Matching Irrigation Water Delivery on Irrigated Pasture to Local Transpiration and a Comparison with the Proposed CSKT Compact Water Use Agreement Irrigation Water Delivery-St. Ignatius, MT July – September, 2012

By

J.R. (Jerry) Laskody*

I. Introduction

As a result of proposed Flathead Irrigation Project water deliveries specified in the CSKT Water Use Agreement, the author began a study of applied water on MacDonald silt loam soils on irrigated pastures located approximately 5 miles Northeast of St. Ignatius, Montana. (T19NR19W Sec 29 W ½ of the SE ¼) The author measured pressure at the midpoint of a wheel line sprinkler system at several field positions and using sprinkler nozzle data obtained from the Bureau of Reclamation (BuRec)'s Agrimet Irrigation Guide (Ref.1) and determined the water delivery from the sprinkler system during an irrigation set. Irrigation scheduling was determined by using the Kimberly-Penman evapo-transpiration data for pasture grass obtained from the BuRec Agrimet Station located at the St. Ignatius Airport (SIGM) (Ref.2) to determine water transpired from pasture grass. The soil is assumed to hold 2 inches of water per foot of soil, the rooting depth is assumed to be two feet and the 50% depletion is assumed at wilt (Ref. 1). (These are typical values for the MacDonald soil types 105 and 106 in a pasture application.) This then implies a requirement for two (2) inches of water in the root zone to meet the plant's requirements. The land in question has a duty rating of 2.0 and the basic quota in 2012 was 12 inches. Thus target water delivery was 24 inches for the irrigation season. It should be pointed out that the land's duty is not recognized in the proposed CSKT Water Use Agreement although it represents historic usage in the Flathead Irrigation Project.
The analysis contained herein conclusively demonstrates that the Compact proposed allocations of water in the Mission Irrigation District of the Flathead Irrigation Project are significantly less (52 % less) than historic usage, thus refuting the Compact Commission's repeated assertions that "...historic usage is protected in the Compact...".

II. Analysis

The typical irrigation process is to fill the soil profile with an irrigation set, wait until the two inches of water has been transpired by the plant and then re-fill the profile, continuing this process throughout the growing season. Since the transpiration varies as a strong function of weather conditions and since the actual delivery of water from the nozzle to the root zone is not 100% efficient (strongly driven by atmospheric conditions also) the time between repeat irrigations is not necessarily a constant time interval. In cool, humid, and calm conditions it is a longer interval than when the weather is hot, dry, and windy. For example if the average transpiration is 0.25 inches /day, and our irrigation efficiency was 67% and our nozzle delivery was 3 inches per set, we Would deliver 2 inches of water to the root zone (3.0 inches/set x 0.67=2.0) every 8 days (2.0 inches/0.25 inch/day=8 days). In the specific case reported here, the transpirations rates were closer to 0.2 inches per day and so the irrigation cycle was repeated every 10 days (2.0 inches/ 0.20 inches/day = 10 days).

The big unknown in this scheduling is "what is the irrigation efficiency?" Measurements have been made on our ranch in hot (95°F,) dry (10%-15% relative humidity), and windy conditions (10mph and gusting) of 46%. This implies that 54% of the water issuing from the nozzle never gets into the ground! It is possible that for a few hours during the night, when the temperatures are cool (55°F), it's humid (>80% relative humidity) and calm and perhaps the irrigation efficiency may reach 70% for short time period. The Montana State University Irrigation Guide (Ref.3) and the BuRec's Agrimet Irrigation Guide recommend irrigation efficiencies 65% for wheel line sprinklers and hand line sprinklers, but based on my experience, 60% is a better value for ambient conditions here in the Mission Valley. Nonetheless, required applied water was determined using a range of efficiencies to show the impact of efficiency on applied water to meet plant needs

The attached sheets graphically display the daily transpiration as measured at the SIGM site approximately 4 miles from our ranch, as well as the individual daily transpiration data. From the time period of July 2, 2012 through September 16, 2012, summing the daily transpiration data yields a value of 14.67 inches of transpired water from the plants. We had 0.8 inches of precipitation during this time period, and assuming 100% irrigation efficiency for the rainfall, would yield a net transpiration requirement of 13.87 inches to be supplied to the root zone to meet plant requirements. (It should be noted the pastures were used in a rotational grazing system for 16 cow calf pairs, 2 first calf heifers a mature bull and a butcher steer so actual transpiration requirements might have been greater. Nonetheless, grass pasture evapo-transpiration data was used to determine plant needs and hence irrigation scheduling.)

Assuming efficiencies of 60%, 65%, and 70%, would imply that for these conditions 23.1 inches, 21.3 inches and 19.8 inches of applied water respectively would be required to meet plant demands.

An analysis of the water actually applied during this time period utilized information from the BuRec Agrimet Irrigation Guide for 13/64" nozzles operating at mean pressures of 49 psi on 40x60 spacing. These yields 0.34 inches of applied water per hour, so for an 11 hour set, 3.74 inches of water would be delivered per set. My records for the E ½ of the N40 (20 acres) show six irrigations in this time period so total delivered water during this time period was 22.4 inches. Additionally, due to abnormally dry conditions, one irrigation in

May, 2012 was needed, so this put the total irrigation requirement for the 2012 irrigation year at 26.1 inches. This compares with the 12.5 inches of delivered water proposed for Mission Irrigation District delivery in the 2012 CSKT Compact Water Use Agreement.

The above data represents one irrigation season and does not take into account yearly variations. The standard deviation of transpiration during this time period, based on a 20 year sample from 1992-2011 in Ref. 4 implies the expected standard deviation of transpiration from year to year to be about +/- 10% of the average for the measured monthly time interval. Applying that to the 2012 data for the July2-September 16 would imply a +/- 1.4 inches variation of Etosgr. This would lead to an expected yearly variation in applied water of 2.3 inches (eta =0.6), 2.1 inches (eta=0.65) and 2.0 inches (eta=-0.7). So natural yearly variations in evapo-transpiration cannot explain the allocation quantities proposed in the CSKT Water Use Agreement.

