MEMORANDUM

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Date: March 3, 2009
To: Fred Corson, Clean Water Coalition of Northern Sonoma County
From: Gus Yates, Consulting Hydrologist
Cc:
Subject: Northern Sonoma County Agricultural Reuse Project: Revised Versions of Nick Johnson's Water and Salt Balance Tables for Dry Creek Basin

As we discussed by telephone, I revised the water balance table (Table 16) and salt balance table (Table 17) in Nick Johnson's December 2008 report "Potential Water Supply Impacts to Dry Creek Valley from NSCARP and a Bypass Pipeline". The purpose of the revisions was to adhere more clearly to well-defined boundaries of the flow system. To that end, I developed a schematic diagram of the hydrologic system in the Dry Creek Valley, including the creek, soil zone and groundwater zone (Figure 1). My water balance is an average annual balance for the groundwater zone.

The revised water balance is shown in Table 1, followed by notes explaining the assumptions and data used to derive various items. I retained Nick's estimates wherever they were consistent with my boundaries and approach, which was the case for most of the flow items. The magnitude of the revised budget (13,400 ac-ft/yr of inflows and outflows) is comparable to the budget in Table 16 (12,300 ac-ft/yr).

In this system, changes in recharge and groundwater pumping are balanced by corresponding changes in seepage to and from Dry Creek. The principal effect of NSCARP on the flow system would be to substantially decrease groundwater pumping, which in turn would convert Dry Creek from a losing stream to a gaining stream in summer. The variations of the project (high or low irrigation rates and optional use of recycled water for frost protection) had the same general effect but with slightly different changes in selected flow items.

The revised water balance table does not include the effects of a bypass pipeline for water deliveries from Lake Sonoma because I do not think a pipeline would cause additional impacts on the water balance. This conclusion is based on the assumption that the pipeline would not be allowed to decrease flows below the levels recommended in the Biological Assessment for steelhead and salmon. The Assessment recommends summer flows of 25 cfs at the mouth of Dry Creek, downstream of the flow gains and losses along Dry Creek valley. Current flow losses are on the order of 11 cfs, and under NSCARP project conditions the creek would gain rather than lose flow. Thus, streamflow in the creek would continue to be able to receive or deliver the flow gains and losses indicated in Table 1 for existing and project conditions.

The revised salt budget table (Table 2) is structured slightly differently than Nick's Table 17, but it retains many of the same assumptions and data. Table 2 calculates the average annual salt inflows and outflows from the basin as mass fluxes (tons per year) rather than as concentrations. The itemization of inflows parallels the diagram and the water balance table. A separate table is shown for existing conditions and each of the four combinations of NSCARP conditions. At the end of each table, the annual increase in salt mass is divided into the estimated total volume of groundwater in the basin to obtain the annual increase in salinity that would result if the net salt load were mixed uniformly throughout the basin. This last assumption is unrealistic, but it provides a basis for comparing the impacts of each project variation and also indicates a general magnitude of the existing and project salinity impacts.

Finally, Table 3 shows the change in TDS concentration of deep percolation below the root zone in a hypothetical vineyard under existing conditions and each of the possible NSCARP project conditions. This analysis shows that the project could double the salinity of deep percolation, which is roughly the same conclusion reached in Nick's analysis.

