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M E M O R A N D U M

DATE: February 10, 2012

TO: Tom Henderson, MT DEQ

FROM: Larry Cawlfield, Bill Thompson

SUBJECT: Sand Coulee Water Use

1.0 INTRODUCTION

The Sand Coulee Water District (District) plans to drill one or more new Public Water Supply (PWS) wells during the upcoming year to supplement or replace their existing aging wells due to declining well yields. This memorandum estimates the Water District's maximum historical water use including total diversion and consumptive use, and compares that with projected future use given an expanded well field capacity. Since the Water District does not have direct documentation available to quantify their historical water use, it was necessary to estimate use from the maximum number of historical service connections, average lawn areas within the water district and average well yields. Although actual use may vary somewhat from the estimated values, the same assumptions are used in establishing historical use and projected use, therefore, the analysis should provide a reliable determination of whether the proposed improvements will result in an increase in the amount of consumptive use compared to the historical maximum diverted by the District. This information is intended to provide a basis for water rights permitting of the new wells and to assess the amount of mitigation, if any, that could be required by DNRC based on potential changes to consumptive use.

2.0 HISTORICAL USE

The District is the claimant of several water rights that supply water for municipal, domestic, and lawn and garden (irrigation) uses. Table 2-1 lists the District's water right claims. The District is supplied water from a well field located atop a bluff just west of the community of Sand Coulee. There are four wells in the well field. However, only two are operational and presently serve the District. The District's wells have a long history of declining production rates over time. The source of this declining production is encrustation of the well screens. Table 2-2 summarizes the characteristics of each of the wells.

TABLE 2-1. SAND COULEE WATER DISTRICT WATER RIGHTS

Water Right No.	Priority Date	Purpose	Source Name	Maximum Flow Rate (gpm)	Maximu m Volume (ac-ft)
41QJ 5056 00	12/31/1918	Multiple Domestic	Groundwater	35	3
41QJ 5057 00	12/31/1918	Municipal	Groundwater	35	48.3
41QJ 5058 00	12/31/1959	Municipal	Groundwater	32	83
41QJ 213044 00	7/5/1960	Municipal	Groundwater	32	45.15
41QJ 6174 00	8/11/1975	Municipal	Groundwater	60	--
41QJ 70692 00	12/20/1988	Municipal	Groundwater	40	40.33

TABLE 2-2 SAND COULEE WATER DISTRICT WELL SUMMARY

Well Number	Date Drille d	Reported Initial Yield (gpm)	Current Yield (gpm)	Current Status
Original #1	1920			Offline due to low yield
1	1960	45	0	Plugged/Abandoned 5/2000
2	1973	60	<5	Taken offline in 2010
3	1999	50	18	Online
4	2008	30	28 (April, 2010)	Online

All of the District's wells have similar completion depths (ranging from 181 feet to 212 feet below ground) and are completed across the lower Kootenai formation and into the coal unit at the top of the Morrison formation.

The population served by the District has decreased over the last 30 years. During 2010, there were 73 active water services within the District (NCI, 2010) all of which are residential single-family dwellings. Historical records are incomplete but the maximum number of documented service connections in the District for which there are records was in the mid to late 1970s with 96 services (Sand Coulee Water District Records). Of this number, two were commercial services (bars) and the remainder (94) was single-family dwellings.

Historical water use estimates were developed based on domestic and irrigation use estimates for the 94 residences. These estimates were then compared to the estimated yield of the well field during that same period to establish whether water use was flow limited during periods of high demand. There are, however, no direct measurements of the available yield of the District's well field and consequently it was necessary to make an estimate. The District had two wells operational during the mid to late 1970s. The District's No. 2 well was installed in 1973 and had a reported yield of 60 gpm. The District's No.1 well had an initial yield of 45 gpm but had been in operation for 15+ years and likely had lost some yield to encrustation of the well screen. No.1 continued to operate until 2000; therefore we assumed a linear decline in well yield over its operational life. Based on this assumption, the projected yield of the No.1 well would have been approximately 25 gpm in the mid to late 1970's giving a total yield for the well field at that time of 85 gpm. Since these reported yields are based on short-term pumping tests at the time the wells were installed we have further assumed that only two-thirds of this yield would have been available for sustained pumping (a standard well design assumption). This results in a sustainable yield for the well field of approximately 57 gpm.

The development of the estimated historical demand and water use for the District is summarized in Tables 2-3 and 2-4, and details are presented below. Hydrometrics estimated the historical domestic use by simply applying per capita water use estimates to the estimated population within the water district based on the maximum number of service connections. According to the 2000 Census, there are approximately 2.47 people per residence in Cascade County (NCI, 2010). This value is assumed to be representative of the District. Based on this value, the peak population within the District was approximately 232 people [94 single family residences multiplied by 2.47 people per residence].

