

Spring, Cave, Dry Lake and Delamar Valleys



SOUTHERN NEVADA
WATER AUTHORITY

Presentation for
Burns and Fenstermaker
September 28, 2011

$$ET_{gw} = ET_T - P \quad (\text{Eq. 5-1})$$

where,

- ET_{gw} = Volume of groundwater ET
- ET_T = Volume of total ET
- P = Volume of precipitation

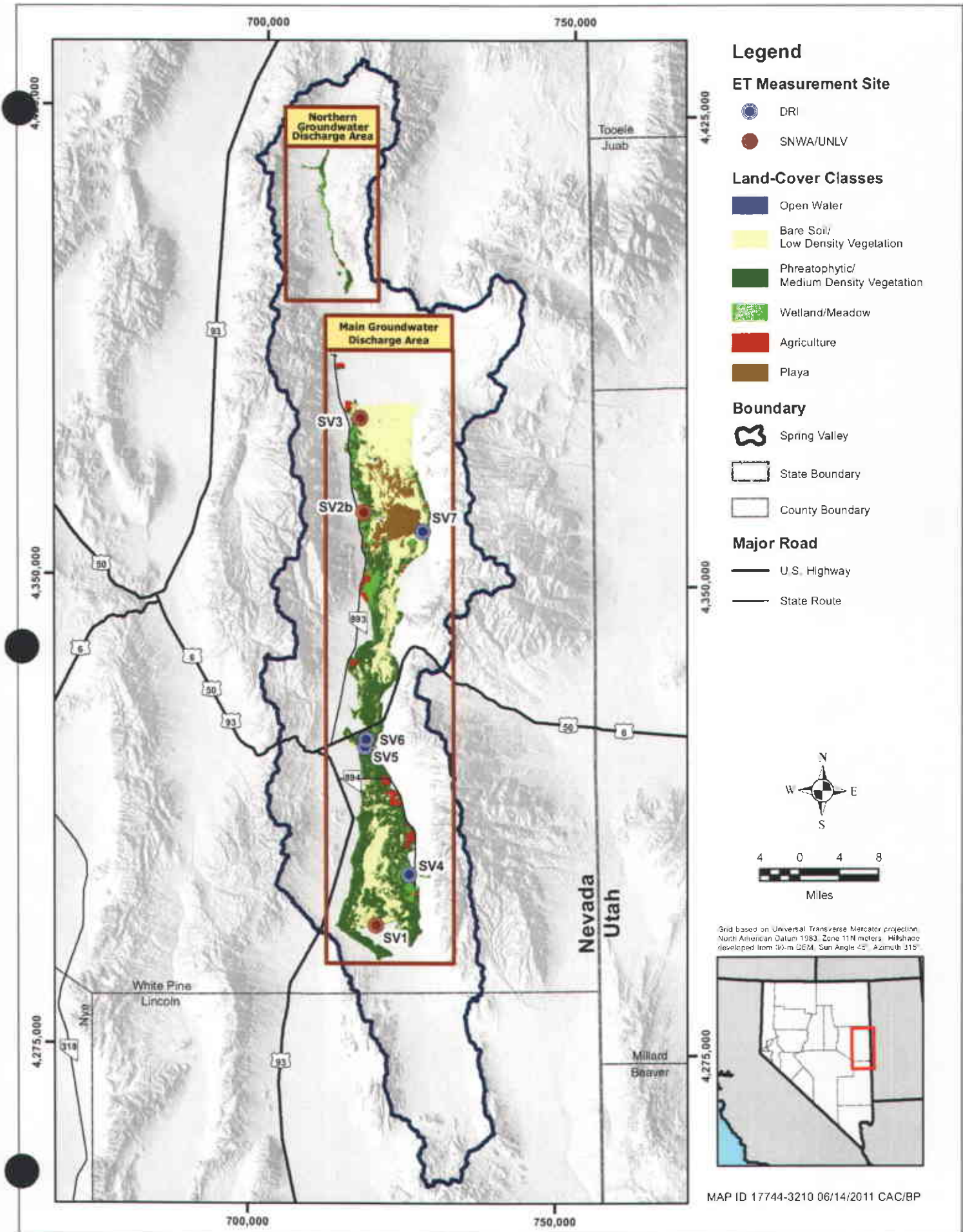


Figure 5-1

Spring Valley Groundwater-ET Extent Map and Location of ET-Measurement Sites

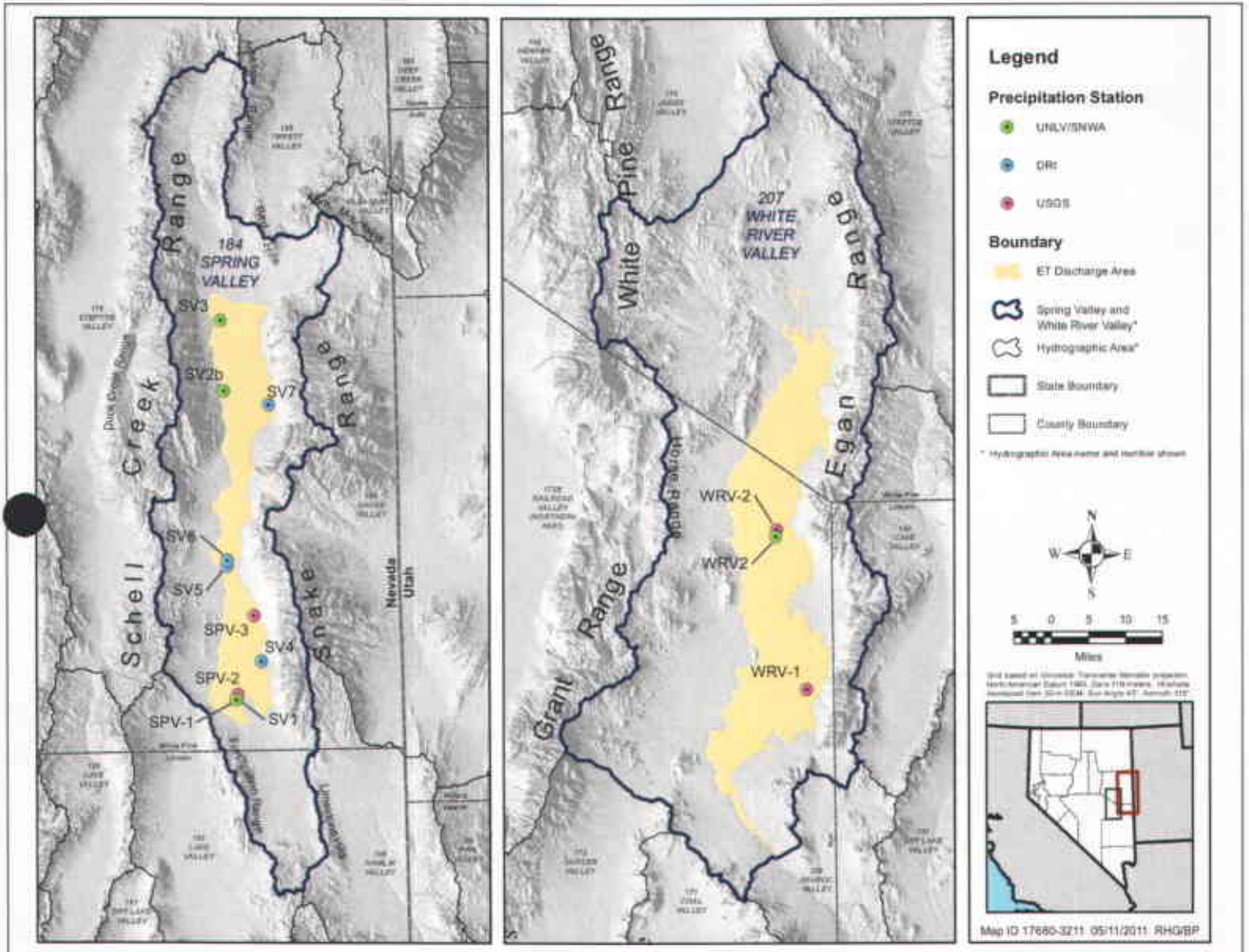


Figure D-2

Locations of Precipitation Stations within Groundwater Discharge Areas of Spring and White River Valleys

Table D-3
Annual Precipitation Station Data for
Spring and White River Valleys (in./yr)

Station Name	2006	2007	2008	2009	2010
WRV2	10.45	6.23 ^a	6.44	9.02	14.13
WRV-1 ^b	7.42	---	---	---	---
WRV-2 ^b	11.49	---	---	---	---
SV1	6.11	5.00	6.00	8.17	12.60
SV2b	---	5.27 ^a	2.79	7.51	8.42
SV3	---	4.21 ^a	3.17	7.78	10.17
SV4	---	5.79 ^a	5.12	6.96 ^a	---
SV5	---	5.44 ^a	3.50	8.70 ^a	---
SV6	---	5.24 ^a	3.37	8.18 ^a	---
SV7	---	3.95 ^a	2.59	6.19 ^a	---
SPV-1 ^b	7.07	---	---	---	---
SPV-2 ^b	7.89	---	---	---	---
SPV-3 ^b	6.60	---	---	---	---

^aMissing months estimated using record of next nearest gage.