Dry Creek Basin Groundwater Balance

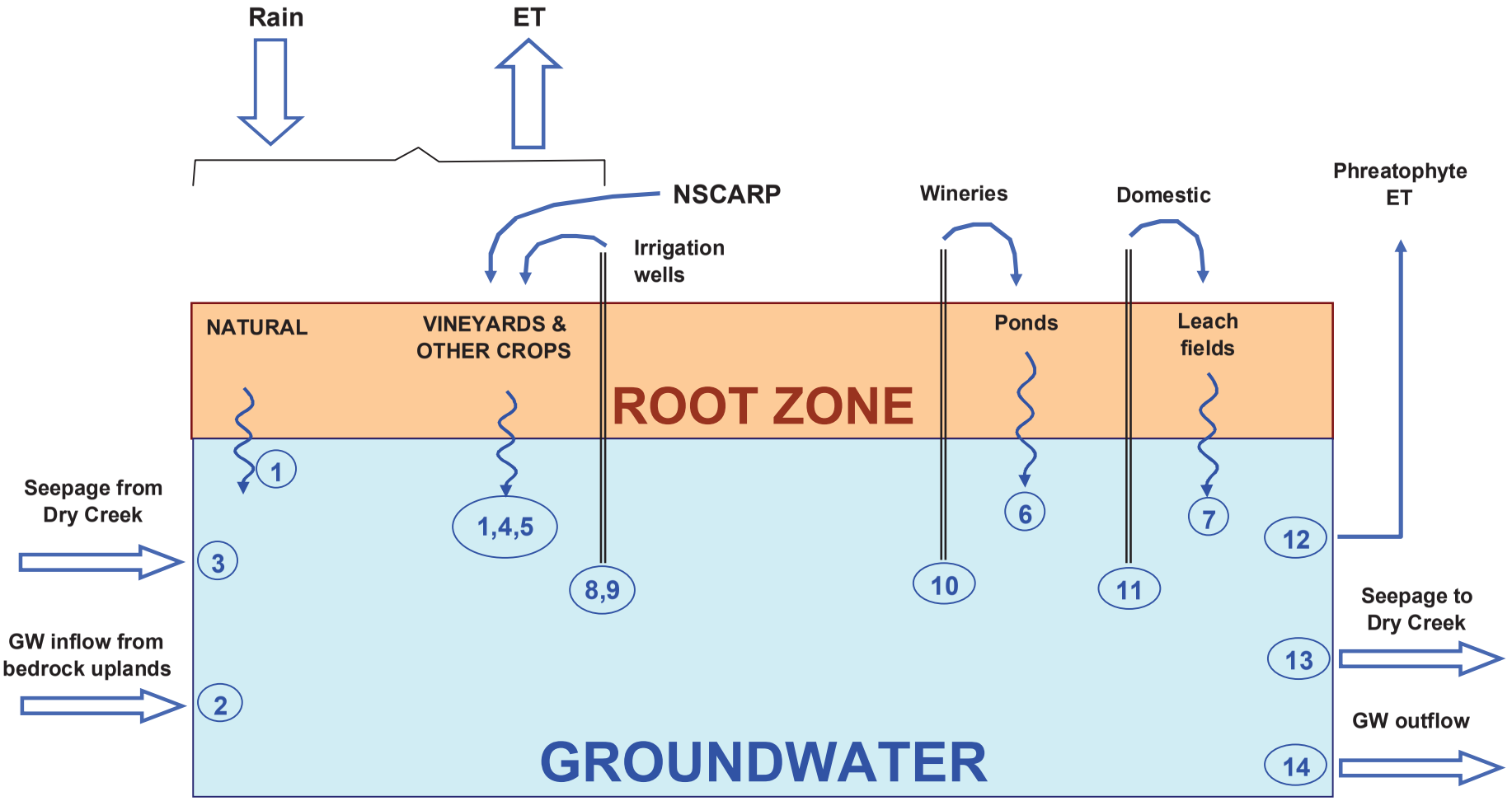

Table 1. Average Annual Water Balance for Dry Creek Groundwater Basin (Acre-Feet per Year)

Diagram Label	Budget Item	Existing	NSCARP, Summer Irrigation Only		NSCARP with Frost Protection	
			Low Irrigation	High Irrigation	Low Irrigation	High Irrigation
	Inflows					
1	Rainfall recharge valley floor	5,658	5,658	5,658	5,658	5,658
2	GW inflow from adjacent bedrock	2,217	2,217	2,217	2,217	2,217
	Percolation from Dry Creek					
3	Summer	4,000	0	0	0	0
3	Winter	0	0	0	0	0
	Irrigation deep percolation					
	Vineyards					
4	Frost protection	1,059	1,059	1,059	1,059	1,059
4	Summer irrigation	0	0	1,017	0	1,017
5	Other crops	160	160	160	160	160
	Other return flows (septic, etc.)					
6	Wineries	125	125	125	125	125
7	Domestic	214	214	214	214	214
	TOTAL	13,433	9,433	10,449	9,433	10,449
	Outflows					
	Groundwater pumping					
8	Vineyard frost protection	1,513	1,513	1,513	0	0
8	Vineyard irrigation	7,800	1,853	1,853	1,853	1,853
9	Other crops	800	800	800	800	800
10	Wineries	250	250	250	250	250
11	Domestic	450	450	450	450	450
12	Phreatophyte GW ET	364	364	364	364	364
	GW seepage into Dry Creek					
13	Summer	0	435	1,452	1,948	2,964
13	Winter	3,434	3,434	3,434	3,434	3,434
14	GW outflow	334	334	334	334	334
	TOTAL	13,433	9,433	10,449	9,433	10,449
	Annual storage change					
	Inflows minus outflows	0	0	0	0	0
	Change in water levels	0	0	0	0	0

