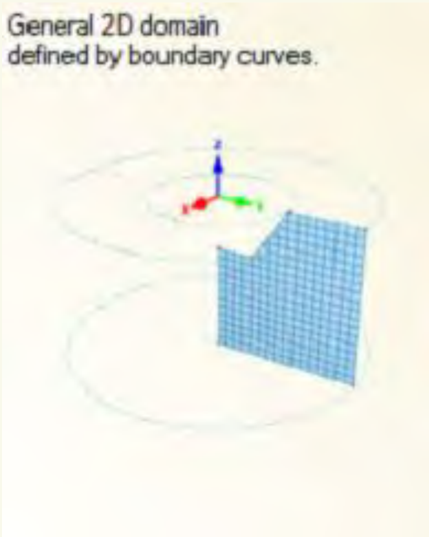
Tomorrow's On-Site M&I Return Flow will be less due to a decrease of Leakage, Over-Irrigation and Septic Tank Effluents as a result of leakage control and water conservation efforts.

The volume of on-site M&I return flow from leaks, over-irrigation and septic tanks depends on:

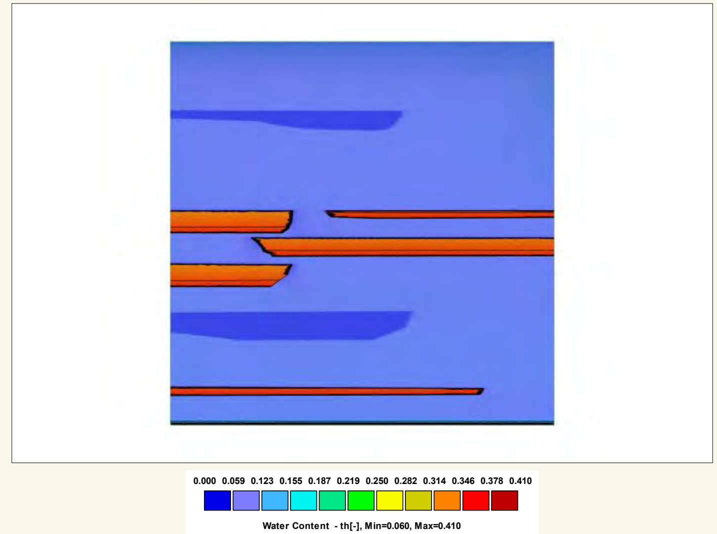
1. The rate of the release (gallons per day).
2. The volume of the release (gallons).
3. The surface area that absorbs the water (square feet).
4. The depth of the groundwater table (feet).
5. The hydrogeological condition of the unsaturated zone.

The HYDRUS2D/3D model has been used to evaluate how these factors determine return flow rates and volumes.
HYDRUS2D/3D: http://www.pc-progress.com/en/Default.aspx?hydrus-3d

HYDRUS2D/3D Example

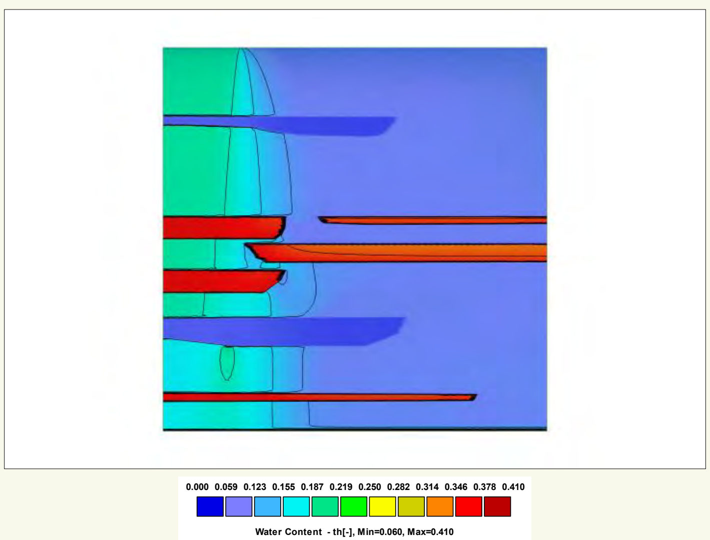


Water Content Distribution Before Over-Irrigation



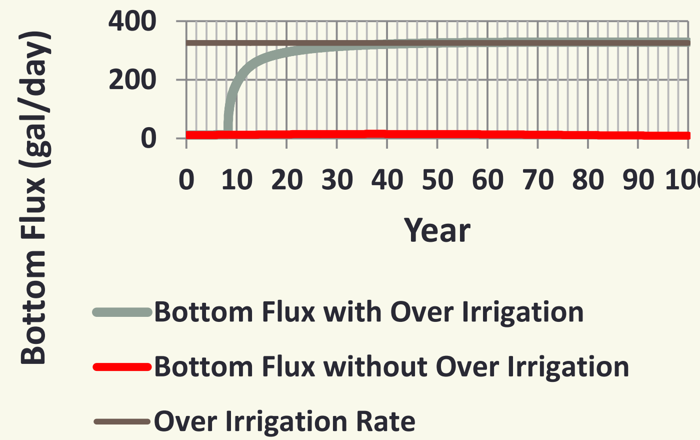
Project Antelope_heterogeneous_profile_desert_over_irrigation_1_run - Antelope heterogeneous test
Results, Water Content, Time 0 - 0.0 days

Water Content Distribution After 20 Years



Project Antelope_heterogeneous_profile_desert_over_irrigation_1_run - Antelope heterogeneous test
Results, Water Content, Time 5 - 7300.0 days

100 Years Over Irrigation
325 gallons/day; volume 10.9 acre-ft



Typical releases are: invisible leaks too small yet for detection, small leaks, and over-irrigation.

Return flow volumes have been determined using HYDRUS2D/3D simulations .

Release	Rate (gal/day)	Duration (days)	Volume (ac-ft)	Area (sq ft)	Return Vol 10 Year# (%)	Return Vol 20 Year (%)
Invisible Leak	296	1095	0.99	27	22	40
Small Leak	6602	46	0.93	616	15	31
Over-Irrigation	325	Forever		3600	6	42

"Return Volume 10 Year (%)" means: the percentage of the total volume of leakage water that has returned to the groundwater after ten years.

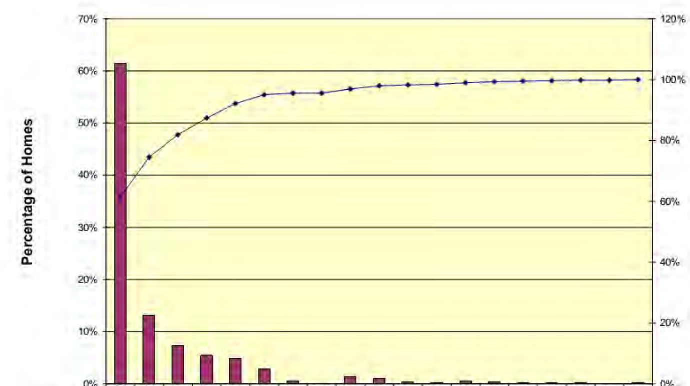
Supply System Leakage

- The water loss due to leaks is 3.0% of total water volume entering the supply system[1].
- The leakage that infiltrates into the unsaturated zone is estimated to be 60 % of the annual leakage loss of 3.0 %, i.e. 1.8 %.
- Ten years after the start of a typical invisible or small leak about 20% of the leakage volume has become return flow (see Return Flow Table). Only the return flow during the first ten years is taken into account because extrapolation of our numbers to a longer period is not justified given the rapid changes in water use in California[2].
- Return flow is assumed to be $3.0 \times 0.6 \times 0.22 = 0.4\%$ of total water volume entering the supply system.