Based on this analysis, the CSKT Compact Water Use Agreement proposes to deliver 52% less water to our ranch than our historic usage!

III. Conclusions

The above results conclusively demonstrate that:

1. The historic Flathead Irrigation Project water deliveries are significantly greater than the proposed delivery in the CSKT Water Use Agreement for irrigators in the Mission Irrigation District. It also validates the use of the duty system for water allocations. This data counters the oft repeated claim by the Montana Reserved Water Rights Compact Commission (COMCOMM) that "...historic usage is protected..." in the CSKT Compact.
2. Since the proposed water delivery was based on CSKT's HYDROSS modeling of the irrigation system and average cropping distributions within the Project, the data presented herein point to a gross error in the modeling/cropping assumptions. The COMCOMM was also apparently concerned about the use of HYDROSS for quantification purposes as noted in their October 25, 2010 letter to the CSKT (Ref.5)
3. This under prediction of water delivery results from flawed modeling of the system by the CSKT and the unwillingness of the CSKT and the COMCOMM to utilize actual "on ranch" usage data to calibrate the HYDROSS model. Calibration of model results to accurate data sets is an absolute necessity! The author proposed this course of action to the Flathead Joint Board of Control and their consultant and also to the COMCOMM in 2012. No response from either party was ever received to this proposal.

IV. Recommendations

In a June, 2013 meeting with Duane Meacham, the Solicitor for the Portland Regional Office of the BIA , stated that in all the compacts the BIA was involved in, irrigators "...never lost a single drop of water as a result of the compacting process". While the results presented herein are taken from a single ranch in the Mission Irrigation District, the gross error between the CSKT Water Use Agreement proposed irrigation water deliveries and the actual plant transpiration required applied water, demand that the *entire question of water delivery* in the Compact Water Use Agreement be *critically* scrutinized.

Further, this scrutiny should be conducted in a public forum, by independent agronomists and others independent experts familiar with the irrigation systems. Such scrutiny must include on farm measurements of representative farms and ranches in all the irrigation districts in the Flathead Irrigation Project. Only then can "historic use" be quantified, only then can irrigators have assurance that they will not lose a single drop of water in this adjudication.

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*The author holds a B.S. Aeronautical Engineering from Purdue University (1965) and an M.S. Engineering (1972) from the University of Washington. Employed as a Propulsion Engineer by the Boeing Company for 34+ years, he was a member of the NASA Aeronautics Propulsion Systems Advisory Committee from 1996 until his retirement in 1999. Retiring as Chief Engineer-Propulsion Research & Preliminary Design, his career specialty was Propulsion Aerodynamics and encompassed both theoretical and empirical work. He was responsible for development of performance specification for propulsion systems and validation methods to verify installed performance as well as the aerodynamic development of engine nacelles. He holds three US Patents for propulsion related devices and led developments teams on the 757, 7J7, 777, 737NG Programs and was Propulsion System Manager for the NASA/Boeing/Douglas High Speed Civil Transport (HSCT) Program. He and his wife operate a small, irrigated cattle ranch near St. Ignatius, MT. Mr. Laskody is Chairman of the Mission Irrigation District in the Flathead Irrigation Project.

V. References

1. "Agrimet Irrigation Guide", US Bureau of Reclamation Agrimet Website
2. "Crop Water Usage-SIGM- 2012" US Bureau of Reclamation Agrimet Website
3. Irrigation Water Management When and How Much to Irrigate" Montguide MT8901, Revised September , 1990
4. "Crop Water Usage-Evapotranspiration Totals and Averages 1992-2011-SIGM" US Bureau of Reclamation Agrimet Website
5. Letter dated October 25, 2010, Bill Schultz (RWRCC) to Clayton Matt (CSKT) Re: Review of HYDROSS Model Jocko and Mission Baseline Condition

VI. Nomenclature

Etosgr - Kimberly-Penman daily transpiration for pasture grass~ inches

aveEtosgr - monthly average Etosgr ~inches

sumEtosgr - ∑ Etosgr in a given month ~inches

stddev - standard deviation of daily Etosgr during given month ~inches

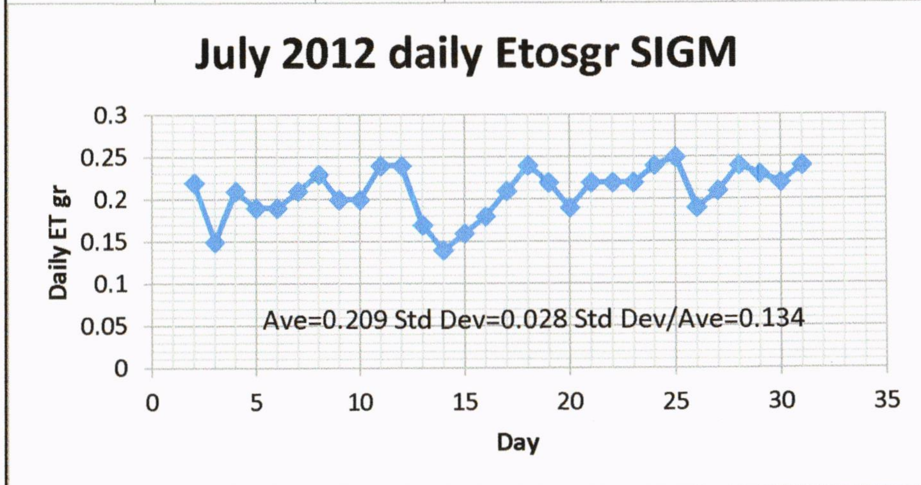
stddev/ave - stddev /aveEtosgr (dimensionless)

