Agreement on H-I Model Changes to Address Increases in Irrigation Efficiency for Pumped Groundwater

September 2011

I. Introduction

This Agreement ("Agreement") is entered into by the State of Colorado and the State of Kansas ("States") to modify the Hydrologic-Institutional Model ("H-I Model") to recognize improved efficiencies of groundwater-supplied irrigation systems. This Agreement modifies the H-I Model code from the version incorporated in the Judgment and Decree entered in March 2009 in *Kansas v. Colorado* (No. 105, Original) (hereafter "Decree") and describes the procedures for determining weighted groundwater maximum farm efficiencies ("weighted efficiencies") and adjusted tailwater factors and using them in the annual update of the H-I Model under the Decree.

II. Background and Context

On July 22, 2010, Kansas submitted a report to Colorado in conformance with the procedures in Section V of Appendix B.1, proposing changes to the H-I Model to reflect the increases in irrigation efficiency of groundwater-supplied irrigation systems in Colorado. Colorado agreed that the H-I Model will more accurately represent current conditions by applying weighted efficiencies and adjusted tailwater factors to reflect the increased consumption of groundwater through improved groundwater irrigation systems in Colorado. On January 24, 2011, Colorado accepted Kansas's proposed change with a modification designed to increase the accuracy of the new weighted efficiencies. On February 22, 2011, Kansas indicated agreement and initiated the Non-Fast Track Issue Dispute Resolution Procedure in Appendix H of the Decree to allow the States more time to develop this Agreement and the related documentation. Section III of the Decree allows Appendices A-J to be modified by agreement of the States. Appendices B.1 and C.1 were modified as follows:

1. Appendix B.1 is modified in Section I with two new paragraphs that reference this Agreement and its requirements, and in Section III.B.5 with a reference to this Agreement and the input data and data assessments it requires.

2. Appendix C.1 is modified in Section 1.4.10, to describe the addition of weighted efficiencies and adjusted tailwater factors; in Section 1.5.3, to describe revisions made involving the LAND Subroutine; in Section 1.6 and paragraph 1.6.1, to describe H-I Model revisions and reference this Agreement; in Section 2.3, to note data input changes; in Section 3.1, to add to the list of H-I Model modifications; in Section 3.2, to add the weighted groundwater farm efficiencies and adjusted tailwater factors as inputs to UPDATE.DAT; in Section 3.3.6 and paragraphs 3.3.6.1 through 3.3.6.7, to describe various data input into UPDATE.DAT; in Section 3.4, to describe adjustments to UPDATE.DAT for weighted groundwater efficiencies and adjusted

tailwater factors; in 6.1, to reflect the updating of the DVD and its contents; and in Attachment 6.12, to insert a full copy of this Agreement into Amended Appendix C.1.

A DVD containing an electronic copy of the H-I Model code was included as Attachment 6.1 to the original Appendix C.1. That original DVD will be replaced with a revised DVD, dated September 2011. In addition, this Agreement will be inserted as Section 6.12 of Amended Appendix C.1. The States will jointly submit Amended Appendices B.1 and C.1 to the Court to replace those original appendices in full.

III. Scope

The requirements listed in this Agreement pertain only to wells diverting groundwater for irrigation use that are within the H-I Model domain and are part of H-I Model Data Set 12. The weighted efficiencies and adjusted tailwater factors will be varied by user in the annual H-I Model update for calendar year 2011, which will be performed in 2012, and for each subsequent year thereafter.

IV. H-I Model Code Revisions

In order to reflect increased groundwater irrigation efficiencies, the input file UPDATE.DAT and H-I Model code were modified. These modifications were necessary because the H-I Model incorporated in the Decree applied a single efficiency value (known as the "maximum farm efficiency" factor) to each canal service area (user) which was used in both the Historical and Compact runs. In the Historical run, the weighted efficiencies will be calculated and may vary for each calendar year (January-December) by user based on the types of irrigation system used. The weighted efficiencies and adjusted tailwater factors described in this Agreement will not be applied in the Compact run; the maximum farm efficiency factors listed in LAND.DAT will continue to be used.

The H-I Model modifications are further described below.

A. UPDATE.DAT: The input file UPDATE.DAT incorporates the weighted efficiencies and adjusted tailwater factors on an annual basis starting with the 2011 H-I Model annual update. Unique efficiencies and tailwater factors are added directly by user group to the UPDATE.DAT file after running COMBINE.C. This data is entered each year for the update period included in the input file.

