ON-FARM STRATEGIES FOR REGULATED DEFICIT IRRIGATION TO MAXIMIZE OPERATIONAL PROFIT POTENTIAL

by

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ABSTRACT

Municipalities and other water providers are expected to seek increasing amounts of agricultural water to meet the demand created by projected future growth along the Front Range of Colorado and within the South Platte Basin. Farms often are acquired outright, the water rights parted off, and the original decree changed to municipal use—a process commonly referred to in the regional water community as “buy and dry”. Concerned about the negative effects of buy and dry on agriculture, rural communities, and the environment, the State of Colorado has funded research into alternative, less permanent methods for transferring water from agriculture. This paper describes a simulation and optimization model that a farmer-user may utilize to evaluate successful future farming operations using a smaller amount of consumptive use water. Optimization algorithms are used within a new Model to evaluate a farmer-considered package of changed practices which may include: regulated deficit irrigation, new crops, dryland crops, permanent or rotational fallowing of fields, and crop rotations. Model results help a farmer understand the options and whether or not they would want to consider changed practices in the future in return for an additional and low-risk revenue stream for the overall farm operation.

KEYWORDS

Irrigation engineering

Water rights quantification

Consumptive use

Evapotranspiration

Expert system

Mathematical optimization

Farming practices

INTRODUCTION

In 2003, the State of Colorado initiated a significant water resources planning effort called the Statewide Water Supply Initiative (SWSI) for the purpose of projecting water supply availability and needs for each of Colorado's river basins in 2030 (Gimbel 2010). Most basins in Colorado were found to be forecasting water shortfalls in 2030. For the South Platte Basin, the SWSI report forecasted a population growth of 65% which equates to 2,000,000 additional people by 2025 and an associated water supply need of an additional 400,000 acre feet. The South Platte is already over appropriated. Transbasin transfers and new storage are essentially no longer feasible or extremely difficult options at best, because of planning and permitting obstacles. The prevalent presumption within the regional water community is that the additional 400,000 acre feet will likely come from irrigated agriculture – water transfers from irrigated agriculture to municipal and industrial (M&I) uses (Colorado Water Conservation Board. et al. 2004).

This population growth and water demand dynamic is also playing out in other states in the West and other basins in Colorado in the form of municipal acquisition of whole farms -- along with the water -- through outright willing-seller, willing-buyer purchases. The consumptive use (CU) portion of the water right is often 100% removed from the farm and the use of the water is most often changed to M&I use. The farm is dried up into perpetuity. This process of permanent dry up is often referred to as "buy and dry" in water planning circles and in the popular press (Gimbel 2010). Some of the municipalities who have availed themselves of this practice are now saying publicly that they do not wish to continue with the practice of buy and dry because of the impact on the rural community and the cumulative negative push back from many sectors. At the same time, municipalities are actively looking for sound alternatives to buy and dry that provide predictable water supply, or what is commonly known as "firm yield", for the cities (CDM 2010).

Alternatives to buy and dry **–** also called alternative transfer methods (ATMs) **–** and often cited in the SWSI reports and elsewhere include:

1. Interruptible water supply agreements.
2. Rotational fallowing.

3. Water banking.
4. Reduced consumptive use through changed irrigation and farming practices.

Interruptible water supply agreements involve temporary arrangements where agricultural water rights can be used for other purposes. Agricultural irrigation is temporarily halted under terms of an agreement in order to make a prescribed and contracted delivery (Trout Witwer & Freeman. 2004). An advantage of this approach is that an interruptible water supply agreement is defined by State Statute (37-92-309). It can be initiated under a contract arrangement between a water right holder (aka “water righter loaner”) and a water user (aka “water right borrower”) – likely a municipality -- needing water to cover a water shortfall in a given year. The statute defines the water transfer frequency to three out of ten years – hence strengthening the temporary aspect of this approach. The Colorado State Engineer is responsible for the oversight and approval of interruptible water supply agreements (Colorado Statutes 2003).

Rotational fallowing is conceived as a one to multi-year fallowing arrangement where, for instance, a fraction of the participating farms in a mutual irrigation company or other entity agree to fallow their farms, and thereby transfer a predetermined amount of water to a municipal interest (HDR Engineering 2007). Multi-year fallowing involves closely prescribed reseeding and establishing a suitable grass cover to protect the fallowed ground from erosion.

