APPENDIX 2-C
MUNICIPAL RETURN FLOW MEMORANDUM

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TECHNICAL MEMORANDUM

DATE: August 28, 2019

TO: Santa Cruz Mid-County Groundwater Agency

FROM: Georgina King and Cameron Tana

PROJECT: Santa Cruz Mid-County Basin Groundwater Model

SUBJECT: Municipal Return Flow

SERVICE AREA WATER SUPPLY

Water supplied or delivered to the various municipal service areas in the model is the source of water from which different components of return flow are estimated.

Individual municipal return flow components estimated are:

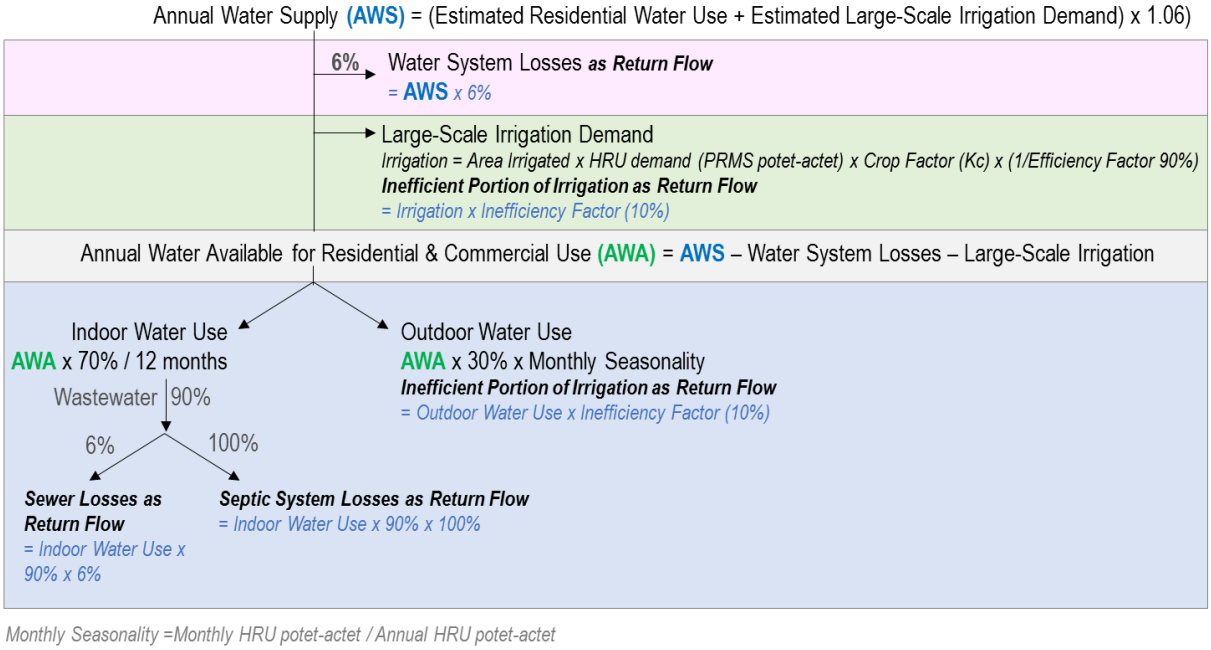
1. Water system losses,
2. Large-scale landscape/field irrigation,
3. Small-scale landscape irrigation (residential and commercial), and
4. Sewer system losses, and septic tank leakage.

The amount of water supplied to each service area is obtained from readily available data provided by the four municipal water agencies in the model area: City of Santa Cruz, Soquel Creek Water District (SqCWD), Central Water District (CWD), and City of Watsonville. If monthly data are not available, annual data are used.

Annual data are used for the Cities of Watsonville and Santa Cruz. Both these municipalities deliver water to customers from both groundwater and surface water sources. Both CWD and SqCWD are able to provide monthly water supply data from well production records as groundwater is their sole source of water.

City of Watsonville

The City of Watsonville was not able to provide readily available water delivery data for the portion of their service area within the model. Their annual water supply (AWS) is estimated as the sum of residential water use and large-scale landscape irrigation, plus 6% to account for water system losses of that water (City of Watsonville, 2016). As an estimate of residential water use, building counts, similar to the approach taken for private water use, are used to estimate annual residential water use to supply areas. The amount of large-scale landscape irrigation is estimated based on irrigated area, water demand, turf crop factor and irrigation inefficiency. The top two rows of Figure 1 show the calculations for estimating AWS for those portions of the City of Watsonville service area within the model.

