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TECHNICAL MEMORANDUM

TO: Michael LeBrun, General Manager NCSD

FROM: Brad Newton, Ph.D., P.G.

RE: Technical Memorandum #30 - Fall 2014 Ground Water Index and Hydrologic Inventory Analysis

DATE: December 5, 2014

INTRODUCTION

Groundwater surface elevations (GSE) underlying the Nipomo Mesa are regularly measured at many places (wells) across the mesa. The Fall 2014 Ground Water Index (GWI) has been computed from GSE and presented herein along with historical GWI from 1975 to present based on these groundwater surface elevation measurements collected during spring and fall across the Nipomo Mesa. Limited measurements of GSE were available for the years 1982, 1983, 1984, 1994 and 1997, thus precluding a reliable calculation of GWI for those years.

An alternate approach to estimate how much water is available in storage has been evaluated, and related to the GWI. This water balance approach inventories hydrologic processes and ranks each by determining its correlation to the GWI. The following water balance equations were presented in a simplified form at the August 13, 2014 NCSD Board of Directors meeting:

Land Surface Water Balance

$R = Ru + I_r + E,$

$P = I_p,$

$I_{tot} = I_r + I_p = R + P$, when Ru and E assumed to equal zero,

Soil Profile Water Balance

$\Delta Ss = I_{tot} - CU - Re,$

Substituting for "I_{tot}" and rearranging yields,

$Re = R + P - CU - \Delta Ss;$

Aquifer Water Balance

$\Delta Sgw = Re + F_{in} - F_{out} - P,$

Substituting for "Re",

$\Delta Sgw = R - CU - \Delta Ss + F_{in} - F_{out},$

Summary Water Balance

$GWI \cong \Delta Sgw = R - CU - \Delta Ss + F_{in} - F_{out},$

where:

R	= Rainfall (measured),
Ru	= Runoff (assumed zero),
E	= Evaporation from surface (assumed zero)
I_r	= Infiltration of Rainfall (calculated from water balance),
I_p	= Infiltration of Pumped Water (calculated from water balance),
CU	= Consumptive Use (calculated from land use and climate),
ΔSs	= Change in Soil Storage (calculated from I, CU, and soil properties),
Re	= Recharge (calculated from I_{tot} and ΔSs),
ΔSgw	= Change in Ground Water (calculated from water balance),
F_{in}	= Ground Water Flow In (calculated from groundwater gradients and stratigraphy),
F_{out}	= Ground Water Flow Out (calculated from groundwater gradients and stratigraphy),
P	= Pumped Water (measured).

The Nipomo Mesa Management Area (NMMA) Technical Group (TG) has not reviewed this technical memorandum, its findings, or any presentation of this evaluation.

RESULTS

The Fall 2014 GWI is 47,140 AF, and is the second year of low Fall values (Table 1, Figure 1), and follows the lowest Spring 2014 GWI on record. The 2013 Water Year (WY), where October 1st to September 30th defines the Water Year, rainfall (8.07 inches) was approximately 50 percent of the long-term average (16.55 inches), and the 2014 WY rainfall (5.75 inches) to-date is approximately 35 percent of the long-term average.

The relationship between each hydrologic process, represented in the summary water balance equation, and the GWI was ranked by computing the correlation coefficient. Large correlation coefficient and causality indicates a high efficacy of developing a successful model. Lagged time series showed no improvement in and often greatly degraded the correlation coefficients. The relationship between the cumulative sum of departure from the mean rainfall ($CSDM_r$) and GWI has the highest correlation coefficient, 0.713. The variation in the $CSDM_r$ explains 71% of the variation in the GWI over time. This is anticipated in this basin where groundwater is primarily replenished by rainfall. The second highest correlation exists between Consumptive Use (CU) and GWI explaining an additional 10% of the GWI variation when added to the $CSDM_r$, a total correlation coefficient of 0.816. Thus, 81% of the variation in GWI is

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explained by the combined $CSDM_r$ and CU. Combining $CSDM_r$ and total production resulted in a lesser correlation coefficient of 0.746. Groundwater Flow in to (F_{in}) and out from (F_{out}) the mesa area, together as net flow (Net F), were added to $CSDM_r$ which slightly degraded the overall correlation with GWI; a correlation coefficient of 0.811. However, when $CSDM_r$, CU, and Net F are combined, the overall correlation with GWI improves very slightly. This final correlation coefficient is 0.817 (Tables 2 and 3). Therefore, rainfall amounts are the largest influence on the amount of ground water. The next most important process related to the amount of ground water is consumptive use. A scatter plot was prepared to determine if this correlation is bias over the range of water levels (Figure 2). The slope of the linear trend line is 0.986 suggesting that no bias as a function of groundwater elevation exists.