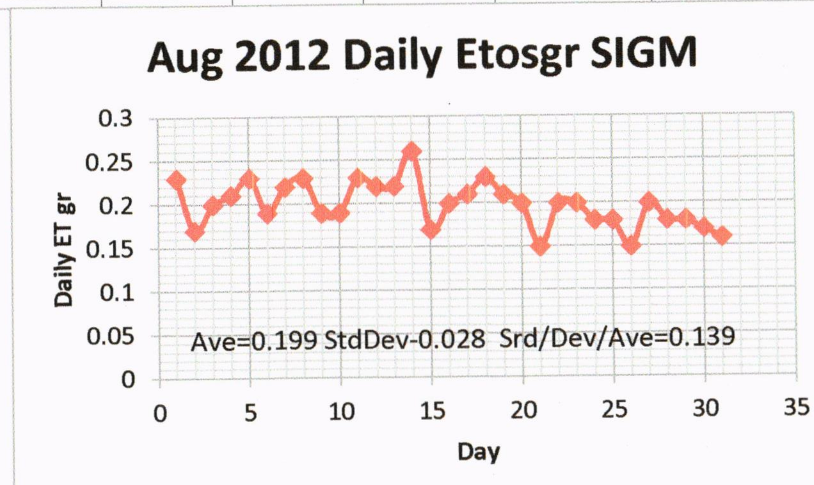
Precip - monthly precipitation ~inches

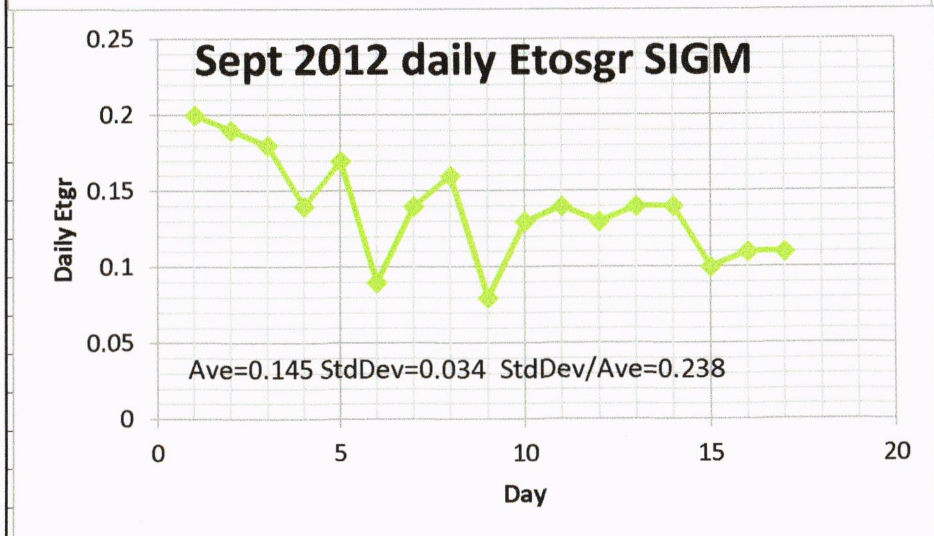
eta-irrigation efficiency =applied water reaching the root zone/applied water (dimensionless)

Etosgr Data-SIGM

					Summary of Results						
	July '12	Aug '12	Sept '12		tot Etosgr		Net Etosgr		eta*	Applied H2O	Actual Appld
ave Etosgr	0.209	0.199	0.145		14.67	inches T	13.87			7/2 to9/16	H20
sum Etosgr	6.270	6.160	2.24						0.6	23.12	
std dev	0.028	0.028	0.034						0.65	21.34	22.4
stdev/ave	0.134	0.139	0.238						0.7	19.81	
Precip	0.8	0	0						* -irrigation efficency		







Etosgr Data-SIGM

			Kimberly - Penman Evapotranspiration-SIGM July 2-September 17, 2012		
July	**Etos(grass)**	**August**	**Etos(grass)**	**Sept**	**Etos(grass)**
		1	0.23	1	0.2
2	0.22	2	0.17	2	0.19
3	0.15	3	0.2	3	0.18
4	0.21	4	0.21	4	0.14
5	0.19	5	0.23	5	0.17
6	0.19	6	0.19	6	0.09
7	0.21	7	0.22	7	0.14
8	0.23	8	0.23	8	0.16
9	0.2	9	0.19	9	0.08
10	0.2	10	0.19	10	0.13
11	0.24	11	0.23	11	0.14
12	0.24	12	0.22	12	0.13
13	0.17	13	0.22	13	0.14
14	0.14	14	0.26	14	0.14
15	0.16	15	0.17	15	0.1
16	0.18	16	0.2	**16**	0.11
17	0.21	17	0.21	17	0.11
18	0.24	18	0.23	18	0.13
19	0.22	19	0.21	19	0.12
20	0.19	20	0.2	20	0.11
21	0.22	21	0.15	21	0.1
22	0.22	22	0.2	22	0.08
23	0.22	23	0.2		
24	0.24	24	0.18		
25	0.25	25	0.18		
26	0.19	26	0.15		
27	0.21	27	0.2		
28	0.24	28	0.18		
29	0.23	29	0.18		
30	0.22	30	0.17		
31	0.24	31	0.16		

DOWL HKM

Memorandum

TO: John Carter and Rhonda Swaney
CSKT Legal Department

FROM: Wade Irion P.E., DOWL HKM

DATE: June 6, 2014
H:\25\20083\Correspondance\20140606 Review of Laskody Report.docx

SUBJECT: Review of J.R. Laskody's Analysis "Matching Irrigation Water Delivery on Irrigated Pasture to Local Transpiration and a Comparison with the Proposed CSKT Compact Water Use Agreement Irrigation Water Delivery –St. Ignatius, MT July – September, 2012"

This memorandum presents a summary of our review of the above-referenced report prepared by J.R. Laskody. Mr. Laskody irrigates a 58 acre pasture just east of the Mission B Canal, roughly 5 miles northeast of St. Ignatius. The pump for his parcel draws from the 21A lateral which is served directly from the main Pablo Feeder Canal. Our findings are presented as follows.