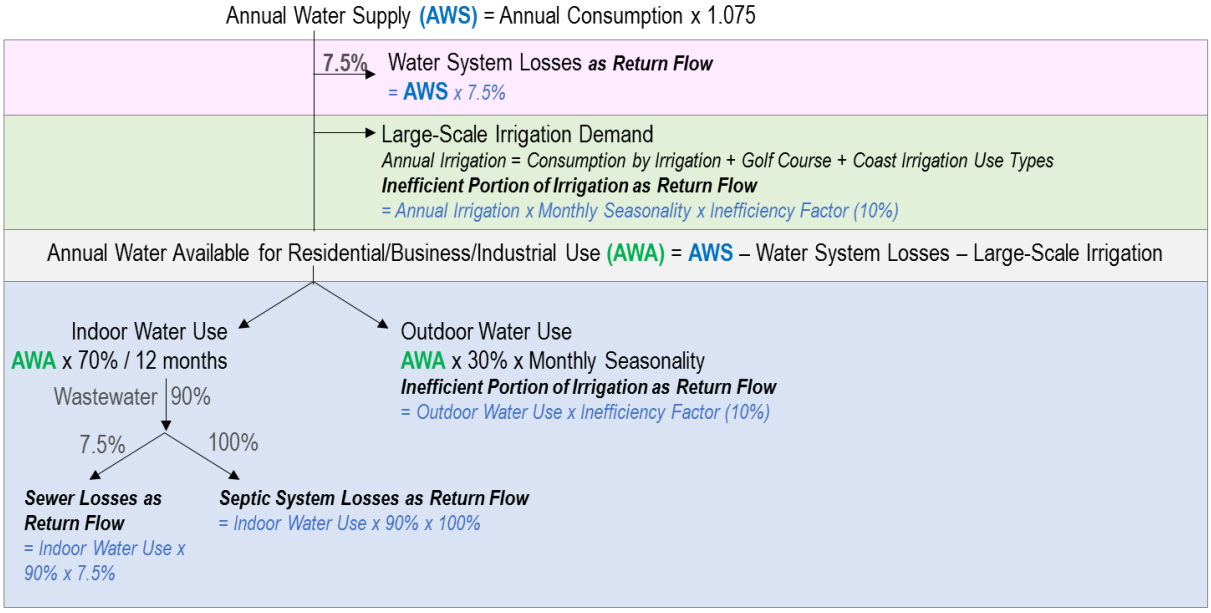


Monthly Seasonality =Monthly HRU potet-actet / Annual HRU potet-actet

Figure 1: City of Watsonville Return Flow Calculations

City of Santa Cruz

As no delivery data are readily available that are specific to the model area, the City of Santa Cruz provided its entire service area annual consumption data from 1983 – 2015 for its different use types. The amount of water delivered to users in the model area was determined from the percentage of each use type within the model area compared to the entire service area (Table 1). The General Plan land use was used to determine relative land use percentages in the model area. As the City of Santa Cruz's consumption data are generated at meters, 7.5% assumed for water losses (WSC, 2016) was added to the consumption data to estimate AWS within their service area in the model. The top line of Figure 2 shows the calculations to estimate AWS.



Monthly Seasonality =Monthly HRU potet-actet / Annual HRU potet-actet

Figure 2: City of Santa Cruz Return Flow Calculations

Table 1: Percentage of All City of Santa Cruz Water Use Types within Model Area

Use Type	Percentage of Total City Land Use within Model Area
Single Family Residential	49%
Multiple Residential	50%
Business	55%
Industrial	34%
Municipal	33%
Irrigation (Large-Scale)	38%
Golf Course Irrigation	100%
Coast Irrigation	55%
Other (Construction & Hydrants)	38% (but negligible return flow assumed)

Central Water District

Groundwater pumped from CWD wells is delivered to both residential/commercial and agricultural customers. The amount of water available for residential/commercial purposes is estimated as the difference between the amount pumped and the amount supplied for agriculture, as shown on Figure 3. Water losses from 1985-1999 are 12%, from 2000-2007 are 7%, and from 2008-2016 are 4%. CWD system loss varies over time based on unaccounted water losses recorded by CWD each fiscal year.