The 2014 KWI value (18.5 ft msl) has slightly increased from the previous year (17.9 ft msl), and is in the Potentially Severe Water Shortage Condition and remains very close to the Severe Water Shortage Condition (16.5 ft msl). The Key Well Index (KWI) generally follows the same historical trends as the GWI (Figure 1).

METHODOLOGY

The calculation of spring and fall GWI are based on GSE measurements regularly made by San Luis Obispo County Department of Public Works (SLO DPW), NCSD, USGS, and Woodlands. The integration of GSE data is accomplished by using computer software to interpolate between measurements and calculate GWI within the principal production aquifer assuming an unconfined aquifer and a specific yield of 11.7 percent. Limited measurements of GSE were available for the years 1982, 1983, 1984, 1994 and 1997, precluding a reliable calculation of GWI for those years.

Groundwater Surface Elevation Measurements

Groundwater surface elevation data were obtained from SLO DPW, NCSD, USGS, and Woodlands. SLO DPW measures GSE in monitoring wells during the spring (April) and the fall (October) of each year. Woodlands and NCSD measures GSE in their monitoring wells monthly. For the years 1975 to 1999, available representative GSE data were used to compute GWI. For the years 2000 to 2011, only GSE data from the same 45 wells were used to compute GWI.

The GSE data was reviewed in combination with well completion reports and historical hydrographic records in order to exclude measurements that likely do not accurately represent static water levels within the principal production aquifer. Wells that do not access the principal production aquifer or were otherwise determined to not accurately represent static water levels within the aquifer were not included in analysis.

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Groundwater Surface Interpolation

The individual GSE measurements from each year were used to produce a GSE field by interpolation using the inverse distance weighting (IDW) method.

Ground Water Index

The GWI is defined as the annually normalized value of the saturated volume above sea level and bedrock multiplied by the specific yield of 11.7 percent. The GWI is comprised from approximately 45 ground water elevation measurements made by the County of San Luis Obispo each April and October. The value of the Ground Water Index was computed for an area approximately similar to the NMMA Boundary. The base of the saturated volume is mean sea level surface (elevation equals zero) or the bedrock, whichever is higher. The bedrock surface elevation is based on Figure 11: Base of Potential Water-Bearing Sediments, presented in the report, Water Resources of the Arroyo Grande – Nipomo Mesa Area (DWR 2002). The bedrock surface elevation was preliminarily verified by reviewing driller reports obtained from DWR. The specific yield is based on the average weighted specific yield measurement made at wells within the Nipomo Mesa Hydrologic Sub-Area (DWR 2002, pg. 86). The GWI is similar to the Key Well Index presented in the Nipomo Mesa Management Area Technical Group annual report to the Court, but is not directly comparable.

Key Well Index

The Key Well Index (KWI) was developed by the NMMA Technical Group from eight inland wells representing the whole of the groundwater basin within the NMMA. The Key Well Index was defined for each year from 1975 to present as the average of the normalized spring groundwater data from each well. The lowest value of the Key Well Index could be considered the "historical low" within the NMMA.

Hydrologic Inventory

The time series values of the components of the hydrologic inventory used in this analysis were taken from trial exhibits presented during litigation. The correlation coefficient was calculated for each element of the inventory and GWI, and then ranked. Time series were lagged where conditions of system memory are physically feasible.

REFERENCES

Department of Water Resources (DWR). 2002. Water Resources of the Arroyo Grande – Nipomo Mesa Area, Southern District Report. 2002.