Table 1, continued -- Notes on Groundwater Balance

Line No.	Data Sources and Assumptions
Global	Changes in GW pumping are primarily compensated for by changes in GW seepage to and from Dry Creek.
Global	The bypass pipeline would not cause any additional changes in the GW balance beyond those caused by NSCARP because Dry Creek summer flows would still be sufficient to absorb the changes in seepage gains and losses. Proposed summer flows in the Biological Assessment are 25 cfs at the mouth of Dry Creek (i.e. after all upstream seepage gains and losses). The magnitude of the seepage changes under NSCARP are a shift from a flow loss of about 11 cfs during a 6-month dry season to a flow gain of about 3 cfs.
1	Johnson, Table 16. 7 in/yr on 9,700 acres.
2	Johnson, Table 16. 2 in/yr on 13,300 acres of adjacent bedrock.
3	Johnson, Table 16. Existing condition summer percolation is difference between gaged flow in Dry Creek at Warm Springs Dam and at the Russian River. Creek assumed to gain flow from GW seepage in winter. Under NSCARP conditions, GW pumping for irrigation is decreased by 5,100 af/yr. It is assumed that this is first balanced by decreasing percolation **from** Dry Creek in summer (to zero), and the remaining imbalance becomes increased seepage **into** Dry Creek.
4	Vineyard irrigation assumed to be 100% efficient at up to 10 in/yr applied water (Johnson, Section 2.6). Any irrigation in excess of 10 in/yr is assumed to be inefficient and to percolate through the root zone to GW. 2 in/yr x 6100 ac of NSCARP vineyards = 1,107 af/yr.
5	400 ac of orchard and pasture receive 24 in/yr applied water at 80% efficiency (Johnson, Section 2.5.2)
6	Johnson, Section 2.6. Wineries use 250 af/yr, half of which percolates back to GW from wastewater storage ponds.
7	Johnson, Section 2.6. Domestic wells pump 450 af/yr of GW, 50% is used indoors and 75% of indoor use percolates to GW via leach fields. 20% of outdoor water use (irrigation) becomes deep percolation below the root zone.
8	Johnson, Section 2.5.2. 8,000 ac of vineyard use 10 in/yr for irrigation and 5 in/yr for frost protection under existing conditions. NSCARP assumes 6100 acres of vineyard would be irrigated at 7 in/yr (low estimate) or 12 in/yr (high estimate). It is assumed here that the remaining 1,900 ac of vineyards would continue receiving 7 in/yr of GW irrigation. Frost protection is assumed to be 5 in/yr supplied by GW on all vineyards. Thus, the decrease in vineyard irrigation pumping is 6,100 ac x 10 in/yr = 5,083 af/yr.
9	Johnson, Section 2.5.2. 400 acres of orchard and pasture receive an estimated 24 in/yr of irrigation.
10	Johnson, Section 2.6. Wineries pump an estimated 250 af/yr of GW for processing.
11	Johnson, Section 2.6. Rural domestic wells pump an estimated 450 af/yr

12 Johnson, Section 2.5.3. Phreatophyte ET of GW estimated to be 15 miles long x 100 ft wide x 24 in/yr

13 Dry Creek assumed to be losing water along its entire length in summer under existing conditions. The gain in winter derives from Johnson's 800 af/yr of "Groundwater discharge to stream baseflow and riparian ET" (which was calculated as the residual in his budget). In this table, phreatophyte ET and subsurface GW outflow are calculated separately (364 and 334 af/yr, respectively), leaving 800-364-334=102 af/yr. This is rounded upward to 176 af/yr to better balance the budget. Under NSCARP, the decrease in GW pumping for irrigation is first balanced by a decrease in seepage **from** Dry Creek, and the remaining imbalance becomes increased seepage **into** Dry Creek.

14 Subsurface outflow to the Russian River and Middle Reach groundwater basin calculated from Darcy's Law: 60 ft/d x 2 mi width x 50 ft depth x 0.00126 ft/ft gradient.

