Irrigation Efficiency, Water Storage, and Long Run Water Conservation

Joel R. Hamilton[1]

David B. Willis[2]

Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Mobile, Alabama, February 1-5, 2003

Corresponding Author:

David B. Willis
Department of Agricultural and Applied Economics
Texas Tech University
Box 42132
Lubbock, TX 79409-2132

Phone Number: (806) 742-0277 ext. 238
Fax Number: (806) 742-1099
E-mail: david.willis@ttu.edu

January 10, 2003

[1]Professor (Emeritus). Department of Agricultural Economics, University of Idaho, Moscow, Idaho, 83844-2334. Phone (208) 885-8949, Email: joelh@uidaho.edu.

[2]Assistant Professor. Department of Agricultural and Applied Economics, Texas Tech University, Box 42132, Lubbock, TX 79409-2132. Phone: (806) 742-0277, ext. 238. E-mail: david.willis@ttu.edu.

ABSTRACT

The 2002 Farm Bill provides $360 million to agricultural producers that adopt on-farm conservation practices that result in a "net water savings". The bill specifically lists increased irrigation efficiency and water storage (banking) as two conservation practices eligible to receive conservation funds. A spreadsheet-based simulation model is used to illustrate the complex relationships between irrigation efficiency, water banking and water conservation under the prior appropriation doctrine. The stylized simulation model is easy to use and understand, making it useful in educational or demonstration settings. The paper includes example applications dealing with the effect changes in irrigation efficiency and/or the establishment of water banks are likely to have on water conservation. Results show that increases in irrigation efficiency and/or the use of water banking do not guarantee water conservation. In the long run, conservation requires reduction in the quantity of water consumptively used by agriculture.

Key Words: Appropriation Doctrine, Irrigation Efficiency, Conservation, Markets, Water Banks

Irrigation Efficiency, Water Storage, and Long Run Water Conservation

Introduction

Given the current national policy focus on increased irrigation efficiency and water banking as water conservation tools, it is crucial that decision makers understand the requirements for the successful implementation of these potential conservation measures. The Ground and Surface Water Conservation section of the 2002 Farm Bill (Section 12401) authorizes $360 million in federal funding, covering the period 2002 to 2007, to be allocated as cost-share payments, incentive payments, and loans to agricultural producers implementing water conservation practices that result in a “net water savings”. Texas, received approximately one-third of the available funds for 2002 ($8 million) and has interpreted “net water savings” to be any practice that increases irrigation efficiency (Underwood, 2002). Texas, like other states, does not restrict the quantity of water that can be applied at the higher irrigation efficiency as long as the total diverted quantity does not exceed the appropriative right. Ironically, as irrigation efficiency is increased the marginal cost of delivering an additional acre foot of consumptively used water is reduced, as a smaller fraction of applied irrigation water becomes return flow, and may create a sufficient economic incentive for farmers to increase their consumptive use of water. Huffaker and Whittlesey (1995) note, irrigation efficiency increases can create the “illusion of water conservation, when in reality, the consumptive use of water may increase”. If the congressional intent of the “net water savings” language is to reduce groundwater mining rates and/or augment stream flow levels, then treating irrigation efficiency increases as a conservation measure, without additional restrictions on water use, may result in outcomes inconsistent with the conservation objective.

In the western United States, water is allocated according to the appropriation doctrine -- "first in time, first in right". Historically, if a miner or farmer could first locate an unused water supply, and then build the required facilities and beneficially use that water, the water would be his in perpetuity. No later, junior, appropriator could do anything that would diminish the senior user's water supply. Such secure water supplies were essential to attract the massive amounts of capital needed for western mining and irrigation development. Western water supplies have been fully and often over-appropriated for years. Western rivers have little unused water in most years. The issue now is how to work within the appropriation doctrine and still respond to changing demands for water and changing ways of using water. Because the appropriation doctrine is firmly entrenched in the water institutions of the west, its imprint will be seen in how river systems respond to policy initiatives such as water conservation, water markets, or flow augmentation for endangered species (Huffaker, Whittlesey and Hamilton, 2000).

The “first in time, first in right” rule is deceptively simple. When applied to conjunctive use of surface water, stored water, and groundwater by a number of users, the results of a policy, technology or management change in one part of the hydrologic system on other parts of the system are not always intuitively predictable. For example, consider a policy that stresses increased irrigation efficiency in an irrigated river basin as a water conservation measure. The hydrologic and economic effects of this policy may be quite complex and may not be readily apparent even to those advocating the policy. Less spillage, seepage, deep percolation, and runoff losses from irrigation systems means less surface return flows to streams and less aquifer recharge via various underground pathways. Changes in these return flows, along with associated reductions in surface water diversions and ground water withdrawals can drastically alter water flow paths, travel times, uses and values within a basin. This is especially critical when significant amounts of return flows are reused at other locations within the basin. Appropriators who use return flows may be harmed by increased water use efficiency unless enough of the "saved water" is delivered to them in a timely manner. There is not even a guarantee that increased irrigation efficiency will reduce total diversions. Junior appropriators with unsatisfied appropriative rights may be able to increase their diversions to the full amount of their rights if senior right holders increase their efficiencies. Effective implementation of a water allocation policy designed to balance in-stream and out-of-stream needs requires a comprehensive understanding of the economic behavior, hydrologic linkages, and institutional mechanisms, that collectively govern water allocation in an irrigated river basin.

This paper presents a small, stylized spreadsheet simulation model that illustrates how water is allocated under the appropriation doctrine in an irrigated river basin. The spreadsheet can be downloaded from the web at http://www.uidaho.edu/~joelh/pubs/download.htm. Versions for Excel and Quattro Pro are available. To use the Excel version of the spreadsheet, the linear programming “solver add-in” must be installed before using the spreadsheet.

