Report structure:

I. Major Section

For each Issue within Section

Background:

• Discussion points

References

I. HYDROSS model

Model objectives and uses

Quantification of current use

Increase instream flow from improvements

Scale appropriate for model use

Water distribution and water balance considerations

Input

Data quality – stream/canal discharge

Measured data vs estimated

NIR or crop consumption

Standard method used

METRIC comparison

"Management factor"

Irrigation efficiencies and conveyance efficiencies

Return flow tracking and routing

Output

Application of model output appropriate

Calibration

Does the model support all the conclusions?

Limitations of the model

Issue: HYDROSS Models

Background: Three separate models were developed with the HYDROSS software to simulate the following major components of the FIIP: the Jocko model, the Mission area model, and the Little Bitterroot model. According to the Bureau of Reclamation and Texas A&M University in their Hydrologic Modeling Inventory, HYDROSS is a "surface water supply model developed to assist in planning studies for evaluating existing and proposed demands on a river system by simulating the effect of existing and proposed features on the historical natural hydrology" (Texas A&M University and Bureau of Reclamation undated). The HYDROSS models operate at a monthly time-step in sequential order (results from one month depend on the system state at the end of the previous month) and sequential space (results at one station depend on what is happening upstream and/or downstream), and priority (earlier water right dates are allowed water before later water right dates). The model can be used to simulate physical features of a river basin (such as irrigation diversions, conveyance, and storage) with input hydrology data, diversion demands, instream flow targets, and other constraints and operational criteria. The scale that the model can be used for is user determined, but typically for a river-basin management area. The HYDROSS modeling software was developed by the Bureau of Reclamation to represent complex river systems and management strategies and has been used in a progression of versions for about 30 years. In the case of the proposed CSKT compact, results from the HYDROSS model were used in quantifying instream flow targets and allowable irrigation water volumes, and to develop future improved management scenarios as described in the WUA. Here are some general facts we have found concerning the HYDROSS models and modeling.

- The HYDROSS modeling software is suitable for representing the components of the FIIP and for running planning scenarios to provide information concerning how frequently instream flow targets might be reached and associated constraints on irrigation water supplies. The models developed appear suitable for simulating how irrigation efficiency improvements and operational improvements might increase flow on some stream reaches, and how these improvements would affect irrigation water use.
- The three HYDROSS models are comprehensive and include the major physical features
 of the systems, such as streams, reservoirs, irrigation canals and blocks of irrigated land.
 The models are not designed to simulate the flow through every irrigation lateral or the
 delivery of water to every farm turn-out.
- The models did not employ optimization algorithms, rather scenarios were run in an iterative manner until results appeared to achieve instream flow, irrigation delivery, and water management objectives.
- The models themselves cannot determine whether or not the irrigation efficiency improvements needed to increase instream flow are achievable.
- The models are primarily surface water models and the simulation of groundwater flow is simplified and restricted to the modeling of stream channel and irrigation canal

- seepage losses and returns, and groundwater return flow from irrigation. Groundwater gains to the system, in some cases, were added through input files to the models.
- The HYDROSS models, in their present form, are not suitable for use as operational model of the FIIP system. It is anticipated that an operational model(s) of the FIIP system would be needed to for adaptive management and to administer the WMA. An operational model should be run at a daily time-step and it does not appear that HYDROSS, in its present form, has this capability. There are other modeling software packages available that could be used to develop daily time-step operational model of the FIIP.

References

Texas A&M University and Bureau of Reclamation undated. Hydrologic Modeling Inventory Website. http://hydrologicmodels.tamu.edu/

Issue: Irrigation Characteristics Input Data to the HYDROSS models

Background: The HYDROSS models simulate irrigation water diversions and deliveries based on irrigation demands, and operations associated with filling the reservoirs on the system and delivering water from this storage to meet irrigation demands. In order to accurately model historic irrigation use and to produce credible future scenarios, the inputs to the model that represent the physical characteristics of the system should be a reasonable representation of actual project characteristics. Furthermore, the model rules that simulate the timing and delivery of water for irrigation and operations of the reservoirs must reflect actual operations of the system. Here are some facts we found concerning how the HYDROSS models simulates operations in the FIIP. Some of the facts concerning inputs to the models, such as crop irrigation requirements, will be discussed in other sections of this report.

- Irrigated acreages are a basis for simulating irrigation diversions in the model. Project-wide acreages input to the model and the assignment of these acreages to irrigation blocks served by the various canals and laterals need to be accurate and representative of the system. Inputs to the latest versions of the HYDOSS models are based on 2009 irrigated acreages as mapped by the Tribe's and their consultants. Earlier versions of the model were used mid-1990s irrigated acres, and the model was calibrated with the mid-1990s acres.
- On-farm irrigation system efficiencies used in the HYDROSS modeling varied based on system type, month, and location in the FIIP. Sprinkler irrigation efficiencies used ranged from 60-to-80 percent, while flood irrigation efficiencies ranged from 35-to-50 percent. The Montana Irrigator's Pocket Guide lists irrigation applications efficiencies that range from 50-to-85 percent for sprinkler systems, and 15-75 percent for the flood systems. The efficiencies for wild flood systems, which range from 15-35 percent in the Pocket Guide, might be overstated in the HYDROSS models. The sprinkler field efficiencies are within the range that typically is used.
- Canal seepage losses were simulated based on the length of the canal and a per-mile loss rate. Per-mile loss rates used range from 0.5% to 5%. Lateral efficiencies used seem to be based on a similar method, with the per-mile percentage loss ranging from 0% (pipelines) to 1%. The 2009 DNRC Canal Seepage Study was used to develop percentper-mile magnitudes and patterns of loss for main canals.
- Canal capacity limitations were input to the model based on maximum recorded diversions for the various canals. Canal diversion capacities also seem to have been limited, in some instances, so that maximum canal diversions better matched crop irrigation as determined through the DNRC METRIC Study (DOWL HKM 2012).
- Return flow was lagged over a 12-month period following irrigation, with the greatest
 amount returning to the source the first month following irrigation and rates decreasing
 by month until the end of the period. It appears that the lagging applied to all return
 flow, and there was not separation of surface and groundwater returns.

- There appear to have been some other irrecoverable losses simulated in the modeling. [I need to check some more on this]
- Stream reaches also were simulated in the HYDROSS models; in some cases, these losses could be simulated to return to a downstream location in the model.

References

DOWL HKM 2012. HYDROSS model Baseline Conditions documentation for the Mission, Jocko, and Little Bitterroot models.

Montana Pocket Irrigators Guide. National center for Appropriate Technology, Butte, MT. Irrigation system efficiency tables are adapted from University of Idaho Extension Service irrigation scheduling tables.