Table 2. Dry Creek Groundwater Basin Salt Balance

Diagram Label	Salt Budget Item	Existing Conditions Acres	in/yr	AFY	WQ mg/L	Salt load ton/yr
	Salt inputs					
1	Rainfall percolation	9,700	7	5,658	0	0
2	GW inflow from bedrock			2,217	200	547
3	Percolation from Dry Creek			4,000	150	740
	Vineyard irrigation water					
4	NSCARP frost protection	0	0	0	432	0
4	NSCARP irrigation	0	0	0	432	0
4	GW frost protection	5,500	3.3	1,513	200	373
4	GW irrigation	8,000	11.7	7,800	200	1,925
5	Orchard & pasture irrigation	400	24	800	200	197
6	Winery wastewater			125	800	123
7	Domestic wastewater			214	800	211
	TOTAL					4,117
	Salt outputs					
	Well pumping					
	Vineyards					
8	Frost protection	5,500	3.3	1,513	200	373
8	Summer irrigation	8,000	11.7	7,800	200	1,925
9	Orchard & pasture			800	200	197
10	Wineries			250	200	62
11	Domestic			450	200	111
12	Phreatophytes			364	0	0
	GW seepage into Dry Creek					
13	Summer			0	200	0
13	Winter			3,434	200	847
14	GW outflow			334	200	83
	TOTAL					3,598
	Inputs minus outputs					519
Basinwide groundwater TDS trend						
	GW volume (Johnson, Table 2) (AF)					70,000
	Average rate of increase (mg/L/yr)					6

Table 2, continued

		NSCARP Low Irrigation, GW Frost Protection				
Diagram Label	Salt Budget Item	Acres	in/yr	AFY	WQ mg/L	Salt load ton/yr
	Salt inputs					
1	Rainfall percolation	9,700	7	5,658	0	0
2	GW inflow from bedrock			2,217	200	547
3	Percolation from Dry Creek			0	150	0
	Vineyard irrigation water					
4	NSCARP frost protection	0	0	0	432	0
4	NSCARP irrigation	6,100	8.7	4,423	432	2,357
4	GW frost protection	5,500	3.3	1,513	200	373
4	GW irrigation	1,900	11.7	1,853	200	457
5	Orchard & pasture irrigation	400	24	800	200	197
6	Winery wastewater			125	800	123
7	Domestic wastewater			214	800	211
	TOTAL					4,266
	Salt outputs					
	Well pumping					
	Vineyards					
8	Frost protection	5,500	3.3	1,513	200	373
8	Summer irrigation	1,900	11.7	1,853	200	457
9	Orchard & pasture			800	200	197
10	Wineries			250	200	62
11	Domestic			450	200	111
12	Phreatophytes			364	0	0
	GW seepage into Dry Creek					
13	Summer			435	200	107
13	Winter			3,434	200	847
14	GW outflow			334	200	83
	TOTAL					2,238
	Inputs minus outputs					2,028
Basinwide groundwater TDS trend						
	GW volume (Johnson, Table 2) (AF					70,000
	Average rate of increase (mg/L/yr)					23

Table 2, continued

Diagram Label	Salt Budget Item	NSCARP High Irrigation, GW Frost Protection Acres	in/yr	AFY	WQ mg/L	Salt load ton/yr
	Salt inputs					
1	Rainfall percolation	9,700	7	5,658	0	0
2	GW inflow from bedrock			2,217	200	547
3	Percolation from Dry Creek			0	150	0
	Vineyard irrigation water					
4	NSCARP frost protection	0	0	0	432	0
4	NSCARP irrigation	6100	13.7	6,964	432	3,712
4	GW frost protection	5,500	3.3	1,513	200	373
4	GW irrigation	1900	11.7	1,853	200	457
5	Orchard & pasture irrigation	400	24	800	200	197
6	Winery wastewater			125	800	123
7	Domestic wastewater			214	800	211
	TOTAL					5,621
	Salt outputs					
	Well pumping					
	Vineyards					
8	Frost protection	5,500	3.3	1,513	200	373
8	Summer irrigation	1,900	11.7	1,853	200	457
9	Orchard & pasture			800	200	197
10	Wineries			250	200	62
11	Domestic			450	200	111
12	Phreatophytes			364	0	0
	GW seepage into Dry Creek					
13	Summer			1,452	200	358
13	Winter			3,434	200	847
14	GW outflow			334	200	83
	TOTAL					2,489
	Inputs minus outputs					3,132
Basinwide groundwater TDS trend						
	GW volume (Johnson, Table 2) (AF					70,000
	Average rate of increase (mg/L/yr)					36