Water banking is a Colorado legislature-authorized approach to storing or setting aside water so that it can be leased to an alternative need during drought or when the water would otherwise not be put to beneficial use (Gimbel 2010). A water bank was initiated and exists in the Arkansas Valley. However, to date, it has not received enough user acceptance to make it truly viable.

Reduced consumptive use through changed farm water management involves identifying a quantified portion saved from the historic crop CU on a farm or farms. This saved portion of the CU would then be parted off and moved toward non-farming beneficial uses. The remaining historical CU would be used to continue agricultural operations. Ideally, this process would be carefully planned and monitored to ensure future farming operations (Gimbel 2010).

The Model (aka Sustainable Water and Innovative Irrigation Management® or SWIIM®) described here focuses on the fourth ATM option noted previously, namely reduced CU through one or more changed farming practices.

CONSUMPTIVE USE AND WATER BALANCES

The estimation of CU can be complex and time-consuming. The historic water diversions (water measured through the mutual irrigation company's river diversion) and season of use can generally be found in the data base of the State of Colorado's South Platte Decision Support System. However, historic cropping data and irrigated acreages are not so easily found, resulting in the need for background investigations of all available historic records over a suitable period of record. Historic irrigation practices, estimates of irrigation efficiency, and delivery efficiency (canal seepage) also come into play with the CU calculations and must be determined or estimated from available records.

This process of estimating historic CU on the South Platte has been facilitated by the Integrated Decision Support Consumptive Use (IDSCU) model that was developed at Colorado State University for the purpose of assisting engineers and attorneys in the development of databases and the calculation of historic ET. Essentially all of the methods and equations for calculating ET can be evaluated and compared when using the IDSCU model (Garcia 2009). In recent years, this model has been almost exclusively used by water resource engineers in Colorado Water Court change cases.

A water balance of the river, canal, or the farm is a useful means of understanding the sources of and the destinations of water. Figure 1 provides a conceptual rendering of water balance analysis, from the river diversion downstream to the on-farm distribution system. Basically, what this illustrative graphic shows is what happens to water once it is diverted into a ditch or canal for irrigation purposes. In many ditch company operations, the character of the water changes significantly as one moves downstream in the canal. Colloquially, some would say that the "color" of the water changes; a reference to where the water came from, or where it is bound, or its decreed use.

After diversion into an earthen canal, the diverted flow immediately begins to diminish because of conveyance losses, the most notable of which is seepage. Other losses are attributable to phreatophytes and evaporation from the water surface. Seepage can be quite significant especially over the full length of the canal and is likely the single highest source of loss in earthen canals. Most seepage returns to the river as subsurface flows and the time it takes to actually arrive at the river is a function of distance from the river and the characteristics of the alluvium. This seepage can vary considerably over the length of a canal as well. With a water right change case, this historic surface and subsurface return flow pattern must be maintained into the future.

Moving downstream through the canal, some water returns to the river via the end of the canal as wastage or operational spill. Some canals have historically diverted a generous amount of water to assist with practical canal operations. It is easier to deliver equitable flows to canal headgates, especially those at the end of the canal, if the canal is flowing nicely with excess water that can be returned to the river for other downstream users.

Continuing reference to Figure 1, a headgate delivery to the farm has similar water balance characteristics as with the main canal. However, the headgate delivery frequently represents the point at which the company's delivery responsibility ends and the individual farmer's responsibility begins. Downstream of the farm headgate, there are often on-farm conveyances (ponds and delivery ditches) from which there are losses, and again, those loses are most notably seepage that constitutes historic return flows that must be maintained.

Once water is delivered to on-farm irrigated fields, and on through the associated farm irrigation systems, the key elements of irrigation water can be identified as consumptive use, surface return flows, and subsurface return flows. Within the consumptive use amount, there is a proportion that may be appropriately termed "conserved" or "saved" or "set-aside" CU. This amount is the water that might be considered for its higher economic value. The total amount of quantified CU can be evaluated in terms of a water budget. The CU volume can be considered, along with old or new proportional uses, and within the confines of the water budget.