Determination of Theoretical Net Irrigation Requirement

Definitions of the following terms are provided to give context to the discussions provided below:

> **Potential Evapotranspiration (ET)** consists of water evaporated from the soil surface, water intercepted by the plants, and water transpired by the plants. Potential Evapotranspiration is an upper benchmark and requires full water supply at all times and ideal water management in order to be achieved.
>
> **Effective Precipitation (Pe)** is the amount of precipitation that can be used to offset crop water requirements.
>
> **Net Irrigation Requirement (NIR)** is the amount of irrigation water required to fully meet the theoretical maximum potential crop consumption (ET – Pe).

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Crop Irrigation Consumption (CIC) is the amount of irrigation water actually consumed by the crop; which is typically less than the theoretical maximum NIR, due to less than perfect water management and less than full water supply.

The study performed by Mr. Laskody is essentially a Net Irrigation Requirement (NIR) evaluation. As such, the evaluation assumes that the crops are receiving a full supply of irrigation water and that the irrigation is managed in such a manner to achieve potential evapotranspiration. It should also be noted that, water supply and water management aside, the impact of concurrent grazing on the irrigated pasture may limit the opportunity for the stand of pasture grass to achieve its full potential for water consumption.

The methods for determining the theoretical maximum Net Irrigation Requirement (NIR) presented in the Laskody report are generally similar to the methods employed by DOWL HKM. The primary differences are:

1. DOWL HKM used the Hargreaves Equation calibrated to the FAO-56 Penman-Monteith Equation. Mr. Laskody utilized the Bureau of Reclamation AgriMet evapotranspiration which is based on the Kimberly-Penman Equation.
2. DOWL HKM used a data set of March through November 1951 to 2007, with the period 1983 to 2002 used in the HYDROSS water budget models. Mr. Laskody used data only from July through September 2012 for his analysis and conclusions.

July through September 2012 is on the extreme dry end of the spectrum (requiring the highest amount of irrigation water) in comparison to climatic conditions throughout the years. Table 1 shows where 2012 falls relative to the 1983-2002 study period based on total precipitation at the St. Ignatius AgriMet station during the irrigation season (May through September) and also during the July through September period selected for analysis by Mr. Laskody.

Table 1 – Precipitation at the St. Ignatius AgriMet Station (in Inches) – 1983 through 2002 in comparison to 2012

Year	May	June	July	August	September	Season	July-September	Dryness Ranking (Jul-Sep)
1983	2.43	3.86	3.42	1.02	1.38	**12.11**	**5.82**	**19**
1984	1.56	1.95	0.31	1.23	1.32	**6.37**	**2.86**	**9**
1985	2.08	0.74	0.07	3.54	3.62	**10.05**	**7.23**	**21**
1986	2.49	3.25	0.98	0.96	3.15	**10.83**	**5.09**	**15**
1987	2.24	1.79	3.54	1.54	0.51	**9.62**	**5.59**	**18**
1988	4.15	0.87	0.59	0.28	1.09	**6.98**	**1.96**	**5**
1989	2.03	1.47	1.38	2.80	2.38	**10.06**	**6.56**	**20**
1990	3.13	1.66	1.69	1.49	0.07	**8.04**	**3.25**	**10**
1991	1.90	3.89	0.46	0.98	0.68	**7.91**	**2.12**	**7**
1992	0.59	2.11	1.91	1.46	1.74	**7.81**	**5.11**	**16**
1993	1.14	2.57	3.00	1.61	0.87	**9.19**	**5.48**	**17**
1994	1.88	1.94	0.28	0.10	0.40	**4.60**	**0.78**	**1**
1995	2.08	2.62	1.21	1.38	1.48	**8.77**	**4.07**	**13**
1996	2.89	1.59	0.59	0.13	1.24	**6.44**	**1.96**	**4**
1997	2.38	2.64	1.89	1.16	1.05	**9.12**	**4.10**	**14**
1998	3.63	3.88	2.41	0.27	0.66	**10.85**	**3.34**	**11**
1999	1.21	1.70	0.48	0.85	0.38	**4.62**	**1.71**	**3**
2000	2.46	0.40	1.18	0.14	2.71	**6.89**	**4.03**	**12**
2001	0.32	4.44	1.74	0.05	0.30	**6.85**	**2.09**	**6**
2002	2.93	3.49	0.88	0.61	0.96	**8.87**	**2.45**	**8**
2012	2.53	3.34	0.70*	0.01	0.00	**6.58**	**0.80***	**2**

*0.80 per Laskody. AgriMet published records for July 2012 is missing daily data for 11 days (July 5 through July 15).

Compared to the precipitation in 2012, there are four years during the 1983-2002 study period with lower May through September precipitation but only one year with lower July through September precipitation (1994).

As expected, the NIR results from the two studies are not identical but they are in reasonable agreement when comparing comparable years. The DOWL HKM NIR for July through September 1994 is 12.31 inches at the St. Ignatius Agrimet station; which compares to Mr. Laskody's estimate of 13.87 inches for this same period in 2012 (see Table 2). Again, 1994 is the driest year, with the highest Jul-Sep irrigation requirement throughout the study period.