Table 2, continued

Diagram Label	Salt Budget Item	NSCARP Low Irrigation, NSCARP Frost Protection				
		Acres	in/yr	AFY	WQ mg/L	Salt load ton/yr
	Salt inputs					
1	Rainfall percolation	9,700	7	5,658	0	0
2	GW inflow from bedrock			2,217	200	547
3	Percolation from Dry Creek			0	150	0
	Vineyard irrigation water					
4	NSCARP frost protection	5,500	3.3	1,513	432	806
4	NSCARP irrigation	6,100	8.7	4,423	432	2,357
4	GW frost protection	0	0	0	200	0
4	GW irrigation	1,900	11.7	1,853	200	457
5	Orchard & pasture irrigation	400	24	800	200	197
6	Winery wastewater			125	800	123
7	Domestic wastewater			214	800	211
	TOTAL					4,699
	Salt outputs					
	Well pumping					
	Vineyards					
8	Frost protection	0	0.0	0	200	0
8	Summer irrigation	1,900	11.7	1,853	200	457
9	Orchard & pasture			800	200	197
10	Wineries			250	200	62
11	Domestic			450	200	111
12	Phreatophytes			364	0	0
	GW seepage into Dry Creek					
13	Summer			1,948	200	481
13	Winter			3,434	200	847
14	GW outflow			334	200	83
	TOTAL					2,238
	Inputs minus outputs					2,461
Basinwide groundwater TDS trend						
	GW volume (Johnson, Table 2) (AF					70,000
	Average rate of increase (mg/L/yr)					28

Table 2, continued

Diagram Label	Salt Budget Item	NSCARP High Irrigation, NSCARP Frost Protection Acres	in/yr	AFY	WQ mg/L	Salt load ton/yr
	Salt inputs					
1	Rainfall percolation	9,700	7	5,658	0	0
2	GW inflow from bedrock			2,217	200	547
3	Percolation from Dry Creek			0	150	0
	Vineyard irrigation water					
4	NSCARP frost protection	5,500	3.3	1,513	432	806
4	NSCARP irrigation	6100	13.7	6,964	432	3,712
4	GW frost protection	0	0	0	200	0
4	GW irrigation	1900	11.7	1,853	200	457
5	Orchard & pasture irrigation	400	24	800	200	197
6	Winery wastewater			125	800	123
7	Domestic wastewater			214	800	211
	TOTAL					6,053
	Salt outputs					
	Well pumping					
	Vineyards					
8	Frost protection	0	0.0	0	200	0
8	Summer irrigation	1,900	11.7	1,853	200	457
9	Orchard & pasture			800	200	197
10	Wineries			250	200	62
11	Domestic			450	200	111
12	Phreatophytes			364	0	0
	GW seepage into Dry Creek					
13	Summer			2,964	200	731
13	Winter			3,434	200	847
14	GW outflow			334	200	83
	TOTAL					2,489
	Inputs minus outputs					3,565
Basinwide groundwater TDS trend						
	GW volume (Johnson, Table 2) (AF					70,000
	Average rate of increase (mg/L/yr)					41

Table 3. Change in Recharge TDS Below a Converted Vineyard

Existing	Frost	Irrig	Combined
TDS applied water (mg/L)	200	200	
Inches applied water	2.31	10	12.31
Inches deep percolation			9.31
TDS deep percolation			264

NSCARP Low Irrigation, GW Frost Protection	Frost	Irrig	Combined
TDS applied water (mg/L)	200	500	
Inches applied water	2.31	8.7	11.01
Inches deep percolation			9.31
TDS deep percolation			517

NSCARP High Irrigation, GW Frost Protection	Frost	Irrig	Combined
TDS applied water (mg/L)	200	500	
Inches applied water	2.31	13.7	16.01
Inches deep percolation			11.31
TDS deep percolation			647

NSCARP Low Irrigation, NSCARP Frost Protection	Frost	Irrig	Combined
TDS applied water (mg/L)	500	500	
Inches applied water	2.31	8.7	11.01
Inches deep percolation			9.31
TDS deep percolation			591

NSCARP High Irrigation, NSCARP Frost Protection	Frost	Irrig	Combined
TDS applied water (mg/L)	500	500	
Inches applied water	2.31	13.7	16.01
Inches deep percolation			11.31
TDS deep percolation			708