The simulation model is sufficiently robust to capture the consequences of water transfers between appropriators, changes in irrigation efficiency, and changes in groundwater use on stream flows, groundwater fluxes, and surface deliveries to appropriators within the institutional structure of the prior appropriation doctrine. The spreadsheet model is easy to use, and incorporates sufficient realism to effectively demonstrate, and provide insight into many of the complexities of allocating water under the appropriation doctrine.

The Water Allocation Simulation Spreadsheet

Water allocation under the appropriation doctrine can be conceptualized as a linear programming problem that optimally allocates scarce water among many competing users or uses.

Linear programming is especially amendable to network problems such as tracking water flow through an irrigated river basin. In the stylized spreadsheet simulation model, each user can have up to three water rights (stored reservoir supplies, surface flows, and groundwater supplies), each with a different priority date. Consistent with the appropriation doctrine, surface inflows can be appropriated to individual users or reservoir storage and are allocated in order of seniority. All users of reservoir storage have a storage priority date identical to the reservoir priority date. All diverted water, regardless of supply source, is either consumed or returns as surface or subsurface flows. To represent the way the appropriation doctrine institutions allocate water, a per acre-foot (af) payoff is entered in the objective function for delivery of water to satisfy each user's water demand, with a larger payoff for more senior rights. Each simulated solution allocates water to maximize the aggregate payoff for demands satisfied. These payoffs are simply a mechanism to implement the water allocation rules and may bear no relation to the economic value of water in alternative uses – values that play no role under the appropriation doctrine.

The Graphic User Interface

The user of the model interacts with the graphic user interface shown as figure 1. Shaded cells represent parameters (demands, efficiencies, and rights to flow, groundwater, and storage) that can be changed. Blue lines (solid lines in black and white) are natural flows, red (dashes) represents storage water deliveries, and green (dots) represents groundwater. The numbers in unshaded cells are model results (flows, water deliveries, return flows, etc) calculated within the spreadsheet. Whenever input parameters are changed, the user must click on the "Press to Solve" button to recalculate model results.

Our base case is shown as Case1 in figure 1. In the base case all three irrigation diverters have identical crop consumptive demand requirements (500 af), irrigation efficiencies (50%), a

600 af flow right, and a 500 af storage right. Of the water not consumptively used, half returns to the river as surface runoff, and half percolates to the aquifer. Users have no groundwater rights. The only difference between the three users is their priority date for surface diversion; User 1 priority date is 1905; User 2 priority date is 1910; and User 3 has a priority date of 1915. The reservoir has the most senior surface diversion right with a priority date of 1900. Baseline surface inflow to the basin is 2300 af, and the storage reservoir has an initial fill of 200 af, and 1,500 af capacity.

The graphic user interface traces water flows through the various hydrologic links. The 2300 af inflow is partitioned 1300 af to storage refill and 1000 af to natural flow. User 1 diverts 600 af of natural flow, leaving 400 af in the river. User 1 also calls for 400 af from storage to get the 1000 af necessary to supply its 500 af crop consumptive demand at 50% irrigation efficiency. At this efficiency, half of User 1's water supply is not consumptively used, 250 af that returns to the river as runoff and 250 af that percolates to the aquifer. (Note the simplifying assumption of 100% channel conveyance efficiency. In the real world evaporation losses, phreatophyte consumptive use, and gains or losses to groundwater would reduce this efficiency. However, evaporation and phreatophyte losses may be quite independent of channel flow, and groundwater links are not losses to the system. While channel losses affect the realism of predicted downstream flow in this model, the model's ability to predict changes in downstream flows may be much better.)

Return flows from User 1 restore the river enough so User 2 can divert its full flow right. This, along with its storage right, provides all the water that User 2 needs.

User 3 is not so lucky in the base case. User 2 only left 50 af of natural flow in the river. When User 2's return flow is added back, this left only 300 af of flow for User 3, which it diverted, drying up the channel. Even taking its full storage right of 500 af, User 3's water supply is short by 200 af, and it suffers a crop consumptive use shortfall of 100 af.

The remaining instream flow at the bottom end of this hypothetical river is only 200 af, consisting entirely of return flows from User 3. Since there are no wells in the base case, the aquifer is receiving a net recharge of 700 af per year, which in the long run would result in either springflows or an underflow of 700 af moving downstream. Beginning and ending reservoir storage is 200 af, meaning no net change to beginning reservoir storage for next year. Thus the long run equilibrium downstream flow at the bottom of this hypothetical system river (which might be thought of as instream flows for fish) is 900 af. (Note a second major simplifying assumption of the spreadsheet – response time lags are ignored. In reality surface return flows happen on a time scale of days to months, and returns via the aquifer on a time scale of months to a century. This model should be viewed as a representation of the long run equilibrium after all lagged responses have played themselves out. A more sophisticated dynamic model might capture temporal nuances of policy alternatives, which could prove to be either hazards or benefits, but are beyond the resolution of this simplified simulator.)

A box in the lower left-hand corner of the graphic interface allows the model user to specify as a behavioral rule whether groundwater or storage water is to be used first. Generally this behavioral rule can be left set to 1 since groundwater is expensive to pump and diverters tend to exhaust their storage rights before pumping groundwater. Case 8, below, is intended as a counter-example.

The Linear Programming Worksheet

The graphic user interface is a convenient way to enter model parameters and observe simulation results. The actual calculations are done on the second spreadsheet page, in the form of the linear programming (LP) problem shown in table 1. The top part of the spreadsheet page passes values to and from the graphic user interface. The bottom two-thirds of the page, shown as table 1, is the LP tableau. The first three columns (activities) of the LP tableau contain the parameter values that govern the water storage function and determine the quantity of water available to fill natural flow rights after reservoir refill. The following three sets of four columns, respectively track groundwater use, stream flow diversions, stored water use, and surface return flows for each appropriator. The first three rows (constraints) directly below the objective function coefficient values and solution row, constrain storage refill to the lesser of available surface inflow and reservoir storage capacity. The next nine rows assure the quantity of water used from each water source by each user is less than or equal to the amounts of the rights specified on the graphic user interface. Three rows assure that natural flow diversions are limited by available natural flow. Three rows track return flows to the river. One row limits the use of stored water to the available amount. Three rows sum the water supplied from surface, storage and groundwater to measure whether the totals meet each user's demand. The last three rows are invoked to distribute storage water proportional to individual stored water right for scenarios where the reservoir does not completely refill. Accounting activities for net groundwater recharge do not appear explicitly in the LP tableau. Instead, the groundwater seepage, springflow and net groundwater recharge shown on the graphic interface are computed from the scenario solution using the efficiency and routing parameters provided by the user.

