Memo

To: High Desert Partnership
From: Bill Jaeger, Professor, Department of applied economics, OSU
Re: Description of Harney Basin hydro-economic model analysis, forthcoming
Date: August 23, 2024

I am summarizing below some elements of the analysis that my co-authors and I hope will be published soon in the journal Water Resources Research titled "Gauging Sustainable Groundwater Management with a Hydro-economic System Model: Investigations in the Harney Basin, Oregon."

In this study of the Harney Basin, Oregon, where groundwater levels have declined in the past 20 years, a detailed hydrology model is coupled with an economic model of irrigated agriculture. The model simulates 30-year future scenarios reflecting a baseline trajectory and alternative management actions. The simulations elucidate the system's dynamics and investigates its adaptive potential to achieve stability in the long-term by, among other things, enabling the assessment of existing institutional capabilities for bringing about and maintaining sustainable groundwater use.

On the question of institutional structure and capabilities, a wide range of possible policy instruments can be used (in principle) to manage groundwater, these include both demand-side and supply-side approaches, and for both there are regulatory options, economic instruments, and collective management approaches. Successful groundwater governance can depend on many factors conditional on the economic drivers underlying decision-making for groundwater use and the potential social welfare and environmental impacts in a particular setting.

In this study we develop a Hydro-Economic Model (HEM) of the Harney Basin. The model characterizes the linkages and feedback between the dynamics of the groundwater system, crop-irrigation decisions and farm economic outcomes, as well as the implications over time of these interactions for non-farm community and environmental impacts. Our Harney Basin HEM integrates a spatial, high-resolution groundwater hydrology model (physics-based MODFLOW) with an economic model of irrigated agricultural decisions at the field level. To our advantage, the Harney Basin agricultural production system is well-documented and highly homogeneous: groundwater irrigation involves mono-cropped alfalfa production almost exclusively using one of three sprinkler systems. Each field and irrigation well is identified spatially and in terms of its cost and returns attributes. Profit maximization at the field level is a reasonable assumption and a straightforward linear programming approach to decision making has strong theoretical and empirical support.

To represent these systems and their interactions, a numerical groundwater model (Harney Basin Groundwater Model; hereinafter HBGM) developed by the USGS (Gingerich et al., 2024; Gingerich, 2024) is coupled with an agricultural economic model of groundwater irrigation in the basin. The basin's human system interacts with the groundwater system in several ways. The first connection is in the supply of water to both groundwater and surface-water irrigated agriculture. The feedback effects of irrigation on the groundwater system include interannual changes in depth to groundwater and groundwater discharge to springs, streams, and wetlands in the basin's lowland areas. These changes in groundwater levels and discharge have impacts on groundwater access for the basin's local communities and enterprises (i.e., dry wells), and as the source of water to streams, wetlands, and other groundwater dependent ecosystems (GDEs). All these uses and impacts have consequences on the basin's social and economic conditions and its future. The model can help better understand the consequences of current patterns of groundwater crop irrigation pumping on groundwater depletion, and also to better understand the responses and impacts of a range of alternative actions and policies.

Agricultural decision-making is modeled at the field level where we assume decisions are made to maximize expected profit, which depends on site-specific crop yield, the expected price of hay, and cost of production composed of fixed and variable cost components for irrigation and other costs.

Our analysis is based on fifteen simulated HEM scenarios of future 30-year trajectories. We include a range of alternatives to simulate policy interventions, both regulatory and incentive-based, and including baseline trajectories. Our first scenario is a status quo characterization for a continuation of the 2018 estimated patterns of groundwater-irrigated farming to provide a "baseline" projection of outcomes for the basin under current business-as-usual assumptions. Given observed declines of groundwater levels over the previous 20 years, alternative scenarios are generated to represent and evaluate a range of actions that could plausibly be implemented to mitigate groundwater depletion within the existing legal and regulatory setting. In some cases, these scenarios reflect proposals made by stakeholders and local officials within the community. These include adoption of water-conserving irrigation technologies, idling fields, and limits on pumping in areas of greatest groundwater-level decline.

In all scenarios, farmlands irrigated by surface water are assumed to continue with no changes in their operations. Surface-water-irrigated fields amount to 31,404 ha (77,600 ac), or 54% of the total irrigated farmland. In addition, no changes occur over the simulated time period with respect to non-irrigation wells: they continue to operate at 2018 rates and only represent about 2% of total 2018 annual rates. Agroclimatic conditions and external influences such as groundwater recharge are assumed to be constant at levels representative of average conditions.

The baseline scenario represents the likely future path under existing incentives, constraints, and conditions facing irrigators in the basin. In particular, it assumes that all groundwater-irrigated fields and wells active as of 2018 continue to be potentially active for our 30-year HEM simulation. No new wells or water rights are introduced, nor is any well deepening allowed to take place. The scenario also includes a set of assumptions considered to be midrange (and unchanging) values for agricultural input and output prices.

Scenario	Description
Scenario 1	Baseline or business-as-usual.
Scenario 2	Water conserving technology required (LESA and LEPA allowed).
Scenario 3a	Land idling #1- on fields with lowest profit per unit of water, pumping reduced 80% by year 3.
Scenario 3b	Land idling #2 - fields with lowest profit per unit of water reduce pumping to zero by year 3.
Scenario 3c	Land idling #3 - on fields with lowest profit per unit of water pumping reduced 50% by year 3.
Scenario 4a	Incentive-based #1 – cost of pumping raised to $1/kwh by year 3.
Scenario 4b	Incentive-based #2 - cost of pumping raised to $0.80/kwh by year 3.
Scenario 4c	Incentive-based #3 - cost of pumping raised to $1.20/kwh by year 3.
Scenario 4d	Incentive-based #4 - cost of pumping raised to $1.40/kwh by year 3.
Scenario 5a	Targeted regulations #1 - in areas where declines exceed 20 feet; pumping reduced gradually from years 2-5 by 50%.
Scenario 5b	Targeted regulation #2 - in areas where declines exceed 30 feet; pumping reduced gradually from years 2-5 by 50%.
Scenario 6	Regulating of junior water rights with priority dates 1992 and later.
Scenario 7a	Pumping limit #1 - maximum rates lowered gradually from years 2-5 to 60% of initial levels.
Scenario 7b	Pumping limit #2 - maximum rates lowered gradually from years 2-5 to 50% of initial levels.

Key outputs for each scenario by year, and for changes from year 1 to year 30:

- Profits (net revenue) for groundwater irrigated fields ($ millions)
- Cumulative number of (residential and livestock) wells going dry
- Environmental flows from wells and into lowland areas (volume)

Results for these three variables are presented in the paper for all 15 of the 30-year scenarios so that tradeoffs among them can be compared.