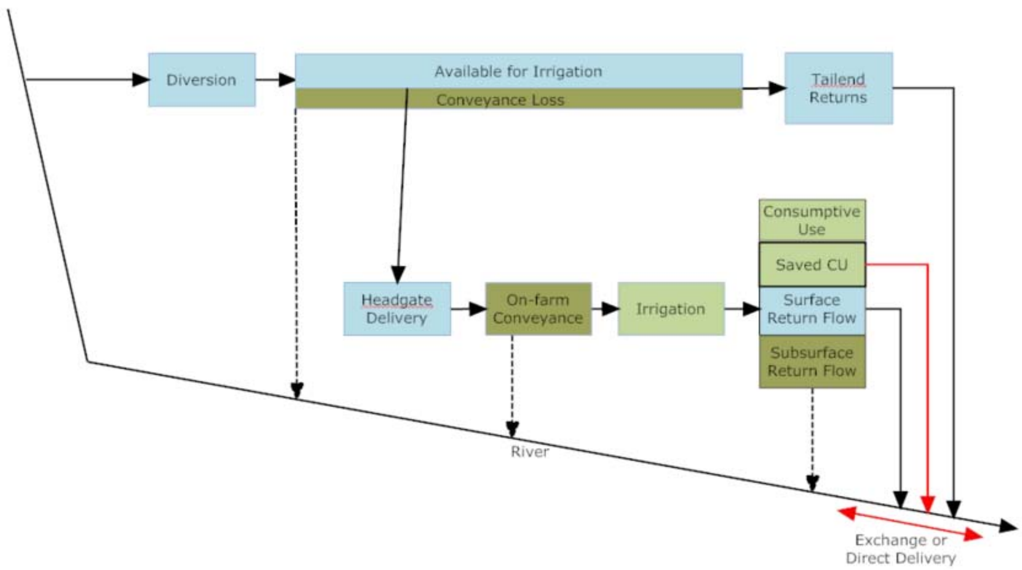

Fig.1 Depiction of the elements of surface water delivered to the farm via canal

The average historically diverted water to the farm can be characterized as consumptive use, surface return flow, and subsurface return flow (Figure 2). Crop consumptive water use is the amount of water transpired during plant growth plus what evaporates from the soil surface and foliage in the crop area. The portion of water consumed in crop production depends on many factors, including whether or not the availability of water is limiting evapotranspiration. Additionally, CU varies with soil texture, crop varieties, and so on.

Once an estimated or a fully decreed consumptive use is known for a given water right, it opens up the potential to consider options for how the CU might be utilized or allocated differently in the future. This could involve addressing differing demands and, for that matter, market forces. The consumptive use could be allocated to a new use priority or some balance between old and new priorities. The consumptive use can now be viewed more rationally as an on-farm CU water budget with potential alternative uses. Obviously, and in point with the overall premise of this paper, a new use of the CU might be to portion off some of this “saved” CU to a municipal or environmental water user for suitable monetary consideration.