In addition to the variables described in Appendix C.1, there are four new variables that are updated annually and included as model input for the Historical run of the H-I Model:

1. **FMESS** – maximum farm efficiency by user for sole source groundwater irrigation systems, weighted by irrigation type;
2. **FMEC** – maximum farm efficiency by user for supplemental (conjunctive use) groundwater irrigation systems, weighted by irrigation type;

3. **TAILSS** – a factor to calculate tailwater by user for sole source groundwater irrigation systems; and
4. **TAILC** – a factor to calculate tailwater by user for supplemental (conjunctive use) groundwater irrigation systems.

B. LAND Subroutine: The revised LAND subroutine provides the H-I Model with the capability to incorporate the maximum farm efficiencies and tailwater factors from UPDATE.DAT when the switch is set to the Historical run. The weighted efficiencies and adjusted tailwater factors are incorporated into UPDATE.DAT beginning with update year 2011 and each year thereafter for the corresponding acreage type.[1] The farm efficiency and tail water data input will be pulled from UPDATE.DAT for the Historical run for years 1995 through the current update year. The maximum farm efficiency and tailwater factors for 1995-2010 will be the same as those previously found in LAND.DAT, and the weighted efficiencies and adjusted tailwater factors will be used for 2011 forward. The Compact run still applies the factors listed in LAND.DAT. Supplemental acreage has both surface water and groundwater applied to it. In recognition of Colorado's *Compact Rules Governing Improvements to Surface Water Irrigation Systems in Arkansas River Basin in Colorado*, logic in the H-I Model code allows for weighting the supplemental efficiency based on the surface and groundwater supply. A ratio of surface water to combined surface and groundwater is used to calculate a weighted efficiency for supplemental, IType III, acreage. The calculation applies the original efficiency to the surface water supply and the modified efficiency to the groundwater supply and is performed every time step in the model, resulting in a monthly prorating of efficiency.

V. Pumping and Acreage Data to be Used in Determining the Annual Weighted Groundwater Maximum Farm Efficiencies and Adjusted Tailwater Factors

The pumped volume of groundwater data (hereafter "pumping data") used to compile Data Set 12 in the H-I Model update will be used for the purpose of calculating the annual weighted efficiencies and adjusted tailwater factors for each H-I Model user. This pumping data is assembled pursuant to the *Amended Rules Governing the Measurement of Tributary Ground Water Diversions Located in the Arkansas River Basin* (referred to as "Colorado's Measurement Rules") and *Amended Rules and Regulations Governing the Diversion and Use of Tributary Ground Water in the Arkansas River Basin, Colorado* (referred to as "Colorado's Use Rules")[2] and in accordance with Appendices A.4[3] and B.1 of the Decree.

Colorado will maintain and provide data to allow determination of pumping by irrigation method for each well, including at a minimum the following:

1. Source of energy used to divert groundwater;

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[1] The H-I Model defines three acreage types, labeled IType I, IType II and IType III. Sole Source lands are IType II. Supplemental lands are IType III. Only sole source and supplemental lands are affected by the 2011 Agreement. IType I, surface water acreage, applies the same efficiencies as the Compact Run.

[2] Appendices J.1 and I.1 to the Decree.

[3] As revised by the States on June 26, 2009.

2. Whether the well is used as a supplemental or sole source irrigation supply or whether it serves as a supply to both sole source and supplemental lands;
3. Parcel ID number from Colorado's GIS coverage for each parcel served by the well for that irrigation year (this number is formatted by location to show the Township, Range, Section and field number and is a unique identifier);
4. Irrigation method (Flood and Furrow, Sprinkler and/or Drip). If the well delivers water to multiple fields that have different irrigation methods:
    a. Measurement of water delivered by irrigation type and method (meter data), or
    b. Acreage used to distribute the prorated pumping amount by irrigation method (pro-rated by acreage);
5. H-I Model user number that the pumping occurred under; and
6. Presumptive depletion factor (PDF).

Colorado will compile acreage data as described in Amended Appendix B.1 for Data Set 49 of the H-I Model update and provide the data to Kansas, including the GIS shapefile and a tabular computation of irrigation application of groundwater by farm unit.

For farm units with wells that serve sole source parcels and supplemental parcels, and/or that deliver water by multiple irrigation methods, pumping will be assigned in Data Set 12 as sole source or supplemental pumping. For any well, if measurements of the amount of groundwater used under each irrigation method are not available, the quantity of groundwater pumped from that well will be prorated by the number of acres under each irrigation method served by groundwater from that well.

Additionally, pivot corners are assumed to be sprinkler irrigated unless field confirmation by Colorado Division of Water Resources staff has documented that they are no longer irrigated. For fields where two irrigation methods are used on the same acreage, the highest efficiency will be applied in the weighted efficiency calculation.

