WRAP Modifications Since March 2003

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The March 2003 version of the *Water Rights Analysis Package (WRAP)* model is documented by a draft *Reference Manual* and draft *Users Manual*, both dated March 2003, which supercede the previous:

> *Reference and Users Manual for the Water Rights Analysis Package (WRAP)*, TWRI TR-180, 1st Edition August 1999, 2nd Edition October 2000, 3rd Edition July 2001.

Modifications made to *WRAP* since the March 2003 version of the model and manual are described as follows. These modifications are incorporated in the June 2003 *WRAP*. Only the program *WRAP-SIM* is affected.

Revisions to the New Type 7 Water Right for Return Flows

Two additional features have been added to the new type 7 right originally introduced in the March 2003 *WRAP*. As described in the March 2003 draft *Users Manual*, the water right type entered in field 6 of the *WR* record now includes a type 7 option as shown below. The *BACKUP* variable entered in field 6 of the supplemental options *SO* record includes a related *RETURN* option as well.

WR Record - Water Right

field	columns	variable	format	value	description
6	36	WRNUM (wr,5)	I4	blank,0,1	Type 1 water right
				2	Type 2 water right (no refilling storage)
				3	Type 3 water right (no streamflow depletions)
				4	Type 4 water right (storage-diversion relationship)
				5,-1	Type 5 water right (hydroelectric power)
				6,-3	Type 6 water right (hydroelectric power)
				7	Type 7 water right (inflow to stream)

The primary reason for the type 7 option is to allow return flows to be assigned priorities that are different than the corresponding diversions. Adding a *WR* record with a type 7 right and a *SO* record with the *RETURN* option along with the *WR* record and other supporting records for a diversion right will reproduce exactly the same simulation results obtained handling the *WR* record return flows in a conventional manner if the priorities are the same. However, the new approach allows the return flows to be placed elsewhere in the priority loop. Likewise, return flows are often treated as constant inflows entered on *CI* records, which makes the flows available at the beginning of the priority-based water rights computations. The type 7 option allows inflows to be inserted at any priority.

With a type 7 right, the annual amount *AMT* entered in *WR* record field 3 is discharged into the stream. The stream inflow amounts resulting from type 7 rights are found in the simulation

results as return flows. A type 7 right may model a return flow or other situations involving discharge of water into the stream system within the water rights priority computation loop. The target amount is computed for a type 7 right just like any other type of right. The annual amount entered in *WR* record field 3 is converted to monthly values by factors on *UC* records and may be adjusted by options specified on *SO*, *TO*, *TS*, and *DI* records. The difference is that a type 7 right is not a diversion from the stream, but rather an inflow to the stream. After the monthly amount is determined just like a diversion target, it is then multiplied by the return flow factor and treated computationally as a return flow.

Two aspects of the type 7 option have been expanded since the March 2003 *WRAP*. In the March 2003 WRAP, all return flow options are valid except monthly return factors (*RF* records) can not be used. *WRAP* has now been modified to allow monthly return factors (*RF* records) to be used with type 7 rights.

The other modification deals with *WRAP-SIM* output. In both the March 2003 and subsequent versions of *WRAP*, the discharges associated with type 7 rights are included in the return flows in the computations and simulation results. *WRAP-SIM* has now been modified to output the type 7 inflows as negative diversions in the *WRAP-SIM* water right output records. Including the negative diversions in water right output records does not affect the control point output records or any other computations. However, *2DIV* and *2SWR* tables created with program *TABLES* for a type 7 right will now show the inflows as diversions preceded by minus signs.

Option to Exclude Channel Losses for Return Flows

Addition of this option was motivated by a strategy for modeling Rio Grande treaty provisions that involves transferring naturalized flows between the United States and Mexico using *WRAP-SIM* diversion and return flow features. Naturalized flows already reflect channel losses; thus, channel loss factors should not be applied to the naturalized flows transferred between nations in the model as diversion/return flows.

If the term *NORFCL* is entered in field 11 of the *SO* record for a water right, channel losses are not applied to return flows associated with this right. This option affects only the routine in subroutine *AVALB* in which downstream flows are adjusted for the effects of a return flow entering the stream at an upstream control point.

SO Record – Supplemental Water Rights Options

field	columns	variable	format	value	description
11	75-80	NORFCL	A6	blank	No-return-flow-channel-loss option is not activated.
				NORFCL	Channel losses are not applied to return flows for this water right.