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**Spring and Fall
Groundwater Index
(GWI, Acre-Feet)**

Year	Rainfall (inches)	Spring GWI (Acre-Feet)	Number of Wells	Fall GWI (Acre-Feet)	Number of Wells	Spring to Fall Difference (Acre-Feet)
1975	17.29	99,000	54	91,000	54	8,000
1976	13.45	82,000	45	76,000	65	6,000
1977	10.23	64,000	59	54,000	63	10,000
1978	30.66	84,000	62	---	35	---
1979	15.80	72,000	57	77,000	63	(5,000)
1980	16.57	88,000	55	89,000	46	(1,000)
1981	13.39	97,000	46	75,000	47	22,000
1982	18.58	123,000	42	---	31	---
1983	33.21	---	35	95,000	42	---
1984	11.22	---	14	76,000	37	---
1985	12.20	106,000	37	82,000	41	24,000
1986	16.85	98,000	51	67,000	51	31,000
1987	11.29	83,000	48	71,000	52	12,000
1988	12.66	80,000	51	66,000	49	14,000
1989	12.22	59,000	47	47,000	57	12,000
1990	7.12	62,000	55	49,000	53	13,000
1991	13.18	62,000	52	55,000	54	7,000
1992	15.66	61,000	52	35,000	48	26,000
1993	20.17	72,000	54	52,000	61	20,000
1994	12.15	60,000	54	---	36	---
1995	25.87	87,000	35	74,000	52	13,000
1996	16.54	76,000	45	62,000	57	14,000
1997	20.50	---	20	91,000	48	---
1998	33.67	105,000	41	93,000	44	12,000
1999	12.98	106,000	56	88,000	49	18,000
2000	17.07*	108,000	44	84,000	41	24,000
2001	18.52*	118,000	43	85,000	35	33,000
2002	8.87*	96,000	29	79,000	41	17,000
2003	11.39	94,000	37	66,000	42	28,000
2004	12.57	89,000	42	81,000	35	8,000
2005	22.23	98,000	38	79,000	39	19,000
2006	20.83	107,000	44	78,000	41	29,000
2007	7.11	93,000	44	66,000	42	27,000
2008	15.18	83,000	43	65,000	42	18,000
2009	10.31	76,000	44	65,000	43	11,000
2010	20.07	80,000	45	67,000	42	13,000
2011	34.05	87,000	43	81,000	43	6,000
2012	15.35	89,000	45	65,000	44	24,000
2013	8.07*	67,000	45	42,000	43	25,000
2014	5.75*	57,000	45	47,000	42	10,000

---: Insufficient for evaluation
*: Preliminary value

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Table 1: Unitless GWI computed from Spring 1975 to Fall 2013.