VI. Procedure for Finding and Correcting Errors in Pumping Data and Acreage Data

Farm Unit Review: Farm units that include parcels that are only served by groundwater ("sole source" acreage) with application rates greater than four (4) acre-feet per acre shall be further evaluated to ensure there are no errors in the base data for pumping and to ensure that all parcels are properly classified for irrigation status. Similarly, farm units that include parcels that are served by groundwater and surface water ("supplemental" acreage) with groundwater application rates greater than three (3) acre-feet per acre shall be further evaluated to ensure there are no errors in the base data for pumping; to ensure that all parcels are properly classified for irrigation status; and to determine whether an adjustment to the presumptive depletion factors (PDFs) pursuant to Rule 4.2 of the Amended Use Rules is appropriate. Review of or adjustments to the presumptive depletion factors (PDFs) do not affect the calculation of weighted efficiencies input to the H-I Model.

If it can be determined that there are no errors in the farm unit pumping or acreage data, that data will remain in Data Sets 12 and 49 and be included in the weighted efficiency calculations. If there are errors in the farm unit pumping and/or acreage data, those errors will be

corrected in cooperation by experts from both States. Those corrections agreed upon by both States and the farm unit data will be used to update Data Sets 12 and 49, and be included in the weighted efficiency calculations. For farm units with a high supplemental pumping rate per acre, if the evaluation indicates that an adjustment to the supplemental presumptive depletion factor (PDF) is appropriate, Colorado will notify the owners and well associations, and will implement the new PDF for the upcoming plan year.

The basic steps to be performed in the Farm Unit Review are as follows:

1. Pumping
   a. Double-check user-supplied meter reading data against most recent well test data and DWR inspection data to ensure readings, multipliers and correction factors are accurate.
   b. Double-check power company-supplied data against most recent well test data and DWR inspection data to ensure readings, multipliers and correction factors are accurate.

2. Acreage
   a. Review parcel assignments against most recent Farm Unit Verification data to ensure parcels are properly assigned to the farm unit.
   b. Review the classification of each parcel to ensure that both the irrigation method (Flood and Furrow, Sprinkler, Drip, and/or Dry) and irrigation supply (GW-groundwater, Both-surface and groundwater, SW-surface water, NI-not irrigated) are correct. Use available imagery or aerial photos to check for irrigation status changes. Double-check with field visit if changes appear to be suggested.

3. Presumptive Depletion Factor Check
   a. For farm units with supplemental wells, perform a Rule 4.2 sliding scale analysis by compiling the annual pumping for the last five (5) year period and estimating the surface water supply using a simplified version of the Irrigation System Analysis Model (ISAM) tool. The Rule 4.2 analysis is only used for the purpose of establishing the PDF to be used in the administration of the Amended Use Rules and is not used for the determination of the annual weighted efficiencies.
   b. Adjust PDF's for upcoming Plan Year (2012-13 for initial process) and notify the owner and well association.

VII. Procedure for Calculating the Annual Weighted Groundwater Maximum Farm Efficiencies and Adjusted Tailwater Factors

After obtaining and processing the pumping and acreage data as described in the previous sections, the weighted efficiencies will be computed using the following procedure:

1. The weighted efficiencies will be computed by H-I Model user based on the pumping data for the calendar year (January-December) for which the H-I Model annual update is being done. This will apply to both supplemental and sole source pumping. The weighted efficiencies will be calculated using the pumping data aggregated by H-I Model user. The factors used to calculate the weighted efficiencies are as follows:

a. 65% for gravity irrigation, except under the Colorado and Lamar Canals where 70% will be applied;
b. 85% for sprinkler irrigation; and
c. 100% for drip irrigation.

2. Sole source and supplemental weighted efficiencies will then be computed separately by applying the following formulas for each H-I Model user:

$$Total\ Pumping = Gravity\ Pumping + Sprinkler\ Pumping + Drip\ Pumping$$

$$Weighted\ Efficiency = \frac{(\qquad\qquad .}{\qquad}$$

3. Tailwater factors will then be adjusted for each H-I Model user based on the weighted efficiencies for each user. The new adjusted tailwater factors decrease linearly from 10% to 0% as the new weighted efficiencies increase from 65% (70% for Colorado and Lamar Canals) to 85% using the following relationship:

$$Adjusted\ Tailwater\ Factor = Max(0, \frac{((1 - Weighted\ Efficiency) - .15)}{2})$$

The following table illustrates the computation of the weighted efficiencies and adjusted tailwater percentages using 2010 pumping data:

Table 1: Illustrative Example of the Computation of Weighted Efficencies and Adjusted Tailwater Factors using 2010 Pumping Data