The channel losses written to field 12 of the *SIM* control point output records and read by the *TABLES 2CLO* record routine are not affected by the new *NORFCL* option. Channel loss factors *CL* and the new *NORFCL* option affect water availability, regulated flows, unappropriated flows,

and various other aspects of simulation results. However, although delivery factors (*1.0-CL*) are applied in several routines, channel losses are actually never computed within the water rights computation loop. Channel losses are computed after completion of the water rights simulation loop and have no impact on other simulation results. The channel losses are computed simply for tabulation in a *2CLO* record table for information purposes. The channel losses for a control point are computed based on the summation of all return flows returned to that control point without differentiating whether some of the return flow is associated with water rights flagged by the *NORFCL* option.

Option Excluding Reservoir Releases in Considering Instream Flow Requirements

A new option activated by field 8 of the instream flow *IF* record was added primarily to address water right permits that specify that:

> *Permit holder is authorized to appropriate water only when the flows at a specified location exceed a specified flow limit exclusive of reservoir releases dedicated for subsequent use downstream.*

IF Record – Instream Flow Requirement

field	columns	variable	format	value	description
					Type of Instream Flow Computations
7	40	IFFLAG (wr)	I4	0	Shortages determined only
				1	Constraints on water availability during first pass
				2	Constraints on water availability during second pass
				3	Constraints during first pass, reservoir storage used
				4	Constraints during second pass, reservoir storage used
				5	Instream flow requirement is ignored
8	44	IFFLAG2 (wr)	I4	blank,0	Instream flow limit is based on total regulated flow.
				1,non-zero	Reservoir releases for downstream use are excluded.
					Drought Index
9	47-48	DINDEX(wr)	I8	blank,0	Drought index is not used for this water right.
				+,-	Integer identifier (1,2,3,...,15) of drought index. If positive, the drought index is applied as step 2 outlined on page 187. A negative sign switches to applying the drought index as step 5 on page 187.
					Water Right Identifier
10	49-64	WRID(wr)	A16	AN	Water right identifier (optional)

Instream flow limits specified by *IF* records are considered in determining the amount of water available for *WR* record water rights. In past versions of *WRAP*, instream flow limits have always been compared to the total regulated flows at specified locations in determining water availability. As long as the new *IF* record field 8 is left blank, nothing changes. However, *IFFLAG2* entered in field 8 activates a new option in which instream flow limits are applied to

regulated flows exclusion of reservoir releases made from upstream reservoirs to meet downstream water right requirements. Thus, with this new option, from the perspective of meeting instream flow requirements, releases from upstream reservoirs dedicated for use further downstream are not credited as contributing to meeting the instream flow targets at intermediate control points. Although water availability and thus water right results may be affected, the regulated flows included in the simulation results are the true total regulated flows.

An *IF* record results in an instream flow limit being set, which is compared with regulated flows in subroutine *AVALB* that is called to determine water availability for each right in the priority loop computations. The only change activated by the new *IFFLAG2* option is the setting of whether or not reservoir releases are included in the regulated flows that are compared with the instream flow limit. *IFFLAG2* is specified individually for each *IF* record, and thus the new option may be switched on and off as needed. If switched on as the most junior *IF* record right at a control point, the final unappropriated flows at that control point will exclude reservoir releases.

Optional Second Pass through the Water Rights Computational Loop

The two modifications described next deal with the second pass through the water rights computational loop associated with instream flow options 2 and 4, which are specified by *IFFLAG(wr)* in field 7 of the *IF* record. The purpose of the second pass option is to help deal with situations discussed later in which junior diversion and/or storage rights might be unnecessarily curtailed to maintain senior instream flow requirements.

New Option to Require Second Pass in All Months

As discussed below, the second pass through the computational loop is activated only if at least one *IF* record has an *IFFLAG* of 2 or 4 and only during months in which at least one such *IF* record right incurs a shortage. A new option activated by *PASS2* entered in field 14 of the *JD* record forces the second pass to be activated in all months regardless of *IF* record *IFFLAG* specifications. The new *PASS2=2* option may possibly help prevent junior diversion and/or storage rights from being unnecessarily curtailed to maintain senior instream flow requirements. The old *PASS2=0* default provides possibly greater assurance that instream flow shortages are not inadvertently incurred in the protection of junior diversion and storage rights.

JD Record – Job Control Data

field	columns	variable	format	value	description
14	104	PASS2	I4	blank, 0, 1 2	IFFLAG in IF record field 7 control 2nd pass option. Second pass is activated for all months regardless.

Correction of Errors Associated with IF Second Pass

Errors have been corrected that caused the second pass computations to be essentially a repeat of the first pass, without providing the intended additional protection to junior diversion and storage rights. With the errors, *IFFLAG* option 2 results were basically the same as with option 1.