1. Table 4-1 in "2010 Integrated Regional Urban Water Management Plan for the Antelope Valley" by LA Waterworks District No. 40).
2. Table 1 in "Residential Water Conservation in Australia and California" by R. Cahill and J. Lund" 2013. Journal of Water Resources Planning and Management. http://cee.engr.ucdavis.edu/faculty/lund/papers/CahillResidentialConservationAustraliaCalifornia.pdf

Irrigation System Leakage

- **Figure 7 by DeOreo et al. (2011) shows that 3% of all homes use 180,000 to 380,000 gallons per year. This usage of about 500 to 1000 gallons per day is caused by irrigation system leakage.**



	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380
Relative	61.4%	13.2%	7.4%	5.5%	4.8%	2.9%	0.5%	0.0%	1.4%	1.0%	0.3%	0.2%	0.5%	0.3%	0.2%	0.2%	0.2%	0.0%	0.2%
Cum %	61%	75%	82%	87%	92%	95%	96%	96%	97%	98%	98%	98%	99%	99%	99%	100%	100%	100%	100%

Excess Application (kgal)

Figure 7: Distribution of excess irrigation by number of accounts

- **Outdoor water use is about 70% of the water consumed by a single-family home[1]. Taking into account the 3% supply system leakage and estimating that 3% of the homes looses about 6% of outdoor water, irrigation system leakage is estimated as (100-3)×0.7×0.06=4% of the water volume entering the supply system.**
- **Using the 10 year return volume estimation of 20%, return flow is estimated as 4×0.2=0.8% of total water volume entering the supply system.**

1. Outdoor water use is 70-75% according to Mr. Akiri's deposition and about 70% according to the web page of LA County Water District 40 http://dpw.lacounty.gov/wwd/web/Conservation/XeriscapeEducation.aspx accessed 2/2/2014.

Over-Irrigation - I

- Figure 6 by DeOreo et al. (2011) shows the distribution of application ratios in representative homes of California. An application ratio of 100% is needed for a good-looking garden.

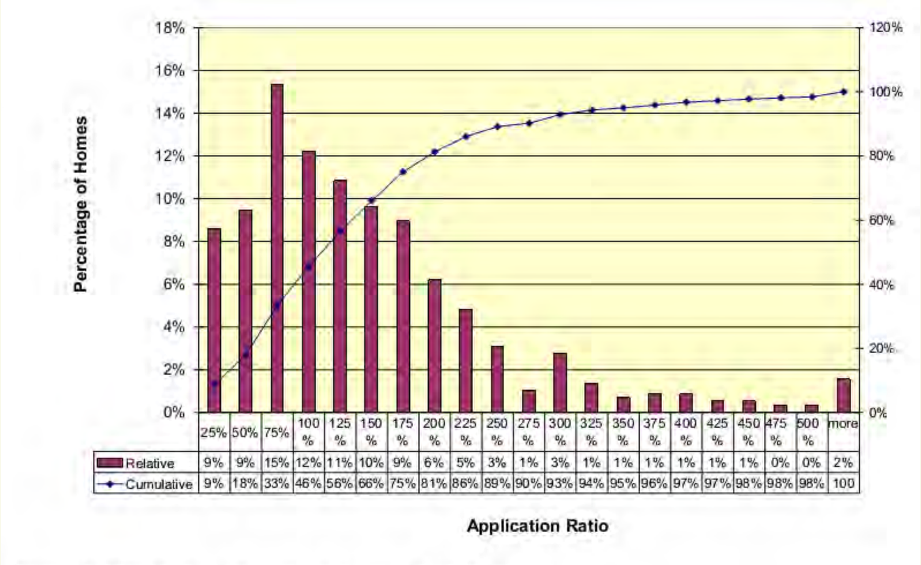


Figure 6: Distribution of application ratios in study homes

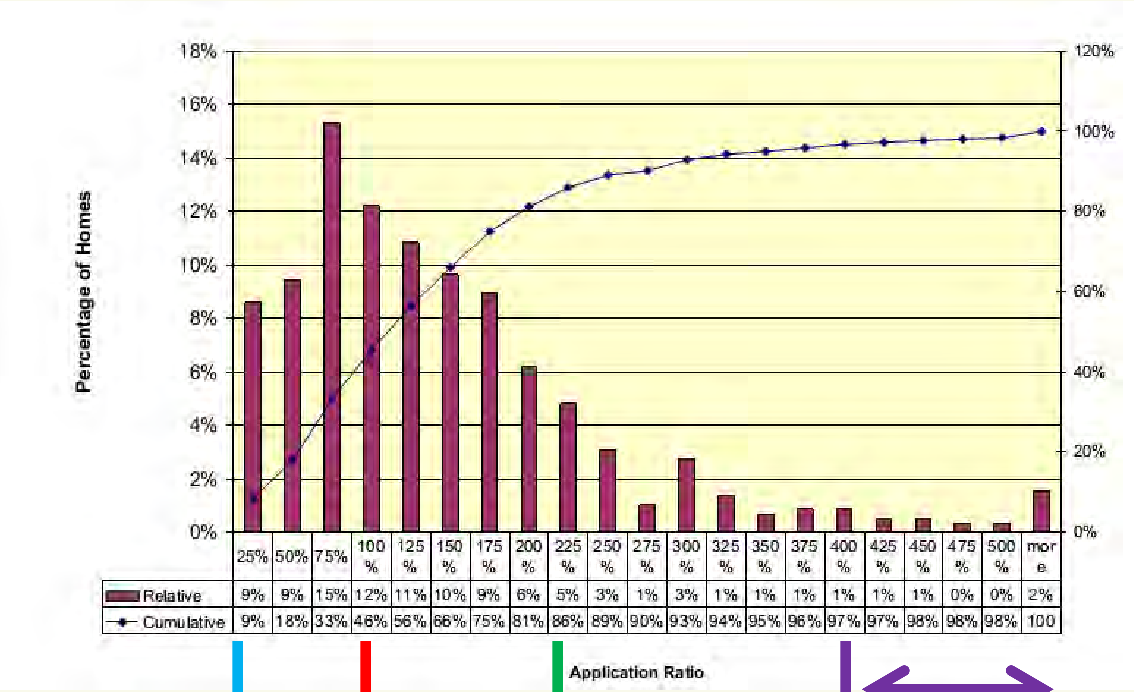
- The application ratio is the ratio of outdoor water use (irrigation) to the Theoretical Irrigation Requirements. Their TIR is based on accurate observations of the size and type of landscape, the local net reference ETo-cimis and whether there is a swimming pool present.
- Figure 6 shows that 46% of homes applies 100% or less. In the previous slide we calculated that about 3% of the homes looses water through irrigation system leaks. Therefore, about 100-46-3=51% of the homes applies excess irrigation.

Over-Irrigation - II

- **For a good-looking garden DeOreo et al. (2011) use crop coefficients (K_c)[1] varying from 0.8 for turf to 0.65 for non-turf plants. They calculate ET = $K_C \times ET_{o\text{-}CIMIS}$ where $ET_{o\text{-}CIMIS}$ is the reference evapotranspiration. This ET defines their 100% application ratio.**
- **Urban landscapes consists of small patches of vegetation surrounded by dry hot surfaces. For these conditions, Allen et al. (1998)[2] recommend to use for well-watered vegetation a crop coefficient with values up to 2.6 depending on the width of the vegetation stand.**
- **For Antelope Valley's over-irrigated gardens we select a crop coefficient of 1.8 that is 1.8/0.8=2.25 times larger than the crop coefficient for a good-looking garden. This means that an over-irrigated garden will have an application ratio of 225%.**

1. DeOreo et al. 2011: Table 9 on p. 68.
2. Allen, R. G., L. S. Pereira, D. Raes, and M. Smith (1998), Crop evapotranspiration: Guidelines for computing crop requirements. Irrigation and Drainage Paper No. 56., 300 pp., Food and Agricultural Organization of the United Nations, Rome, Italy. Figure 46 on p. 203.