H-I Model User Number	Sole Source Pumping (acre-feet)				Supplemental Pumping (acre-feet)				Weighted Efficiency (%) [1]		Adjusted Tail Water Factor (%)	
	Gravity Irrigation	Sprinkler Irrigation	Drip Irrigation	Total Pumping	Gravity Irrigation	Sprinkler Irrigation	Drip Irrigation	Total Pumping	Sole Source	Supple-mental	Sole Source	Supple-mental
1	1,906	843	8	2,756	5,556	93	44	5,693	71%	66%	6.9%	9.7%
2	265	1	9	274	0	0	0	0		66%		9.4%
3	888	715	29	1,631	0	0	0	0		74%		5.3%
4	0	0	0	0	143	0	0	143		65%		10.0%
5	1,195	219	550	1,964	371	0	0	371	80%	70%	3.3%	10.0%
6	392	9	0	401	3,189	0	0	3,189	65%	65%	9.8%	10.0%
7	59	108	12	179	2,808	0	0	2,808	79%	65%	2.8%	10.0%
8	8	0	0	8	516	0	0	516	65%	65%	10.0%	10.0%
9	1,086	454	1,287	2,827	6,357	281	52	6,689	84%	66%	0.4%	9.4%
10	1,687	1,138	426	3,252	10,345	1,687	0	12,032	77%	68%	4.2%	8.6%
11	372	329	525	1,226	4	0	0	4	85%	65%	0.0%	10.0%
12	374	0	255	629	1,122	119	89	1,330	79%	69%	2.9%	7.9%
13	663	32	0	695	234	0	0	234	66%	65%	9.5%	10.0%
14	1,468	820	0	2,288	0	0	0	0	72%		6.4%	
15	40	314	0	354	1,091	155	0	1,246	83%	67%	1.1%	8.8%
16	0	0	0	0	0	0	0	0				
17	2,094	3,682	0	5,776	3,343	521	0	3,864	78%	68%	3.6%	8.7%
18	332	292	120	743	5,202	1,033	78	6,312	81%	73%	2.8%	8.1%
19	1	58	0	59	122	0	0	122	85%	65%	0.2%	10.0%
20												
21	2,615	1,688	0	4,304	423	0	0	423		72%		6.4%
22	26	0	284	310	1,432	0	0	1,432	97%	65%	0.0%	10.0%
23	0	751	0	751	0	0	0	0		85%		0.0%
24	1,928	7,731	0	9,659	0	0	0	0	81%		2.0%	

Note:

(1) Because the H-I Model represents all acreage under the Booth (2), Excelsior (3), Keesee (16) X-Y (21) and Sisson (23) ditches as supplemental acreage, the pumping is listed in the column for supplemental groundwater in this table even though it may be classified as sole source pumping in Colorado's monthly augmentation accounting.

VIII. Schedule for Annual Farm Unit Review and Determination of Weighted Groundwater Maximum Farm Efficiencies and Adjusted Tailwater Factors

On or before March 1 of each year, Colorado will provide initial pumping and acreage data to Kansas for the cooperative effort of identifying possible errors using the Farm Unit Review screening criteria described in Section VI above. An updated version of the Farm Unit Review shall be provided by Colorado to Kansas by March 31st.

The calculation of weighted efficiencies and adjusted tailwater factors will be performed during the annual update of H-I Model input data beginning in 2012 for the update of input data for the calendar year 2011, which shall be provided to Kansas by March 31, 2012. Thereafter, on or before March 31st each year, Colorado will provide Kansas with its calculations and the corresponding back-up data described in this Agreement, concurrent with Colorado's submission of its H-I Model results, ten-year Compact compliance table, and Annual Report to Kansas.

IX. General Terms

A. The narrative included in this Agreement and in Amended Appendices B.1 and C.1 is intended to describe the H-I Model as accurately as possible; however, if any description or representation of the H-I Model in this narrative conflicts with the code, data files, processing programs, calibration programs, or H-I Model outputs on the revised DVD (Attachment 6.1 to Amended Appendix C.1), the information on the DVD will control.

B. If any of the amendments to the text of Appendices B.1 or C.1 that were made pursuant to this Agreement to reflect this Agreement conflict with the terms of this Agreement, this Agreement will control.

C. This Agreement fully resolves the matter and terminates the dispute resolution procedure.

D. This Agreement shall become effective when both States have approved it by the signatures of their Engineers as provided for below on counterpart copies, and telecopies or electronic versions of the same have been received by the other State. Two originals of this Agreement will be circulated for signature, one original to be retained by each State.

STATE OF COLORADO

_____

Dick Wolfe
Colorado State Engineer

Date: _____

STATE OF KANSAS

David W Barfield

David W. Barfield
Kansas Chief Engineer

Date: 9/15/2011

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STATE OF COLORADO

Dick Wolfe
Colorado State Engineer

Date: 9/15/2011

STATE OF KANSAS

David W. Barfield
Kansas Chief Engineer

Date: _____