^bJanuary 2006 through August 2006 data as reported by Moreo et al. (2007, Table 7, p. 20) with September, 2006 through December, 2006 data considered provisional (per. comm. M. Moreo, January 11, 2008)

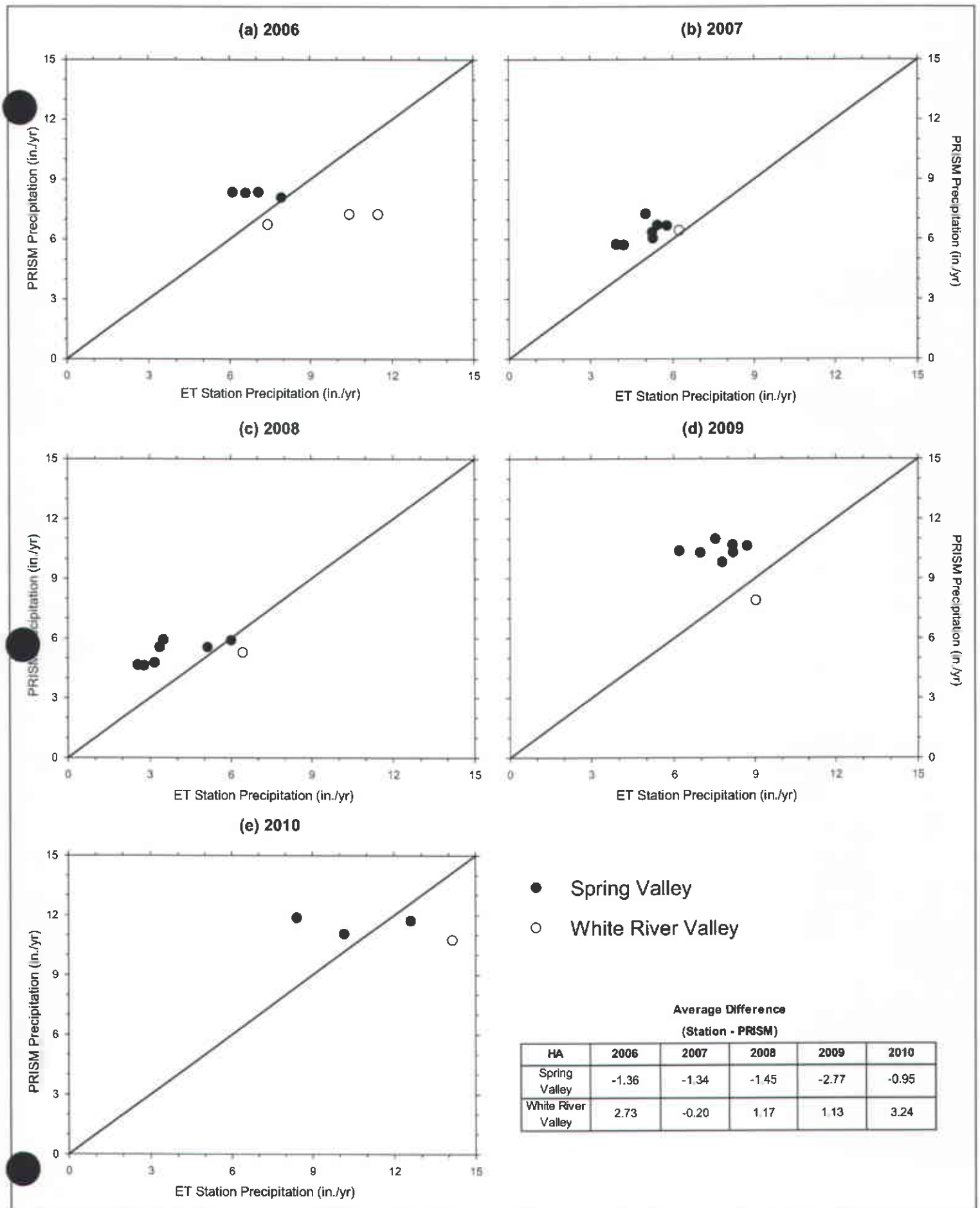


Figure D-5
Comparison of PRISM Precipitation Values to Station Values in Groundwater ET Areas

**Table D-4
Comparison of 4-km Annual PRISM Precipitation to Station Data
in Groundwater ET Areas of Spring and White River Valleys**

Station Name	2006			2007			2008			2009			2010		
	Station	PRISM	Difference	Station	PRISM	Difference	Station	PRISM	Difference	Station	PRISM	Difference	Station	PRISM	Difference
WRV2	10 45	7 22	3 23	6 23 ^a	6 43	-0.20	6 44	5 27	1 17	9 02	7 89	1 13	14 13	10 89	3 24
WRV-1 ^b	7 42	6 72	0 70	---	---	---	---	---	---	---	---	---	---	---	---
WRV-2 ^b	11 49	7 22	4 27	---	---	---	---	---	---	---	---	---	---	---	---
Average	---	---	2.73	---	---	-0.20	---	---	1.17	---	---	1.13	---	---	3.24
SV1	6 11	8 35	-2 24	5 00	7 25	-2 25	6 00	5 90	0 10	8 17	10 68	-2 51	12 60	11 60	1 00
SV2b	---	---	---	5 27 ^a	6 04	-0.77	2 79	4 62	-1 83	7 51	10 98	-3 47	8 42	11 80	-3 18
3	---	---	---	4 21 ^a	5 54	-1 33	3 17	4 55	-1 38	7 78	9 60	-1 82	10 17	10 84	-0 67
SV4	---	---	---	5 79 ^a	6 67	-0 88	5 12	5 55	-0 43	6 96 ^a	10 29	-3 33	---	---	---
SV5	---	---	---	5 44 ^a	6 70	-1 26	3 50	5 91	-2 41	8 70 ^a	10 63	-1 93	---	---	---
SV6	---	---	---	5 24 ^a	6 33	-1 09	3 37	5 54	-2 17	8 18 ^a	10 31	-2 13	---	---	---
SV7	---	---	---	3 95 ^a	5 72	-1 77	2 59	4 65	-2 06	6 19 ^a	10 38	-4 19	---	---	---
SPV-1 ^b	7 07	8 35	-1 28	---	---	---	---	---	---	---	---	---	---	---	---
SPV-2 ^b	7 89	8 09	-0 20	---	---	---	---	---	---	---	---	---	---	---	---
SPV-3 ^b	6 60	8 30	-1 70	---	---	---	---	---	---	---	---	---	---	---	---
Average	---	---	-1.36	---	---	-1.34	---	---	-1.45	---	---	-2.77	---	---	-0.95

^aMissing months estimated using record of next nearest gage.