Over-Irrigation - III



	25%	50%	75%	100 %	125 %	150 %	175 %	200 %	225 %	250 %	275 %	300 %	325 %	350 %	375 %	400 %	425 %	450 %	475 %	500 %	more
Relative	9%	9%	15%	12%	11%	10%	9%	6%	5%	3%	1%	3%	1%	1%	1%	1%	1%	1%	0%	0%	2%
Cumulative	9%	18%	33%	46%	56%	66%	75%	81%	86%	89%	90%	93%	94%	95%	96%	97%	97%	98%	98%	98%	100

Typical Palmdale street
Google Earth

Irrigation System Leakage in 3% of homes: return flow

Over-Irrigation in 11% of homes: return flow

Excess Irrigation in 40% of homes: no return flow

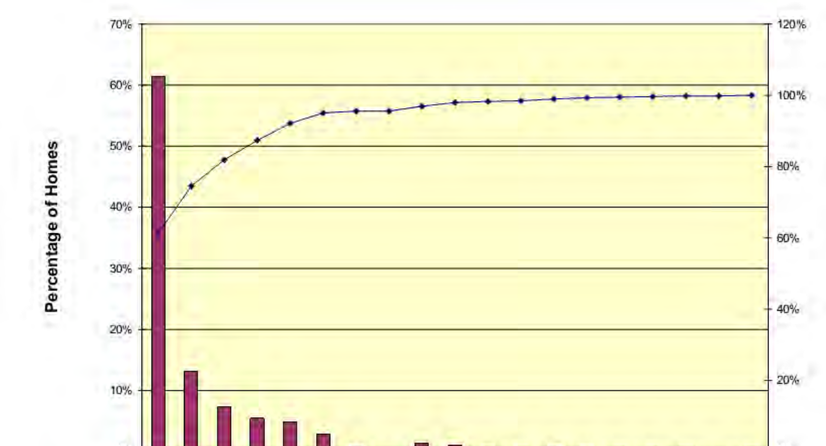
Under Irrigation in 46% of homes: no return flow

Over-Irrigation - IV

- The data by DeOreo et al. (2011) do not provide information on the amount of Over-Irrigation in Antelope Valley. However, we can estimate Over-Irrigation in Antelope Valley assuming that DeOreo's California data are representative of consumer behavior in Antelope Valley.
- Using CIMIS data for Palmdale we find the net ETo to be 61.5 inch/year. Net ETo is ETo minus effective precipitation.
- Some water is lost due to runoff and wind spray. DeOreo et al. (2011) use a "minimum acceptable efficiency" of 71 percent.
- When home owners apply more that $2.25 \times 61.5 / 0.71 = 194.8$ inches/year, over-irrigation will lead to deep percolation below the root zone and possible return flow.
- The average amount of over-irrigation is estimated from the application ratios where over-irrigation occurs; it is about 29% of 194.8 inches/year or 56.6 inches/year which equals a deep percolation rate of 0.16 inch/day or 0.39 cm/day.

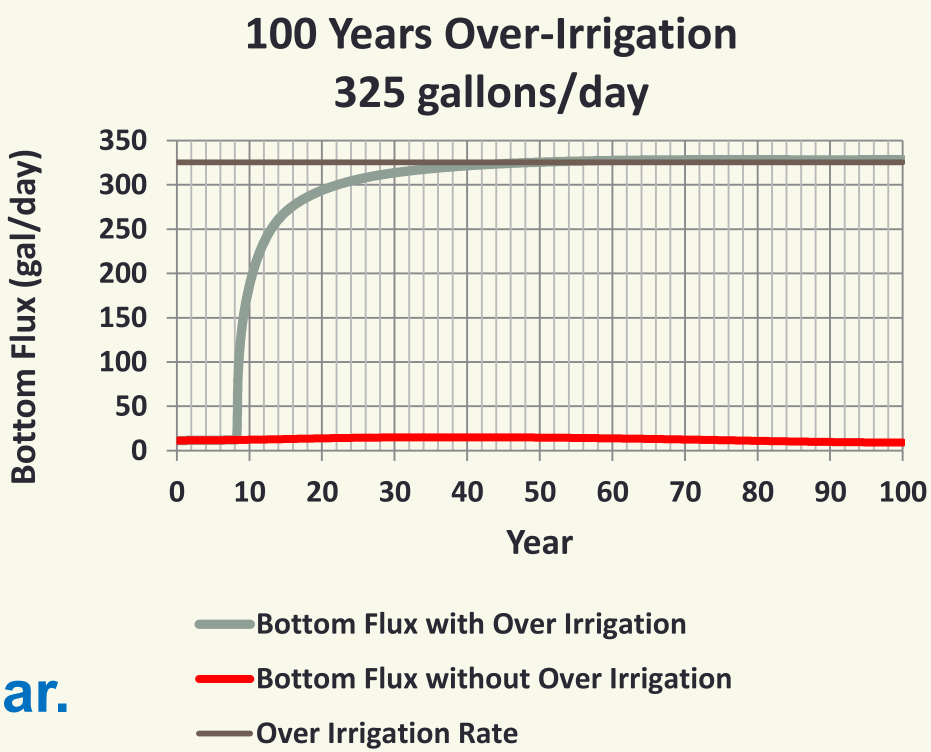
Over-Irrigation - V

- **The average irrigated area is about 3600 square feet. A 100 year long simulation of 0.39 cm/day over-irrigation in a garden of 3600 square yard equals a water application of 325 gallon per day. Only 6% of the over-irrigated water becomes return flow within ten years (see Return Flow Table).**



	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380
Relative	61.4%	13.2%	7.4%	5.5%	4.8%	2.9%	0.5%	0.0%	1.4%	1.0%	0.3%	0.2%	0.5%	0.3%	0.2%	0.2%	0.2%	0.0%	0.2%
Cum %	61%	75%	82%	87%	92%	95%	96%	96%	97%	98%	98%	98%	99%	99%	99%	100%	100%	100%	100%

Figure 7: Distribution of excess irrigation by number of accounts



Over-Irrigation of 325 gallons per day equals 120 kgal per year.

Over-Irrigation - VI

- Outdoor water use is about 70% of the water consumed by a single-family home. Taking into account the 3% supply system leakage and estimating from the data by DeOreo et al. that 11% of the homes looses about 9% of outdoor water due to over-watering their gardens, over-irrigation is estimated as $(100-3)\times0.7\times0.09=6.1\%$ of the water volume entering the supply system.
- Using the 10 year return volume estimation of 6%, return flow is estimated as $6.1\times0.06=0.4\%$ of total water volume entering the supply system.

Septic Effluents UnSewered Zone - I

- Mr. Wagner and his colleagues estimated that the effluents from septic tanks in unsewered homes represent 5.6% of the total water volume that enters the supply system.
- Mr. Wagner estimated an effluent rate of about 61 gallon per day per person. For households with two to four persons the daily effluent rate is about 122 to 244 gallon per day.
- On April 18, 2013 I interviewed Mr. Alex Pivovaroff, owner of Alex Sanitation in Lancaster. He informed me that on about 25% of leach fields signs of evapotranspiration are visible: taller trees, stained soils, weed growth. This is evidence that ET of septic effluent does occur.