Table 2 – July through September Net Irrigation Requirement for Pasture Grass at St. Ignatius AgriMet Station from Dowl HKM Crop Water Requirements work

Year	Irrigation Consumptive Index	Jul – Sep Evapotranspiration (Inches)	Jul-Sep Effective Precipitation (Inches)	Jul-Sep Full-Supply Net Irrigation Requirement (Inches)
1983	**19**	10.56	5.82	4.74
1984	**9**	11.54	2.87	8.67
1985	**17**	11.12	5.41	5.71
1986	**13**	10.72	3.84	6.87
1987	**15**	11.42	5.59	5.84
1988	**4**	11.83	1.96	9.87
1989	**18**	11.39	6.56	4.83
1990	**10**	11.82	3.18	8.64
1991	**2**	12.37	2.12	10.25
1992	**16**	10.92	5.11	5.81
1993	**20**	9.63	5.48	4.15
1994	**1**	12.99	0.68	12.31
1995	**12**	11.07	4.07	7.00
1996	**5**	11.62	1.88	9.74
1997	**14**	10.87	4.10	6.76
1998	**7**	12.30	3.34	8.96
1999	**6**	11.41	1.71	9.70
2000	**11**	11.69	3.51	8.18
2001	**3**	12.22	2.04	10.18
2002	**8**	11.36	2.45	8.91
Avg.	**4 Wettest**	**10.68**	**5.82**	**4.86**
Avg.	**12 Typical**	**11.40**	**3.47**	**7.92**
Avg.	**4 Driest**	**12.35**	**1.70**	**10.65**

The Laskody parcel falls within Climatic Zone B (Ronan RAWS, St. Ignatius NWS, St. Ignatius AgriMET, Round Butte AgriMET, and Polson Kerr Dam NWS). The average July through September Net Irrigation Requirement for these stations, for an extreme dry year like 1994 is 11.77 inches (see Table 3).

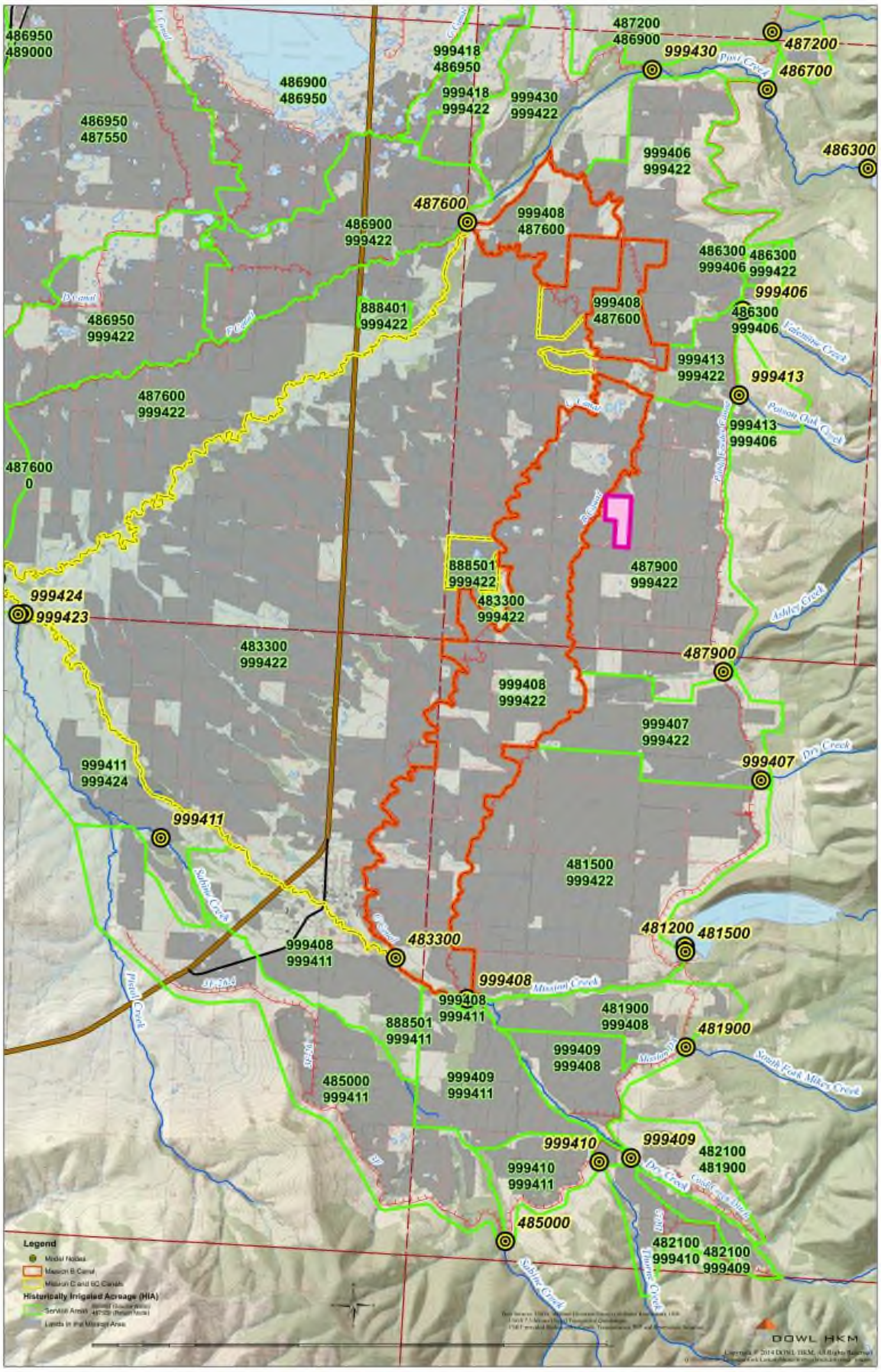
Table 3 – July through September Net Irrigation Requirement for Pasture Grass in Climatic Zone B from DOWL HKM Crop Water Requirements work