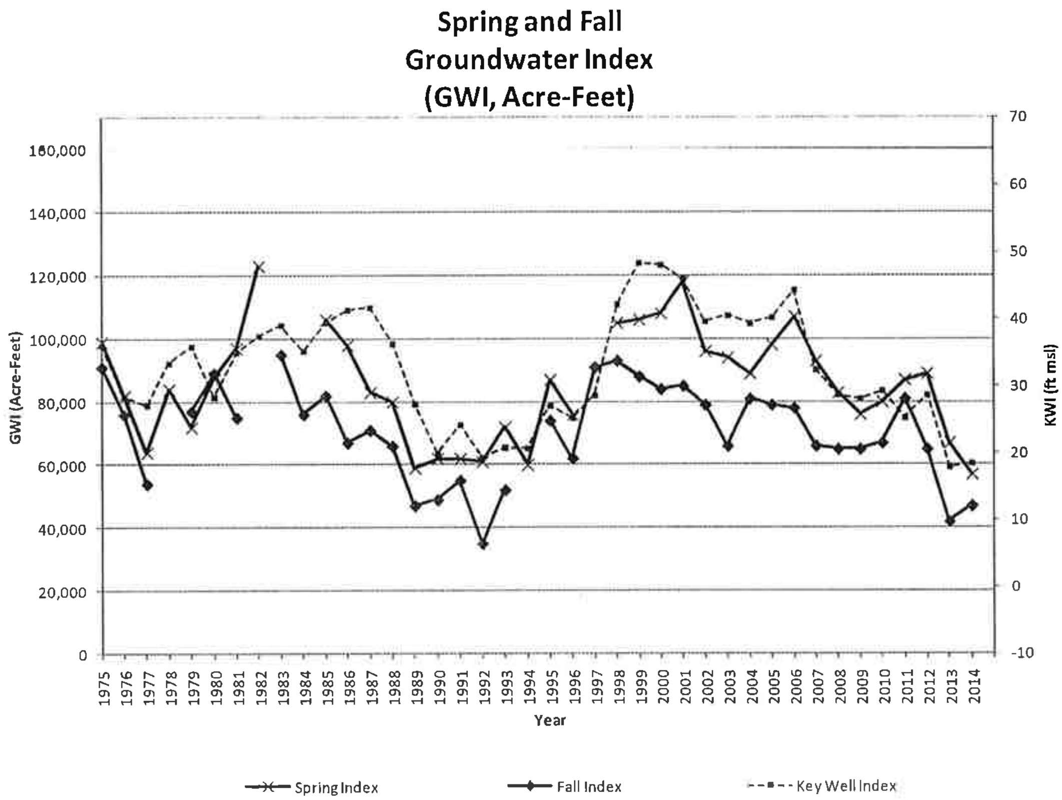

Figure 1: GWI and KWI from 1975 to present.

Year	Spring GWI (AF)	Fall GWI (AF)	Rainfall (in)	CSDM Ave 16.32 (in)	CSDM Ave 16.32 (AF)	CU Prod (AF)	Deep Perc from Rain (AF)	Total CU (AF)	Fin (AF)	Fout (AF)	Fin - Fout (AF)	Total Production (AF)
1975	99000	91000	17.29	17.29	27966.575	3340	2153	29153.575	110	1710	-1600	4420
1976	82000	76000	13.45	14.42	23324.35	3480	890	25914.35	220	1660	-1440	4610
1977	64000	54000	10.23	8.33	13473.775	3760	60	17173.775	400	1670	-1270	5040
1978	84000	77000	30.66	22.67	36668.725	3470	18814	21324.725	340	1610	-1270	4640
1979	72000	89000	15.80	22.15	35827.625	3800	2673	30954.625	410	1630	-1220	5110
1980	88000	75000	16.57	22.40	36232	3920	3241	36911	460	1700	-1240	5280
1981	97000	95000	13.39	19.47	31492.725	4050	1170	34172.725	610	1610	-1000	5500
1982	123000	76000	18.58	21.73	35148.275	4170	3380	35938.275	680	1630	-950	5680
1983		82000	33.21	38.62	62467.85	4110	21564	45013.85	800	1570	-770	5630
1984		67000	11.22	33.52	54218.6	4570	680	58108.6	790	1770	-980	6330
1985	106000	71000	12.20	29.40	47554.5	4640	850	51344.5	810	1720	-910	6420
1986	98000	66000	16.85	29.93	48411.775	5240	3210	50441.775	1030	1720	-690	7200
1987	83000	47000	11.29	24.90	40275.75	5520	790	45005.75	1210	1720	-510	7680
1988	80000	49000	12.66	21.24	34355.7	5640	1190	28806.7	1260	1690	-430	7860
1989	59000	55000	12.22	17.14	27723.95	5840	960	32603.95	1400	1710	-310	8180
1990	62000	35000	7.12	7.94	12842.95	6500	10	19332.95	1490	1710	-220	9230
1991	62000	52000	13.18	4.80	7764	6070	3097	10737	1600	1710	-110	8560
1992	61000	74000	15.66	4.14	6696.45	6070	4315	8451.45	1560	1690	-130	8530
1993	72000	62000	20.17	7.99	12923.825	5980	8895	10008.825	1700	1650	50	8430
1994	60000	91000	12.15	3.82	6178.85	6110	930	11358.85	1740	1670	70	8540
1995	87000	93000	25.87	13.37	21625.975	5860	15193	12292.975	1690	1590	100	8230
1996	76000	88000	16.54	13.59	21981.825	6260	5947	22294.825	1720	1590	130	8770
1997		84000	20.50	17.77	28742.975	6340	11504	23598.975	1770	1530	240	8990
1998	105000	85000	33.67	35.12	56806.6	6640	25257	38189.6	1830	1470	360	9380
1999	106000	79000	12.98	31.78	53404.15	7250	1520	57134.15	1610	1530	80	10230
2000	108000	66000	21.62	37.08	59976.9	7420	2772	64624.9	1600	1610	-10	10530
2001	118000	81000	10.25	31.01	50158.675	7400	8387	49171.675	0	0	0	10570
2002	96000	79000	14.47	29.16	47266.3	7860	0	55026.3	0	0	0	11270
2003	94000	78000	11.39	24.23	39192.025	7630	890	45932.025	0	0	0	10980
2004	89000	66000	12.57	20.48	33126.4	7660	1570	39216.4	0	0	0	11020
2005	98000	65000	22.23	26.39	42685.825	7550	12401	37834.825	0	0	0	10950
2006	107000	65000	20.83	30.90	49980.75	7940	10968	46952.75	0	0	0	11480
2007	93000	67000	7.11	21.69	35083.575	8670	0	43753.575	1400	30	1370	12550
2008	83000	81000	15.18	20.55	33239.025	8290	5974	35555.625	0	0	0	12600
2009	76000	65000	10.31	14.54	23518.45	8580	130	31968.45	0	0	0	12210
2010	80000	67000	20.07	18.29	29584.075							10850
2011	87000	81000	34.05	36.02	58262.35							10538
2012	89000	65000	15.35	35.05	56693.375							11249
2013	67000	42000	8.07	26.80	43349							16349
2014	57000		5.75	16.23	26252.025							