Issue: HYDROSS models Calibration

Background: The HYDROSS models were calibrated to baseline conditions but there are two iterations of the baseline run. The first models the systems based on supplying irrigation demands to acreages considered to be irrigated during the mid-1990s. These were the model runs to which the models were calibrated. Later, the "baseline" was updated to simulate irrigation as represented in a 2009 irrigated lands mapping, but it does not appear that further calibration adjustments were made to the models during this baseline update. Goals of model calibration appear to have been to better match 1983-2002 model results to the historic records for end-of-month reservoir storage, gaged streamflow, and recorded canal diversions. Other goals of calibration were to better match irrigation water consumption with that estimated by the DNRC funded METRIC study, and to check that water budgets and mass balances were reasonable. Here are some of the facts we found concerning the calibration of the three HYDROSS models.

- The models are able to reasonably simulate the historic end-of-month contents of the various reservoirs in the system.
- The ability of the models to closely replicate historic streamflow is more variable and might be the result of inexactness in estimating water consumption or in accounting for all inflow.
- Overall, the models do a good job at simulating historic canal diversions.
- Canal capacity limits appear to have been adjusted during the calibration so that diverted amounts better matched crop irrigation consumption determined through the DNRC funded METRIC study.
- Other parameters were adjusted during calibration, although which were most important to the calibration is not apparent in the model documentation. [Need to do some more checking on this]
- The calibration was based on a mid-1990s irrigated land base while the baseline run
 used for comparison to future water management scenarios used a 2009 irrigated lands
 mapping base. The differences in irrigation consumption modeled with the two baseline
 scenarios is summarized in the table below. Overall, modeled irrigation consumption
 was about 4 percent less for the 2009 irrigated lands baseline.

Comparison of Acres and Irrigation Crop Consumption for Baseline and 2009 Irrigated Lands Mapping Model Runs. (From HLM HYDROSS Model baseline and 2009 irrigated lands mapping reports.

HYDROSS	Baseline Models			2009 Irrigated Lands Adjusted Models		
Model	Acres	AF	AF/acre	Acres	AF	AF/acre
Mission	113,105	81,018	0.72	109,140	79,548	0.73
Jocko	14,685	10,016	0.68	12,648	8,997	0.71
Little Bitterroot	21,551	14,360	0.67	18,827	12,942	0.69

• Water shortages were modeled. This resulted in modeled irrigation use being much less than the theoretical water demand and somewhat less than the water use estimated by METRIC as summarized in the table below.

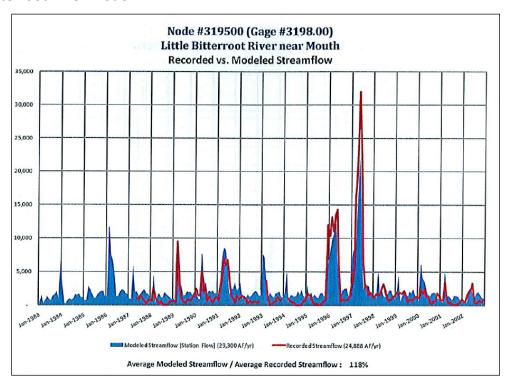
Comparison of Theoretical, HYDROSS modeled, and METRIC estimated Crop Irrigation consumption.

HYDROSS	Total	Theoretical Demand		HYDROSS Modeled		METRIC Estimated	
Model	Acres	AF	AF/acre	AF	AF/acre	AF	AF/acre
Mission	113,105	116,123	1.03	81,018	0.72	95,552	0.84
Jocko	14,685	15,682	1.07	10,016	0.68	10,755	0.73
Little Bitterroot	21,551	27,694	1.29	14,360	0.67	14,952	0.69

Issue: HYDROSS Model Output as a Water-Balance Check on Irrigation Consumption

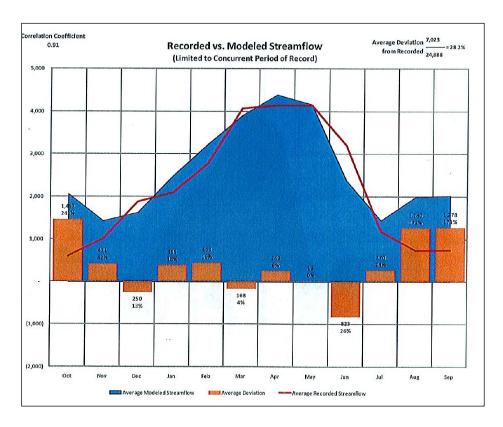
Background: The HYDROSS models account for water flowing into the systems as well as flow out of the system. The primary losses of water from the modeled systems should be due to irrigation consumption, as well as some losses to reservoir evaporation and possible some losses to groundwater. If irrigation consumption and other losses are being satisfactorily simulated, modeled outflow from the lower-most river reaches should match, relatively closely, that which has been recorded as leaving the system at downstream gaging stations. As a check, modeled and simulated flow was compared for a representative station for each of the three HYDROSS models: the Little Bitterroot, Jocko, and Mission. The graphs and discussions below describe some of our findings. All the presented graphs have been copied from the DOWL HKM 2012 HYDROSS Model Baseline Conditions reports.

Little Bitterroot River Model



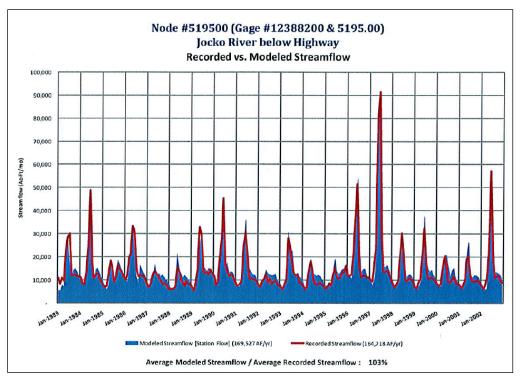
The average modeled flow near the mouth of the Little Bitterroot River is about 118% higher than gaged flow for the overlapping period of record. From examining the second graph of averages and deviations from averages by month, it seems that the model generally is overestimating streamflow during the August through September period and underestimating flow during June. Deviations during the other months are smaller in comparison. On an average annual basis, the model seems to be overestimating Little Bitterroot river outflow by about 4,500 acre-feet per year. This <u>could</u>, at least partially, be the result of an underestimation of irrigation depletions. It also might result from an overestimation of inflow into the system. Another possibility is that there are natural losses in the system that the model is not properly simulating. The Little Bitterroot might be the best area we have on the FIIP to make this type of

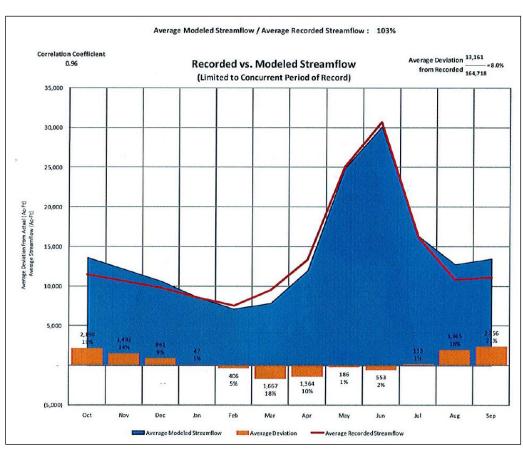
comparison because the lower gage and associated modeling node are downstream of all of the irrigation.