^bJanuary 2006 through August 2006 data as reported by Moreo et al. (2007, Table 7, p 20) with September 2006 through December 2006 data considered provisional (per. comm. M. Moreo, January 11, 2008)

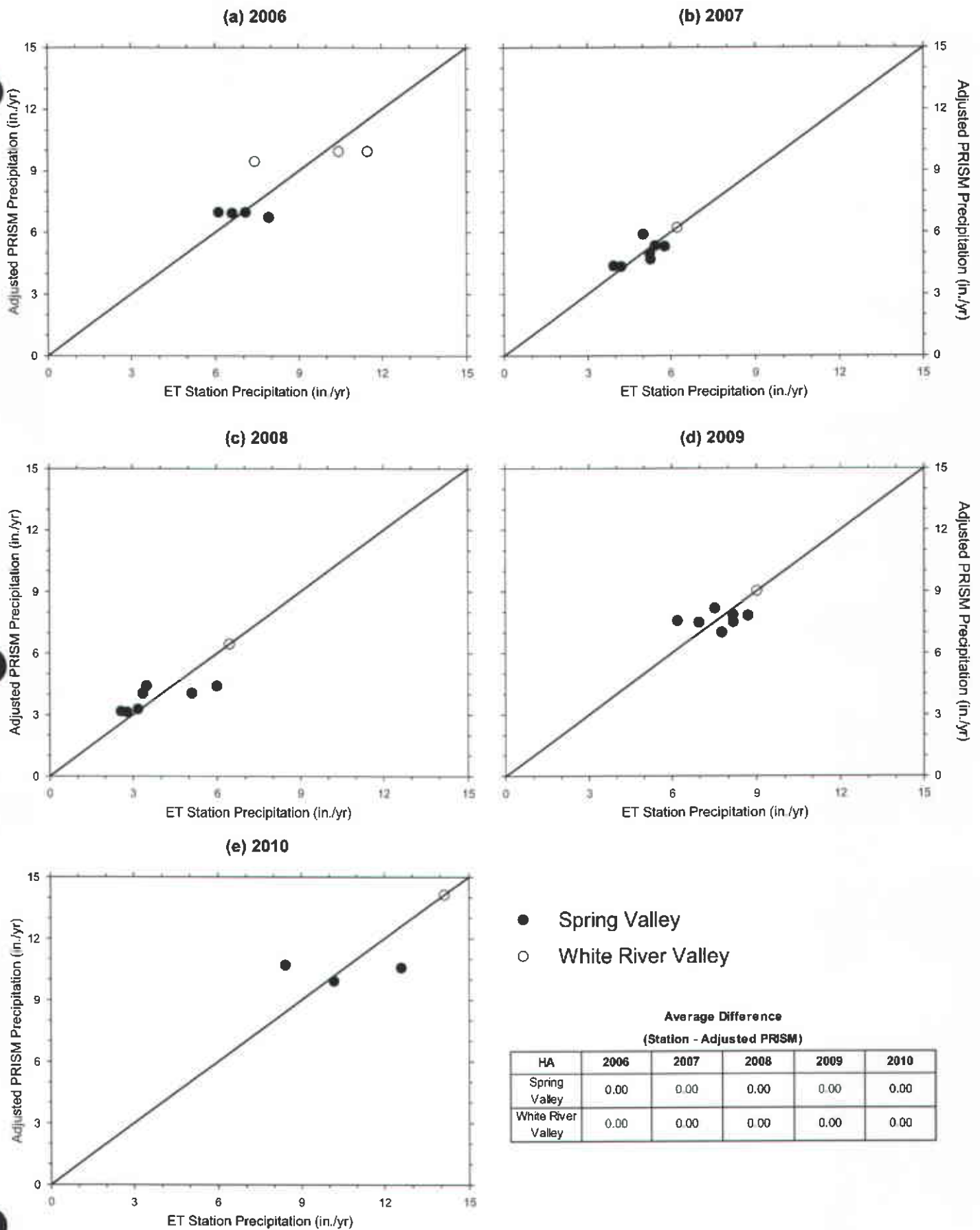


Figure D-6
Comparison of Adjusted PRISM Precipitation Values to
Station Values in Groundwater ET Areas

**Table D-5
PRISM Precipitation Volumes for Spring and
White River Valleys for Groundwater Discharge Areas (2006-2010)**

Method	2006	2007	2008	2009	2010	Source
Spring Valley (PRISM; afy) ^a	100,500	81,900	68,800	135,700	151,400	Daly et al. (2011)
Spring Valley (adjusted PRISM; afy) ^a	82,900	64,500	50,000	99,700	139,200	This Study
White River Valley (PRISM; afy) ^a	91,600	79,400	66,200	96,100	129,400	Daly et al. (2011)
White River Valley (adjusted PRISM; afy) ^a	123,300	76,300	79,400	108,800	167,100	This Study
US Climate Division NV-2 (in./yr)	11.13	8.31	7.75	11.94	12.62	NOAA/ESRL ^b

^aValues are rounded to the nearest 100 afy.

^bNOAA/ESRL is the National Oceanic and Atmospheric Administration Earth System Research Laboratory.

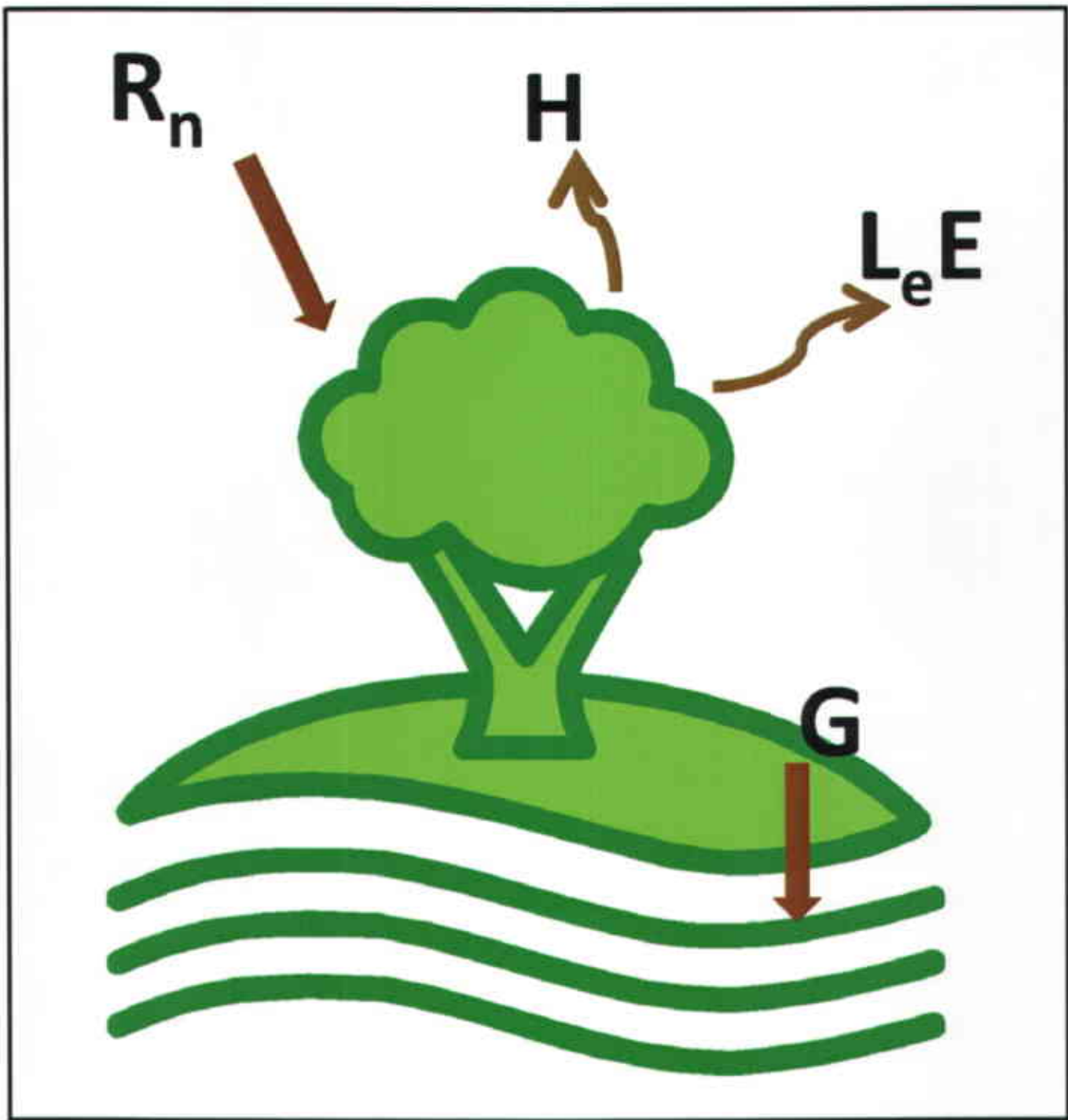
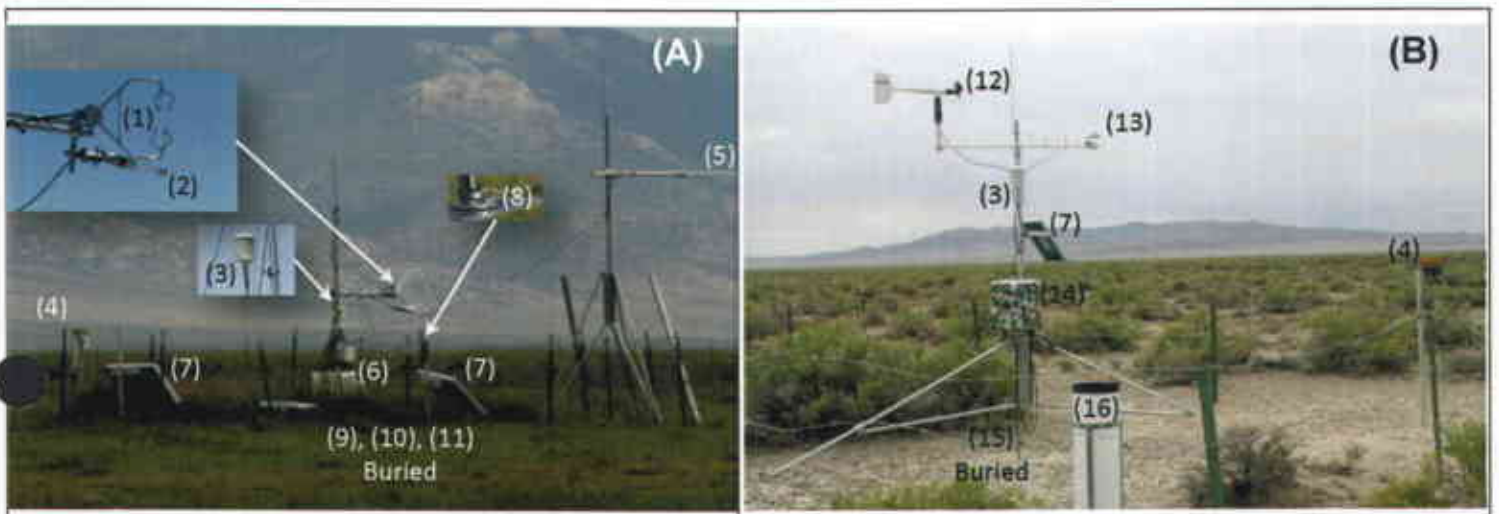