Year	Irrigation Consumptive Index	Evapotranspiration (Inches)	Effective Precipitation (Inches)	Full-Supply Net Irrigation Requirement (Inches)
1983	**18**	10.82	4.87	5.95
1984	**9**	11.70	3.10	8.60
1985	**15**	11.54	4.79	6.75
1986	**14**	11.11	4.32	6.79
1987	**12**	11.59	4.53	7.06
1988	**4**	12.20	2.34	9.86
1989	**19**	11.31	6.45	4.86
1990	**10**	12.05	3.62	8.43
1991	**3**	12.40	2.16	10.24
1992	**17**	10.68	4.63	6.05
1993	**20**	9.67	6.37	3.30
1994	**1**	12.69	0.92	11.77
1995	**13**	10.97	4.10	6.87
1996	**6**	11.55	2.17	9.38
1997	**16**	11.10	4.44	6.66
1998	**7**	12.36	3.53	8.83
1999	**5**	11.51	1.82	9.69
2000	**11**	11.80	3.81	7.99
2001	**2**	12.37	1.50	10.87
2002	**8**	11.47	2.84	8.63
Avg.	**4 Wettest**	**10.62**	**5.58**	**5.04**
Avg.	**12 Typical**	**11.56**	**3.59**	**7.97**
Avg.	**4 Driest**	**12.42**	**1.73**	**10.68**

Actual Crop Irrigation Consumption (CIC)

The Flathead Indian Irrigation Project (FIIP) does not operate under a full irrigation water supply. Although individual parcels may approach full supply due to their location in the system or due to intense management practices, FIIP is generally a deficit irrigation project. This fact has been established by others in the past and agrees with the results of DOWL HKM's water budget modeling work. To illustrate this point, the Laskody parcel is located directly adjacent to the Mission B canal and in the vicinity of the Mission B and Mission C/6C canal service areas (see map 1).

Map 1 – Irrigated Lands within the Mission B and C/6C Canal Service Areas
Laskody parcel shown for reference



As summarized in Table 4, the Mission B Canal serves 3,214 acres of irrigation. Records of diversion into the Mission B Canal at the stream headworks average 3,637 acre-feet for the April through October irrigation season and 2,799 acre-feet for the July through September period. This equates to a stream headworks diversion volume of 0.87 acre-feet per acre (10.4 inches per acre of total diversion for the Jul-Sep analysis period). Similarly, the Mission C and Mission 6C canals serve a total of 7,540 acres of irrigation. Records of combined diversion for these two canals average 9,102 acre-feet for the April through October irrigation season and 7,111 acre-feet for the July through September period. This equates to 0.94 acre-feet per acre (11.3 inches per acre of total diversion for the Jul-Sep analysis period). Reducing these volumes for canal conveyance losses and conversely, accounting for interception of irrigation wastewater into the canals, this leaves a composite total of 0.80 acre-feet per acre of total farm delivery.

On-farm efficiencies used in the water budget modeling provide reasonable allowance for existing on-farm efficiency, dependent on existing irrigation methods (sprinkler or flood), water management, and soils. On-farm efficiency allowance for sprinkler irrigation ranges from 60% to 80%, peaking at 75% to 80% during the driest periods. On-farm efficiency allowance for flood irrigation ranges from 35% to 50%, peaking at 45% to 50% during the driest periods. These assumptions are in reasonable agreement with the on-farm efficiency assumptions included in the Laskody report (60% to 70%) for his side-roll sprinkler system.

Reducing the composite total farm delivery (0.80 acre-feet per acre) to account for on-farm irrigation efficiencies, the average July through September Crop Irrigation Consumption (CIC) ranges from 0.47 to 0.50 acre-feet per acre (5.6 to 6.0 inches per acre) for the composite Mission B and C/6C Canal service areas.

Table 4 – Water Budget for the Mission B and Mission C/6C Canal Service Areas

Stream Diversion	Recorded Apr–Oct Stream Headworks Diversion (Ac-Ft)	Recorded Jul–Sep Stream Headworks Diversion (Ac-Ft)	Irrigated Acres	Recorded Stream Headworks Diversion for Apr–Oct (Ac-Ft/Acre)	Recorded Stream Headworks Diversion for Jul–Sep (Ac-Ft/Ac)	Modeled Farm-Turnout for Jul–Sep (Ac-Ft/Ac)	Modeled CIC for Jul–Sep (Ac-Ft/Ac)	METRIC CIC for Jul–Sep (Ac-Ft/Ac)
Mission B Canal near Headworks (4827.10) Recorded 1992-2002]	3,637	2,799	3,214	1.13	0.87	0.80	0.50	0.56

Stream Diversion	Recorded Apr–Oct Stream Headworks Diversion (Ac-Ft)	Recorded Jul–Sep Stream Headworks Diversion (Ac-Ft)	Irrigated Acres	Recorded Stream Headworks Diversion for Apr–Oct (Ac-Ft/Acre)	Recorded Stream Headworks Diversion for Jul–Sep (Ac-Ft/Ac)	Modeled Farm-Turnout for Jul–Sep (Ac-Ft/Ac)	Modeled CIC for Jul–Sep (Ac-Ft/Ac)	METRIC CIC for Jul–Sep (Ac-Ft/Ac)
Mission C Canal (4829.10) & Mission 6C Canal (4831.50) near Headworks [Recorded 1992-2002]	9,102	7,111	7,540	1.21	0.94	0.80	0.47	0.53