The objective function row contains the arbitrary payoffs per acre foot for satisfying each users' water demands. The base case payoff coefficients are computed by the spreadsheet and are shown in Table 2. Larger coefficients are assigned to more senior rights, and larger coefficients are assigned to surface rights than to groundwater rights. This implies that users will use their surface rights in preference to their groundwater rights, a realistic assumption in most cases.

It turns out that assigning the payoff coefficients is a complication that limits the size and complexity of the model which can to be handled as a classic LP problem. Unless the payoff coefficients are widely separated in magnitude, feedback linkages through the return flow equations may result in inappropriate model results. For this reason, the spreadsheet model presented in this paper should only be used for small-scale demonstration applications, and should not be scaled up for empirical application. A more robust software package such as Modsim should be used for such empirical applications (Labadie, 1995, and for example applications see US Bureau of Reclamation, 1999, and Miller, 2000).

Some Applications of the Spreadsheet Simulation Model

The following examples illustrate how the spreadsheet simulation model can be used to project the long-run consequences for a variety of real-world water policy issues.

Case 2: Bank Sales from Users 1 & 2 to User 3

User 3 is water-short in the base case. Suppose a water bank is created that allows transactions between irrigators. We could imagine users 1 and 2 each agreeing to bank 100 af so that User 3 could get a full supply. (Using the graphical interface this task is accomplished by reducing the storage rights of users 1 and 2 from 500 to 400 af, and increasing User3's storage right to 700 af., and then clicking on "Press to Solve" to update the flow figures.)

With User 3 now fully supplied, stream flow increases to the amount of User 3's return flow, 250 af. There is a similar increase in aquifer recharge and springflow. This comes, however, at a cost to long run downstream flow. In the base case, users 1 and 2 left a total of 200 af of storage water unused in the reservoir. Now the water bank is sending that storage water to User 3, where half of it is consumptively used by crops. Next spring, when the reservoir is being refilled, an additional 200 af will need to be diverted into storage to fill that space, reducing next year's natural flow by 200 af.

The net effect of this water bank transaction was to reduce long run downstream flow by 100 af – a reduction exactly equal to User3's increased crop consumptive use. This illustrates a rule of water banks – <u>if a water bank or market facilitates an increase in consumptive use by eliminating water supply shortages, the long run downstream flow will be decreased by the amount of the consumptive use increase</u>.

Case 3: Efficiency Increase by User 1

Faced with a need for more downstream water (e.g. to aid endangered salmon on the Snake / Columbia Rivers) people tend to eye irrigation efficiency as a possible answer. Shouldn't there be more water for these other uses if some of the irrigators were more efficient? To illustrate what happens, increase User1's irrigation efficiency from 0.50 to 0.7143 to simulate the adoption of a new more efficient irrigation practice. At the higher irrigation efficiency User 1 now needs only 700 af as a full water supply to meet crop consumptive use requirements.

After pressing the “Press to Solve" button we discover that User 1 still diverts his entire flow right of 600 af, and now only needs to divert 100 af of storage water to provide a full supply to his crop. At this higher efficiency User 1 now sends only 100 af of return flow to the river, and percolates only 100 af to the aquifer. User 2 diverts the entire 500 af of natural flow available from the river, which he supplements with his full storage allocation of 500 af, to just satisfy his full water supply.

User 3, the most junior right holder, draws the short straw. Drying up the river, User 3 only gets 250 af of natural flow. Together with 500 af of storage, this increases User 3's water supply shortage by 50 af relative to the base case, and decreases crop consumptive use by 25 af. This illustrates a basic rule of water allocation – <u>policies that promote increases in irrigation efficiency are likely to effect the water supplies of other irrigators through the linkages of hydrology and water allocation rules</u>.

User 1's efficiency increase allowed him to retain 300 af in storage compared to the base case, while User2 increased his storage use by 100 af. This net 200 af decrease in storage use means that 200 af less water is needed to refill storage next year, and next year's natural flow will increase by that amount. Most of this 200 af increase will be offset by natural flow and springflow declines at the bottom end of the system caused by User 1's increased efficiency and User 3's supply shortfalls. Note that the 25 af decrease in consumptive use by User 3 is exactly reflected in the 25 af net increase in long run downstream flow. <u>Changes in irrigation efficiency don't create additional water, they only change the flow patterns between river, storage, and aquifer. In the long run only reduced consumptive use can deliver more water downstream</u>.

Case 4: Efficiency Increase by User 1, Water savings to User 3

Perhaps the reason User 1 increased his irrigation efficiency was the enticement of being able to sell his excess storage to a water bank. If such a bank were in place, we might also expect User3 to buy 250 af to cover his supply shortage. To model this transaction we change User 1's, storage right to 250 af, change User 3's storage right to 750 af, and press to solve.

User 3 is now fully supplied, increasing his consumptive use by 125 af compared to case 3. Predictably, long run downstream flow decreases by exactly the same amount as User 3's increased use. The 800 af long run downstream flow is the same as it was in case 2. User 1's increased efficiency had no effect on the exact relationship between increased consumptive use by water buyers and decreased long run downstream flow. <u>If a water bank encourages efficiency</u>

increases in order to sell water, this can damage the water supplies of other users. If the bank makes possible transactions among irrigators, and reduces irrigation supply shortfalls, this can decrease long run downstream flows.