Figure 3-1
Simplified Schematic of
the Energy Budget



Note: (1) CSI CSAT3 3-D sonic anemometer; (2) LiCor 7500 open-path IRGA; (3) Vaisala HMP probe; (4) tipping bucket rain gage; (5) Kipp & Zonen NR-Lite net radiometer; (6) CSI CR5000 data logger; (7) solar panel; (8) LiCor 190SA quantum sensor; (9) CSI CS 616 water-content reflectometer; (10) CSI TCAV-Averaging soil thermocouple probe; (11) Hukseflux HFP01SC-L soil heat flux plates; (12) RM Young wind monitor; (13) LiCor 200SZ pyranometer sensor; (14) CSI CR10X data logger; (15) Acclima Digital TDT sensors; (16) bulk storage rain and snow gage.

Figure 3-2
Typical Deployment of EC (A) and Meteorological (B) Stations

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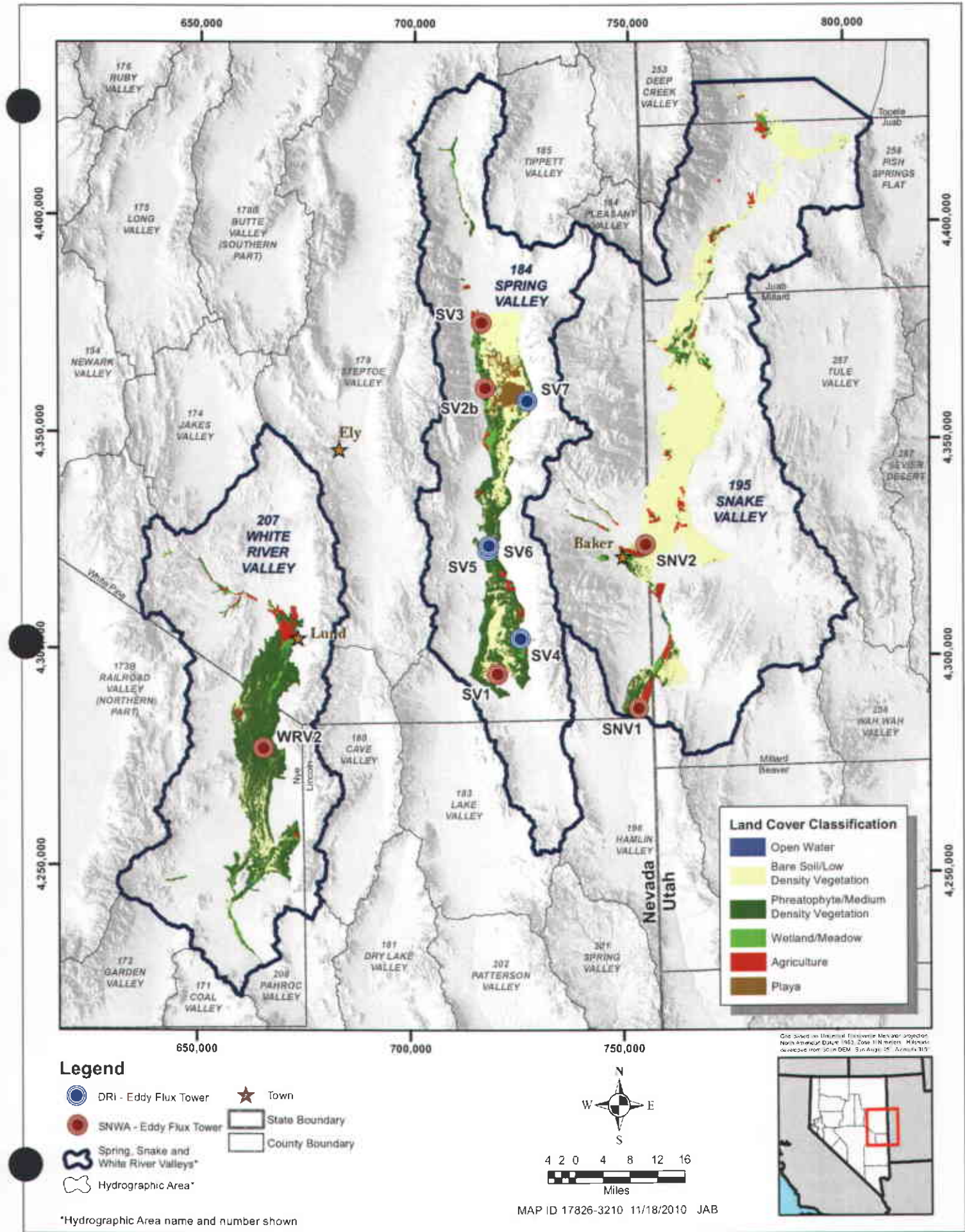


Figure 1-1
Locations of UNLV, DRI, and SNWA ET-Measurement Sites

**Table A-1
Annual ET (ft)**

Site Name	2006	2007	2008	2009	2010	Period of Record ^d
WRV2	1.39 ^a	0.72 ^b	0.74	0.86	1.08	January 2006 - November 2010
SV1	0.79 ^a	0.61 ^b	0.63	0.77	0.96	January 2006 - November 2010
SV2b	---	3.57 ^b	3.63	3.52	3.62	March 2007 - November 2010
SV3	---	0.79 ^b	0.78	0.99	1.16	March 2007 - November 2010
SV4	---	2.46 ^c	3.43 ^c	4.19 ^c	---	April 2007 - November 2009
SV5	---	0.80 ^c	1.09 ^c	1.61 ^c	---	April 2007 - December 2009
SV6	---	0.68 ^c	0.87 ^c	1.28 ^c	---	April 2007 - November 2009
SV7	---	0.43 ^c	0.61 ^c	0.80 ^c	---	April 2007 - October 2009
SnV1	---	1.60 ^b	1.04	0.85	1.02	May 2007 - November 2010
SnV2	---	0.65 ^b	0.65	0.73	0.74	May 2007 - November 2010

Note: All annuals are January through December.