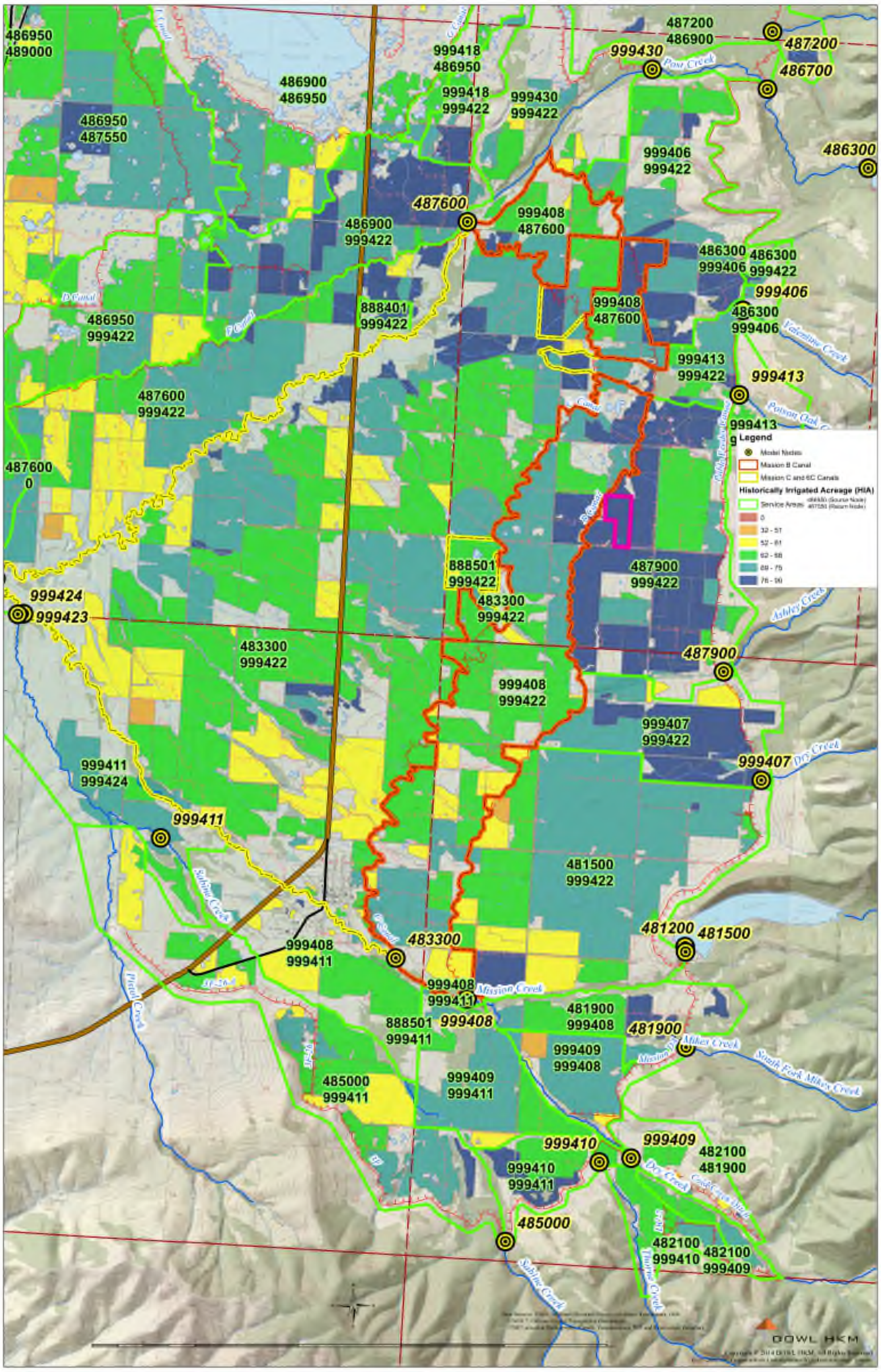
*Mission B modeled application efficiency was 59% for July and 64% for August and September (weighted average based on surface irrigation acreage at 45%/50% and sprinkler irrigation at 75%/80%). Mission C modeled application efficiency was 56% for July and 61% for August and September (weighted average based on surface irrigation at 45%/50% and sprinkler irrigation at 75%/80%).

Variability in Crop Irrigation Consumption (CIC) and Comparison with METRIC

Dr. Richard Allen of the University of Idaho pioneered the use of the METRIC method (Mapping EvapoTranspiration at high Resolution with Internalized Calibration) using spectral and thermal data from Landsat Satellite imagery to compute and map evapotranspiration. The Idaho Department of Water Resources (IDWR) has been using this method extensively since 2000 to monitor crop water consumption and to administer water rights, especially in the Snake River Plain region of the state. The method has also been utilized in over a dozen other states and abroad. The Montana DNRC retained Dr. Allen to apply the METRIC method on the Flathead Indian Reservation. Landsat Imagery was obtained for the years 2006, 2007, and 2008 for this purpose. Although these years do not coincide with the study period for the water budget modeling effort (1983 through 2002), the results can be used as a reasonableness test of those results. As shown in Table 4, the independent METRIC method similarly shows actual Crop Irrigation Consumption in the range of 0.53 to 0.56 acre-feet per acre (6.4 to 6.7 inches per acre).

As mentioned previously, although individual parcels may approach full supply due to their location in the system or due to intense management practices, FIIP is generally a deficit irrigation project. This is illustrated on Map 2 which shows the results of the DNRC METRIC study expressed as a percentage of the maximum potential for individual parcels. As shown, the actual Crop Irrigation Consumption (CIC) in this area generally ranges from 50% to 90% of the theoretical maximum.

Map 2 – Irrigated Lands by METRIC Factor (Percent of Maximum) within the Irrigation Service Areas in the vicinity of the Laskody parcel



Mr. Laskody's parcel is at the upper end of the range of actual Crop Irrigation Consumption (76% to 90% of maximum) according to the results of the METRIC study for the years 2006 through 2008.