Photo by Mr. Pivovaroff; 6/21/2013; 40015 172nd St E; Palmdale

Photo by Dr. Hendrickx; 4/18/2013; 40227 167th Street W, Lake Los Angeles

Septic Effluents UnSewered Zone - II

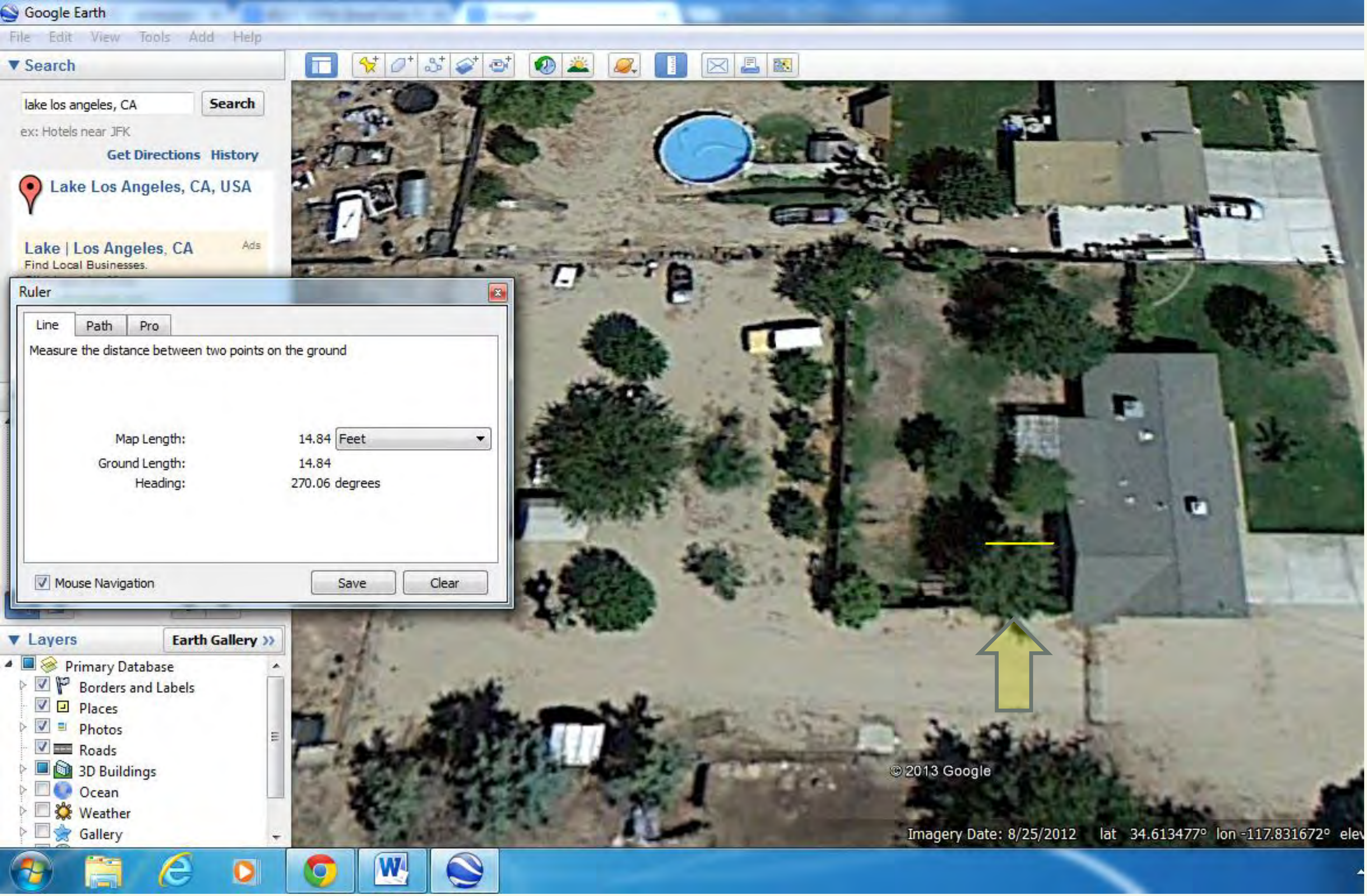
- Mr. Alex Pivovaroff also told me that a 2008 EPA regulation promotes the installation of shallow rather than deep septic systems. This policy change will increase evapotranspiration of septic effluents.
- Based on (1) the information given by Mr. Pivovaroff, (2) my field and Google observations, and (3) the high crop coefficients for small stands of well-watered vegetation it is estimated that 20% of septic effluents will be lost to evapotranspiration. The volume of deep percolation is 5.6 – 5.6 × 0.2 = 4.5% of total water volume entering the supply system.
- Taking evapotranspiration into account the daily rate of septic tanks varies between 100 to 250 gallon per day which is somewhat lower than the ones analyzed in the Return Flow Table. It is estimated that about 20% of the total volume of septic tank effluents in unsewered homes will return to the groundwater within ten years.
- The return flow is estimated as 4.5 × 0.20 = 0.9% of total water volume entering the supply system.

Google Image 5/24/2013

Alex Pivovaroff

6/21/2013

40015 172nd St E; Palmdale



40227 167th Street W, Lake Los Angeles. The large tree is about 15 feet away from the house. Homeowner Jim informed that the tree is right next to septic tank and there is no need to irrigate the tree. Other trees receive irrigation water.

Table 1: Historical comparison of average residential water use (in liters (gallons) per capita per day, or lpcd (gpcd)) in Australia and California, 1994-2009

Sources: ABS 1997, ABS 2000, ABS 2002, ABS 2004, ABS 2006, ABS 2010, NWC and WSAA 2011, DWR 2011

Year	California Residential Use, lpcd (gpcd)	Australian Residential Use, lpcd (gpcd)
1994	397 (105)	290 (77)*
1997	443 (117)	295 (78)*
2000	441 (117)	315 (83)*
2004	446 (118)	245 (65)
2005	421 (111)	238-282 (63-75)*
2006	425 (112)	248 (65)
2007	445 (118)	221 (58)
2008	417 (110)	198 (52)
2009	397 (105)	203-222 (54-59)*

Notes:

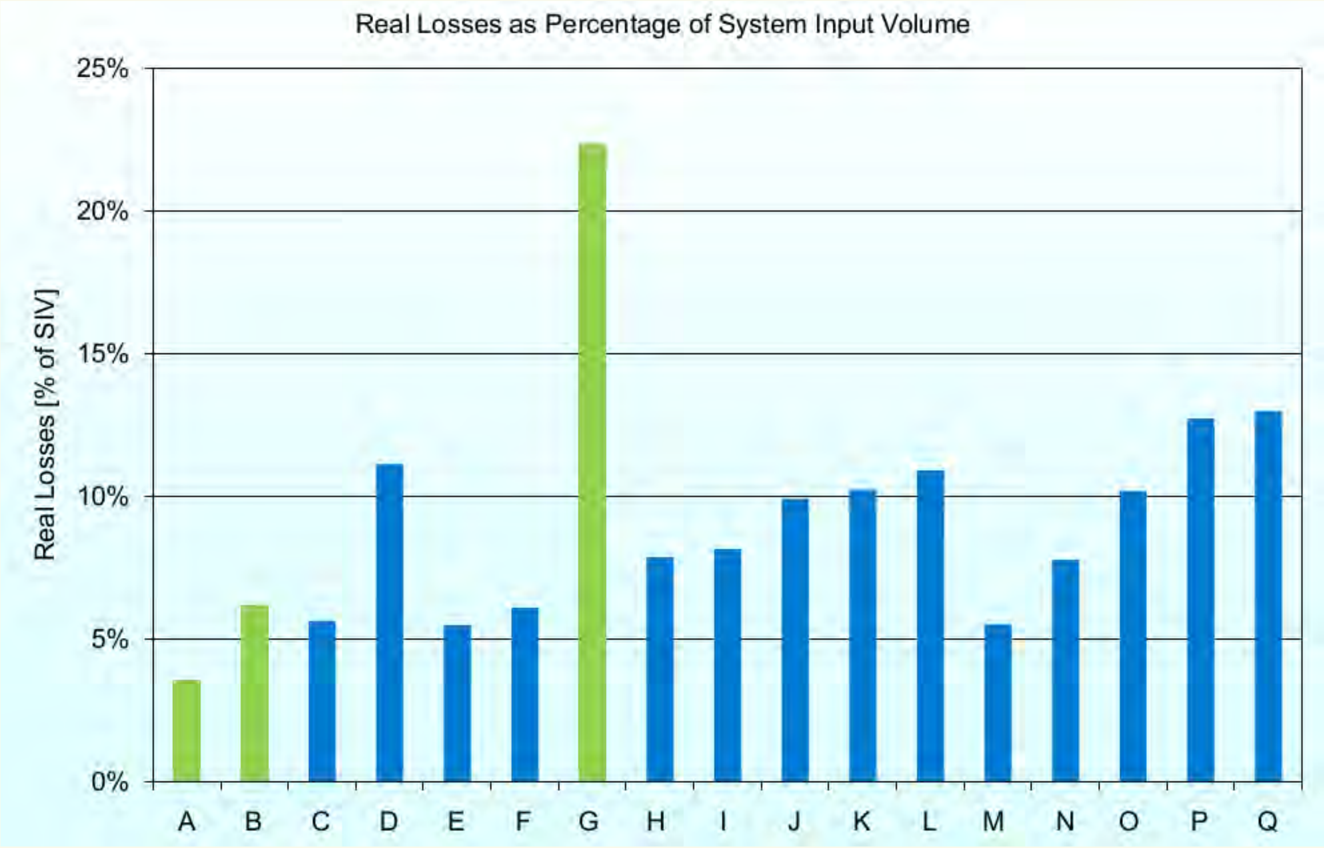
* From ABS Water Account

http://cee.engr.ucdavis.edu/faculty/lund/papers/CahillResidentialConservationAustraliaCalifornia.pdf

District No. 40 2009 Water Use	Water Use (AF)	Water Use (%)	Meters (#)	Meters (%)
Single-Family	33548	68.2	50532	92.4
Commercial	3707	7.5	1581	2.9
Landscape Irrigation	3486	7.1	818	1.5
Multi-Family complex	3398	6.9	683	1.2
Public/Government Agencies	2847	5.8	215	0.4
Firefighting, flushing, theft and leaks	1489	3.0	n/a	n/a
Other	715	1.5	878	1.6
	49190	100	54707	100

Supply System Leakage

Leakage rates of 17 California water utilities vary from 4 to 22% with an average loss of 9%.



Water Systems Optimization, San Francisco CA
http://www.gwpc.org/sites/default/files/event-sessions/22Sturm_Reinhard.pdf; accessed on 1 February 2014.

Sewage Leakage

- Small component of urban water balance. For example, the Albuquerque rate of sewer leakage is on the order of 10 % of base flow or indoor water use (Amick et al, 2000).
- Another study using USA and European data found 5–10% of total sewer volumes are lost to groundwater. Contribution from foul sewage (i.e. from indoor water use) is about half of this volume (Rueedi et al., 2009).

Amick, R. S., E. H. Burgess, and A. Selvakumar (2000), *Exfiltration in Sewer Systems*, 41 pp., National Risk Management Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

Rueedi, J., A. A. Cronin, and B. L. Morris (2009), Estimation of sewer leakage to urban groundwater using depth-specific hydrochemistry, Water and Environment Journal, 23(2), 134-144.

Sewage Leakage

- Most sewer lines operate by gravity flow (close to zero pressure) or have a pressure much less than typical pressures in water supply systems. The lower the pressure, the less the leakage rate.
- Sewer pipe leaks and joints tend to self-seal due to accumulation of sediment and bio-materials (Ellis et al., 2008).
- It remains a challenge to measure the leakage rate of sewage systems (Orange County Sanitation District, 2005).

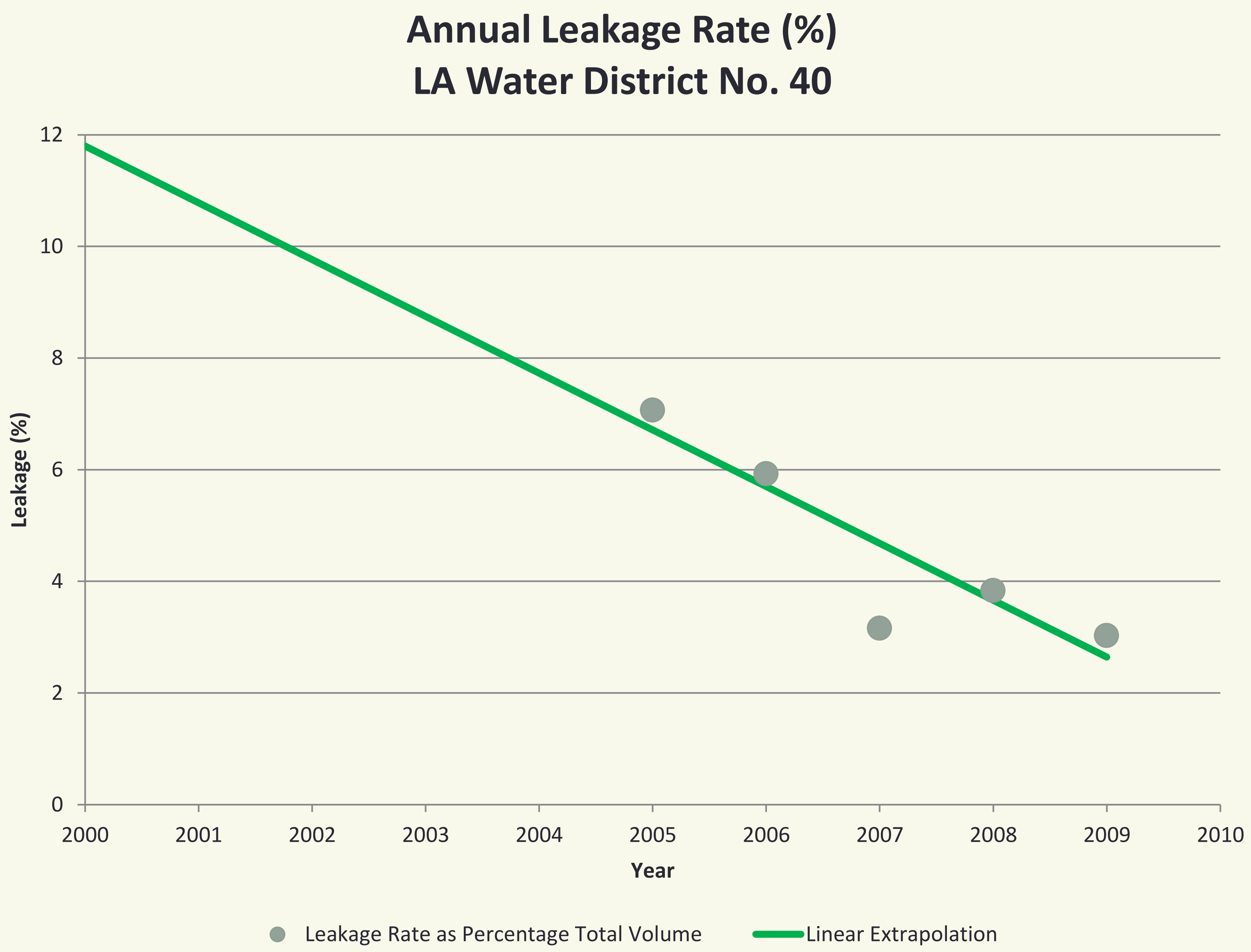
Ellis, J. B., D. M. Revitt, J. Vollertsen, and D. J. Blackwood (2008), Factors influencing temporal exfiltration rates in sewer systems, in *11th International Conference on Urban Drainage*, edited, p. 10, Edinburgh, Scotland, UK.