^aDevitt et al. (2008, p. 40).

^bThese include additional data not reported in Devitt et al. (2008).

^cData collected by DRI personnel and processed by SNWA.

^dSites were not operational during periods of sensor calibration (typically late December through middle February).

**Table 3-5
Comparison of Annual ET Rates**

Source	Site Name	Land Cover Description	Period of Record	ET (mm)	ET (ft)
This Study	WRV2	55% cover; predominantly sagebrush and greasewood with minor amounts of shadscale	January 2006 - December 2006	423.67	1.39
Moreo et al. (2007)	WRV-2	Moderately dense desert shrubland	September 1, 2005 - August 31, 2006	309.37	1.02
This Study	SV1	27% cover; predominantly sagebrush with rabbitbrush and greasewood; shadscale and buckwheat also present	January 2006 - December 2006	240.79	0.79
Moreo et al. (2007)	SPV-1	Sparse desert shrubland	September 1, 2005 - August 31, 2006	254.51	0.84
This Study	SV2b	Irrigated pasture/grassland; 100% cover of perennial grasses	March 2007 - November 2010	1,094	3.59
Huntington and Allen (2010)	---	Highly-managed pasture grass	---	1,097	3.6
This Study	SV4	Irrigated pasture/grassland; 100% cover of perennial grasses	April 2007 - November 2009	1,024	3.36
Huntington and Allen (2010)	---	Low-managed pasture grass	---	914	3.0

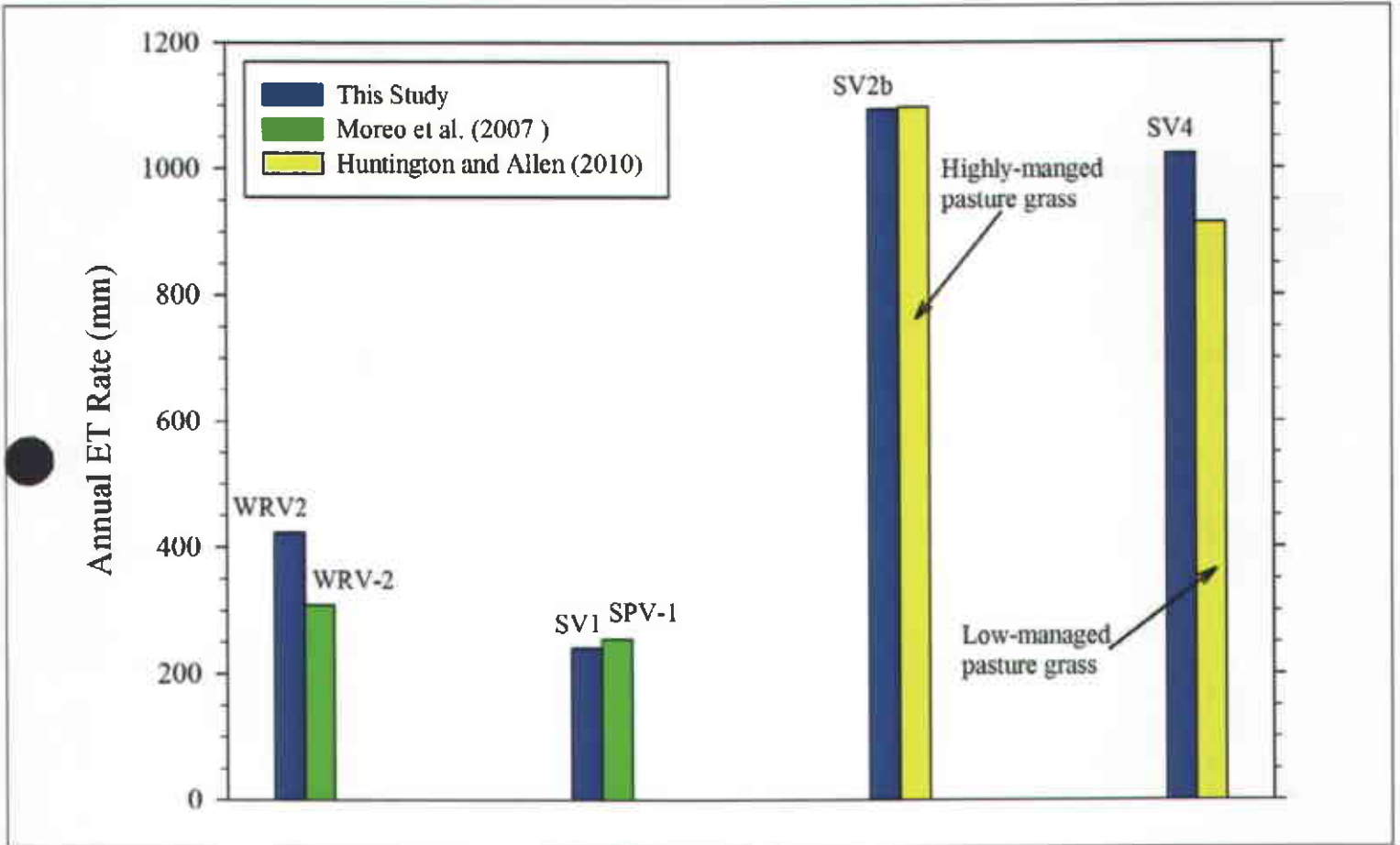
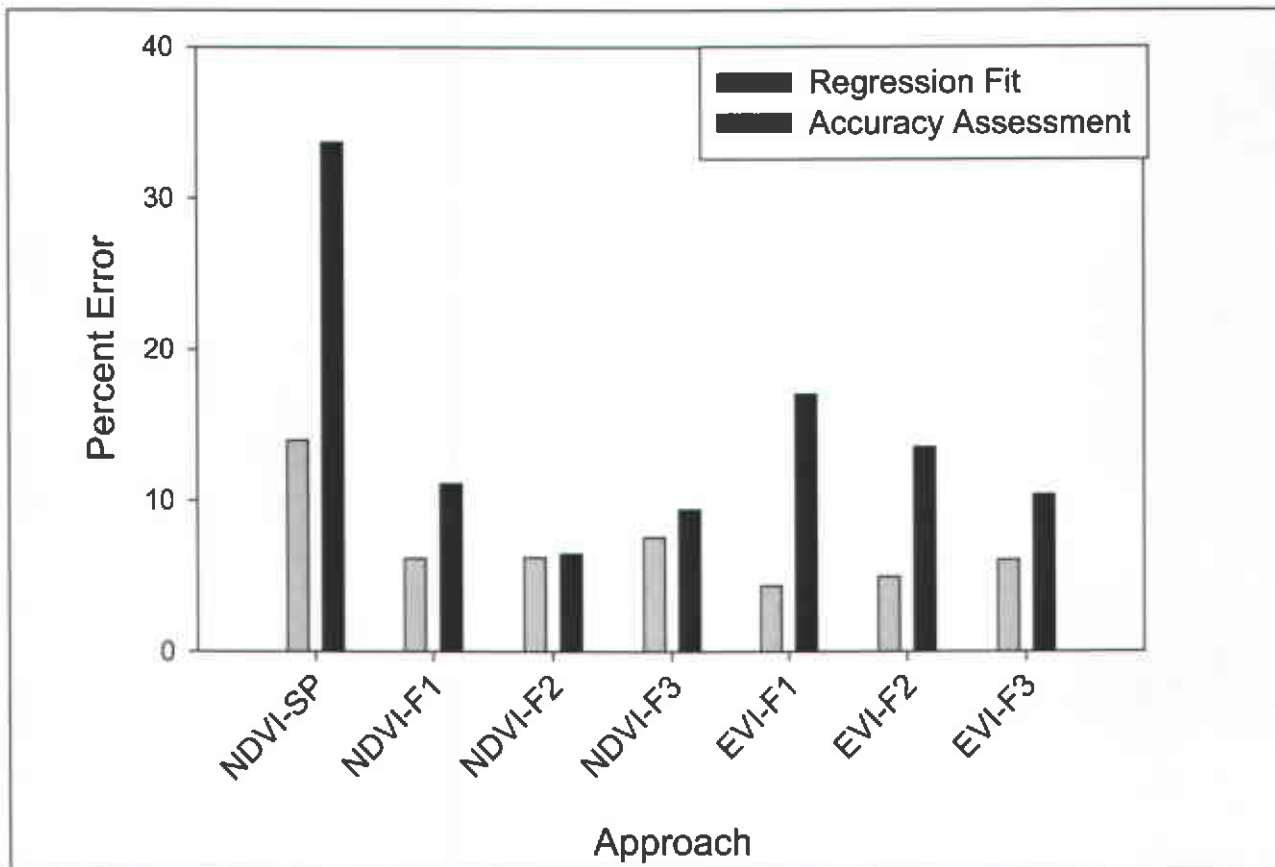