The Montana Department of Environmental Quality (DEQ) requires that in the absence of measured water use, small communities design for an average domestic use of 100 gallons per capita per day (gpcd) (DEQ, 2006). Consequently, a reasonable estimate of average domestic use is 23,200 gallons per day (gpd) [100 gpcd multiplied by 232 people], which is the equivalent of approximately 16 gpm, or 26 acre-feet per year.

To estimate historical water use for irrigation of lawns, the average acreage of irrigated lawn per residence within the water district was estimated by examining aerial photos and delineating lawns within the District in a representative section of the town where there is minimal tree cover and clearly defined lot boundaries (Figure 2-1). A representative area was selected because mature tree cover and limited photo resolution make it difficult to accurately quantify irrigated areas over the entire town. It was necessary to rely on current aerial photos to delineate irrigated lawn area since the resolution of historical photos was insufficient for this purpose; however, this is believed to produce a reasonable approximation of the conditions in the 1970s since residential development has not changed significantly in this area since that time.

TABLE 2-3. ESTIMATED HISTORICAL IRRIGATION DEMAND VERSUS AVAILABLE YIELD					
Application Period		**Net Monthly Lawn Irrigation Requirement (IWR)**		**Adjusted Total Irrigation Diversion Requirement(3)**	**Available Yield from Wellfield for Irrigation(4)**
Month	**No. days**	**Inches (1)**	**Acre-Feet(2)**	**Acre-Feet**	**Acre-Feet**
April	7	0.42	0.39	0.49	1.1
May	31	2.36	2.2	2.8	5.1
June	30	4.05	3.8	4.8	4.9
July	31	5.69	5.3	**6.7**	5.1
August	31	4.87	4.6	**5.7**	5.1
September	30	2.59	2.4	3.0	4.9
October	17	0.58	0.55	0.68	2.8
Annual	177	20.56	19.3	24.2	28.8

1. IWR calculated net irrigation requirement (consumptive use) in inches of water based on climate data from the Great Falls Weather Service Office.
2. Net irrigation volume based on 11.3 irrigated acres of lawn
3. Adjusted total irrigation requirement (consumptive use multiplied by 1.25) to account for application efficiency. Bolded values exceed available yield.
4. Calculated available yield from wellfield based on pumping rate of 56 gpm (72 gpm max pumping rate less 16 gpm for domestic use). Assumes sustained pumping at two-thirds of max well yield.

INPUT ASSUMPTIONS

94	services	historical maximum (1 service per single-family dwelling)
232	residents	94 residences x 2.47 people per residence
100	gpcd	average domestic use per household
26.0	ac-ft/yr	total domestic use
16.1	gpm	average pumping rate to meet total domestic use
72	gpm	max historic pumping rate
55.9	gpm	net available yield for irrigation
94	yards	total # yards
0.12	acres	irrigated acres per yard
11.3	acres	total acres irrigated

TABLE 2-4

Month	Irrigation Diversion (acre-feet)[1]	Consumptive Use (acre-feet)[2]
April	0.49	0.39
May	2.8	2.2
June	4.8	3.8
July	5.6	4.5
August	5.6	4.5
September	3.0	2.4
October	0.68	0.55
Annual	**24.2**	**19.3**

Notes:

1. Estimated by month as the smaller diversion requirement or the available diversion from Table 2-3.
2. Obtained by multiplying the Historical Diversion by an assumed efficiency of 80%.

LEGEND

Irrigated lawn area

Lots showing minimal irrigation

scale (ft)

0 100 200 300

Site No.	Lawn Area (ft2)	Lawn Area (acres)
1	3604	0.08
2	6767	0.16
3	6742	0.15
4	4227	0.10
5	7438	0.17
6	8527	0.20
7	1916	0.04
8	2414	0.06
9	5792	0.13
10	7172	0.16
11	5139	0.12
12	unirrigated	0.00
13	unirrigated	0.00
14	unirrigated	0.00
15	5182	0.12
16	5891	0.14
17	2838	0.07
18	5340	0.12
19	6389	0.15
20	9079	0.21
21	unirrigated	0.00
22	12475	0.29
23	20965	0.48
24	unirrigated	0.00
25	10030	0.23
26	7539	0.17
27	7539	0.17
28	4205	0.10
29	unirrigated	0.00
30	4263	0.10
31	7713	0.18
32	4190	0.10
Average		**0.12**

SAND COULEE HISTORICAL WATER USE ASSESSMENT	REPRESENTATIVE IRRIGATED LAWN AREA IN SAND COULEE	FIGURE 2-1

k:/project/10039/water rights/sand coulee lots.srf

The irrigated lawn areas are shown in Figure 2-1. The average irrigated lawn area is 0.12 acres per residence. Applying these assumptions to the 94 single-family residences that were historically served by the Water District results in an estimated total irrigated area within the district of 11.3 acres. The estimated irrigation demand was then calculated for this lawn area using a computer program called Irrigation Water Requirement (IWR) developed by the NRCS (2003). Water use was calculated based on climate data from the Great Falls Weather Service Office. For lawns, a surrogate crop of pasture grass was assumed under dry year conditions (per recommendation of James Hefner, DNRC (Pers. Communication, 2010)).