Case 5: Base Case with Wells

Wells are common for irrigation, municipal, and rural residential use, so lets turn to an example that includes wells. Let's have User 3 rely on an 850 af groundwater right and a right to 250 af of storage. Let's also change the system inflow to 2000 af and the beginning reservoir storage to 450 af to make the case more interesting.

Under these assumptions, all three users are fully supplied. User 2 takes all the available natural flow at its diversion, but then supplements it with enough stored water to make a full supply. With the behavioral rule left set to1, User 3 first draws all 250 af from his storage right, and then satisfies the rest of his demand by pumping 750 af from the aquifer, a pumping rate exactly equal to groundwater recharge.

Case 6: Case with Wells, Efficiency Increases by User 1

Now suppose User 1 decides to increase his irrigation efficiency to 71.43%. What happens?

At these higher efficiency levels User 1 loses less water to runoff and deep percolation. User 2, who relied on runoff from User 1 for part of his water supply, is now short — short enough that his storage right can no longer make up the difference. User 3 is OK, at least for the moment — but he's mining groundwater at the rate of 162.5 af per year. The long run downstream flow is increased by 25 af — exactly equal to User 2's reduction in consumptive use. The new lesson illustrated in case 6 is that irrigation efficiency changes can also affect aquifer recharge and well pumping depths.

Case 7: Case with Wells, Efficiency Increases, Water savings to User 2

Suppose we now allow water banking. Because of efficiency increases, User 1 now has lots of excess stored water, and User 2 is now water short. Let User 1 transfer 100 af through the bank to User 2.

All three users now have full water supplies. However, User 2 is now paying for water from the water bank that he would have received as a matter of right without the efficiency increase and the bank. User 3 is now suffering from a declining water table, compared to the stable water table without the bank. Finally, the long run downstream flow is still 500 af, unchanged from case 5, since none of the users have changed their consumptive use. <u>Policies must assure that water bank activities involve real changes in consumptive use if the goal is to get real flow effects downstream. Otherwise water banks may affect both groundwater and surface water supplies of third parties, while making no contribution to downstream flows.</u>

Case 8: Case with Wells, User 3 Uses Storage after Groundwater

Suppose the incentives facing User 3 are altered. Perhaps there is uncertainty whether the reservoir will refill and provide a full water supply next year. As a prudent risk manager, User 3 might decide to maximize his use of groundwater, reserving stored surface water to fill out the balance of his water needs and saving the excess as a hedge against shortage next year.

So long as User 3's fears are unjustified and the reservoir actually fills, the altered behavior rule makes no difference in long run downstream flow. The 100 af increase in reservoir overdraft compared to Case 5 is exactly offset by the increased storage carryover and consequent increase in spring spill after the reservoir is filled.

On the other hand, if User 3's fears are correct, and his new strategy successfully avoids a water supply shortage, his maintained consumptive use is purchased at the cost of reduced long run downstream flows. Any action that maintains consumptive use, when it might otherwise be reduced by uncertain inflows, will reduce long run downstream flows.

Conclusions

This paper presents a spreadsheet model of water allocation under the appropriation doctrine. The model is user friendly, and is designed to illustrate and educate audiences about the way that appropriation rules affect basin hydrology, water allocation and water use. The included examples demonstrate how the spreadsheet can be used to illuminate policy issues related to water conservation and water banks or markets. The educational illustrations revealed that:

- Increasing irrigation efficiency does not create additional water supplies. Efficiency changes only change the flow patterns between river, storage, aquifer, and irrigators. In the long run, consumptive water use must decrease if water is to be conserved.
- Any policy action that maintains consumptive use, when it might otherwise be reduced by uncertain supplies, will reduce long run downstream flow levels.
- If a water bank facilitates an increase in consumptive use by eliminating water supply shortages, the long run downstream flow will be decreased by the amount of the consumptive use increase.
- If a water bank encourages efficiency increases in order to sell water, this can damage the water supplies of other users as recharge and return flows are reduced.
- If a water bank is established to conserve water and increase downstream flow levels, officials must assure that water banking activities lead to real reductions in consumptive use. Otherwise water banking activities may affect both groundwater and surface water supplies of third parties, and fail to enhance the downstream flow level.

This educational model is not offered as a practical analytic tool, and more robust tools should be used for that purpose.

References

Labadie, J.W. “Modsim: River Basin Network Flow Model for Conjunctive Stream-Aquifer Management: Program User Manual and Documentation” Department of Civil Engineering, Colorado State University, Ft. Collins, CO. September 1995.

Miller, S., “Incorporation of Ground Water Interactions into a Network Flow Model of the Snake River”, MS Thesis in Hydrology, University of Idaho, Moscow, ID, October 2000.

Huffaker, R. and N. K. Whittlesey. “Agricultural Water Legislation, Will it Save Water?” Choices, Vol. 10(4): p. 24-28.

Huffaker, R., N.K. Whittlesey, and J.R. Hamilton, "The Role of Prior Appropriation in Allocating Water Resources into the 21st Century," Water Resources Development, June 2000.

Underwood, Randy. Personal communication. Conservation Specialist, Natural Resource Conservation Service, Lubbock District, Lubbock, Texas 2002.

US Bureau of Reclamation, “Snake River Flow Augmentation Impact Analysis”, Boise, ID, February 1999.