Figure 3-4
Comparison of Annual ET Rate



The percent error between predicted and measured ET are graphed for each of the seven empirical approaches examined collectively by Devitt et al. (2008) - NDVI-SP and Arnone et al. (2008) - NDVI-F1, NDVI-F2, NDVI-F3, EVI-F1, EVI-F2 and EVI-F3. The gray bars depict the percent error of the regression fit for the measured data used to generate each empirical approach. The black bars are the percent error for the independent station data used in the accuracy assessment.

Figure 2-2
Percent Error of Devitt et al. (2008) and
Arnone et al. (2008) Regression Relationships

**Table 4-1
List of Landsat TM 5 Scene Dates for Each Year
by Landsat TM 5 Path/Row**

Year/Path-Row	Path 39, Rows 32, 33 (Spring and Snake Valleys)	Path 40, Row 33 (White River Valley)
2006	5/12, 6/29, 7/15, 8/16, 9/1, 9/17	5/19, 6/4, 6/20, 8/7, 9/8, 9/24
2007	4/29, 5/15, 5/31, 6/16, 7/2, 7/18, 8/19, 9/20	5/6, 5/22, 6/23, 7/9, 8/10, 9/27
2008	5/1, 5/17, 6/18, 8/21, 9/6, 9/22	5/8, 6/9, 6/25, 7/11, 8/12, 8/28, 9/13
2009	4/18, 6/21, 7/7, 7/23, 9/9, 9/25	5/11, 6/28, 7/14, 8/15, 9/16
2010	5/7, 6/8, 8/11, 8/27, 9/12	5/14, 7/1, 7/17, 8/2, 9/3

$$NDVI = (R_{NIR} - R_{RED}) / (R_{NIR} + R_{RED})$$

(Eq. 4-1)

where,

- R* = Reflectance for the waveband indicated by each subscript
- NIR* = Near infrared waveband from 0.76 to 0.90 nm
- RED* = Red waveband from 0.63 to 0.69 nm.

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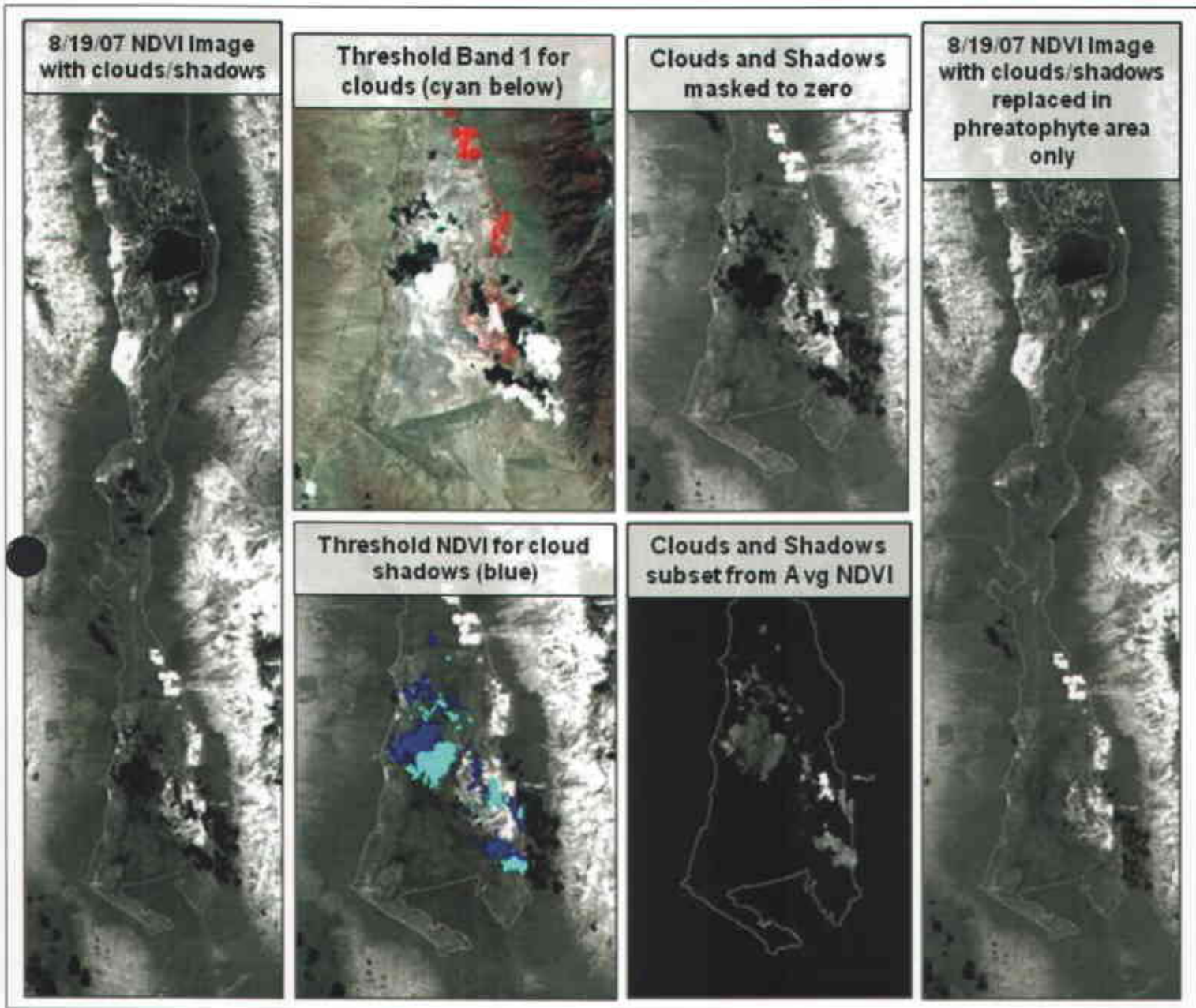
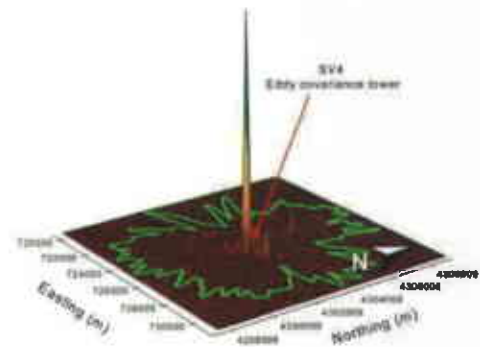
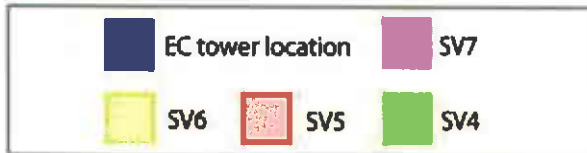
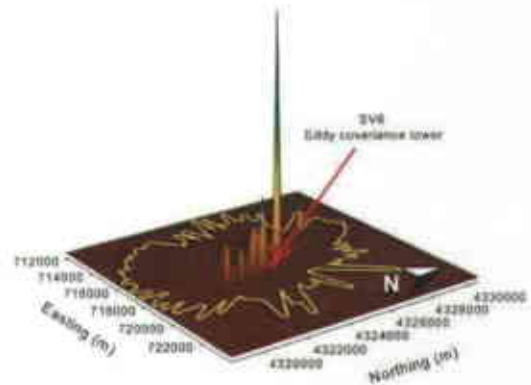
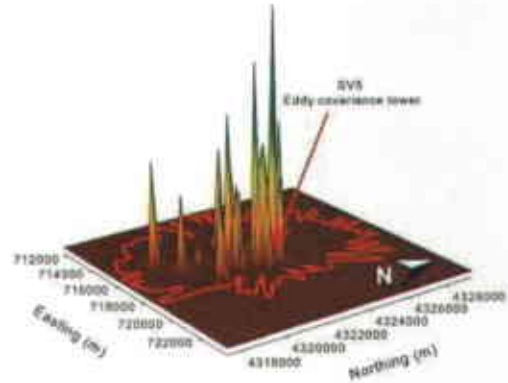
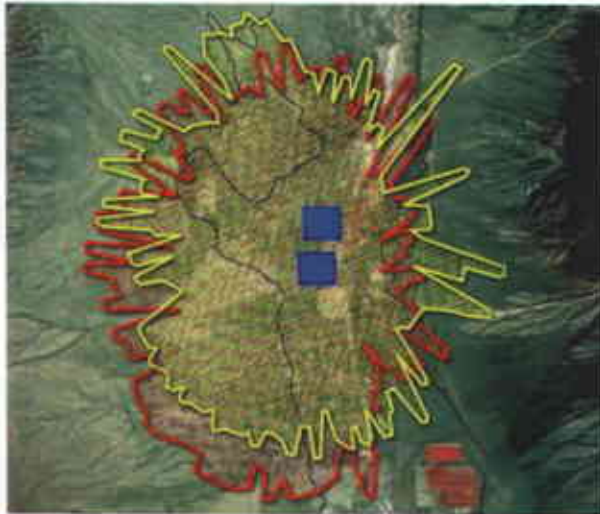
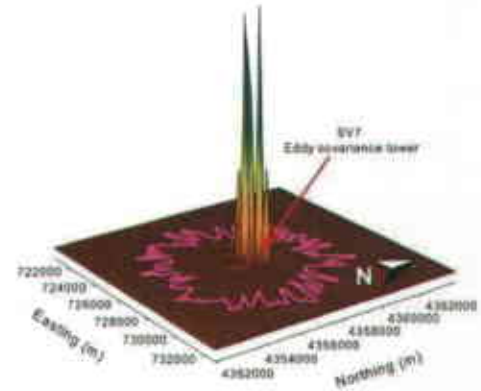