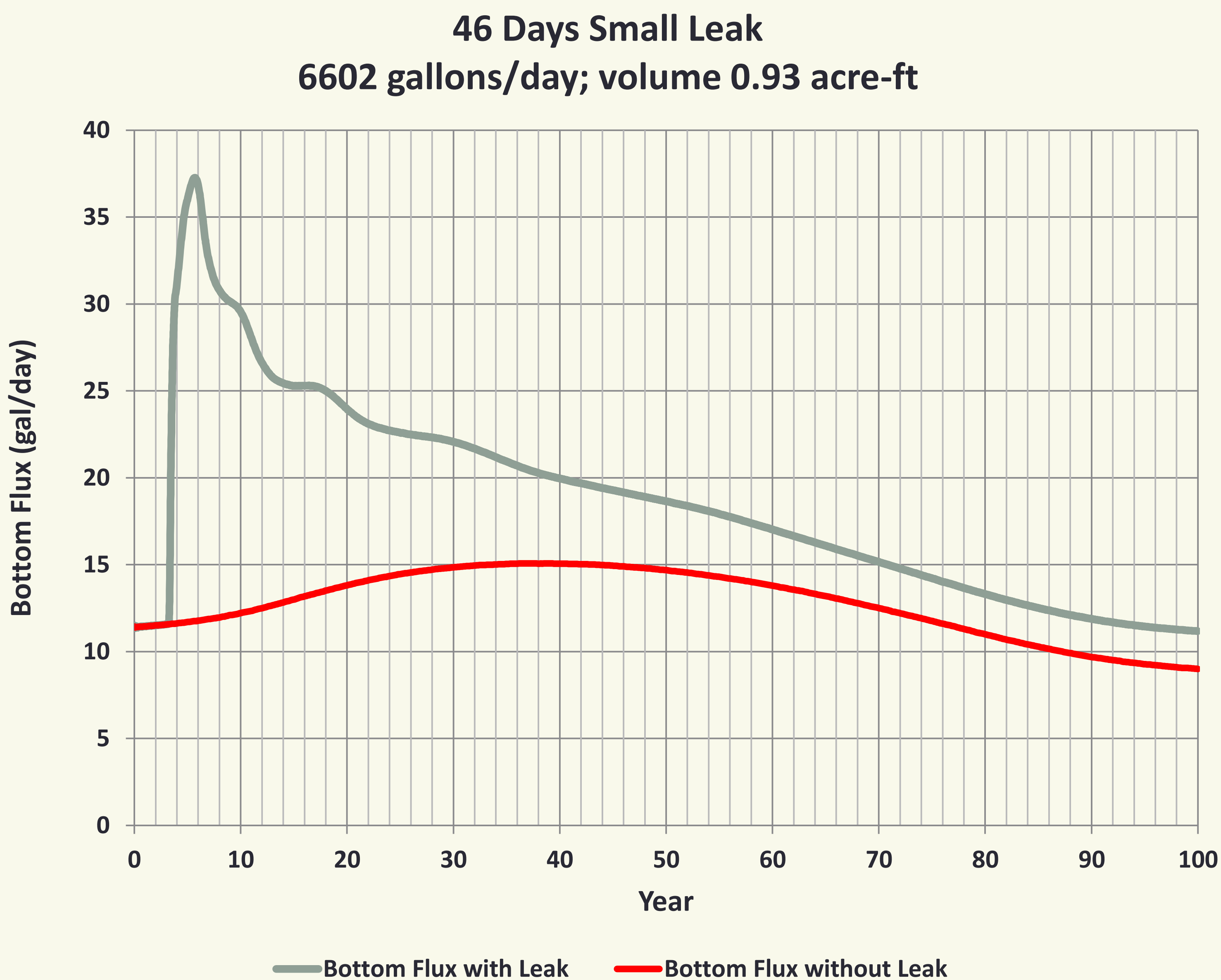
Orange County Sanitation District (2005), Status Report on the Development of a Reporting Methodology for Subsurface Discharges of Sewage. *Rep.*, 209 pp, Brown & Caldwell, Irvine, California, US.

Sewage Leakage

- The sewer system of the City of Palmdale is in excellent condition but some leakage does occur (Palmdale Sewer Master Plan, 2009).
- Sewage system leakage of indoor water is estimated to be 2.5% of indoor water use or $0.025 \times 30 = 0.75\%$ of total water supply. Part of this will be transpired by deep-rooted vegetation and the remainder will infiltrate into the unsaturated zone and typically travel 40 years or more to arrive at the water table.
- Sewage return flow is assumed to be very little and put at 0% of total water volume entering the supply system.

Agricultural return flow originates from large fields (100 to 1000 m scale)
M&I return flow originates from leaks and excess irrigation (1 to 10 m scale)


Annual Leakage Rate (%)
LA Water District No. 40
Leakage (%)
0
2
4
6
8
10
12
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year
Leakage Rate as Percentage Total Volume
Linear Extrapolation


46 Days Small Leak
6602 gallons/day; volume 0.93 acre-ft
Bottom Flux (gal/day)
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
100
Year
Bottom Flux with Leak
Bottom Flux without Leak