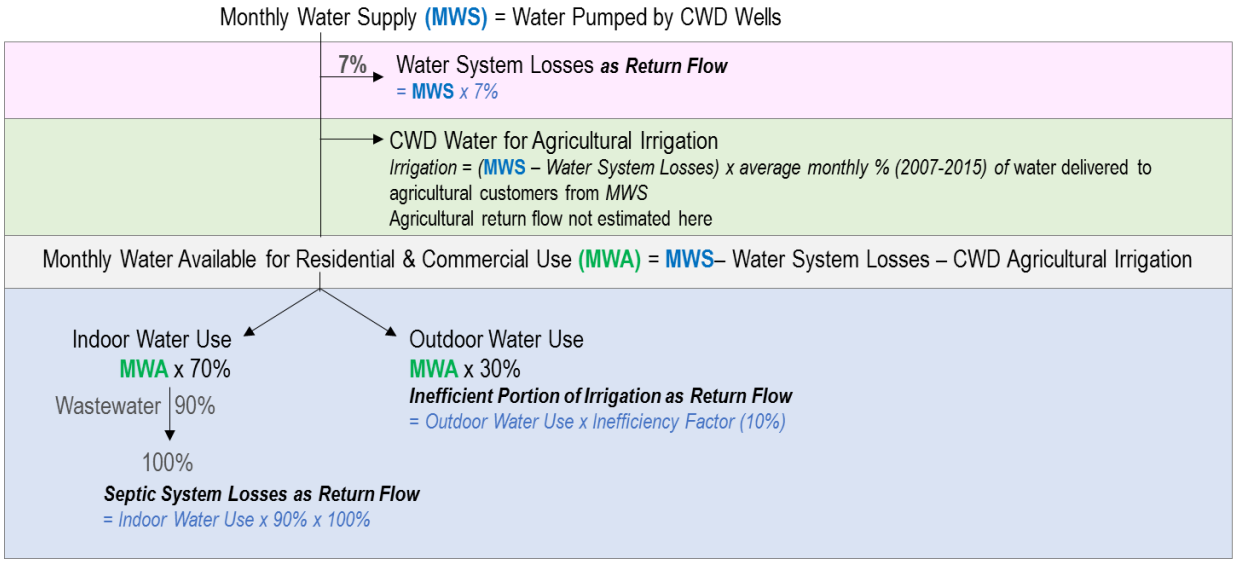


Figure 3: Central Water District Return Flow Calculations

Soquel Creek Water District

Water delivered to each of their four service areas (SA) is determined from the amount of groundwater pumped within each SA plus factoring in transfers that occur between service areas. Delivery data for each SA compared to groundwater pumped within each SA from 2014-2016 was used to estimate the average transfer from SA1 to SA2, SA3 to SA2, and SA3 to SA4. Table 2 summarizes the transfers used to estimate water delivered to each SA that is then used to estimate various components of return flow. The top line on Figure 4 shows the calculation to estimate monthly water supply to each SA. A water loss percentage of 7% is assumed from groundwater pumped (WSC, 2016).

Table 2: Summary of SqCWD Service Area Transfers between 2014 and 2016

Transfer From/To	Percent of Groundwater Produced in Originating Service Area
SA1 to SA2	8.5%
SA 3 to SA2	1.7%
SA3 to SA4	14.3%

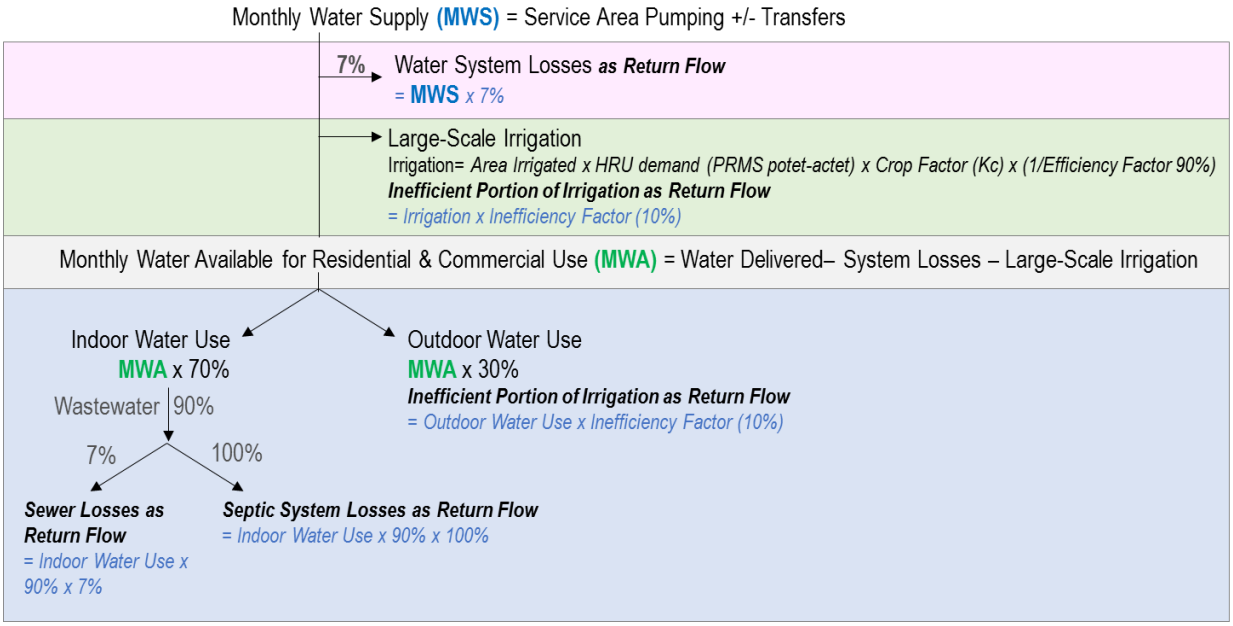


Figure 4: Soquel Creek Water District Return Flow Calculations

RETURN FLOW ESTIMATES

Different municipal water uses have their own proportion of water that percolates into the ground as return flow. Water system losses from both the water distribution and sewer systems are considered return flow. Water system losses are subtracted from water supply and thereafter, any water required to meet large-scale irrigation demand is subtracted from the supply. This leaves an amount of water that can be used for residential/commercial indoor and outdoor use. Assumed indoor and outdoor use is 70% and 30%, respectively. We assume 90% of indoor use becomes wastewater. For areas not connected to sewers, it is further assumed that 100% of wastewater percolates from septic systems into the unsaturated zone as return flow.

Inefficiencies in both residential irrigation (outdoor use) and large-scale irrigation result in an assumed return flow of 10% of the applied water. For the Cities of Santa Cruz and Watsonville, CWD, and SqCWD, Figure 1 through Figure 4, respectively, illustrate the methods for estimating each municipality's return flow estimates. Summaries by water year of each

component of return flow are provided in Table 3 through Table 6. The last column of these tables provides the percentage of the total water supply that comprises return flow.