Figure 4-1
Subsets for Spring Valley Demonstrate the Cloud and
Cloud Shadow Identification and Pixel Replacement Process

Table 4-3

List of Images Requiring Cloud Removal and Replacement for Each Valley by Year

HA Name	2006	2007	2008	2009	2010
Snake Valley	---	8/19	5/1, 9/22	4/18, 6/21, 7/23	8/27
Spring Valley	6/29	8/19, 9/20	5/1, 9/22	7/23	6/8, 8/27
White River Valley	5/19, 8/7	6/23	7/11	6/28, 8/15	5/14, 7/17, 8/2



Source: Amone et al. (2008).

Note: The location and size of the footprint for each of the four EC sites located in Spring Valley between April 20, 2007 and April 20, 2008 are depicted in the left panel. In the right panel, three-dimensional mesh images depict the level of representation of 250 x 250 m grid cells (cell size for graph preparation) within each EC tower footprint to annual ET over the study year. The footprint extent encompassed the area that contributed 90 percent of the ET fluxes during the year.

Figure 4-2

Footprint Extents for Selected EC Stations in Spring Valley (April 2007-April 2008)

**Table 5-1
Footprint-Weighted Average NDVI and Annual ET for ET-Measurement Sites
Located in Snake, Spring, and White River Valleys, Nevada**

Site	Footprint-Weighted Average NDVI					Measured Annual ET (mm)				
	2006	2007	2008	2009	2010	2006	2007	2008	2009	2010
WRV2	0.0934	0.0808	0.0937	0.0924	0.0700	423.67	219.46	225.55	262.13	329.18
SV1	0.0483	0.0533	0.0616	0.0634	0.0658	240.79	185.93	192.02	234.70	292.61
SV2b	---	0.4029	0.3199	0.4720	0.4103	---	1,088.14	1,106.42	1,072.90	1,103.38
SV3	---	0.0586	0.0487	0.0549	0.0786	---	240.79	237.74	301.75	353.57
SV4	---	0.2823	0.2967	0.4363	---	---	749.81	1,045.46	1,277.11	---
SV5	---	0.0776	0.0859	0.1142	---	---	243.84	332.23	490.73	---
SV6	---	0.0778	0.0827	0.1087	---	---	207.26	265.18	390.14	---
SV7	---	0.0460	0.0395	0.0490	---	---	131.06	185.93	243.84	---
SnV1	---	0.1104	0.1143	0.1025	0.1027	---	487.68	316.99	259.08	310.90
SnV2	---	0.0715	0.0624	0.0561	0.0620	---	198.12	198.12	222.50	225.55

$$\text{Annual ET (mm)} = 65.426 + (2,749.087 \times \text{Avg NDVI}); (n = 31, r^2 = 0.953) \quad (\text{Eq. 5-1})$$

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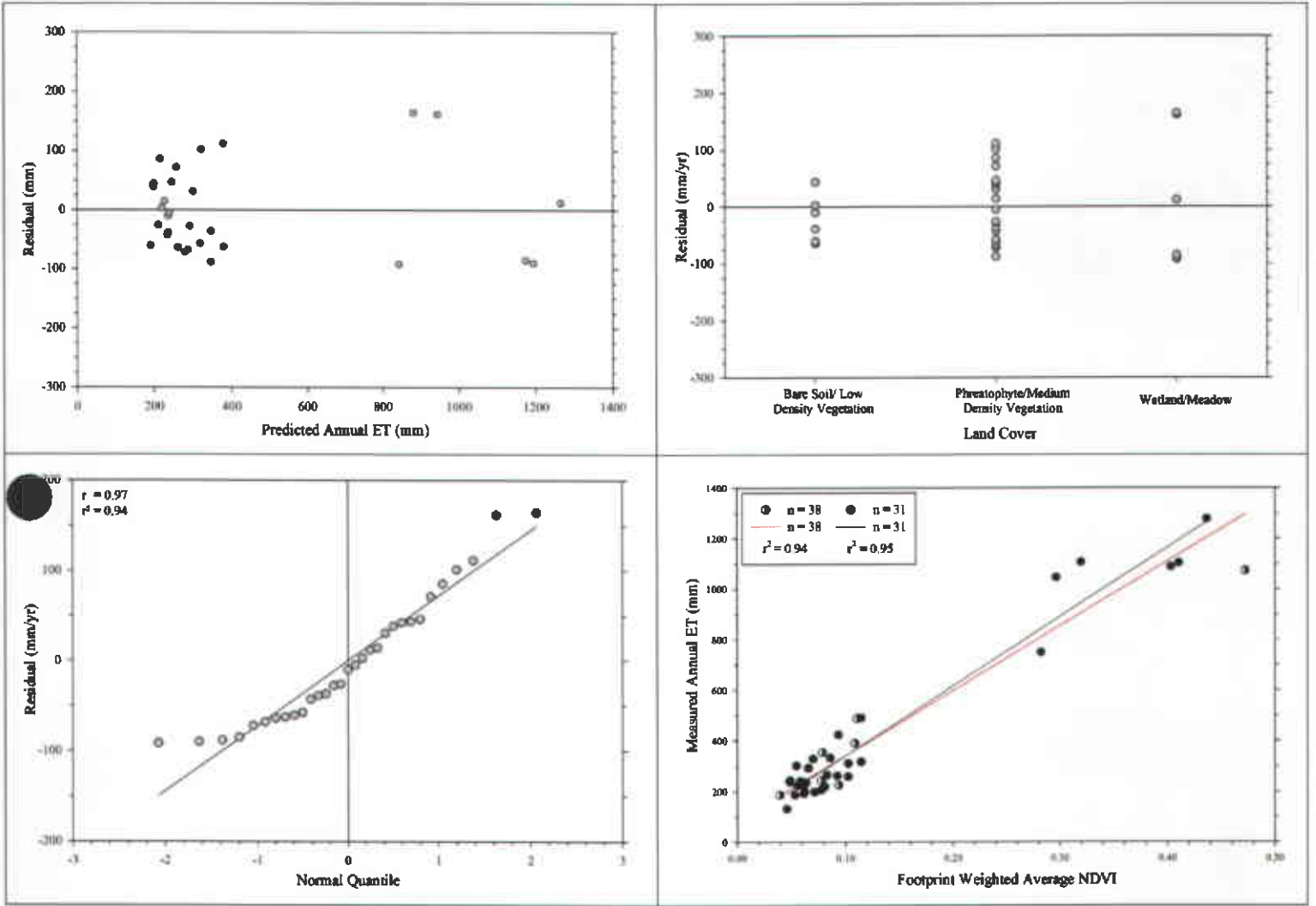