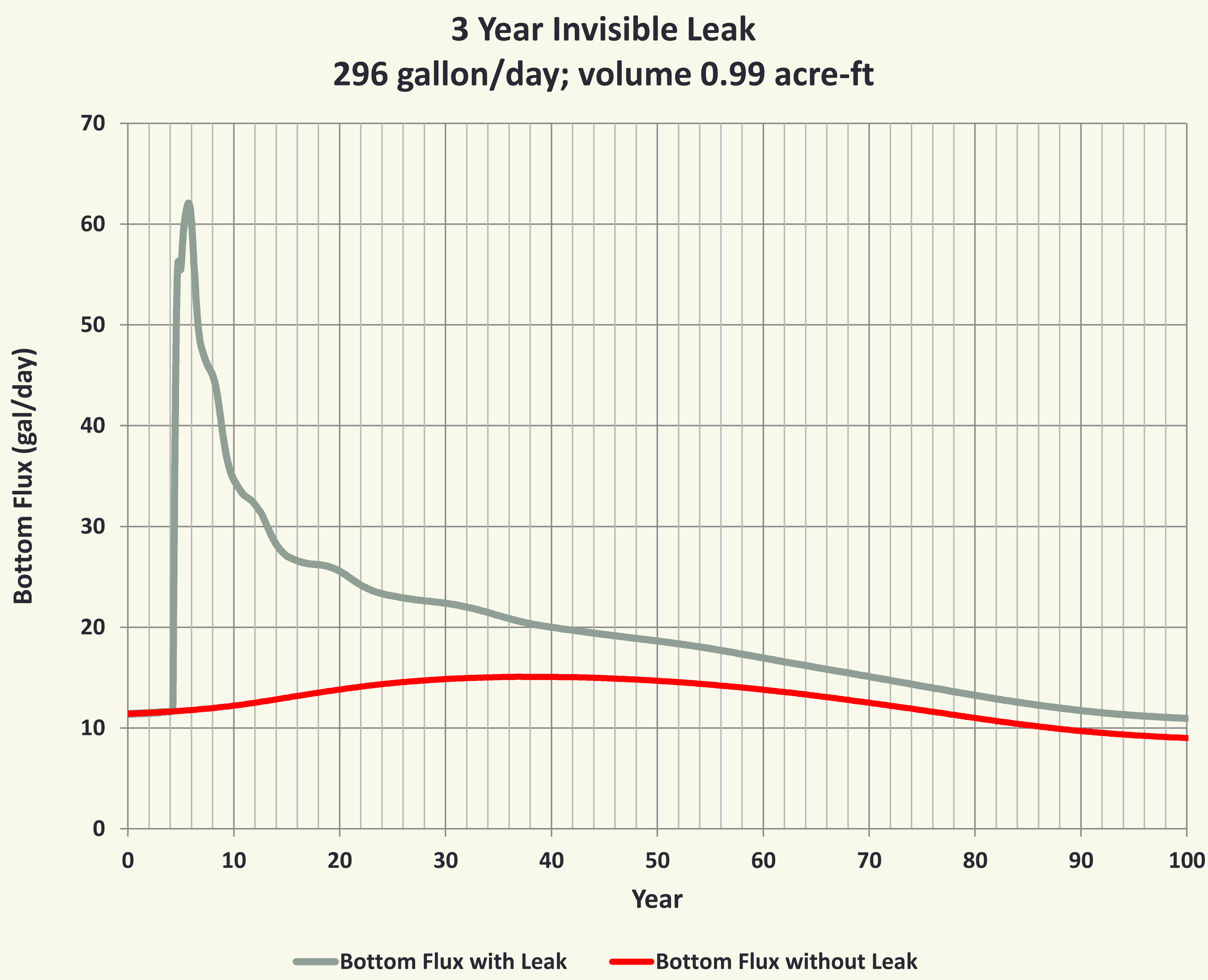
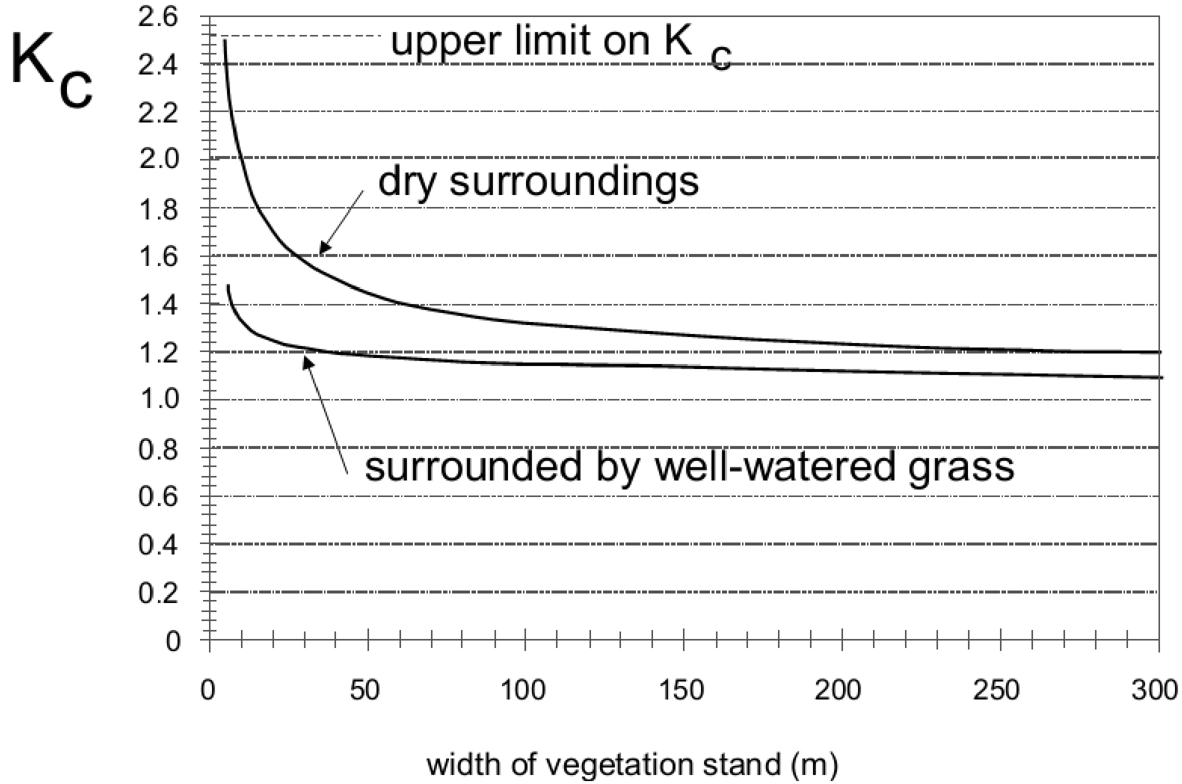

3 Year Invisible Leak
296 gallon/day; volume 0.99 acre-ft
Bottom Flux (gal/day)
0
10
20
30
40
50
60
70
0
10
20
30
40
50
60
70
80
90
100
Year
Bottom Flux with Leak
Bottom Flux without Leak

FIGURE 46

K_c curves for small areas of vegetation under the oasis effect as a function of the width of the expanse of vegetation for conditions where RH_{min} = 30%, u_2 = 2 m/s, vegetation height (h) = 2 m and LAI = 3



$$ET_{actual} = K_C \times ET_{O\text{-}CIMIS}$$

Allen, R. G., L. S. Pereira, D. Raes, and M. Smith (1998), Crop evapotranspiration: Guidelines for computing crop requirements. Irrigation and Drainage Paper No. 56., 300 pp., Food and Agricultural Organization of the United Nations, Rome, Italy.

[Lerner, 2002; Lerner, 1986]Lerner, D. (2002), Identifying and quantifying urban recharge: a review, Hydrogeology Journal, 10(1), 143-152.
Lerner, D. N. (1986), Leaking Pipes Recharge Ground Water, Ground Water, 24(5), 654-662.

Reed, E.C. 1980. Report on water losses. Aqua no. 8, p 0178-0191

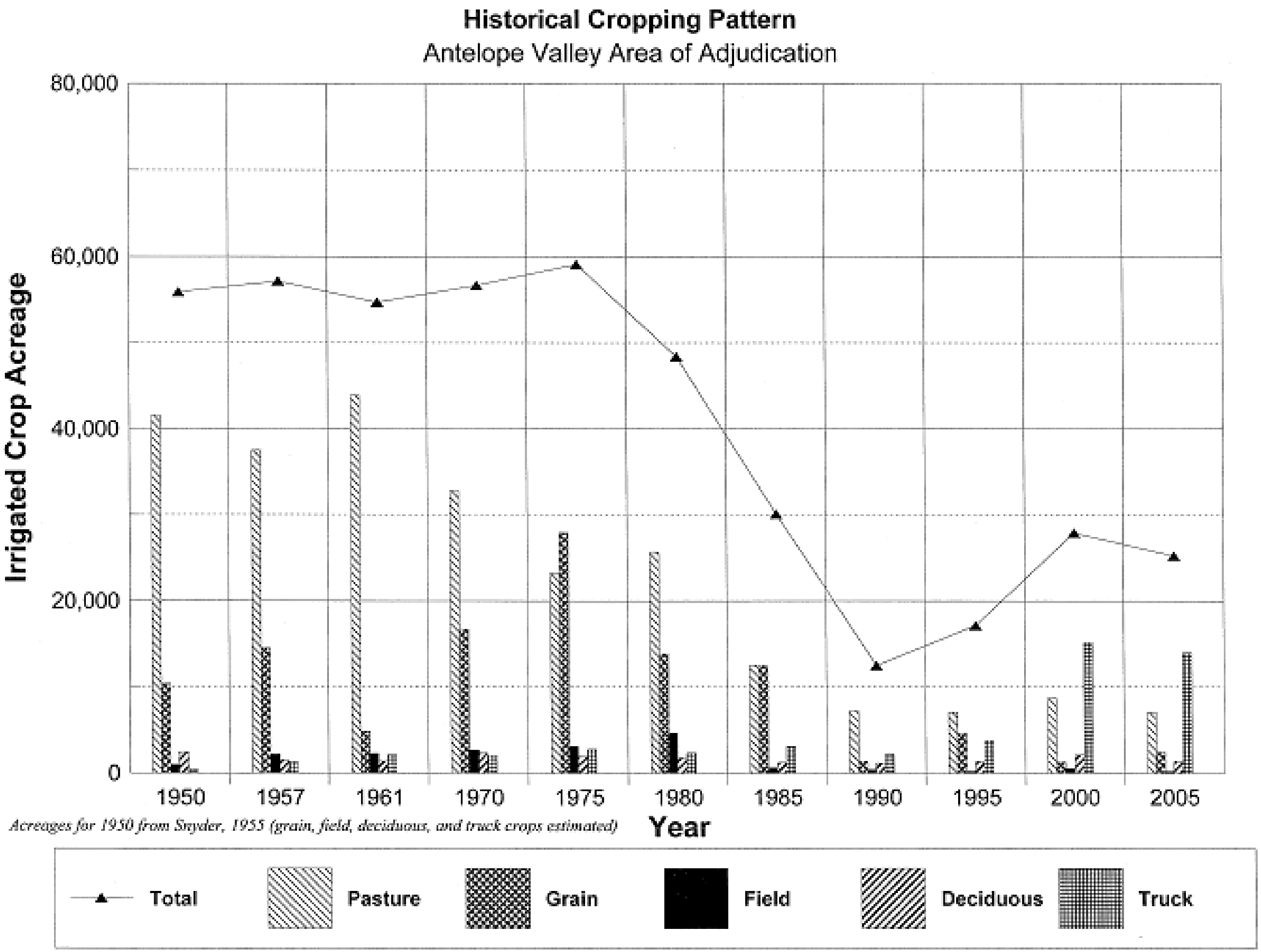
Agricultural return flow originates from large fields (100 to 1000 m scale)