The return flow estimates are applied to the model cells based on the ratio of the area of the model cell that receives municipal water for residential /commercial use compared to the entire service area. Figure 5 shows the location of the residential/commercial and large-landscape irrigation areas within each service area. Figure 6 shows the location of sewered and unsewered (septic tank) areas. Both figures also show model cell boundaries for the municipal water uses.

HOW WATER DELIVERED IS APPLIED TO MODEL CELLS FOR EACH MONTHLY MODEL STRESS PERIOD

For CWD and SqCWD, where monthly data are available, the deliveries to each service area are obtained from the service area pumping +/- any transfers, as described above. For the Cities of Watsonville and Santa Cruz, where annual data are only available, the amount of water applied to each model cell is distributed differently for indoor residential and irrigation use. Monthly indoor use is estimated as 70% of annual water delivered divided by 12 months. Monthly outdoor residential/commercial and large-scale irrigation use are based on irrigation demand (difference between monthly PRMS modeled potential ET (potet) and actual ET (actet)).

- For the City of Santa Cruz, where the water use type was 100% irrigation, the annual volume is distributed to months based on the ratio of monthly to annual irrigation demand for each model cell. For the outdoor portion of residential and commercial water use, the same ratio of monthly to annual irrigation demand for each model cell is used to distribute the annual volumes to monthly volumes.
- For the City of Watsonville, the amount of water to apply to each model cell for either large-scale or residential irrigation is distributed to months based on the ratio of monthly to annual irrigation demand for each model cell.

REFERENCES

City of Santa Cruz Water Department, 2016, City of Santa Cruz Water Department 2015 Urban Water Management Plan. August 2016.

City of Watsonville, 2016 City of Watsonville 2015 Urban Water Management Plan.

Water Systems Consulting, Inc., 2016, Soquel Creek Water District 2015 Urban Water Management Plan. Prepared for Soquel Creek Water District, June 2016.

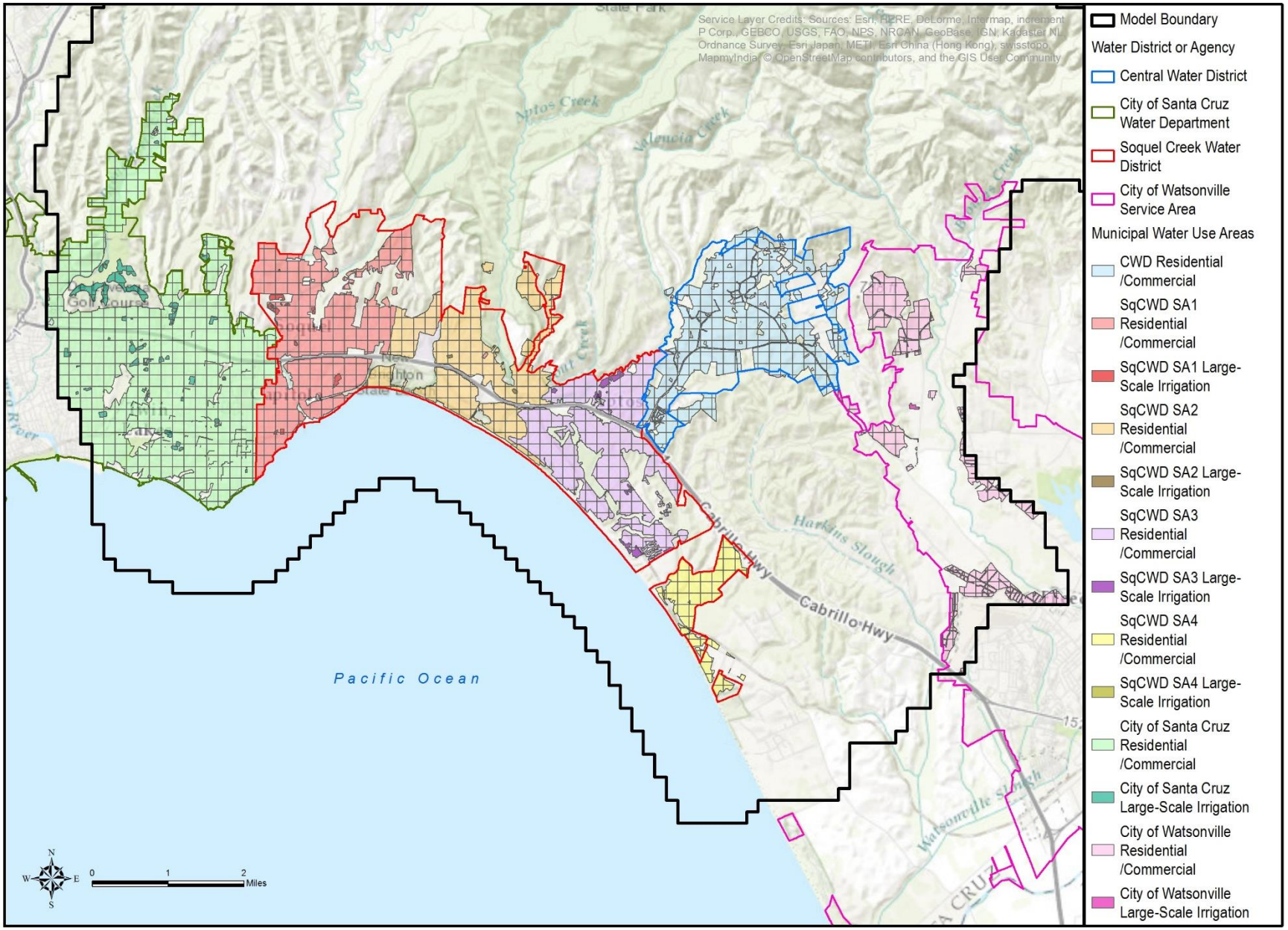


Figure 5: Residential/Commercial and Large-Scale Irrigation Areas within Municipal Service Area