Table 2: Hydrologic Inventory.

Correlation Coefficients		
	Spring GWI (AF)	*Rainfall (inches)*
Spring GWI (AF)	1	
Rainfall (inches)	0.321931649	1
	Spring GWI (AF)	*$CSDM_r$, Ave 16.32 (in)*
Spring GWI (AF)	1	
$CSDM_r$ Ave 16.32 (in)	0.713615266	1
	Spring GWI (AF)	*$CSDM_r$ - Total Production (AF)*
Spring GWI (AF)	1	
$CSDM_r$ - Total Production (AF)	0.746482469	1
	Spring GWI (AF)	*$CSDM_r$ - CU Prod (AF)*
Spring GWI (AF)	1	
$CSDM_r$ - CU Prod (AF)	0.816018004	1
	Spring GWI (AF)	*$CSDM_r$ + Net F (AF)*
Spring GWI (AF)	1	
$CSDM_r$ + Net F (AF)	0.811533071	1
	Spring GWI (AF)	*$CSDM_r$ - CU Prod + Net F (AF)*
Spring GWI (AF)	1	
$CSDM_r$ - CU Prod + Net F (AF)	0.816884199	1

Table 3: Correlation Coefficients.

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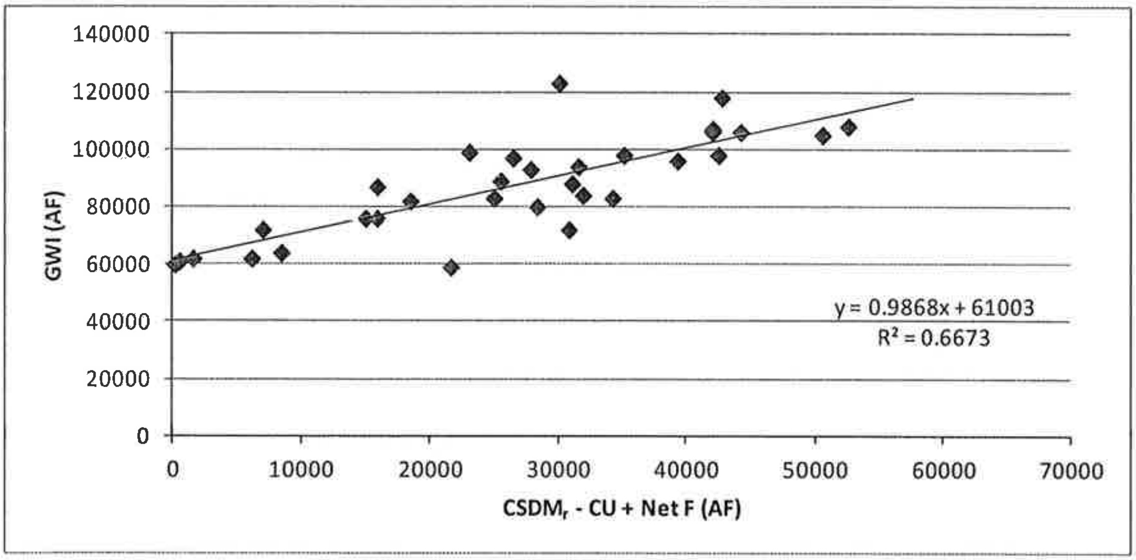

Figure 2: Scatter plot of GWI and CSDMr - CU + Net F data from 1975 to 2009.