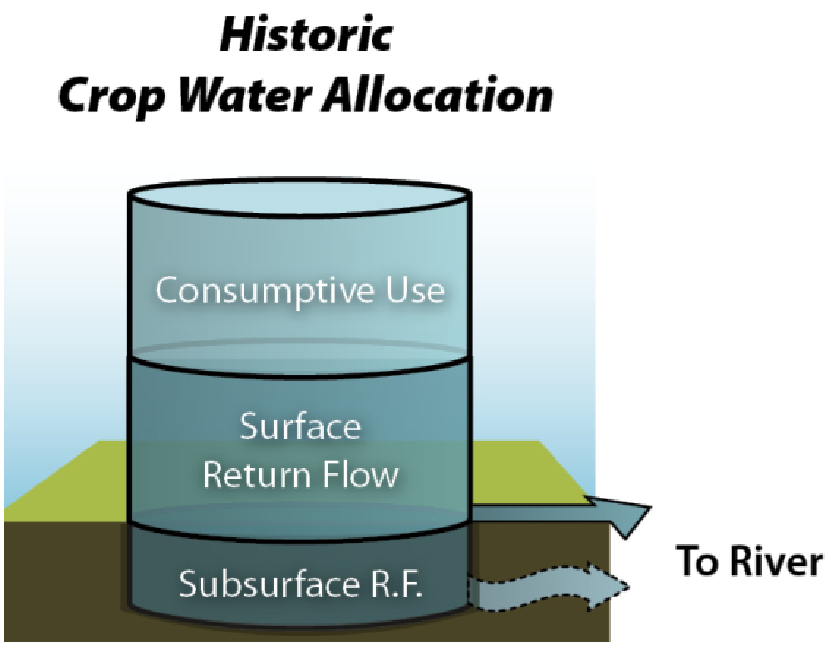

Fig.2 Depiction of the primary named use of water in a water balance on the farm

It is good to review some key framing points. First, it is clear that water resources in the South Platte Basin are currently over appropriated. Second, a significant amount of the water to sustain the anticipated and continued population growth in the basin is likely to come from agriculture in one way or another. Third, many observers are not viewing so-called “buy and dry” options as a suitable method of obtaining municipal and industrial (M&I) water, primarily because of the tremendous negative impact on rural communities. Fourth, and central to this dissertation, alternatives to “buy and dry” may be attractive to those acquiring future water supply as well as those currently owning water rights.

A Model has been developed to assist farmers in evaluating alternative irrigation or cropping practices, in order to help understand the options and whether or not they would want to consider changed practices in the future in return for an additional revenue stream for the overall farm operation.

Net return is the income from an investment after deducting all expenses from the gross income generated by the investment. Net returns in a farming operation are defined to be farm revenues minus the fixed operating costs. Net return has also been defined as the return to land and management. On the other hand, farm net returns, by definition, does not include land costs, interest, taxes, and other costs that are fixed regardless of irrigation decisions (Martin 2010).

$$net\ returns\ = revenue - fixed\ operating\ costs$$

This approach to using net returns as the primary means of comparing one model run to another is affected by some important farmer client issues as well. These include:

1) The availability of detailed farm financial data.
2) Potential reticence of the farmer to disclose detailed personal financial data, even if readily available.
3) Time considerations – the desirability of farmers to quickly enter input data to see some preliminary results, combined with their possible lack of willingness to spend hours on data entry and setup.

Figure 3 graphically shows the inputs to the model and the optimized (modeled) net return. A successful run of the optimization model indicates the projected net return associated with the crops to be grown along with predicted crop yields, the practices to be adopted, and the anticipated unit prices. This modeled net return can then be contrasted with the historic net return from the farming operation.