Jocko Model

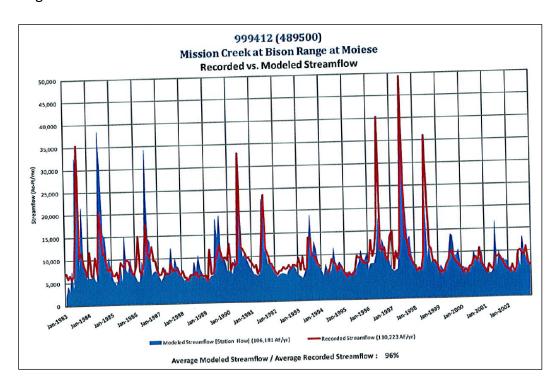
An accounting of the flow through the Jocko Basin area is more complex than the Little Bitterroot basin because water is imported into and exported out of the basin and because there are some irrigated lands and irrigation return flow below the lower-most gaging station on the stream. For this comparison, the lowermost Jocko River gaging station and associated model node output are compared. Visually, at least, the modeled flow appears to closely follow the gaged flow and overall is only about 3 percent higher. Overestimation of flow greater than 10% occurs during the August through November period. Flow is underestimated, by greater than 10%, during March and April. On an average annual basis, the model seems to be overestimating flow at this station by about 4,800 acre-feet per year. This <u>could</u> at least partially be the result of an underestimation of irrigation depletions during the late summer.

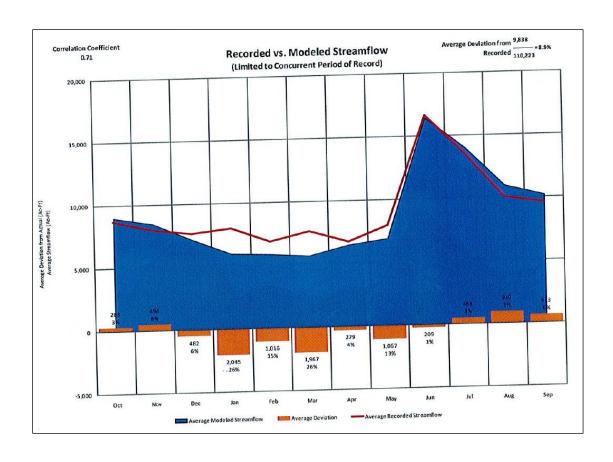




Mission Model

The Mission area model probably is the most complex and there isn't any one modeling point that captures nearly all of the outflow. One model node that captures a good portion of the outflow from the systems is at the Mission Creek gage near Moiese. Modeled flow at this station is generally lower than the gaged flow. There is some overestimation of flow occurring for the August through November period. Flow is underestimated at greater than 10% during January through March and May. Overall, on an average annual basis, the model seems to be underestimating flow by about 4,800 acre-feet per year. The underestimation could be because not all inflow is being accounted for in the model, or that the model isn't properly simulating all irrigation return flow.





Background: Objectives of the proposed WMA would be to increase the flow of many stream reaches, first through operational improvements and then through betterment of irrigation infrastructure. The HYDROSS models were used to simulate how instream flow might increase under future scenarios, by comparing improved operational and betterment scenarios to baseline conditions. The following are some pertinent facts concerning this issue.

- The model is capable of simulating and tracking streamflow increases, at model node locations, that might occur under operational and irrigation efficiency improvements.
- For most monitoring points, streamflow is modeled to increase under operational improvement and betterment scenarios, although there are some modeled decreases in streamflow at some locations for some year types.
- Under the operational improvements alternatives, much of the reduced overall
 diversions on some streams, and associated increases in streamflow, would be due to
 the elimination of stock water diversions and non-essential flow through the canals
 which would not occur under the improved operations.
- Although, under the operational improvements and betterment scenarios, modeled crop consumption for the FIIP was not simulated to be reduced on average, there are individual irrigation blocks that are simulated to have reduced consumption. Decreases in crop consumption seem more likely to occur under the private (non-FIIP) irrigation blocks.
- The model results seem to indicate that operational and efficiency improvements might result in an overall increase in irrigation water consumption on the FIIP.

II. METRIC

Proper comparison to methods used in model Proper comparison to other methods

III. Crop Water Use by current irrigation practices

Standard methods METRIC Other

Issue: Evapotranspiration, Net Irrigation Requirements, and Crop Consumptive Use

Background: There seems to be some confusion concerning how irrigation water demands and use were simulated for the FIIP with the HYDROS models. Concern was expressed that the crop net irrigation requirements (NIR) input files to the HYDROS model might have had a "management factor" incorporated into them, prior to running the model, under the assumption that the FIIP is a "deficit irrigation project". Here are some of the facts we have found concerning this issue of concern.

- NIR input files to the HYDROS model were derived by computing reference evapotranspiration
 (ET) with the Hargreaves Equation calibrated to the FAO-56 Penman-Monteith Equation (DOWL
 HKM 2014) and then by subtracting effective precipitation. A management factor was not
 applied in the process of deriving these NIR input file.
- Overall, crop irrigation water consumption was modeled to be substantially below that which
 would be needed to fully satisfy the NIRs on the FIIP. In other words, water shortages were
 modeled. Reasons for these shortages appear to be inadequate available water supplies, canal
 capacity limitations, and possibly other factors.
- There was some discussion of the METRIC analysis (Mapping Evapotranspiration at high Resolution with Internalized Calibration) by the University of Idaho that was used to estimate evapotranspiration in the Mission Valley under contract with the Montana Reserved Water Rights Compact Commission. The METRIC analysis was not used in developing the NIR input files to the HYDROS model. It was used by the RWCC as a check to see if the HYDOS modeled baseline total crop water use on the FIIP was similar to that estimated using the METRIC approach. However, canal diversion capacities also seem to have been limited, in some instances, so that maximum canal diversions better matched crop irrigation as determined through the DNRC METRIC Study (DOWL HKM 2012).

References

DOWL HKM 2012. HYDROSS model Baseline Conditions documentation for the Mission, Jocko, and Little Bitterroot models.