Discussion

Within *WRAP-SIM*, water allocation computations are performed in a water rights loop in which the requirements of each individual right are met in priority order. Thus, senior rights affect the amount of water available to junior rights. As each water right is considered in priority order in the water rights computational loop, regulated flows and the flows available to more-junior rights usually decrease but may also increase. Diversions and reservoir storage decrease flows at their control point and at downstream control points. Conversely, flows are increased by hydropower releases and return flows from diversions from storage. Reservoir releases may increase flows at intermediate control points between the reservoir and downstream diversion site. Fluctuating decreases and increases in water availability are a fundamental complexity in developing and applying *WRAP-SIM*. A diversion and/or storage right may be unnecessarily curtailed (shorted) due to computationally not having access to water made available by more junior rights in the form of return flows or hydropower releases. Likewise, reservoir releases that increase flows at intermediate control points between the reservoir and downstream diversion site may not be properly credited as contributing to instream flows at the intermediate control points.

The following *WRAP-SIM* options have generally been adopted to deal with the complexities of fluctuating decreases and increases in water availability in the water rights priority loop. The next-month return flow option makes the return flows available in the next month at the beginning of the water rights loop. Thus, all rights have access to the return flows in priority order. Likewise, entering return flows as constant inflows on *CI* records makes the flows available at the beginning of the water right computations. The next-month hydropower option serves this same purpose.

The optional second-pass feature associated with *IF* record rights addresses this same complexity. Assume a senior instream flow requirement has been activated in the water rights loop and a junior diversion or storage right is curtailed because the regulated flow drops below the instream flow target. However, later in the loop, an even more junior right increases the regulated flow above the instream flow target with a return flow, hydropower release, or reservoir release. Thus, the intermediate priority right may have been curtailed unnecessarily. Since return flows and hydropower releases are usually handled with next-month options and *CI* record inflows, the second pass option is probably most relevant for situations in which reservoir releases increase flows at intermediate control points between the reservoir and downstream diversion site.

Assuming the new *JD* record *PASS2* option is not activated (blank *JD* field 14), the second pass option is activated only if one or more *IF* records specify an *IFFLAG* option of 2 or 4. An input file may contain numerous *IF* records with different *IFFLAG* options specified for each. During the initial (first) pass through the water rights computation loop, option 2 and 4 instream flow

requirements are not considered in determining the water available to diversion and storage rights. Instream flow shortages are computed for the *IFFLAG* option 2 and 4 rights, but these *IF* record rights do not affect any other rights. In a particular month, if the option 2 and 4 instream flow rights incur no shortages, there is no second pass. The basic concept is that the computations are not redone if the option 2 and 4 instream flow requirements are fully met even without curtaining (shorting) any other right during that month. However, unnecessary curtailment is still possible even if the regulated flow exceeds instream flow target even without enforcing the instream flow target in the first pass of the simulation. The new *PASS2* switch entered in the *JD* record field 14 provides a little more flexibility for experimentation.

IFFLAG option 1 and 3 rights are enforced during the initial pass through the computations and may cause other rights to incur shortages. If all *IF* records are option 1 or 3, a second pass is not an option and is not considered. Although *IFFLAG* option 1 and 3 right shortages do not trigger a second pass, option 1 and 3 rights are enforced during a second pass just like the option 2 and 4 *IF* record rights.

At the end of the initial pass through the computations, if at least one option 2 or 4 right has a non-zero shortage, a second pass through the computations is performed. All of the computations for all of the water rights are repeated from scratch. There are two differences in the second pass compared to the first: (1) all instream flow requirements including options 2 and 4 are activated and may affect other rights and (2) a *REGFLOW(cp)* array sets lower limits on regulated flows.

The *REGFLOW(cp)* feature is solely for the purpose of addressing the problem that diversion and storage rights may be unnecessarily curtailed due to the complexity previously noted. The *REGFLOW(cp)* array is the regulated flows at each control point at the end of the first pass. *REGFLOW(cp)* are the flows that occur if rights are not curtailed to meet option 2 and 4 instream flow requirements. In most cases, second-pass curtailment of diversion and storage rights should either increase the regulated flows or at least not decrease them. During the second pass, when determining water availability for each right, regulated flows are compared to instream flow targets. *REGFLOW(cp)* is used as a lower limit on the regulated flows used in this comparison. The second-pass available flows are not allowed to drop below the corresponding available flows at the end of the first pass. This feature is designed to minimize the unnecessary curtailment of rights due to fluctuating decreases/increases of flows in the priority-ordered computations, but may not guarantee the elimination of all such unnecessary curtailments. Thus, the second pass options help minimize the problem but do not totally solve it.