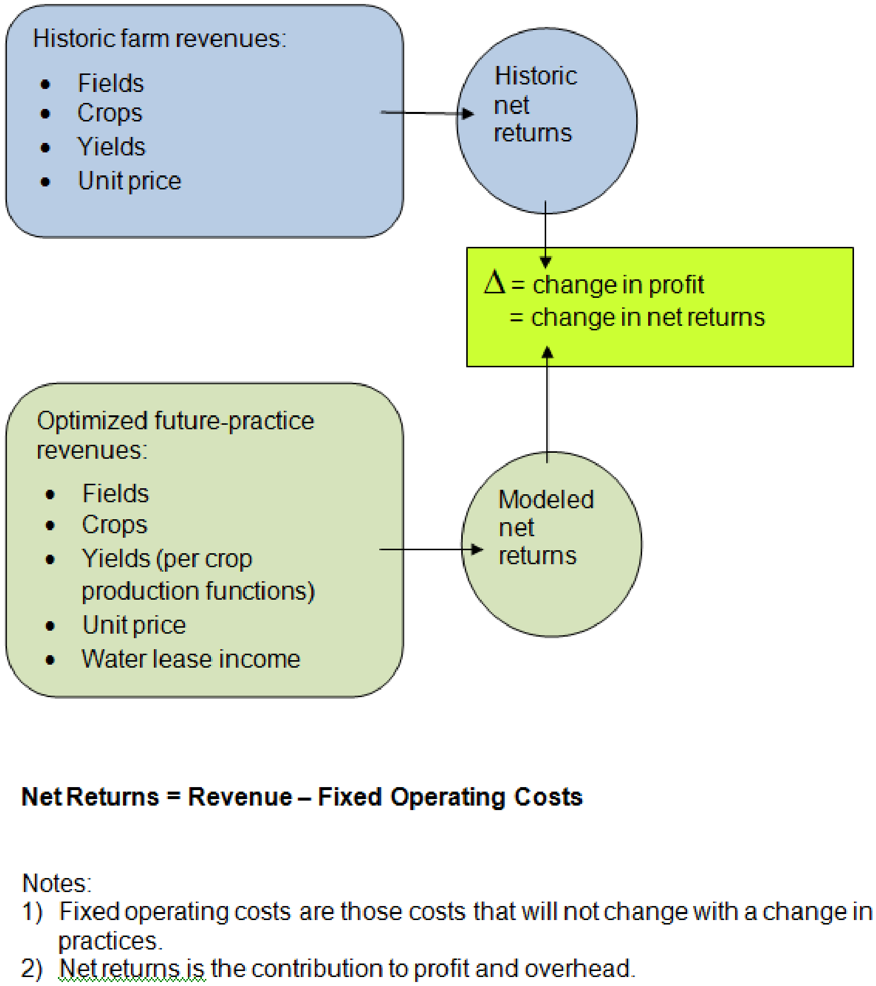

Fig. 3 Optimized future practices compared to historic practices on the basis of net returns

The Model was first developed in Excel using the Solver add-in to Excel. More specifically the Premium Solver Platform was used so as to not significantly limit the number of fields or optimization defining constraints. As the developing Excel spreadsheet became functional and stable, the Model was brought into a web interface so that:

1) The program could be delivered to a farmer-user by downloading it from a server.
2) The user interface could be narrowly and cleanly defined, better than in Excel, to enhance the user experience.

THE MODEL

The Model utilizes farmer-user inputs for the simulated farming operation to mathematically optimize future farming operations against a quantified or presumed consumptive use water budget for the farm. Default data are available with the program data base as extracted from the National Agricultural Statics Service (http://www.nass.usda.gov/). A successful run of the model constitutes a "scenario" that can be evaluated.

The farm simulation input is easy to use by simple point and click entry of boundaries over the top of aerial imagery to outline the farm itself and existing or proposed fields, then inputs such as planned "willing to grow" crops and practices are added. When finished, the farmer has a precise computer-generated map of the farm that becomes the basis for planning and running scenarios.

Inputs include fields (up to 20 fields), acceptable crops and irrigation practices that the farmer is willing to consider by field (up to 18 combinations). Practices for farmer-consideration include full irrigation, deficit irrigation, dryland crops, and fallowing. Default values for crop market price and per crop input costs are used or any of the default inputs can be changed as may be desirable from the farmer's experience or perspective.

With input entry completed, a mathematical optimization is performed based on those inputs to provide a scenario that can be named and saved. Optimization output data compares historical net revenues with the forecast of net revenues based on the scenario. The forecast of net revenues will likely be less than the historic net revenues but the lease value of the consumptive use water is forecast as well. The lease value of the water, when added to the forecast net revenues, will likely exceed the historic net return.

Several screen captures exemplify the user experiences in exercising the model as found in the web-delivered and server based program offering. Figure 4 shows the geographic information system (GIS) style field data entry screen. The user does not need to know GIS programing or input features in order to input field data into the system. Data entry is facilitated by using intuitive point and click tools. Field boundaries can be input, color coded, named, and resultant acreage returned. The input screen can be set up to show attributes of interest by picking suitable attributes from the list on the left.

Figure 5 shows the user interface for inputs of crops that the farmer is willing to grow along with the acceptability, or not, of certain practices to the farmer. Also, note the input of maximum and minimum acreage for both irrigated and dryland crops on this input screen.

Figure 6 shows the reported results of the optimization run and indicate the projected net return given the farmer inputs.

SUMMARY

An optimized package of irrigated farming practices, based on a consumptive use (CU) water budget, can help demonstrate the feasibility and basic concept of selling or leasing a fraction of a water right to make farming more attractive, profitable, and sustainable.

Through an engineering study of crops, acreages, evapotranspiration, and water diversions, water rights in Colorado can be quantified for the historic consumptive use. Quantification is necessary if one is to change the water right from the decreed type of use, place of use, point of diversion, and season of use. The costly engineering and legal effort to change a water right (aka transaction cost) is undertaken in order to bring greater value to the right and increase flexibility for future use. Municipal, industrial, and environmental interests are actively searching for senior surface water rights, usually agricultural water rights that can be moved from agriculture to other purposes. This process of locating and moving a water right often results in farms being bought up and permanently dried up. This is a dynamic that is occuring in the South Platte River Basin and believed to not be in the best interests of the larger community or in maintaining a sustainable irrigated agricultural system. Total water management is an admirable concept that can be furthered using the optimization Model and the follow-on implemented system. Use of this technology helps answer the question of how to bring more cooperation between conflicting users, share valuable water resources, bring benefits to the community, and sustain a viable agricultural economy.