DOWL HKM, 2014. June 6, 2014 Memorandum from Wade Irion P.E, DOWL HKM to John Carter and Rhonda Swaney, CSKT Legal Department.

Issue: Evapotranspiration, Net Irrigation Requirements, and Crop Consumptive Use

Whether the ET, NIR, and CCU estimates input to HYDROSS are reasonable can be evaluated by comparison to values calculated by Jerry Laskody, the DNRC consumptive use rules and from satellite imagery and METRIC.

HKM derived NIR input files to the HYDROS model by computing reference evapotranspiration (ET) with the Hargreaves Equation calibrated to the FAO-56 Penman-Monteith Equation (HKM 2014) for a specific mix of crops and then by subtracting effective precipitation. Values in Table 1 are for the Polson Kerr Dam weather station to facilitate comparison with Montana DNRC consumptive use rules. A management factor was not applied by HKM in the process of deriving these NIR input file or determining the 1.4 AF/acre irrigation delivery found in the water use agreement.

HKM based their analyses on the proportion of sprinkler versus flood irrigation and associated application efficiencies, and net irrigation requirement for a specific mix of crops. They used 67% sprinkler irrigation and 33% flood irrigation for the Mission District and 58% sprinkler irrigation and 42% flood irrigation for the Jocko District with associated application efficiencies that varied by district and by month. They used 45% to 50% for flood irrigation and 75% to 80% for sprinkler irrigation. HKM varied crop patterns by area ranging that are dominated by pasture (54% to 64%) and grass and alfalfa (25% to 36%), with small amounts of spring grains and winter wheat.

Jerry Laskody used data from the St. Ignatius Airport Agrimet station for pasture grass to evaluate ET and NIR on his property for 2012. He also provided estimates of water application based on soil-water holding capacity, irrigation records, and water delivery rates. Mr. Laskody calculated total ET of 14.67 inches, NIR of 13.87 inches, and application of 22.4 inches during July, August, and September based on efficiencies of 60 to 70 percent. He reported additional application of 3.7 inches in May, but did not account for additional crop water use. The primary difference in the crop consumption estimate by Mr. Laskody is the low effective precipitation relative to values used by others.

Mr. Laskody's property is double duty allowing him 24 inches of water under current FIIP practices. Furthermore, evidence from aerial photography indicates that Mr. Laskody's property was one of the higher producing properties in the area.

• Montana DNRC rules for evaluating historic use in ARM 36.12.1902 employs a separate estimate of crop consumptive use relying on the Blaney-Criddle method and management factors based on a comparison of historical hay production to obtainable yields. Alfalfa production data come from the United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS). The online NASS database was queried to acquire irrigated alfalfa yields (tons/acre) by county. County-wide alfalfa yields have been surveyed since 1964 and state wide yields since 1929. ET and NIR data were generated using the USDA Natural Resources Conservation Service (NRCS) Irrigation Water Requirements (IWR) program. IWR estimates net monthly and seasonal crop irrigation requirements based on crop needs, effective precipitation, and the growing season length using the Blaney-Criddle (TR21) method. The estimated obtainable yield at each weather station was determined by dividing the total crop water requirement calculated with the IWR program, by 6 in/ton/acre. The county wide alfalfa hay yields from the NASS data were

then divided by the estimated yields for the four analysis periods to obtain a management factor. The management factors give an estimate of what percent of the obtainable yield producers are typically obtaining in the field at a particular area.

Values listed in Table 1 are for data from the National Weather Service weather station at St. Ignatius. NIR values assume ½ inch and 1 inch of carryover moisture for pivot and flood irrigation respectively. Carryover moisture accounts for water stored in the soil profile at the start of an irrigation season prior to irrigation as well as irrigation water applied at the end of the irrigation season that is not consumed.

The METRIC (Mapping Evapotranspiration with high Resolution and Internalized Calibration)
procedure using a surface energy balance methodology, Agrimet weather data, and Landsat
satellite imagery was applied to assess whether ET and NIR values used by HKM are reasonable.
The METRIC procedure yields a management factor that relates actual crop irrigation
consumption to a reference ET.

Method	Total ET (in)	NIR (in)	MF (%)	Crop Irrigation	Applied (in)
				Consumption	
				(in)	
HKM - Mission	23.90	12.32		8.76	17.14*
HKM - Jocko	23.90	12.75		8.54	17.14*
Laskody	14.67	13.87		13.87	22.4
ARM	26.98	19.53 – 22.33	55	10.74 – 12.28	15.35 -17.90**
36.12.1902		(pivot – flood)			
METRIC	25.30	17.00	56 - 66	7.82	13.03***

^{*}assuming 1.4 AF/acre in water use agreement

Overall, crop irrigation consumption was modeled or calculated by all methods to be substantially below that which would be needed to fully satisfy the NIRs on the FIIP. Reasons for these shortages appear to be inadequate available water supplies, canal capacity limitations, and field-level water management. Estimated application by Laskody relative to the 1.4 AF/acre specified in the water use agreement is consistent with the double duty status and aerial photography evidence that his property was one of the higher producing properties in the area. Also notable is the considerably lower consumption obtained from METRIC.

References

RWCC, 2014. METRIC eval bg.xls spreadsheet of analysis of METRIC data.

HKM, 2014. June 6, 2014 Memorandum from Wade Irion P.E, DOWL HKM to John Carter and Rhonda Swaney, CSKT Legal Department.

HKM, 2014. June 12, 2014. Technical basis for proposed Flathead Indian Irrigation Project water use agreement. Presentation to WPIC CSKT Technical Working Group.

^{**}assuming 60% efficiency for flood and 80% for pivot

^{***}assuming 60% efficiency

Laskody, J.R., June 25, 2014. 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. Presentation to WPIC CSKT Technical Working Group.

Issue: Farm Turnout Allowances (FTAs)

Background: FTAs refer to the water delivered to a farm turnout. The proposed WUA, Appendix A defines FTAs for three areas in the FIIP and for three hydrologic conditions. Here are some of the facts we have found concerning this issue of concern.

- Page A-16 of the WUA defines per acre FTAs for different areas in the FIIP under varying hydrologic conditions ranging from 1.03 to 1.30 acre-feet per acre. There also is a maximum FTA of 1.40 acre-feet per acre.
- Page 11 of the WUA states that the FIIP shall serve no more than 130,000 acres of irrigation.
- The weighted average FTAs for the FIIP (pro-rated based on the acreage irrigated in each area) are about 1.07 af/acre for wet years, 1.09 af/acre for normal years, and 1.15 af/acre for dry years.
- Based on these weighted average FTAs and the WUA maximum acreage limitation of 130,000 acres, the FIIP project-wide summation of FIIP FTAs by year type would be as follows: 139,100 acre-feet for wet years; 141,700 acre-feet for normal years, and 149,500 acre-feet for dry years.
- If it were assumed that all irrigated lands were able to reach a maximum FTA of 1.40 af/acre, the summation of the maximum FTAs for the FIIP (130,000 acres maximum) would be 182,000 acre-feet.