Table 1: Linear Programming Model

			Direct	Water Use by 1:				Water Use by 2:				Water Use by 3:					
	Initial	ReFill	Stream	Use	Use	Use	Return	Use	Use	Use	Return	Use	Use	Use	Return		
	Storage	Storage	Supply	Stream	GW	Stor	Flow	Stream	GW	Stor	Flow	Stream	GW	Stor	Flow		
Obj Function	0	120000	0	60000	900	2000	0	30000	500	2000	0	11000	200	2000	0		
Solution	200.0	1300.0	1000.0	600.0	0.0	400.0	250.0	600.0	0.0	400.0	250.0	300.0	0.0	500.0	200.0		
Refill Equations																**RHS Values**	
Initial Storage	1															=	200
Storage Refill	1	1														<=	1500
Residual Stream		1	1													<=	2300
Individual Water Rights																	
Stream Use 1				1												<=	600
GW Use 1					1											<=	0
Storage Use 1						1										<=	500
Stream Use 2								1								<=	600
GW Use 2									1							<=	0
Storage Use 2										1						<=	500
Stream Use 3												1				<=	600
GW Use 3													1			<=	0
Stoage Use 3														1		<=	500
Streamflow Balance Equations																	
User 1			-1	1												<=	0
User 2			-1	1			-1	1								<=	0
User 3			-1	1			-1	1			-1	1				<=	0
Return Streamflow Equations																	
From User 1				-0.25	-0.25	-0.25	1									=	0
From User 2								-0.25	-0.25	-0.25	1					=	0
From User 3												-0.25	-0.25	-0.25	1	=	0
Max. Storage Use																	
Stor Transfer	-1	-1				1				1				1		<=	0
Allocate water to meet onfarm demand																	
Demand at 1				1	1	1										<=	1000
Demand at 2								1	1	1						<=	1000
Demand at 3												1	1	1		<=	1000
Constraints to allocate storage water when reservoir doesn't completely refill																	
Restrict Stor 1	-1	-1				3.00										<=	0
Restrict Stor 2	-1	-1								3.00						<=	0
Restrict Stor 3	-1	-1												3.00		<=	0

Table 2: Assignment of Payoff Coefficients

Appropriator Parameter Data Used to Derive LP Penalty Weights							
Stream User	Priority Date	Priority Ranking	Penalty Weight	GW User	Priority Date	Priority Ranking	Penalty Weight
Resevoir Refill	1900	1	120000	User 1	1920	1	900
User 1	1905	2	60000	User 2	1925	2	500
User 2	1910	3	30000	User 3	1930	3	200
User 3	1915	4	11000				