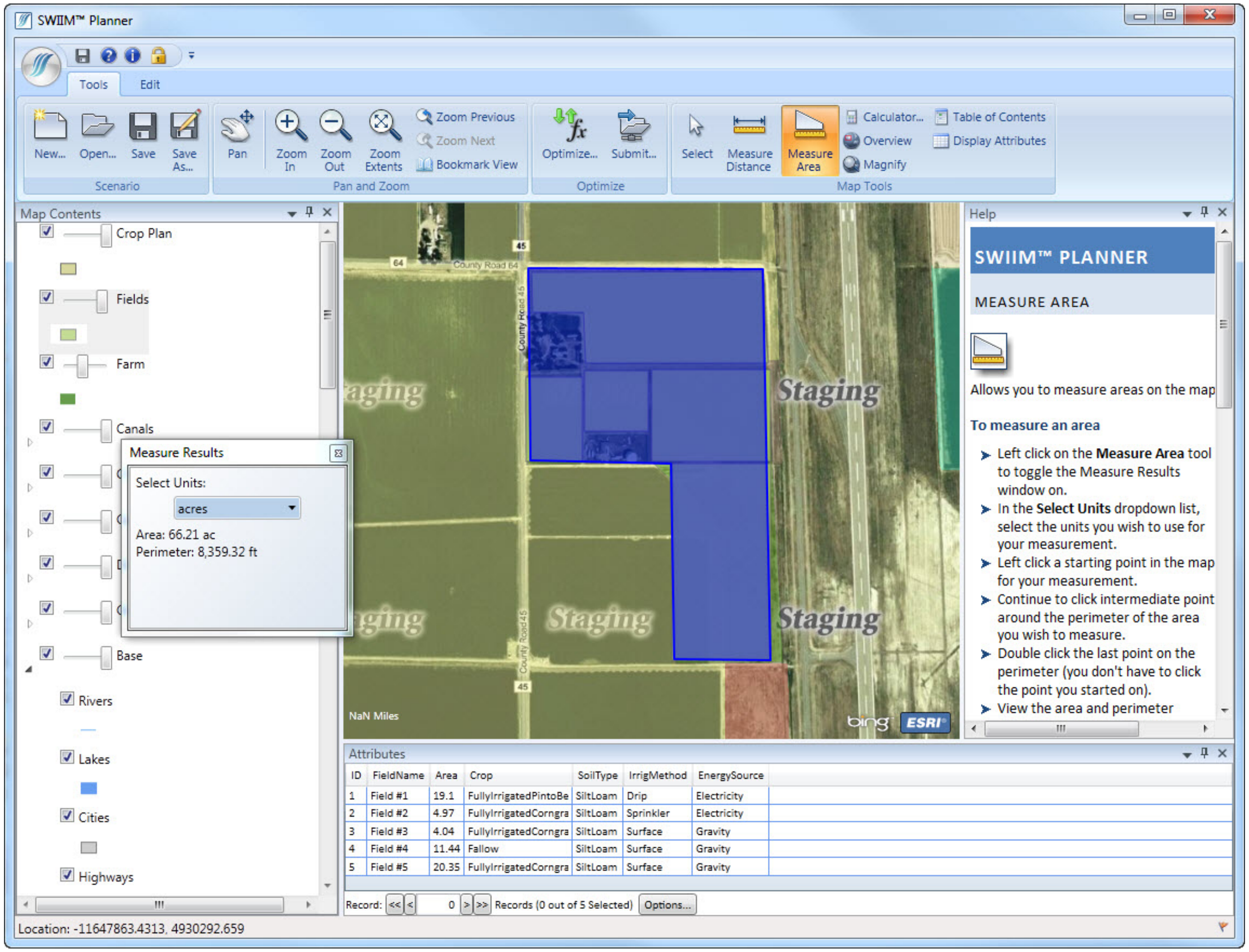

Fig. 4 Optimization program GIS-like data entry screen

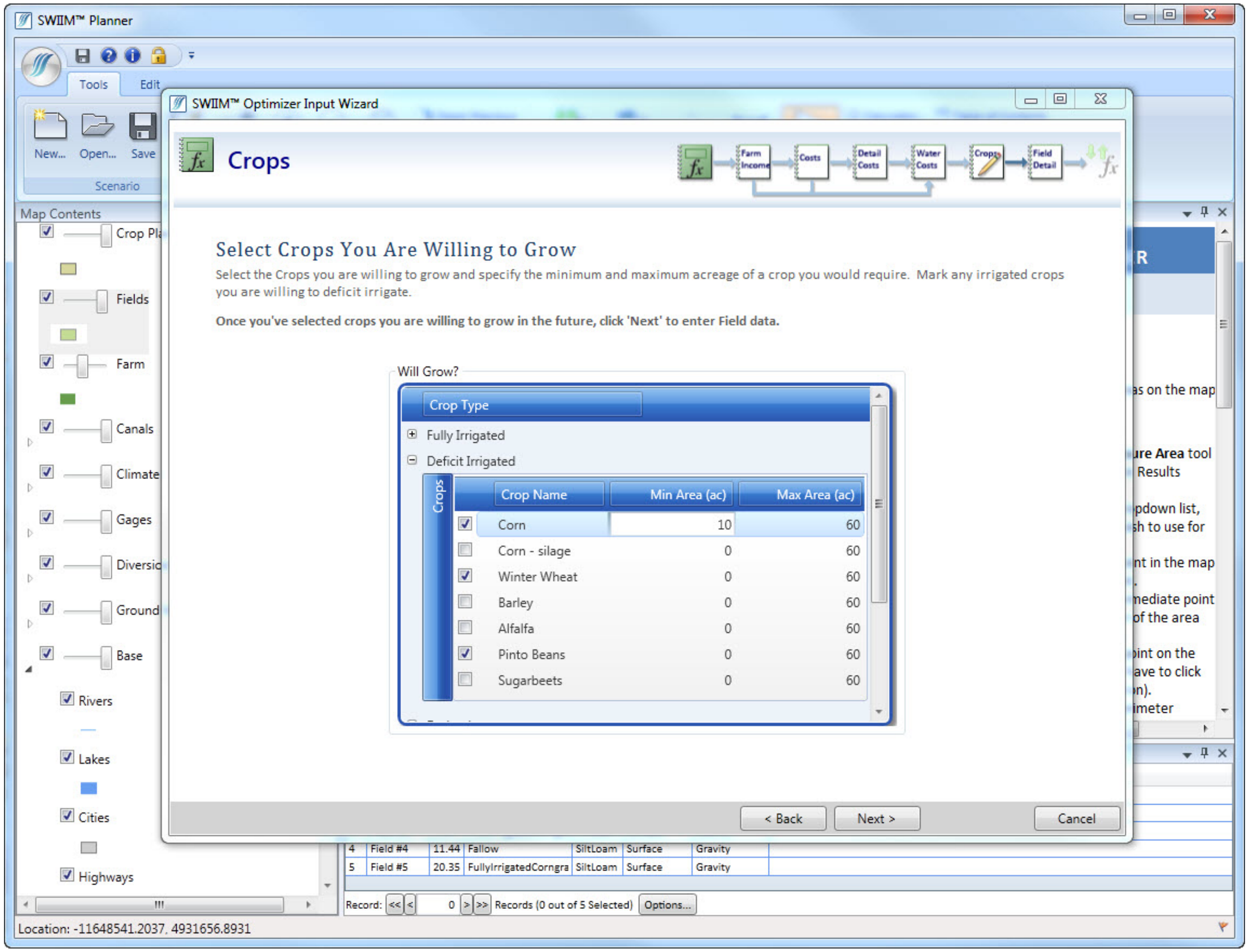

Fig. 5 Optimization program input screen for crops and acceptable practices

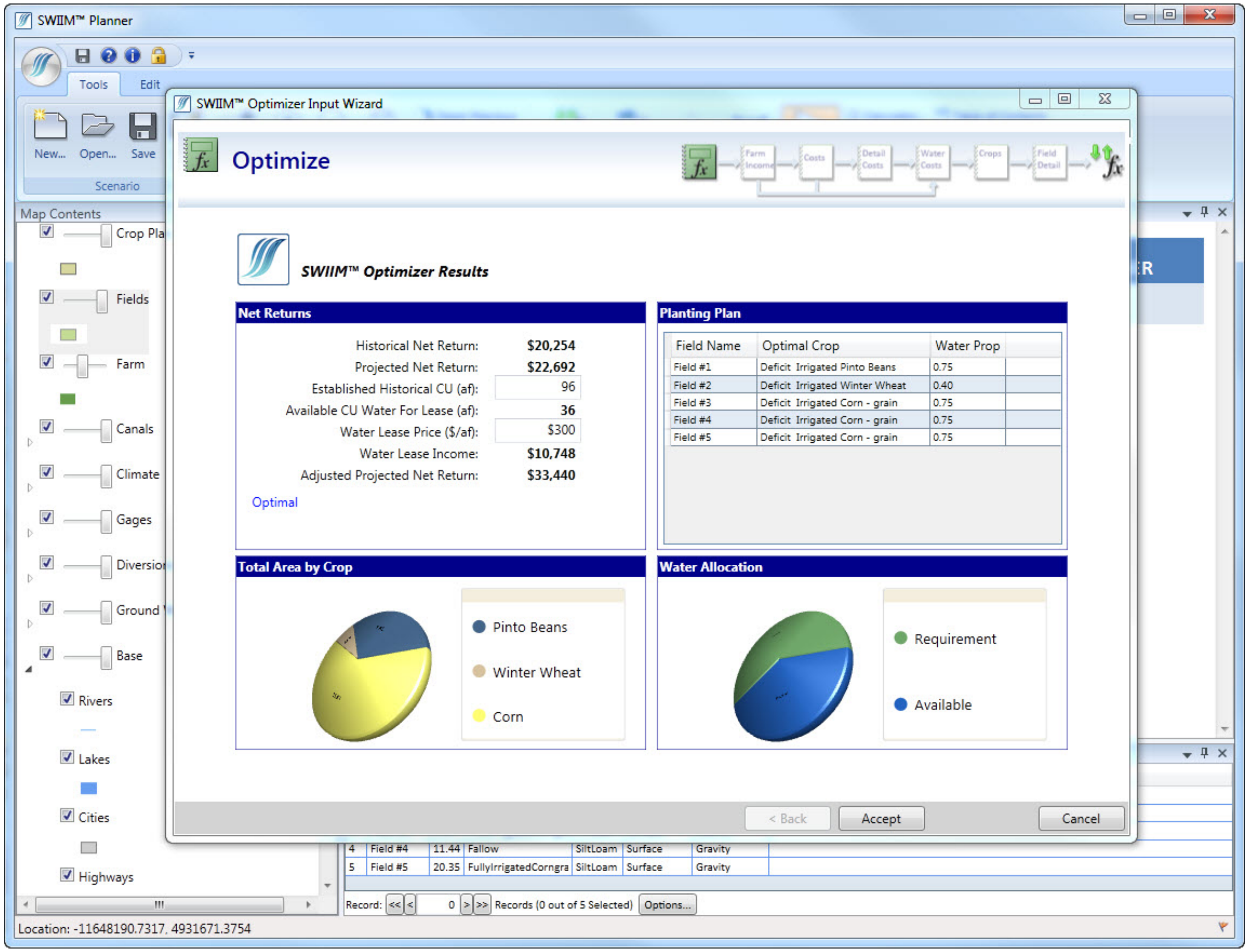

Fig. 6 Optimization program output report screen indicating the modeled net returns based on user inputs

The Model, a simulation and optimization model as described, is researched and developed to allow a farmer user to view the CU water differently than in the past. Namely, the CU can be viewed within a farm water budget and evaluated for future uses. Might the farmer wish to part off a portion of the CU, under contract, to a higher economic value driven by non-agricultural interests? The optimization of future net returns, based on adoption of a package of changed farming practices, allows for a comparative analysis. Multiple runs of the model can provide understanding of the potential and, in effect, a useful sensitivity analysis.

Farmers operating under a senior surface irrigation right within a ditch system may wish to work together as a new cooperative group, or as a subset of shareholders, wishing to implement this technology. This affords a larger block of CU water, and a larger block will be more attractive to the leasing entity. The ditch company or the cooperative would become the managing entity. The resulting implemented system would include SCADA hardware, software, and instrumentation suitable to farm management objectives, ditch company management objectives, and Colorado State Engineer operational reporting requirements.

Some farmers will not consider using this technology. Some farming operations are profitable, sustainable, and doing well in today’s agricultural economy. Other farmers are farming in a marginal financial sense. An operational change using these technologies might help increase profits, allow for, or support irrigation system improvements, and otherwise help those farmers stay in business and continue providing significant regional economic benefits.

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