Issue: River Diversion Allowances (RDAs)

Background: RDAs refer to the volume of water that is allowed under the proposed WUA to be diverted or pumped from the various water source for use in the FIIP. RDAs, in total and for a given portion of the FIIP, should exceed the FTAs because RDAS include canal seepage losses, operational spills, and other factors. Because the RDAs would place an upper limit on what the irrigators in the FIIP will be able to divert or from source streams, a FIIP-wide comparison might provide some useful information. Here are some of the facts we have found concerning this issue.

- Without including Flathead River pumping and incremental inflow (spring, small tributary, some waste-water and routed canal flows) total river diversion allowances for the FIIP would be as follows: 225,900 acre-feet for wet years, 218,700 acre-feet for average years, and 194,700 acre-feet for dry years.
- Adding incremental inflow raises the total RDA amounts to the following: 276,220 acrefeet for wet years, 260,600 acre-feet for average years, and 227,400 acre-feet for dry years. However there appears to be some double-counting of already diverted water when incremental inflow is added.
- The average volume of water estimated to be diverted (excluding Flathead River diversions) for the FIIP for the 1983-2002 period based on recorded diversions is about 193,000 acre-feet (based on data presented by DOWL HKM 2014). Annual diversions for a particular year might fluctuate about 20 percent above or below this average. [Note: total diverted amount does not seem to include Jocko area diversions]
- We could find no definitive information documenting higher total FIIP project diversions prior to 1983. A document stamped by the BIA on December 23, 1946 with the title "Reservation — Flathead: Project — Flathead" contains a table with the FIIP water supply for irrigation "Grand Total" listed at 490,859 acre-feet. However, this appears to be an estimate of the source water supply rather than measured diversions. A June 1946 BIA report lists total project diversions at the land for the 1911 through 1923 period with an average of 99,895 acre-feet and a maximum of 113,114 acre-feet. A table in that same report lists average annual deliveries based on Watermaster's reports for the 1933-1946 period that sum to 122,402 acre-feet. Again, these are deliveries to the farm headgate (more comparable to FTAs) and would not include conveyance system losses between the river headgate and farm turnouts, such as seepage and operational spills. In his July 17, 2014 presentation to the TWG, Seth Makepeace with the CSKT Tribes presented some farm delivery totals for the Little Bitterroot and Mission Valley portions of the FIIP. Visually, the 1970s diversions appeared to be somewhat higher than those during the 1980s, although the 1970s were generally good water supply years, with the exception of 1977 which was a dry year.
- There could be up to an additional 65,000 acre-feet made available to the FIIP through the RDA for the Flathead River Pumping Plant.

- Page 11 of the WUA states that the FIIP shall serve no more than 130,000 acres of irrigation.
- The table below summarizes FIIP total diversion allowances by year type, with and without incremental inflow and with and without Flathead River pumping. It also includes a FIIP project average acre-feet/acre annual diversion which might be realized under the RDA.
- Averaged over the project, the 65,000 AF Flathead River Pumping Plant allowance might add up to another .5 feet per-acre to the total volume of water available to irrigators. However, not all irrigators would have direct access to this water.
- Little Bitterroot area irrigators might be the most limited, as measured by total diversions allowed at the river headgate per acre. In the case of the Little Bitterroot area, the RDAs might result in a similar limitation to total diversions as the FTAs.
- RDAs exceed FTAs by year-type as follows: 86,800 acre-feet for wet years, 77,000 acre-feet for average years, and 45,200 acre-feet for dry years. These differences do not include incremental inflow or any pumping from the Flathead River.

RDA Summation Table

	River Diversion Allowance in acre-feet by Year Type (acre-feet per acre in parenthesis)		
	Wet Year	Normal Year	Dry Year
Sum of RDAs – no incremental inflow	225,900	218,700	194,700
	(1.74)	(1.68)	(1.50)
Sum of RDAs – with incremental inflow	276,220	260,600	227,400
	(2.12)	(2.0)	(1.75)
Sum of RDAs – no incremental inflow + Flathead River Pumping	290,900	283,700	259,700
	(2.24)	(2.18)	(2.00)
Sum of RDAs – with incremental inflow + Flathead River Pumping	341,220	325,600	292,400
	(2.62)	(2.50)	(2.25)

^{*} Assumes total FIIP irrigated area of 130,000 acres

References

BIA 1946. Report on Conditions Found to Exist on the Flathead Irrigation Project, Montana; Volume 1.

DOWL HKM 2014. June 12, 2014 Presentation "Technical Basis for Proposed Flathead Indian Irrigation Project Water Use Agreement" to the CSKT Technical Working Group. 193,000 acrefeet total is a summation of the information presented in slides 58 and 59.

IV. Stream discharge network

Adequate for quantifying stream flow in detail sufficient for:

Modeling
Estimating management factor

Other analyses (eg by Andrew B.)

V. Aquifer Characterization

model input
Estimating
return flows,
stream depletion,
canal loss, etc.

Issue: Aquifer Characteristics: values estimated for or calculated by HYDROSS for return flows, stream depletion, canal loss, etc.

Background: How are irrigation return flow factors, rates, and volumes calculated or estimated, and are they used as input values for the HYDROSS model, or are they a calculated result of the model?

Irrigation return flows, stream depletion, canal loss, and groundwater evaluations noted in presentations:

According to Dowl-HKM (Presentation: Technical Basis for Flathead Indian Irrigation Project Water Use Agreement September 4, 2012 – Polson, and June 12, 2014 – Helena), key model inputs included Flathead Indian Irrigation Project (FIIP) irrigation system canal losses. The presentations refers to several studies:

- Canal seepage study from DNRC
- Stream seepage runs from CSKT
- SS Papadopulos & Associates (SSPA) Ground Water Modeling Work
- Surface Water Budget is also balanced with Groundwater budget

The 2014 presentation includes a slide elaborating on the last point above, that the surface water budget is also balanced with the groundwater budget, further noting that elements from the HYDROSS models used by SSPA groundwater modeler included:

- Total stream and canal inflows
- Irrigated acreage
- Crop water use
- Canal and site losses to seepage
- Reach/diversion loss to seepage
- Total stream and canal outflows

The 2014 presentation also describes groundwater monitoring conducted at up to 72 wells starting in 1982, with data maintained in the Montana Bureau of Mines and Geology (MBMG) Ground Water Information Center (GWIC) database. Also, water quality sampling was performed under contract with MBMG during aguifer characterization studies in the mid-1990's.