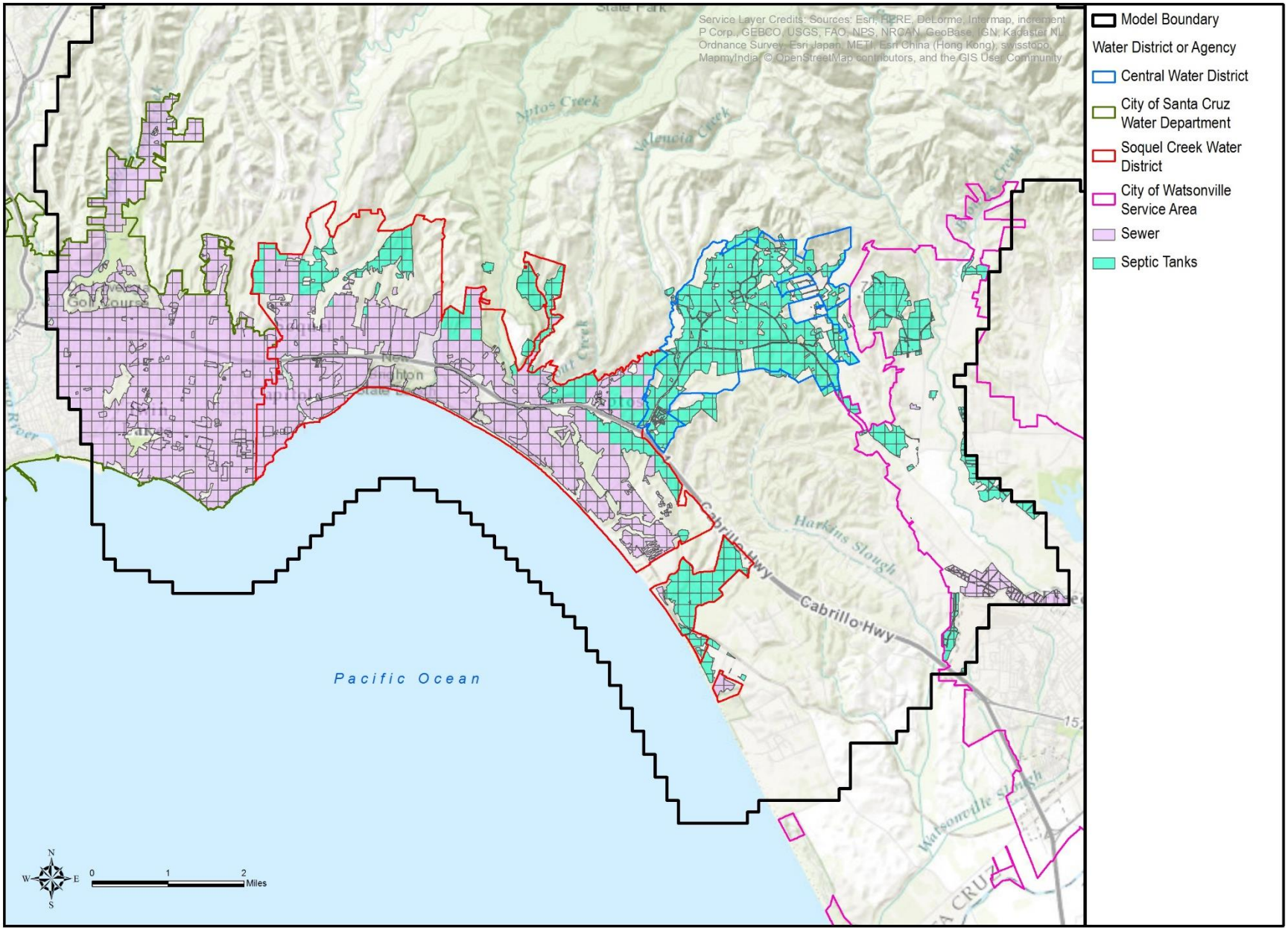


Figure 6: Municipal Sewered and Septic Tank Areas

Table 3: City of Watsonville Return Flow Estimates

Water Year	Water Supply to Service Area in Model, acre-feet	Return Flow in acre-feet						Percentage of Water Supply that Becomes Return Flow
		Water System Losses	Large-Scale Landscape Irrigation	Small-Scale Landscape Irrigation	Sewer Losses	Septic Systems	Total Return Flow	
1985	478.1	28.7	0.3	14.2	6.5	206.8	227.9	47.7%
1986	497.3	29.8	0.3	14.8	6.7	215.2	237.1	47.7%
1987	511.9	30.7	0.3	15.3	6.9	221.6	244.1	47.7%
1988	529.1	31.7	0.3	15.8	7.2	229.1	252.3	47.7%
1989	543.1	32.6	0.3	16.2	7.4	235.2	259.0	47.7%
1990	561.0	33.7	0.3	16.7	7.6	243.0	267.6	47.7%
1991	577.5	34.6	0.3	17.2	7.8	250.2	275.5	47.7%
1992	596.8	35.8	0.3	17.8	8.1	258.6	284.8	47.7%
1993	614.0	36.8	0.3	18.3	8.3	266.1	293.0	47.7%
1994	633.2	38.0	0.3	18.9	8.6	274.4	302.2	47.7%
1995	650.5	39.0	0.3	19.4	8.8	282.0	310.5	47.7%
1996	708.8	42.5	0.3	21.2	9.6	307.4	338.5	47.7%
1997	724.8	43.5	0.3	21.7	9.8	314.3	346.1	47.7%
1998	742.7	44.6	0.3	22.2	10.1	322.1	354.7	47.8%
1999	766.0	46.0	0.3	22.9	10.4	332.2	365.8	47.8%
2000	816.4	49.0	0.3	24.4	11.1	354.2	390.0	47.8%
2001	823.0	49.4	0.3	24.6	11.2	357.1	393.1	47.8%
2002	819.0	49.1	0.3	24.5	11.1	355.3	391.2	47.8%
2003	828.3	49.7	0.3	24.8	11.2	359.4	395.7	47.8%
2004	850.9	51.1	0.3	25.4	11.5	369.2	406.5	47.8%
2005	843.1	50.6	0.3	25.2	11.4	365.8	402.7	47.8%
2006	860.6	51.6	0.3	25.7	11.7	373.5	411.2	47.8%
2007	868.5	52.1	0.3	26.0	11.8	376.9	414.9	47.8%
2008	872.4	52.3	0.3	26.1	11.8	378.6	416.8	47.8%
2009	850.2	51.0	0.3	25.4	11.5	368.9	406.2	47.8%
2010	852.1	51.1	0.3	25.5	11.6	369.7	407.1	47.8%
2011	858.4	51.5	0.3	25.7	11.6	372.5	410.1	47.8%
2012	861.6	51.7	0.3	25.8	11.7	373.9	411.6	47.8%
2013	866.0	52.0	0.3	25.9	11.8	375.8	413.7	47.8%
2014	798.0	47.9	0.3	23.9	10.8	346.2	381.2	47.8%
2015	744.0	44.6	0.3	22.2	10.1	322.7	355.3	47.8%