The IWR estimated irrigation requirements are shown in Table 2-3 and are assumed to represent the amount of water that would be used if the well capacity were sufficient to provide full irrigation throughout the irrigation season. Since the District has not always been able to meet full irrigation requirements, the estimated monthly irrigation demand was compared to the available monthly yield from the well field to identify months when full irrigation may not have been available. As previously described, the sustainable yield of the well field at that time was estimated to be 57 gpm. Up to 16 gpm of this amount would have been necessary for domestic use, which leaves a remaining capacity of 51 gpm available for irrigation of lawns and gardens. The total available yield from the well field is estimated on a monthly basis and compared to the estimated irrigation requirements in Table 2-3. Based on these numbers, the available yield of the well field was not sufficient to provide a full water supply to lawns during peak demand months (July and August). During these months water users would have been limited to the maximum available yield of the system. The full irrigation requirement would potentially have been available the remaining months. Table 2-4 lists estimated diversions and consumptive use based on this schedule.

As indicated above the historical diversion from irrigation is estimated to be approximately 24.2 acre-feet. The total diversion for domestic use plus irrigation would have been 50.2 acre-feet per year (26.0 acre-feet domestic plus 24.2 acre-feet irrigation). Assuming 10% of the domestic use is consumptive (a typical assumption) results in a total historical consumptive use of 21.9 acre-feet (2.6 acre-feet domestic use plus 19.3 acre-feet irrigation).

3.0 PROJECTED FUTURE USE

Projected future water use for the District and projected yields from the new well field are summarized in Table 3-1. The estimates of current irrigation diversions and consumptive use differ from the historical diversion analysis in Tables 2-3 and 2-4 in two ways. First, the District's population has been decreasing over time. There are now only 73 water services in the District. Assuming 2.47 residents per service equates to a current service population of approximately 180 residents. Assuming as before a demand for domestic water of 100 gpcd, the estimated future diversion for domestic use is approximately 20 acre-feet per year or the equivalent of 15.6 gpm.

Second, if the proposed wells increase the yield to 100 gpm as intended, then there will be approximately 84 gpm available for irrigation [100 gpm yield minus 16 gpm domestic use], compared with the 41 gpm available under the historic use assumptions. Current and future

TABLE 3-1. CURRENT IRRIGATION DEMAND VERSUS PROJECTED YIELD WITH NEW WELLS					
Application Period		Net Monthly Lawn Irrigation Requirement (IWR)		Adjusted Total Irrigation Diversion Requirement[(3)]	Available Yield from Wellfield for Irrigation[(4)]
Month	No. days	Inches[(1)]	Acre-Feet[(2)]	Acre-Feet	Acre-Feet
April	7	0.42	0.31	0.38	1.8
May	31	2.36	1.72	2.2	7.9
June	30	4.05	2.96	3.7	7.7
July	31	5.69	4.15	5.2	7.9
August	31	4.87	3.56	4.4	7.9
September	30	2.59	1.89	2.4	7.7
October	17	0.58	0.42	0.53	4.3
Annual	177	20.56	15.01	18.8	45.2

1. IWR calculated net irrigation requirement (consumptive use) in inches of water based on climate data from the Great Falls Weather Service Office.
2. Net irrigation volume based on 8.8 irrigated acres of lawn
3. Adjusted total irrigation requirement (consumptive use multiplied by 1.25) to account for application efficiency.
4. Calculated available yield from wellfield based on pumping rate of 87 gpm (100 gpm max pumping rate less 13 gpm for domestic use). Assumes sustained pumping at two-thirds of max well yield.

INPUT ASSUMPTIONS

73	services	2010 single family dwellings (1 service per dwelling)
180	residents	73 residences x 2.47 people per residence
100	gpcd	average domestic use per household
20.2	ac-ft/yr	total domestic use
12.5	gpm	average pumping rate to meet total domestic use
100	gpm	projected pumping rate
87.5	gpm	net available yield for irrigation
73	yards	total # yards
0.12	acres	irrigated acres per yard
8.8	acres	total acres irrigated

irrigation demands are calculated in Table 3-1 using similar assumptions to the historical use analysis, but are based on the current number of service connections (73) and a higher system capacity (100 gpm). Results indicate a total irrigation demand of approximately 18.8 acre-feet.