Groundwater Modeling described in presentation:

Note: the following section could be paired down to the last paragraph for our report – just thought I would elaborate a bit on how I arrived at it.

A slide show from a presentation by Deborah L. Hathaway, P.E., S.S. Papadopulos & Assoc., Inc., May 26, 2010 provides a summary description of groundwater modeling efforts for the Jocko Basin, Mission Valley, and Little Bitterroot Valley. Most illustrations of results include "Work in-progress, results subject to change" labels. Based on the illustrations and presentation, the groundwater modeling was reasonably comprehensive, and appears to have included most elements that an experienced modeler would expect for basin-scale modeling designed to evaluate or analyze the groundwater budget and groundwater-surface water interactions. Model inputs are stated to include recharge from leaking canals and streams, excess water from irrigated fields, mountain front recharge, and groundwater inflow. Model input features include groundwater withdrawals from wells and riparian transpiration. Hydraulic conductivities were entered for various zones based on geologic units. No values are provided for any of the model recharge or sink features or hydraulic conductivities. No details about the model grid size, number of layers, and layer thickness or configuration are provided, however the available figures at least imply a reasonable grid cell size for such large-area models.

One slide with numerical data provides gains and losses for the upper and lower Jocko River. Gains in the lower Jocko River average around 30,000 acre-feet per year (af/yr), or 41 cubic feet per second (cfs). Another slide shows the potential elimination of 2,400 af/yr in canal losses for the Jocko basin – which represents perhaps 8 cfs per month for a five-month irrigation season – by lining of canals. The groundwater model reportedly indicates this would result in decrease in flow in the Jocko River of about 1,800 af/year, and groundwater level declines of up to a few feet at designated observation points in the basin. There are colorful groundwater level elevation maps compared with mapped potentiometric surfaces that both look reasonable for such a basin-scale effort. The slides include numerous examples of model results for a variety of scenarios which, based on my impression of the model scales and inputs, are appropriate applications of basin scale models.

In summary, the slide show provides information suggesting that the groundwater models are probably reasonable for general evaluations of groundwater budgets at a basin scale, and evaluating groundwater – surface water interactions. However, comprehensive data tables and descriptions of model details, including aquifer characteristics such as hydraulic conductivity, transmissivity, and storage coefficients typically expected in a report accompanying models of this nature, are unavailable. Therefore the groundwater flow models cannot be fully evaluated.

HYDROSS Model

Reviewing the report: "Mission HYDROSS Model Baseline Conditions, Run Date 8/27/2010" reveals the following information.

In the Model Structure section at the beginning of the report, it is stated (in Section 1.2.4.3) that the physical description of the study area is represented through a network identifying the following:

- How the stations connect;
- Physical facilities (reservoirs, power plants, canals, etc.);
- Location of water allocation demands (diversions, instream flow requirements); and
- Location of return flows back to the system.

Schematic diagrams illustrate the nature of stations used in the model network. According to these diagrams, return flows and other gains are added to upstream inflows to stations. Stations may or may not include a reservoir with potentially changing water content, diversions, evaporation, and reach losses. Water discharges from stations as "flow to next station."

For each station, a variety of actions are modeled. Pertaining to return flows, these actions include the assignments of percentages of canal loss to return flow and site loss to return flow. Reach losses, schematically shown to occur near the downstream end of each station, are explained in Section 1.2.13. According to this section, reach losses are used to simulate the loss of surface water within the stream channel to ground water. Not all of the reach losses are required to return to a designated station downstream. The reach loss return flows can be lagged up to eleven months and cannot return in the same month.

A table presented as Section 1.3 Model Limitations in the report notes that HYDROSS "Doesn't explicitly simulate ground water / surface water interrelationships except for irrigation and stream reach loss return flows. According to the table, this limitation is overcome in the modeling effort by this approach: "Use other gains/losses file(s) to simulate natural ground water inflows and maintain close coordination with the ground water modeling expert (S.S.P.A)." Where S.S.P.A. apparently refers to SS Papadopulos & Associates (SSPA).

Natural groundwater flows to five nodes are presented in Section 2.2. Most tables have the same values for every month, and because the tables are presented only for 1983, these same values are use throughout the modeled time frame, as explained in Section 1.2.4.2. The natural ground water inflow (gains) are provided as negative numbers in units of cubic feet per second (cfs) and range from -3 to -22 cfs. This section notes that these natural groundwater inflows were derived in close coordination with the ground water modeling expert, and a later in the report (Section 3.1.3) explains that where necessary, ground water inflows are injected at the downstream end of certain reaches to bring the model results into closer agreement with the measured flows, as the only other unexplained source of water.

Canal seepage losses were assigned in the model by assigning percent losses per mile of canal for specific canals, and then determining canal efficiencies for each canal reach based on the assigned percentage of loss and either their reach lengths or service acreage. The assigned loss percentages are stated to be based on the 2009 DNRC (Montana Dept. of Natural Resources and Conservation) Canal Seepage Study. Such losses were either applied directly to modeled canal reaches studied, or by using them as a general guide for assigning loss percentages to other modeled canal reaches. The table in Section 2.3.7.3 of the report lists the resulting canal efficiencies applied to diversion canals. The nomenclature of modeled canal reaches and that used in the DNRC makes it problematic to directly compare the numbers used in the Mission HYDROSS model with the DNRC study results; however Section 2.3.7.3 indicates that longer canal reaches typically have decreased efficiencies, as would be expected.

Site efficiencies were derived from lateral and on-farm irrigation estimates as described in some detail in the report. The resulting efficiencies assigned are listed in a table in Section 2.3.8.4.

Return flows from canals, sites, and stream reaches are distributed back to specified destination nodes. Tables in Section 2.7 of the report specify lag times for return flow delays from canals and sites (one

table) and from reach losses (a second table). The return flows can only occur in the twelve months following their origin. No explanation is provided as to how the lag times were determined. However, they are generally greatest in the months following their generation and decrease in subsequent months. About 90 percent of modeled return flows occur within 7 months of modeled time. In this same section, additional tables specify for each node with return flows, the destination node or nodes and percentage of return flows assigned.

The flows modeled as groundwater inflows, and listed as Imports from Natural GW (groundwater) in Section 3.2.3 (a table showing the average annual mass balance), may include irrigation return flows that exceed the 11 to 12 month lag times that HYDROSS can model. Many of the stations where groundwater inflow is applied appear to be located downstream of sizeable irrigated areas, based on the model schematic (Section 1.5).