Average	727.3	43.6	0.3	21.7	9.9	315.4	347.3	47.7%

Table 4: City of Santa Cruz Return Flow Estimates

Water Year	Water Supply to Service Area in Model, acre-feet	Return Flow in acre-feet					Percentage of Water Supply that Becomes Return Flow
		Water System Losses	Large-Scale Landscape Irrigation	Small-Scale Landscape Irrigation	Sewer Losses	Total Return Flow	
1985	6,593.7	461.6	72.1	162.3	238.6	934.6	14.2%
1986	6,663.3	466.4	68.7	165.3	243.0	943.4	14.2%
1987	6,941.7	485.9	84.4	168.3	247.4	986.1	14.2%
1988	6,258.3	438.1	77.5	151.3	222.5	889.4	14.2%
1989	5,749.4	402.5	61.8	141.9	208.6	814.7	14.2%
1990	5,209.9	364.7	55.0	126.8	186.4	732.9	14.1%
1991	4,891.0	342.4	53.1	120.3	176.8	692.6	14.2%
1992	5,419.7	379.4	57.6	133.7	196.5	767.2	14.2%
1993	5,455.4	381.9	47.1	137.9	202.8	769.7	14.1%
1994	5,648.9	395.4	47.4	143.2	210.5	796.4	14.1%
1995	5,777.5	404.4	47.1	147.0	216.1	814.6	14.1%
1996	6,143.6	430.1	51.7	155.8	229.0	866.6	14.1%
1997	6,633.3	464.3	64.7	165.5	243.2	937.7	14.1%
1998	5,887.4	412.1	43.9	151.0	221.9	828.9	14.1%
1999	6,192.2	433.5	52.4	156.9	230.7	873.4	14.1%
2000	6,183.4	432.8	51.5	157.0	230.7	872.0	14.1%
2001	6,255.6	437.9	63.6	155.4	228.4	885.2	14.2%
2002	6,072.7	425.1	62.4	150.5	221.3	859.4	14.2%
2003	6,072.7	425.1	69.6	148.4	218.2	861.4	14.2%
2004	6,191.6	433.4	75.0	150.1	220.6	879.2	14.2%
2005	5,780.4	404.6	58.0	143.7	211.3	817.6	14.1%
2006	5,579.3	390.6	62.6	136.8	201.0	790.9	14.2%
2007	5,477.2	383.4	54.7	136.3	200.4	774.8	14.1%
2008	5,537.2	387.6	60.7	136.1	200.1	784.6	14.2%
2009	4,840.5	338.8	44.0	121.7	178.9	683.5	14.1%
2010	4,764.2	333.5	41.4	120.4	177.0	672.4	14.1%
2011	4,569.3	319.8	36.8	116.4	171.1	644.2	14.1%
2012	4,870.7	341.0	47.2	121.7	178.8	688.7	14.1%
2013	5,078.7	355.5	54.5	125.3	184.1	719.4	14.2%
2014	4,083.1	285.8	35.7	103.1	151.6	576.3	14.1%
2015	3,837.2	268.6	42.4	94.3	138.6	543.9	14.2%
Average	5,634.2	394.4	56.3	140.1	206.0	796.8	14.1%