Adding the 20 acre-feet of domestic use yields a total diversion volume of 39 acre-feet per year. Assuming that essentially 10% of the domestic uses are consumptive, and that the consumptive use from irrigation is 80% of the total irrigation diversion (as previously), then the projected consumptive use is approximately 17 acre-feet (2.0 acre-feet domestic plus 15.0 acre-feet irrigation). The results are summarized in Table 3-2, which compares historical use to projected use.

TABLE 3-2. SUMMARY OF RESULTS COMPARING HISTORICAL USE AND PROJECTED USE

	Estimated Historical Use (ac-ft/yr)	**Projected Use (ac-ft/yr)**
Diversion Amount		
Domestic Use	26.0	20.2
Irrigation Use	23.0	18.8
Total	49.0	39.0
Consumptive Use		
Domestic	2.6	2.0
Irrigation	16.6	15.0
Total	19.2	17.0

Even with a higher projected yield and the ability to meet full irrigation demand, the total projected consumptive use (17 acre-feet) is less than historical consumptive use (19.2 acre-feet) due to the decrease in the number of service connections and the resulting decrease in the estimated total irrigated acres (from 11.3 to 8.8 acres). Since the projected consumptive use is less than peak historical consumptive use, mitigation should not be necessary for the proposed modifications; however, it should be noted that DNRC would ultimately make this determination based on their own review. Since there is limited documentation of historical pumping rates, this analysis incorporates numerous assumptions to estimate historical use. Although we have relied to the extent possible on well-established assumptions in the development of these estimates, there are no explicit protocols for developing historical water use estimates for residential lawns. Consequently, DNRC may utilize different assumptions when reviewing application materials for the proposed modification. The conclusions presented here should therefore not be considered definitive until DNRC has completed technical review of a complete water rights application.

4.0 REFERENCES

DEQ, 2006. Circular DEQ-3, Standards for Small Water Systems. Montana Department of Environmental Quality. February 24, 2006.

NCI, 2010. Water System Preliminary Engineering Report. NCI Engineering Inc, Great Falls, MT. April, 2010.

NRCS, 2003. Irrigation Water Requirements. Version 1.0. March 1, 2003

Historical Records for the Sand Coulee Water District. Obtained from Mr. Kent Luoma 2011.

ATTACHMENT A

IRRIGATION WATER REQUIREMENTS

Irrigation Water Requirements
Crop Data Summary

Job: **Example**
Location: **Sand Coulee**
By: **JH**
Weather Station: **GREAT FALLS WSCMO AIRPO**
Latitude: **4729** Longitude: **11122**
Computation Method: **Blaney Criddle (TR21)**
Crop Curve: **Blaney Criddle Perennial Crop**
Begin Growth: **4/19** End Growth: **10/18**

Crop: **Pasture (grass)**
County: **Cascade, MT**
Date: **08/09/10**
Sta No: **MT3751**
Elevation: **3660** feet above sea level

Net irrigation application: **1** inches
Estimated carryover moisture used at season:
Begin: **0.25** inches End: **0.25** inches

Month	Total Monthly ET (3) inches	Dry Year 80% Chance (1)		Normal Year 50% Chance (1)		Average Daily ETc inches	Peak Daily ETPk inches
		Effective Precipitation inches	Net Irrigation Reqirements inches (2)	Effective Precipitation inches	Net Irrigation Reqirements inches (2)		
January	0.00	0.00	0.00	0.00	0.00	0.00	
February	0.00	0.00	0.00	0.00	0.00	0.00	
March	0.00	0.00	0.00	0.00	0.00	0.00	
April	0.86	0.19	0.42	0.25	0.36	0.07	
May	3.30	0.94	2.36	1.24	2.06	0.11	0.12
June	4.98	0.93	4.05	1.22	3.76	0.17	0.20
July	6.37	0.67	5.69	0.88	5.48	0.21	0.26
August	5.60	0.73	4.87	0.95	4.64	0.18	0.22
September	3.06	0.48	2.59	0.63	2.44	0.10	0.12
October	1.03	0.20	0.58	0.26	0.52	0.06	
November	0.00	0.00	0.00	0.00	0.00	0.00	
December	0.00	0.00	0.00	0.00	0.00	0.00	
TOTAL	**25.18**	**4.13**	**20.55**	**5.43**	**19.26**		

(1) For 80 percent occurrence, growing season effective precipitation will be equaled or exceeded 8 out of 10 years. For 50 percent chance occurrence, effective precipitation will be equaled or exceeded 1 out of 2 years.

(2) Net irrigation requirements is adjusted for carryover moisture used at the beginning of the season and carryover moiature used at the end of the growing season.

(3) ET Evapotranspiration) is adjusted upwards 10% per 1000 meters above sea level.

Date: 8/9/2010