M&I return flow originates from leaks and over-irrigation (1 to 10 m scale)

www.allianceforwaterefficiency.org

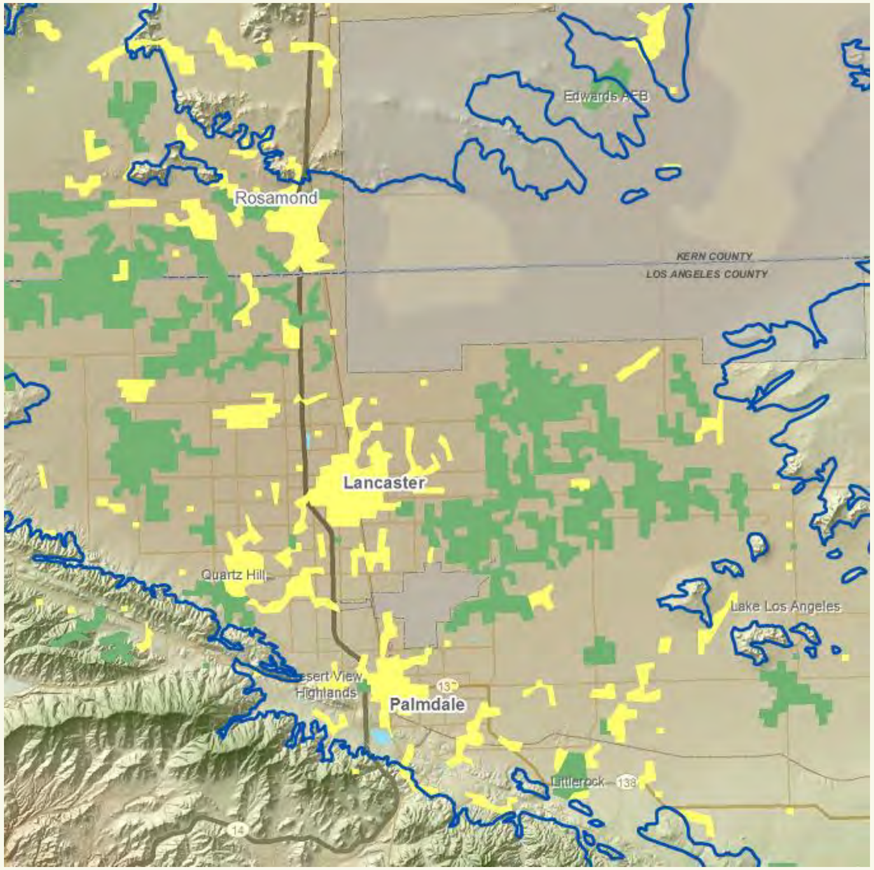
Typical Palmdale street, Google

Figure D.2-4

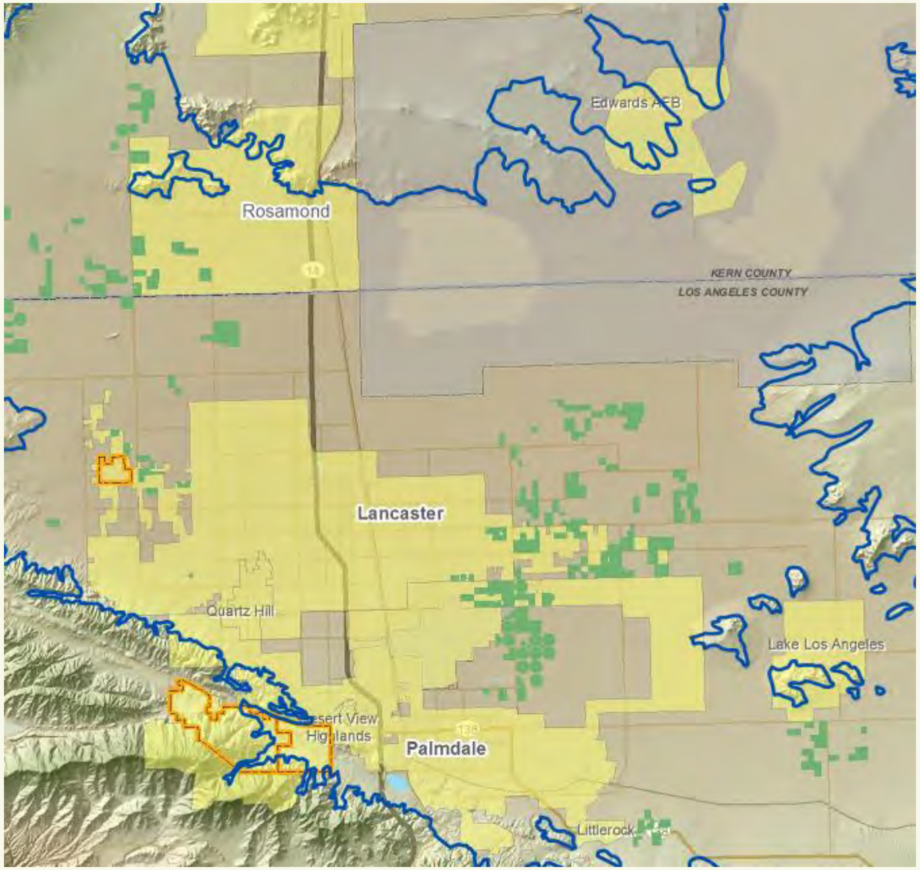

Historical Cropping Pattern
Antelope Valley Area of Adjudication
80,000
60,000
40,000
20,000
0
Irrigated Crop Acreage
1950
1957
1961
1970
1975
1980
1985
1990
1995
2000
2005
Year
Acreages for 1950 from Snyder, 1955 (grain, field, deciduous, and truck crops estimated)
Total
Pasture
Grain
Field
Deciduous
Truck

Land Use

1972



2005



Supply System Leakage

Leakage rates of 17 California water utilities vary from 4 to 22% with an average loss of 9%[$] while those of 21 utilities nationwide vary from 3 to 42% with an average of 17% (Chastain-Howley et al., 2012).

$ http://www.wpc.org/sites/default/files/event-sessions/22Sturm_Reinhard.pdf; accessed on 19 March 2013.

Chastain-Howley, A., G. Kunkel, and W. Jernigan (2012), Establishing the first validated dataset of North American water utility water audit data, *Water Loss 2012*, 10.