Figure 1: Case 1, Base Case

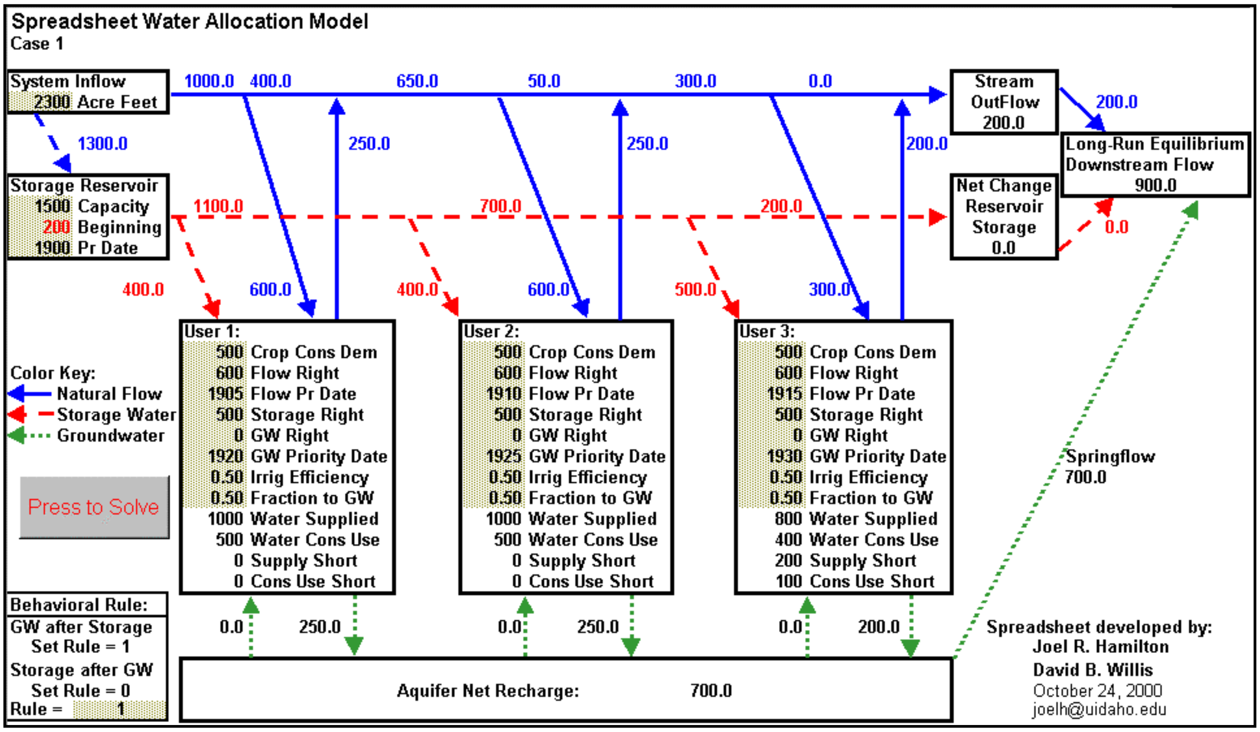

Figure 2: Case 2, Bank Sales from Users 1 & 2 to User 3

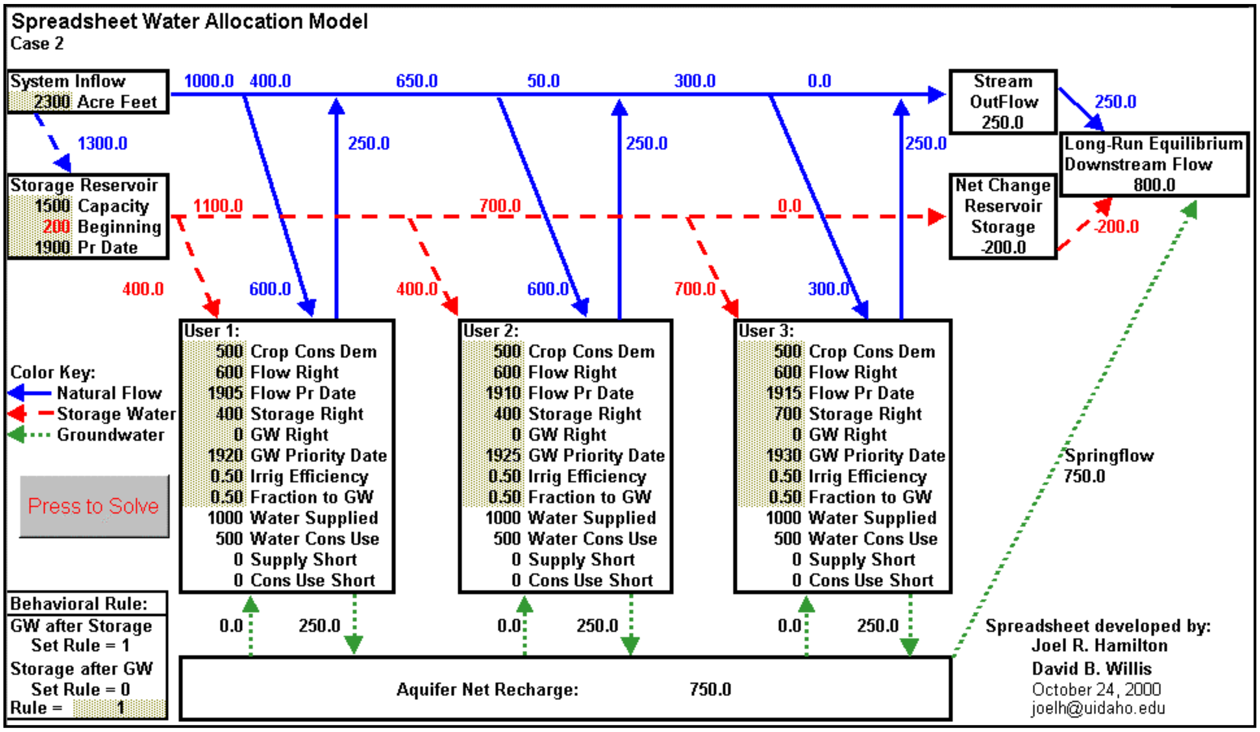

Figure 3: Case 3, Efficiency Increase by User 1

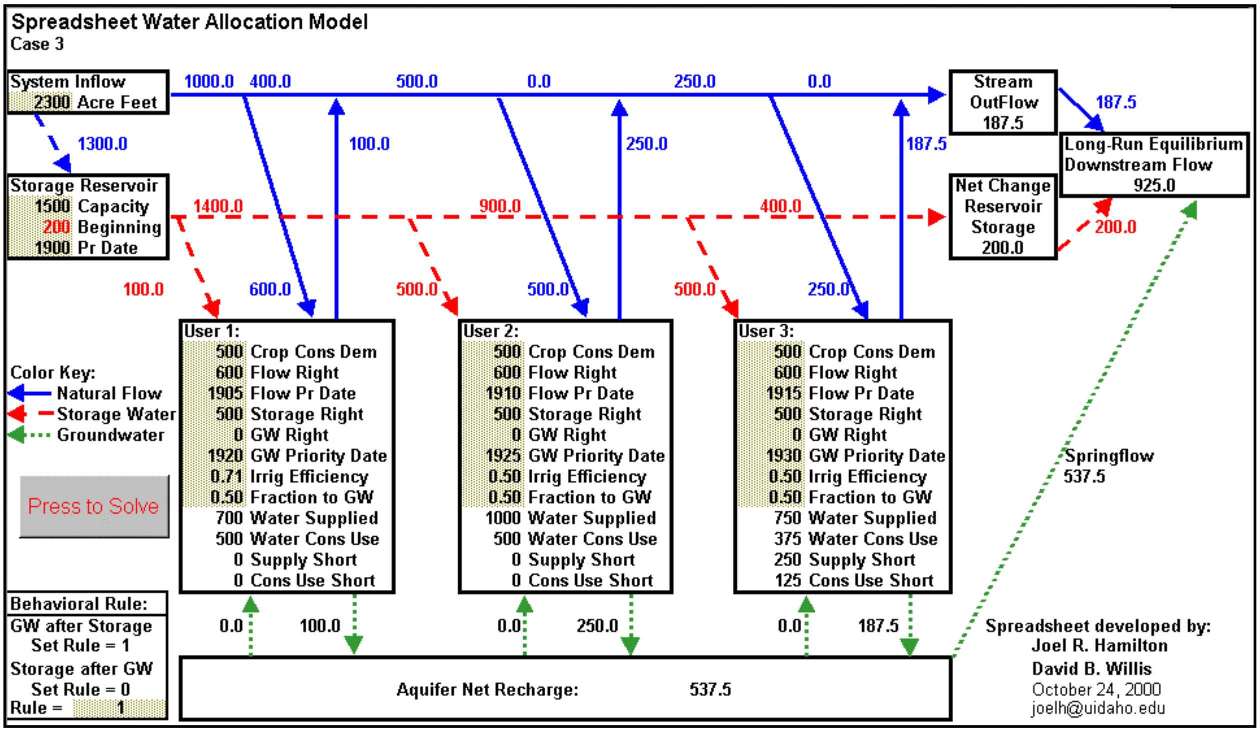