Discussion

- Return flows modeled in the HYDROSS Mission Model are based on assigned canal and site efficiencies based approximately upon expected ranges of canal efficiencies and the observed stream flows at sites downstream of modeled irrigated areas. Stream losses contribute additional return flows to downstream reaches. In some cases, what may be return flows exceeding the 11 to 12 month duration capability of the HYDROSS return flow scheme, probably contribute to assigned ground water inflows at certain stations downstream of large irrigated areas. Thus, return flows are generated from input values that control their source. From these values, and the assigned distribution of return flows from one model station to other downstream stations, and based on specified lag times, HYDROSS calculates the amounts that show up as flow in downstream stations.
- Overall, the return flow rates and volumes, and the lag times used in the model seem within
 reason. However, the lack of details provided concerning the groundwater model effort and
 results limits our ability to thoroughly evaluate the issue from a groundwater perspective. The
 adequacy of return flow responses in the surface water hydrographs should best be evaluated
 by hydrologists.

VI. In stream flow quantification methods

Issue: "Robust River Standard"

Background: Questions have arisen regarding the application of the "Robust River Standard" in developing instream flow values. There is concern that the related high stream flows would negatively impact channel stability and irrigation infrastructure as well as the fishery.

- The terms "Robust River" or "Robust River Standard" are not used or defined in the proposed compact or supporting documentation. Neither are they generally accepted terms regularly used by professional instream flow scientists. To some the terms mean a healthy, fully-functioning river ecosystem while to others it apparently means a high flow maintained over an abnormally extended period of time. The latter interpretation seems to be the reason for the concern with respect to negative high flow impacts on channel stability, irrigation infrastructure and the fishery.
- The proposed instream flows are generally higher than the current interim instream flows. The interim instream flows are base-flow values below which instream flow should not drop during natural low-flow periods. The interim instream flows do not reflect the higher flows needed during times of the year to provide for a healthy stream ecosystem.
- Flows substantially higher than interim and higher than proposed instream flows are already occurring due to natural events and the use of streams to move water to and from storage reservoirs. The proposed instream flows do not present a threat to channel stability, irrigation infrastructure, or the fishery as they would not result in flows above naturally and already occurring levels and time periods.

References:

Brummond, A. August 1, 2014a, Memorandum to WPIC CSKT Technical Working Group, Evaluation of CSKT Instream Flow Levels for Streams with USGS Gages.

Issue: Quantification of on-Reservation instream flow rights

Background: The proposed compact contemplates instream flow water rights on the Flathead Indian Reservation. Questions have arisen as to how the amounts for these water rights were determined.

- There are three categories of on-Reservation instream water rights; natural, Flathead Indian Irrigation Project (FIIP) related and other non-FIIP related. Natural flow rights cover streams above diversions and reflect maintenance of the existing natural flow conditions without anthropogenic influence. The FIIP related instream rights occur in stream reaches immediately below FIIP diversions and directly influenced by the operations of FIIP. The other non-FIIP related instream rights cover stream reaches outside the FIIP area of influence, but do sustain non-FIIP related anthropogenic impacts. These instream flows will have a time immemorial priority date.
- The FIIP related instream rights are based on the streamflow remaining after irrigation diversions have occurred. These instream rights include water added due to the benefits of operational improvements (e.g. elimination of shoulder season stockwater diversion, reducing ditch tail-water loss to 3%, and increased pumping from the Flathead pumping station). No specified instream flow methodology was used to derive the FIIP related instream rights. Rather, they are defined as the water left instream after irrigation diversions have occurred.
- The current interim instream flows will continue to be used and the FIIP instream flow values will be deferred for at least five years after funding is appropriated for operational improvements.
- The FIIP related values, particularly in summer and early fall, is substantially lower than that which would have naturally occurred in most cases. However, in some stream reaches, the use of streams to carry water to or from storage reservoirs inflates these numbers above that which would have naturally occurred.
- When compared to instream flows generated using a hydrology based instream flow methodology used in British Columbia at 4 sites where U.S. Geological Survey streamflow data is available, the FIIP related values are lower than those generated using the recognized methodology. On whole across the FIIP instream flows generated using recognized methodologies would likely result in higher instream flows with less water available for irrigation than if the proposed FIIP related instream flow values are used.
- While not directly based on specific instream flow methodologies, the FIIP related instream rights do exhibit the intra and inter-annual variability that is a recognized

cornerstone of instream flow science. This is accomplished by the variable monthly flow rates that generally follow the shape of the natural hydrograph and by the different dry (MEF), normal and wet year instream flow levels.

• For the other non-FIIP related instream rights they are based on the Tennant instream flow methodology which is based on percentages of average annual flow in the stream. The following table reflects the application of the Tennant method:

Narrative Description of Flow ^a	April to September	October to March
Flushing or maximum flow	200% from 48 to 72 hours	
Optimum range of flow	60-100%	60-100%
Outstanding habitat	60%	40%
Excellent habitat	50%	30%
Good habitat	40%	20%
Fair or degrading habitat	30%	10%
Poor or minimum habitat b	10%	10%
Severe degradation	<10%	<10%

^a For fish, wildlife, recreation, and related environmental resources.

References:

Annear, T., I. Chisholm, H. Beecher, A. Locke, and 12 other authors. 2004. Instream Flows For Riverine Resources Stewardship, Revised Edition. Instream Flow Council, Cheyenne, WY.

Brummond, A. August 1, 2014a, Memorandum to WPIC CSKT Technical Working Group, Evaluation of CSKT Instream Flow Levels for Streams with USGS Gages.

^b This is only for short-term survival in most cases.

Issue: Quantification of water right claims to be co-owned with FWP

Background: The proposed compact contemplates that several existing instream (Rock Creek, Blackfoot River, Flathead River and its forks, and Bitterroot River) and inlake water rights (Clearwater Chain of Lakes, Upsata Lake, Harpers Lake and Browns Lake) held by Montana Fish, Wildlife & Parks (FWP) would be co-owned by the Confederated Salish and Kootenai Tribes. Questions have arisen as to the methodologies used to quantify these water rights.

• The "Murphy" instream flow water rights for the Blackfoot, South Fork, Middle Fork, North Fork and main stem Flathead Rivers, and Rock Creek are based on the dominant discharge/channel morphology concept (high flow period-generally April - July) and wetted perimeter method (low flow period — August - March). The dominant discharge/channel morphology concept focuses on the need for higher flows for bed load movement and sediment transport which are essential functions in maintaining good fish habitat in a river. For the high flow period monthly flows equating to that which are exceed during 8 out of 10 years were selected to provide for sufficient channel forming function while still allowing for a reasonable level of new water development in most years. The wetted perimeter method used for the lower flow period is now recognized in statute (85-20-1401, MCA) which defines it as follows:

"Wetted Perimeter Methodology" means an instream flow methodology for fisheries flow based on habitat for food production in the shallow, fast-moving water of a stream. The wetted perimeter is the distance across the bottom and sides of a stream channel, measured at a riffle area, that is in contact with the water. A graph of the wetted perimeter versus discharge generally yields two inflection points. The upper inflection point of the graph is the level above which large increases in discharge result in a small increase of the wetted perimeter. The lower inflection point of the graph is the level below which small decreases in discharge result in large decreases of the wetted perimeter.