Water Delivery Provisions of the Proposed Water Use Agreement

Current levels of farm turnout water delivery were determined through the course of the water budget modeling work for individual irrigation Service Areas throughout FIIP. These water deliveries represent an average within each respective Service Area, with some parcels likely being delivered more and some less than these average values. Existing farm turnout water deliveries were provided to the FJBC negotiating team for various FIIP sub-areas within the Mission division including Upper Mission Creek, the Kicking Horse/Ninepipe Complex, Moiese, Pablo Feeder North, Pablo A Canal, and Polson areas. Wet Year FTA's ranged from 0.89 to 1.17 acre-feet per acre across these sub-areas. The FTA for Normal Years ranged from 0.93 to 1.21 acre-feet per acre and Dry Year FTA ranged from 0.94 to 1.36 acre-feet per acre. The FJBC negotiating team requested a weighted-average FTA for each respective FIIP Division (Jocko, Mission, and Little Bitterroot) to facilitate equity in water allocation (unit volume of water delivered is the same, just as the assessment is the same) and also for ease of administration. The resulting proposed FTAs included in the proposed Water Use Agreement (WUA) for the Mission area were as follows:

Wet:	1.03 Ac-ft/Ac
Normal:	1.07 Ac-ft/Ac
Dry:	1.14 Ac-ft/Ac
Maximum:	1.40 Ac-ft/Ac

Mr. Laskody indicates that the farm turnout delivery allowance from the proposed WUA was 12.5 inches for the Mission division. It is not clear where this value came from. The basic FTA as included in the proposed WUA for a dry year such as 2012 was 1.14 acre-feet per acre (13.7 inches per acre). Mr. Laskody estimated his farm water delivery in 2012 to be 26.1 inches based on the size and spacing of his irrigation nozzles, on the pipeline pressure, and estimates of the number of irrigation sets and set time. It is very difficult to assess the reasonableness of the resulting water delivery estimate. Actual delivery records such as can be obtained from a totalizing flow meter would be much more helpful. In any case, assuming that Mr. Laskody in fact delivered 26.1 inches of water to his 58 acre parcel, the proposed WUA explicitly allows for an increased delivery allowance above the basic FTA, up to 2.0 acre-feet per acre (24 inches per acre). This is the proposed "Measured Water Use Allowance".

The Measured Water Use Allowance (MWUA) was proposed to be an allocation of water that may be delivered to farm turnouts that is greater than the maximum Farm Turnout Allowance. The Measured Water Use Allowance is intended to address variability in the FIIP irrigation distribution works and soil and climate variability that exists across the acres that are served by FIIP. In order to be eligible for this extra allocation, it was proposed that the irrigator would need to illustrate through flow measurement that this amount of water is needed and that the water is being used beneficially and without unreasonable waste.

SUMMARY

This purpose of this memorandum is to present our findings from a review of the report by Mr. Laskody "Matching Irrigation Water Delivery on Irrigated Pasture to Local Transpiration and a Comparison with the Proposed CSKT Compact Water Use Agreement Irrigation Water Delivery –St. Ignatius, MT July – September, 2012". Our findings are briefly summarized as follows:

1. The period July through September of 2012 selected for analysis is on the extreme dry end of the spectrum compared to climatic conditions for other years. Compared to the July through September period of 2012, there is only one year during the 1983 through 2002 study period with lower precipitation (1994).

2. The analysis presented is basically a Net Irrigation Requirement estimate of the amount of irrigation water required to fully meet the theoretical maximum potential crop irrigation consumption. The theoretical maximum crop irrigation consumption is seldom achieved due to less than perfect water management and less than full water supply.

3. Although the methods are somewhat different, the Net Irrigation Requirement (NIR) estimated by Mr. Laskody (13.87 inches) is in reasonable agreement with the NIR determined by DOWL HKM for the July through September period of similar extreme dry years such as 1994 (12.31 inches).

4. FIIP is a deficit irrigation project as illustrated by the water budget of the nearby Mission B and Mission C/6C irrigation service areas. Stream headworks diversion volumes for these service areas total 1.1 to 1.2 acre-feet per acre (13.5 to 14.5 inches per acre) for the irrigation season and 0.87 to 0.94 acre-feet per acre (10.4 to 11.3 inches per acre) for the July through September analysis period. Adjusting for water lost through conveyance losses and water gained through wastewater reentering the canals, the total volume of farm turnout delivery in this area is 0.80 acre-feet per acre (9.6 inches per acre). Adjusting for on-farm irrigation efficiencies, results in average Crop Irrigation Consumption of 0.47 to 0.50 acre-feet per acre (5.6 to 6.0 inches per acre) for the July through September period.

5. Results from the DNRC METRIC study can be used as a reasonableness test of these results. Although for different time periods (2006-2008 vs. 1983-2002), the independent METRIC method similarly shows actual Crop Irrigation Consumption in the range of 0.53 to 0.56 acre-feet per acre (6.4 to 6.7 inches per acre).

6. Actual Crop Irrigation Consumption varies across FIIP and generally ranges from 30% to 90% of the theoretical maximum in the vicinity of the Laskody parcel. The Laskody parcel is at the upper end of the range of actual Crop Irrigation Consumption (76% to 90% of maximum) according to the results of the METRIC study for the years 2006 through 2008.

7. Mr. Laskody indicates that the proposed Water Use Agreement (WUA) only allowed for farm water delivery of 12.5 inches in the Mission area. The proposed Farm Turnout Allowance from the WUA for a dry year such as 2012 in the Mission area was 1.14 acre-feet per acre (13.7 inches per acre). Further, the proposed WUA also made provision for an increased farm delivery allowance, up to 2.0 acre-feet per acre (24 inches per acre), through the "Measured Water Use Allowance" (MWUA). The MWUA was intended to address variability in the FIIP irrigation distribution works and soil and climate variability that exist across FIIP.