Figure 4: Case 4, Efficiency Increase by User 1, Market Savings to User 3

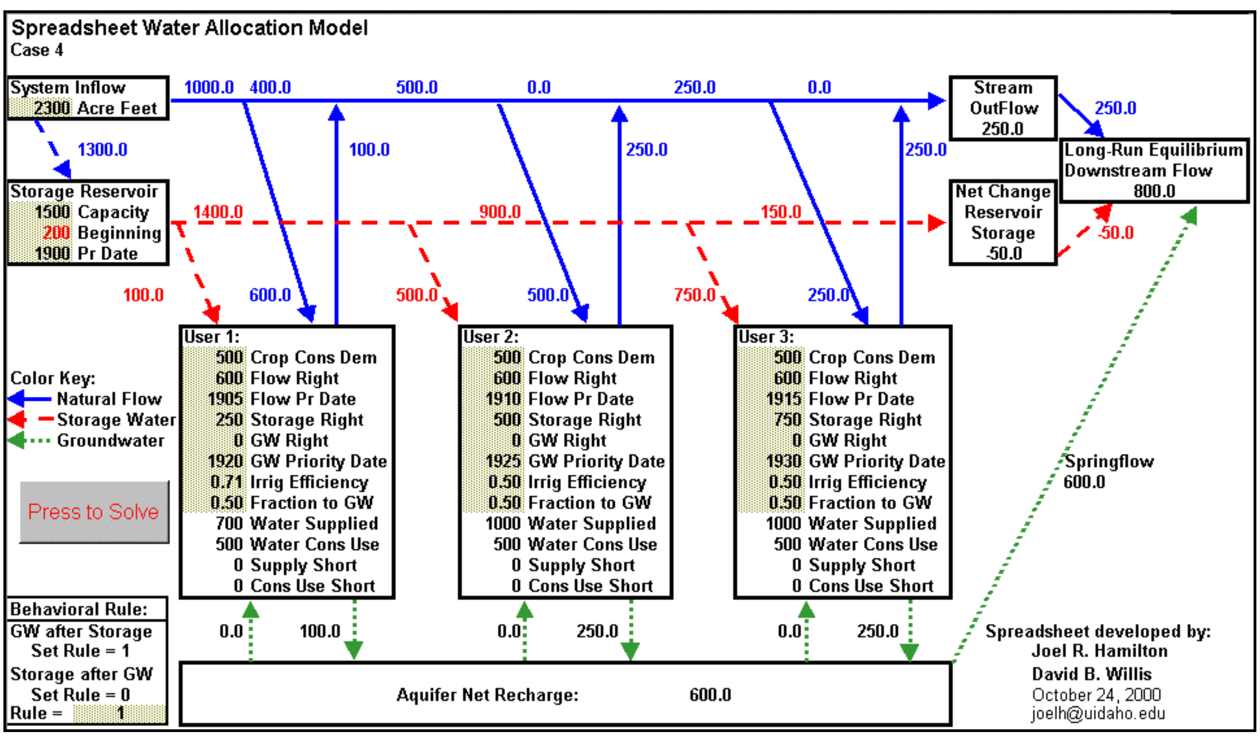

Figure 5: Case 5, Base Case With Wells

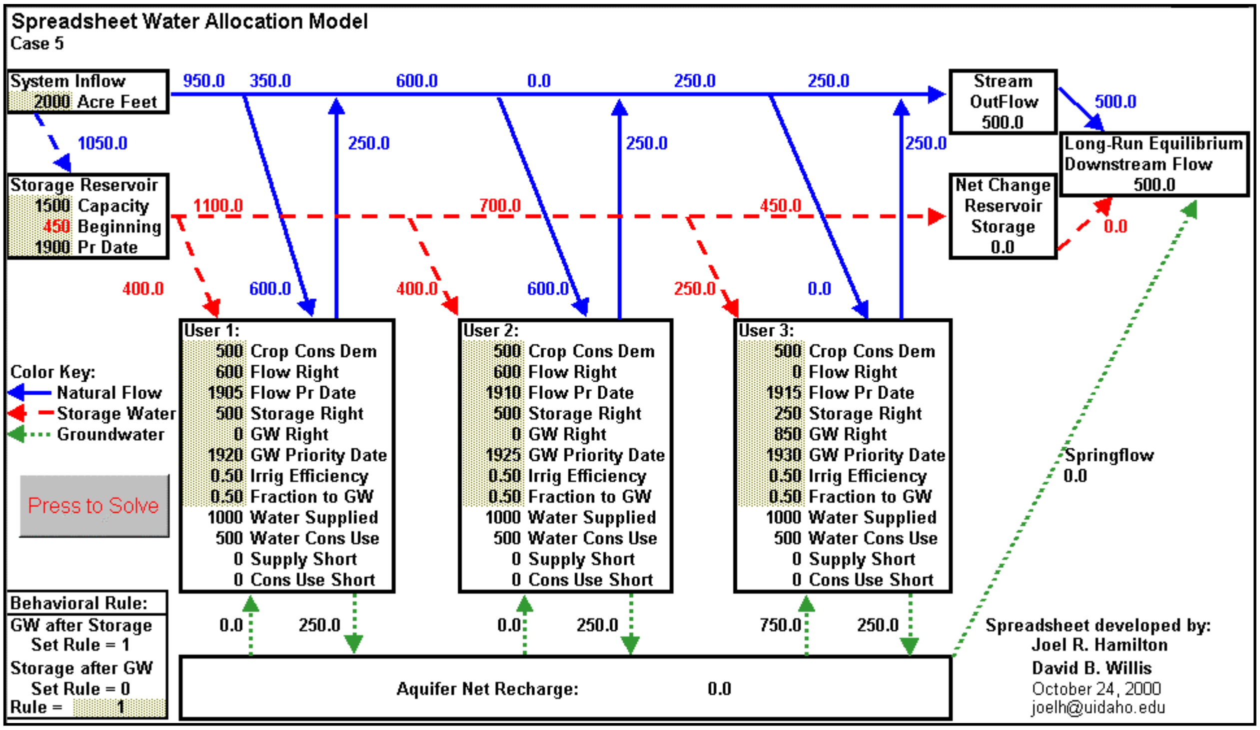

Figure 6: Case 6, Case With Wells, Efficiency Increase by User 1