Figure 5-5
Regression Model Residual Plots and a Comparison of Sample Size (n=31 versus n=38)

**Table 5-3
Difference of Annual Predicted ET minus Annual Measured ET**

HA Name	Land Cover	Station Name	Year	Annual Predicted ET (mm)	Annual Measured ET (mm)	Predictive Error (mm)	Percent Error (%)
Snake Valley	Phreatophyte/Medium Density Vegetation	SnV1	2007	368.93	487.68	-118.75	32
Spring Valley	Bare Soil/Low Density Vegetation	SV7	2008	174.01	185.93	-11.92	7
		SV3	2010	281.50	353.57	-72.07	26
	Phreatophyte/Medium Density Vegetation	SV5	2007	278.76	243.84	34.92	13
		SV6	2009	364.25	390.14	-25.89	7
		SV2b	2009	1,363.00	1,072.90	290.10	21
Wetland/Meadow	SV2b	2009	1,363.00	1,072.90	290.10	21	
White River Valley	Phreatophyte/Medium Density Vegetation	WRV2	2008	323.02	225.55	97.47	30

**Table 5-1
Land-Cover Classification**

ET Class	Classification	Description	DTW Range^a (ft bgs)
1	Open Water	Bodies of open water fed by groundwater sources (direct hydraulic connection, springs, seeps, etc.)	Above ground surface
2	Bare Soil/Low Density Vegetation	Shrubland less than or equal to 20% plant cover - Areas dominated by bare soil and low- to moderate-density desert shrubland, including greasewood, rabbit brush, and other phreatophytic species	Mostly 10 to <60
3	Phreatophytic/ Medium Density Vegetation	Shrubland with plant cover greater than 20% - Areas dominated by desert shrubland, including mixed stands of medium-density greasewood, rabbit brush, and other phreatophytic species	2 to 60
4	Wetland/Meadow	Area of shallow groundwater near bodies of open water consisting of wetland vegetation, marshland, woodland, and dense meadows - additionally includes riparian corridors in the southern part of study area, consisting of saltcedar, desert willows, cottonwood, and mesquite trees with underlying shrubs and grasses	0 to 20
5	Agriculture	Areas where crops are grown and harvested (i.e. alfalfa, hay, etc.), but not grassland/meadowland areas	NA
6	Playa	Bare-soil flat areas located in the bottoms of some basins. Classified as potential groundwater ET areas in basins where the water table is within 10 ft of the land surface	0 to 10

^aSNWA (2009a; Table E-2, p. E-9)

NA = Not applicable

Table 5-2
Annual Total-ET Estimates for the Main Groundwater
Discharge Area of Spring Valley (afy)

2006	2007	2008	2009	2010	Period of Record Average
184,900	162,900	153,500	186,600	184,700	174,500

Totals were derived from annual total ET grids and exclude ET on playa areas.

Table 5-3
Annual Groundwater-ET Estimates for
the Main Groundwater Discharge Area of Spring Valley (afy)

2006	2007	2008	2009	2010	Period of Record Average
104,400	99,700	104,700	92,000	56,700	91,500

Totals were derived from annual groundwater-ET grids

**Table D-7
Average Annual Groundwater-ET Rates for the
Groundwater Discharge Area in Northern Spring Valley**

Class	Site Name	Source	Year	Total ET Rate (ft/yr)	Precipitation		Groundwater ET Rate (ft/yr)
					(in./yr)	(ft/yr)	
Bare Soil/Low Density Vegetation	SV7	DRI	2007	0.43	3.95	0.33	0.10
			2008	0.61	2.59	0.22	0.39
			2009	0.80	6.19	0.52	0.28
Sparse Desert Shrubland	SPV-1	USGS ^a	2006	0.84	8.58	0.72	0.12
Bare Soil/Low Density Vegetation				0.67	5.33	0.45	0.23
Phreatophyte/Medium Density Vegetation	SV1	SNWA/UNLV	2006	0.79	6.11	0.51	0.28
			2007	0.61	5.00	0.42	0.19
			2008	0.63	6.00	0.50	0.13
			2009	0.77	8.17	0.68	0.09
			2010	0.96	12.60	1.05	0.00
	SV3	SNWA/UNLV	2007	0.79	4.21	0.35	0.44
			2008	0.78	3.17	0.26	0.52
			2009	0.99	7.78	0.65	0.34
			2010	1.16	10.17	0.85	0.31
	SV5	DRI	2007	0.80	5.44	0.45	0.35
			2008	1.09	3.50	0.29	0.80
			2009	1.61	8.70	0.73	0.89
	SV6	DRI	2007	0.68	5.24	0.44	0.24
			2008	0.87	3.37	0.28	0.59
			2009	1.28	8.18	0.68	0.60
Moderately Dense Desert Shrubland	SPV-2	USGS ^a	2006	1.01	9.17	0.76	0.25
Phreatophyte/Medium Density Vegetation				0.93	6.68	0.56	0.37
Wetland/Meadow	SV2b	SNWA/UNLV	2007	3.57	5.27	0.44	3.13
			2008	3.63	2.79	0.23	3.40
			2009	3.52	7.51	0.63	2.89
			2010	3.62	8.42	0.70	2.92
	SV4	DRI	2007	2.46	5.79	0.48	1.98
			2008	3.43	5.12	0.43	3.00
			2009	4.19	6.96	0.58	3.61
Grassland/Meadowland	SPV-3	USGS ^a	2006	2.25	7.97	0.66	1.59
Wetland/Meadow				3.33	6.23	0.52	2.81

^aMoreo et al. (2007, p. 20)

Table D-8
Annual Groundwater-ET Estimate for the
Groundwater Discharge Area in Northern Spring Valley

Class	Area (acres)	Groundwater ET	
		(ft/yr)	(afy)
Bare Soil/Low Density Vegetation	540	0.23	100
Phreatophyte/Medium Density Vegetation	1,720	0.37	600
Wetland/Meadow	920	2.81	2,600
		Total	3,300

**Table 5-5
Selected Observed ET Rates Used to Estimate ET**

ET Class	Selected ET Site	Description of Selected ET Site	Total ET Rate (ft/yr)	Adjusted Total ET Rate (ft/yr)
Bare Soil/Low Density Vegetation	Long-Term Mean Rate/BARCASS Region	Areas within the phreatophytic boundaries exhibiting ground cover densities of less than 20%, considered to be either bare soil or sparse vegetation cover	1.00 ^{a,b}	1.00
Phreatophytic/Medium Density Vegetation	WRV-1, WRV-2, and SPV-2	Medium-density phreatophytes, greasewood and shrubs, such as sagebrush	1.03 ^{c,d}	1.03
Wetland/Meadow	SPV-3	Wetland/meadow land cover surrounding riparian corridors throughout the project area	2.25 ^c	2.17

^aWelch et al. (2007)

^bAverage of the area-weighted average annual ET for the sparse and moderately dense shrubland ET Units reported by Welch et al. (2007)

^cMoreo et al. (2007)

^dAverage annual ET rate from WRV-1, WRV-2 and SPV-2

Table 5-6
Estimated Annual Total ET, Precipitation, and
Groundwater-ET Volumes for Land-Cover Classes in Cave Valley

ET Class	Area (acres)	Adjusted ET Rate (ft/yr)	Total ET Volume (afy)	Average Precipitation Rate (ft/yr)	Precipitation Volume (afy)	Groundwater ET Volume (afy)
Bare Soil/Low Density Vegetation	5,914	1.00	5,914	1.06	6,269	0
Phreatophytic/Medium Density Vegetation	9,651	1.03	9,940	1.05	10,134	0
Wetland/Meadow	1,084	2.17	2,352	0.98	1,062	1,290
Basin Total	16,649	---	---	---	---	1,290