Table 5: Soquel Creek Water District Return Flow Estimates

Water Year	Water Supply to Service Area in Model, acre-feet	Return Flow in acre-feet						Percentage of Water Supply that Becomes Return Flow
		Water System Losses	Large-Scale Landscape Irrigation	Small-Scale Landscape Irrigation	Sewer Losses	Septic Systems	Total Return Flow	
1985	4,318.5	302.3	13.2	116.5	135.8	559.0	1,126.8	26.1%
1986	4,272.5	299.1	10.3	116.1	137.1	529.0	1,091.6	25.5%
1987	5,234.6	366.4	13.8	141.9	163.7	708.1	1,393.9	26.6%
1988	4,858.7	340.1	14.8	131.1	151.0	658.1	1,295.2	26.7%
1989	4,797.2	335.8	12.7	130.0	149.0	664.8	1,292.3	26.9%
1990	4,818.5	337.3	13.3	130.5	150.6	649.1	1,280.7	26.6%
1991	4,703.0	329.2	10.4	128.1	148.1	634.4	1,250.3	26.6%
1992	4,908.3	343.6	13.9	132.8	152.6	672.0	1,314.9	26.8%
1993	4,863.2	340.4	11.6	132.2	152.2	665.2	1,301.7	26.8%
1994	5,089.3	356.2	10.4	138.9	159.4	706.7	1,371.6	27.0%
1995	4,854.9	339.8	9.9	132.5	153.5	650.6	1,286.3	26.5%
1996	5,183.2	362.8	12.7	140.8	163.4	688.0	1,367.7	26.4%
1997	5,570.8	390.0	14.7	151.0	174.1	755.0	1,484.8	26.7%
1998	4,966.1	347.6	7.8	136.2	157.8	670.0	1,319.4	26.6%
1999	5,211.5	364.8	8.2	142.9	165.0	712.3	1,393.2	26.7%
2000	5,270.8	369.0	9.9	144.1	166.6	712.7	1,402.2	26.6%
2001	5,174.7	362.2	9.7	141.5	164.3	688.2	1,365.9	26.4%
2002	5,375.8	376.3	9.6	147.1	172.6	689.3	1,394.9	25.9%
2003	5,331.8	373.2	11.1	145.4	171.4	667.7	1,368.9	25.7%
2004	5,372.0	376.0	13.0	146.0	172.8	659.2	1,367.0	25.4%
2005	4,543.8	318.1	7.3	124.6	147.2	566.2	1,163.4	25.6%
2006	4,548.6	318.4	10.2	123.9	144.5	591.7	1,188.7	26.1%
2007	4,625.8	323.8	12.0	125.5	144.9	623.6	1,229.7	26.6%
2008	4,557.0	319.0	12.6	123.4	141.7	625.9	1,222.6	26.8%
2009	4,162.1	291.3	12.5	112.4	131.6	529.8	1,077.6	25.9%
2010	3,932.5	275.3	10.3	106.6	127.5	461.6	981.3	25.0%
2011	4,011.2	280.8	8.7	109.3	131.0	467.1	997.0	24.9%
2012	4,159.1	291.1	12.7	112.2	134.0	487.8	1,037.9	25.0%
2013	4,217.5	295.2	19.2	111.9	132.2	509.1	1,067.6	25.3%
2014	3,702.9	259.2	20.0	97.3	115.6	432.6	924.7	25.0%
2015	3,153.9	220.8	22.4	81.3	96.9	355.8	777.2	24.6%
Average	4,702.9	329.2	12.2	127.5	148.6	612.6	1,230.2	26.1%

Table 6: Central Water District Return Flow Estimates

Water Year	Water Supply to Service Area in Model*, acre-feet	Return Flow in acre-feet				Percentage of Water Supply that Becomes Return Flow
		Water System Losses	Small-Scale Landscape Irrigation	Septic Systems	Total Return Flow	
1985	352.9	27.5	9.8	205.0	242.3	68.7%
1986	363.0	28.3	10.0	210.9	249.2	68.7%
1987	399.4	31.1	11.1	232.1	274.2	68.6%
1988	393.2	30.6	10.9	228.4	270.0	68.6%
1989	363.2	28.4	10.0	210.9	249.4	68.7%
1990	387.1	30.1	10.7	224.9	265.7	68.6%
1991	383.9	29.8	10.6	223.1	263.5	68.6%
1992	417.5	32.7	11.5	242.5	286.7	68.7%
1993	429.6	33.7	11.9	249.4	295.0	68.7%
1994	431.2	33.7	11.9	250.4	296.1	68.7%
1995	409.5	32.2	11.3	237.7	281.2	68.7%
1996	469.4	36.8	13.0	272.5	322.3	68.7%
1997	539.5	42.3	14.9	313.2	370.4	68.7%
1998	476.0	37.4	13.2	276.3	326.9	68.7%
1999	479.9	37.7	13.3	278.6	329.6	68.7%
2000	489.2	38.3	13.5	284.1	335.9	68.7%
2001	496.7	39.0	13.7	288.4	341.1	68.7%
2002	529.1	41.5	14.6	307.2	363.3	68.7%
2003	519.3	40.8	14.4	301.5	356.7	68.7%
2004	565.6	44.3	15.6	328.4	388.4	68.7%
2005	456.9	36.0	12.6	265.2	313.8	68.7%
2006	483.1	38.1	13.3	280.3	331.8	68.7%
2007	532.3	41.7	14.7	309.1	365.5	68.7%
2008	520.0	40.9	14.4	301.9	357.1	68.7%
2009	530.4	41.6	14.7	307.9	364.2	68.7%
2010	428.8	33.6	11.9	248.9	294.4	68.7%
2011	434.4	34.1	12.0	252.2	298.3	68.7%
2012	479.3	37.5	13.3	278.4	329.1	68.7%
2013	501.2	39.1	13.9	291.1	344.1	68.7%
2014	452.3	35.0	12.5	262.9	310.4	68.6%
2015	352.7	27.4	9.8	204.9	242.1	68.6%
Average	453.8	35.5	12.5	263.5	311.6	68.7%