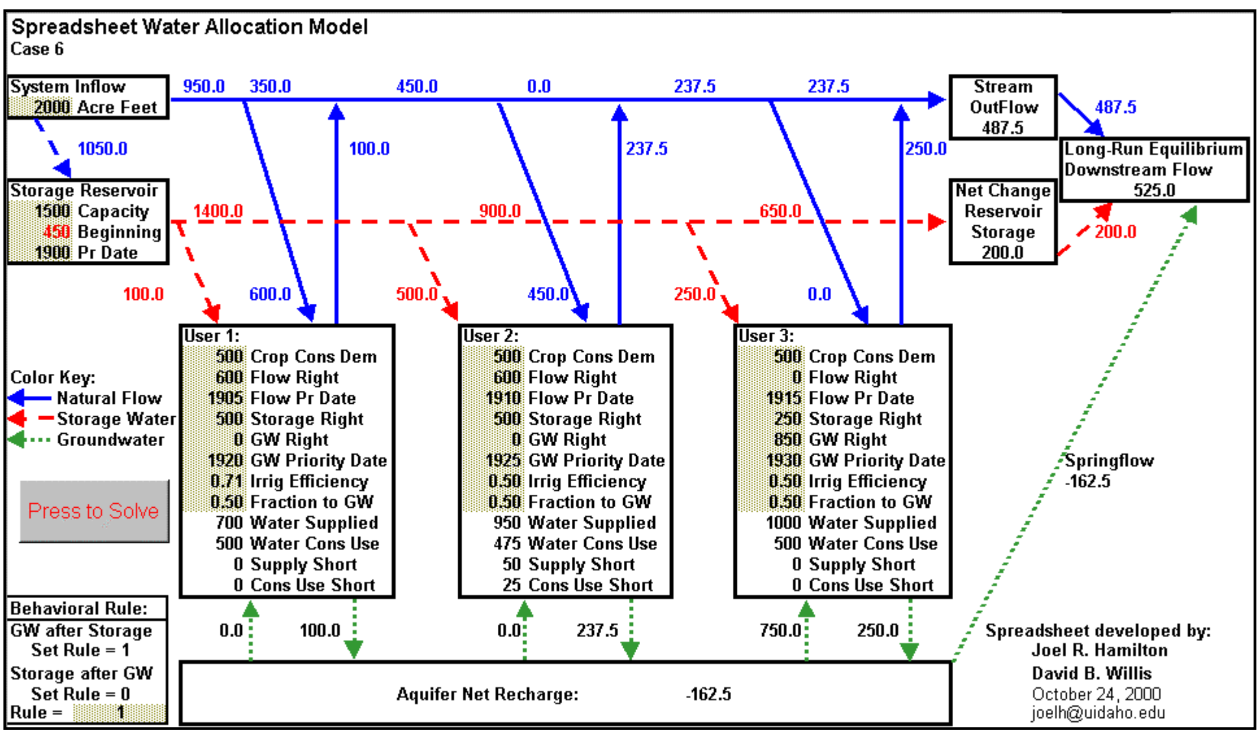

Figure 7: Case With Wells, Efficiency Increase by User 1, Savings Marketed to User 2

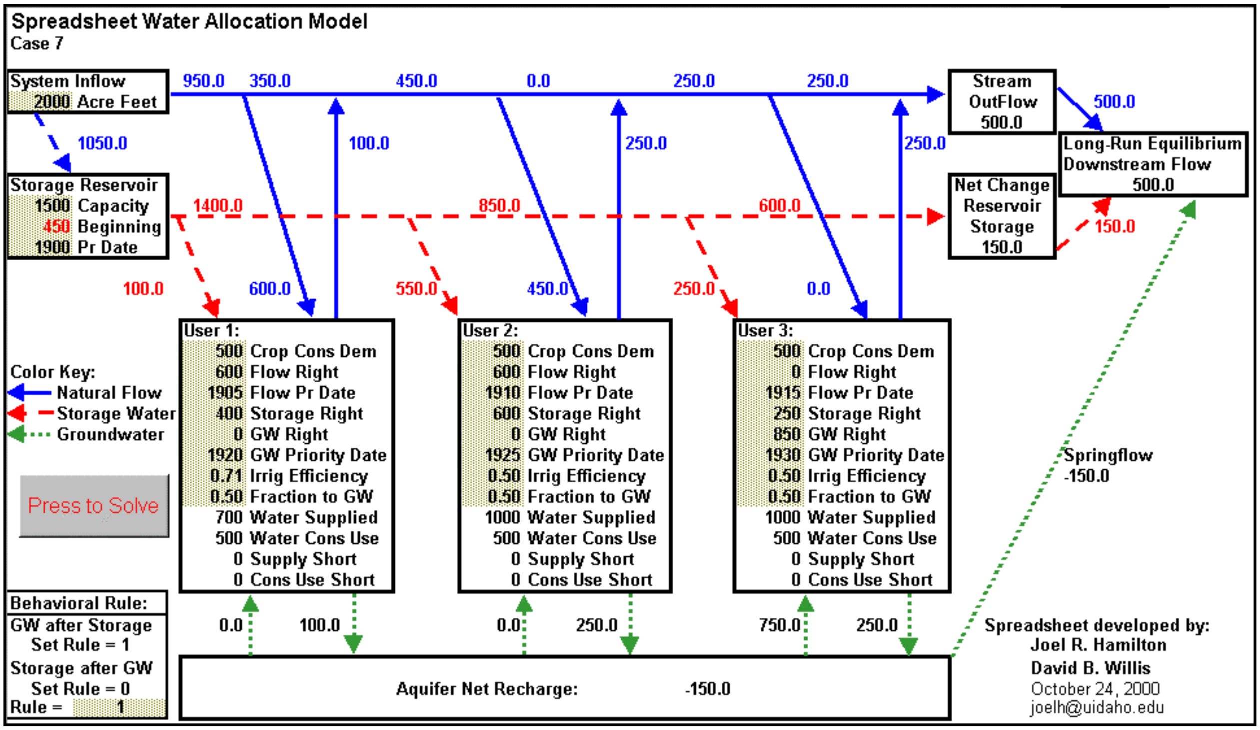

Figure 8: Case 8, User 3 Uses Storage After Groundwater