The wetted perimeter method has long been recognized in Montana as a practical means of determining instream flows during the base or low-flow portion of the year and serves as the basis for over 200 instream flow reservations held by FWP. The results of the aforementioned analysis was compared to the notices of appropriation filed in the local county courthouses for the Murphy rights and the claimed flow rate was reduced where the instream flow methodology suggested a value lower that that found in the notice of appropriation.

 The Bitterroot River Public Recreation water rights filed in accordance with §85-2-223, MCA are based on the dominant discharge/channel morphology concept discussed above as well as the flow necessary for floating of the river and preservation of existing winter flows. Unlike the Murphy right rivers previously discussed (possibly excluding the Blackfoot River) existing irrigation has a significant impact on flow observed in the Bitterroot River. For that reason the mean monthly streamflow was used to determine the necessary flow needed in the high flow period (May and June) instead of the relatively lower 80th percentile exceedence (8 out of 10 year) flow that was used for the Murphy right rivers. For the July – September period the flow is that necessary to maintain adequate depth (1-2 feet) for floating over riffles. During the winter period the mean monthly streamflow again serves as the basis for the instream flow value as it provides adequate habitat during periods when ice can severely limit available impact causing significant negative impact to the fishery.

- A water quality model designed to prevent eutrophication, a water temperature model and fish passage depths were used to quantify the monthly volumes of water for the Clearwater chain of lakes (Salmon, Placid, Seeley, Inez, Alva, Rainy and Clearwater Lakes).
- For Upsata, Harpers and Browns Lakes the Supreme Court Claim Examination Rule was applied that provides for quantification of a fish and wildlife lake equal to a volume of water equal to the capacity of the lake plus annual evaporation.

References:

Water Right Statements of Claim files for the Bitterroot, Blackfoot, South Fork, Middle Fork, North Fork and main stem Flathead Rivers, Rock Creek, Upsata, Harpers and Browns Lakes and the Clearwater chain of lakes (Salmon, Placid, Seeley, Inez, Alva, Rainy and Clearwater Lakes).

Supreme Court Claim Examination Rule 29(c).

Brummond, A., Knotek, W., Flynn, K. 2014. Water Right Volumes Necessary to Support Recreation on the Clearwater Chain of Lakes. Montana Fish, Wildlife & Parks

<u>Issue:</u> Changes in legal availability of water due to new proposed off-Reservation instream rights – basin closures/calls and methods of quantification.

Background: Off-Reservation instream flow water rights have been proposed for the lower Clark Fork, Swan and Kootenai Rivers as wells as Big, Boulder and Sutton Creeks, all tributaries to Lake Koocanusa and Steep Creek a tributary to Big Creek. Concerns have been raised that these instream rights would close these basins to new appropriations of water and would result in existing water users being called upon to cease diversion when flows drop below the level of the instream rights. Questions regarding how these rights were quantified have also been raised.

- Unlike some other federal agency and tribal compacts, the proposed compact does not close any basin to new appropriations of water.
- Calls on existing water rights based on the proposed instream rights would be limited to irrigation water rights on the main-steam Clark Fork and Kootenai Rivers. This would include irrigation rights from groundwater connected to the rivers pumping at a rate in excess of 100 gpm.
- The proposed instream right for the lower Clark Fork River of 5,000 CFS matches the
 minimum flow required under the FERC license for Cabinet Gorge Dam. If this minimum
 flow requirement were to be reduced under the FERC license, the instream flow right
 would be reduced to the same level.
- Flow in the Clark Fork River exceeds 5,000 CFS during the normal irrigation period of April through September in even very dry years (driest year in 20 on a statistical basis) making a call on Clark Fork River irrigators extremely unlikely. This instream right would not impact new water users ability to obtain a new water right under present circumstances as DNRC typically evaluates legal availability based on water being available in excess of existing water rights in 5 out of 10 years.
- The proposed instream right for the Kootenai River would not be in effect unless protocols for operations of Libby Dam under requirements of the Endangered Species Act are lifted. The instream right is approximately the daily flow level that is met or exceeded 1 out of 10 years meaning in about 9 out 10 years the instream flow right is met. Calls on existing water rights would potentially occur very infrequently. This instream right would not impact new water users ability to obtain a new water right under present circumstances. While the instream flow values were negotiated, they are lower than values generated by hydrologic instream flow methodologies such as the Alberta Desktop Method of the DFO method which both allow for no diversion below 80th percentile exceedence flows (flow exceeded in 8 out of 10 years).

- Calls on existing water rights based on the proposed instream right for the Swan River would be limited to irrigation rights including those from groundwater connected to surface water pumping at a rate in excess of 100 gpm. Unlike the Clark Fork and Kootenai Rivers this call could extend to tributaries in the Swan River basin. The instream right is essentially the daily flow level that is met or exceeded 2 out of 10 years meaning in about 8 out 10 years the instream flow right is met while on a statistical basis existing water rights may be subject to call in about 2 out of 10 years. This instream right would not impact new water users ability to obtain a new water right under present circumstances.
- Quantification or the selection of the approximate 80th percentile exceedence flow for the Swan River instream right was based very roughly on the Alberta Desk-top Method. However, a strict application of the Alberta Desktop Method would yield higher instream flow values in normal an wetter years allowing no more than 15% of the natural flow to be diverted.
- Big, Boulder, Steep and Sutton Creeks all lie entirely on U.S. Forest Service land and do
 not have any private water rights diverting from them. The quantifications of these
 rights are designed to protect the existing natural flow regime in these streams. It is
 unlikely new water users could obtain a water right from these streams with the
 proposed compact in place.

References:

Brummond, A. August 1, 2014b, Memorandum to WPIC CSKT Technical Working Group, Changes in legal water demand due to CSKT Compact.

DFO. 2004. Synopsis of Instream Flow Thresholds for Fish and Fish Habitat as Guidelines for Reviewing Proposed Water Uses. British Columbia Ministry of Water, Land and Air Protection (MWLAP), Ministry of Sustainable Resource Management (MSRM), Land and Water BC Inc. (LWBC), and Fisheries and Oceans Canada (DFO)

Locke, A. and Paul, A. 2011. A Desk-top Method for Establishing Environmental Flow in Alberta Rivers and Streams. Alberta Environment and Alberta Sustainable Resource Development.