* This column is water supply for residential/commercial use only, and does not include water delivered for agricultural use.

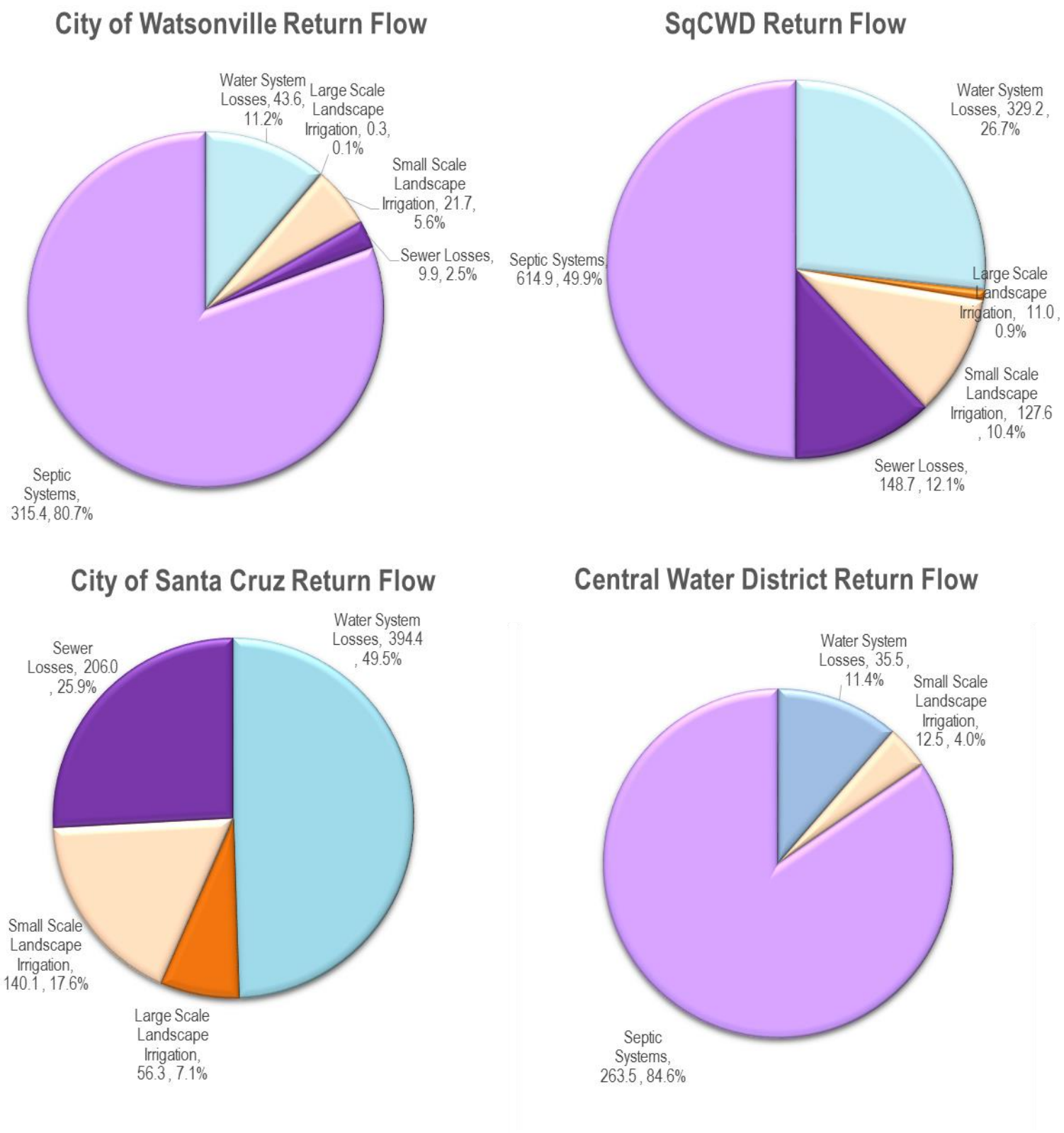


Figure 7: Municipal Return Flow Pie Charts (in acre-feet per year)