

Economics of a Potential Groundwater Management Area in Oklahoma Panhandle

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Introduction

Background

The goal of this research is to identify strategies by which Oklahoma Panhandle Area (OPA) producers can wisely maximize the value of their remaining but declining groundwater. The USGS (2012) report shows that the average water level decline in the OPA is 2.5 feet per year. The major irrigated crops in OPA are corn, sorghum, and winter wheat. Irrigated corn gives greater net returns per acre than sorghum, but irrigated sorghum gives greater net returns per unit of water. Completed studies show that it is more profitable to follow a long-term profit maximizing strategy by replacing irrigated corn with grain sorghum (uses less water) and conventional pivot irrigation with Subsurface Drip (SDI) when well capacity declines below 600 GPM per acre.

Past conservation efforts to slow down the aquifer decline and establish the economic viability of the region have been largely unsuccessful (Golden, 2017). Achieving higher discounted profits over a longer time period, means the Long-Term Profit Maximizing producer (LPM) would use less water and earn slightly less income in the near-term than surrounding annual profit maximizers (APM), the LPM would receive higher discounted returns from a longer aquifer life. Producers may hesitate to follow a LPM strategy because of fear that water conserved may flow to and be used by a nearby APM producer. However, it is expected the proportion of lateral groundwater loss from a contiguous group of LPM producers would be less than from a single LPM producer. Accordingly, Local Enhanced Management Areas (LEMA) have been formed in Kansas, where producers have agreed to reduce annual application rates by 20 %.

The main objective of this study is to determine the minimum contiguous size of the land area that a cooperative irrigation district (CID) of LPM producers must have to retain an expected portion of their conserved groundwater. The size of the CID and the amount of groundwater migration from a group of LPM producers is expected to depend upon the hydraulic gradient (difference in groundwater levels, and distance), hydraulic conductivity, and specific yield.

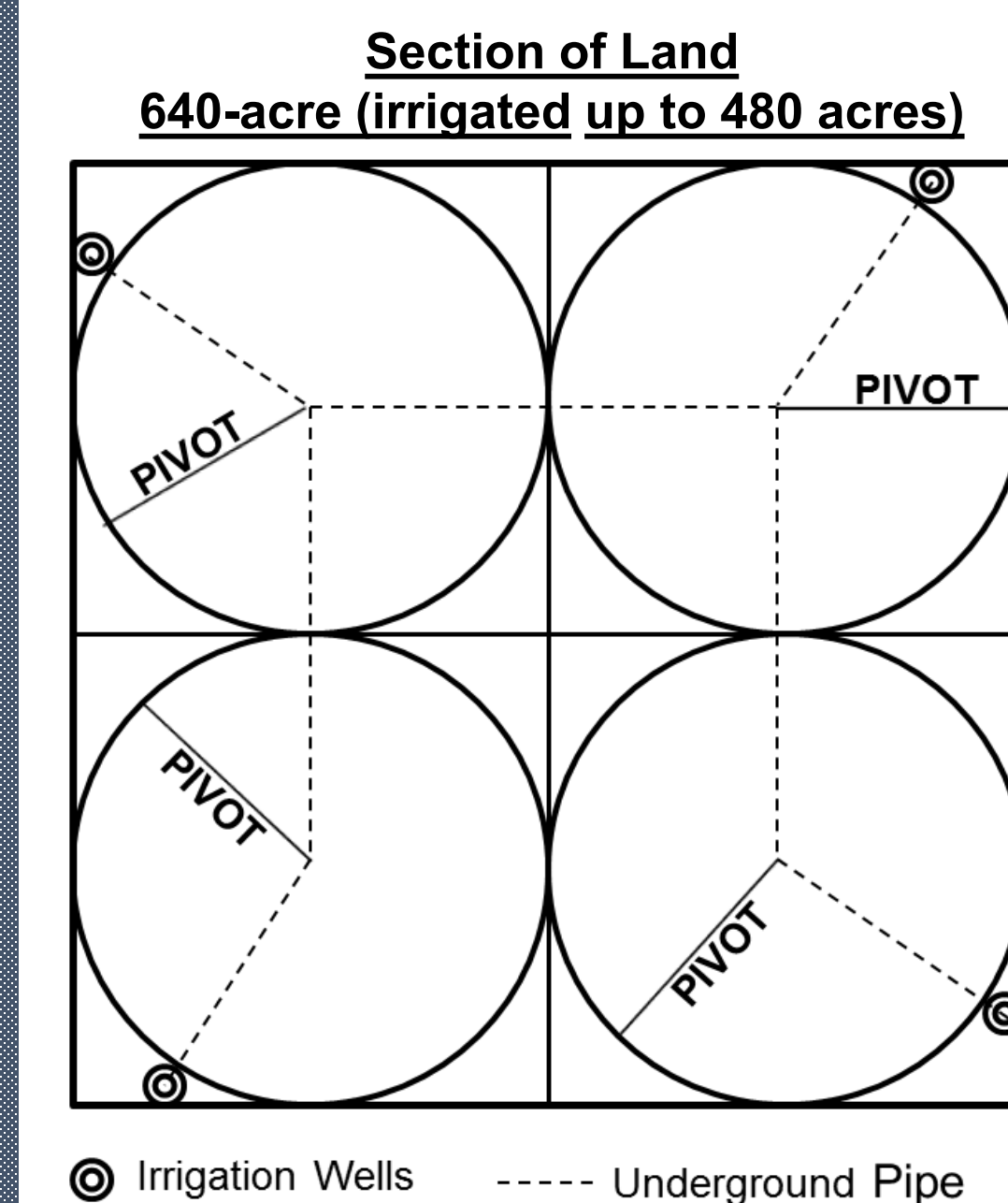
Objective

The overall objective of this research is to determine the effects of groundwater interaction and observe the benefits and costs between groups of APM and LPM producers over a 30-year long-term planning horizon. The overall sub-objectives are:

1. Estimate the drawdowns and well interference effects at various levels of the aquifer when multiple wells are extracting groundwater from the shared saturated sand of the Ogallala aquifer.
2. Quantify the effects of the hydraulic gradient, hydraulic conductivity and specific yield on the movement of groundwater between producer groups and on the minimum size of the CID.

Study Methods

In this study, two groups of producers are assumed to compete for a common pool of groundwater. The APM group chooses crops (grain sorghum or corn) and irrigation levels that give maximum annual profits. The LPM group chooses crops and irrigation levels that maximize the Net Present Value (NPV) from the remaining groundwater supply over the 30 year period. This is determined by a mathematical programming model assuming a single cell aquifer. Each individual producer is assumed to have a 640-acre field with four wells. Initially, the producer could irrigate up to four 120-acre pivot circles. A representative section of land is shown below.

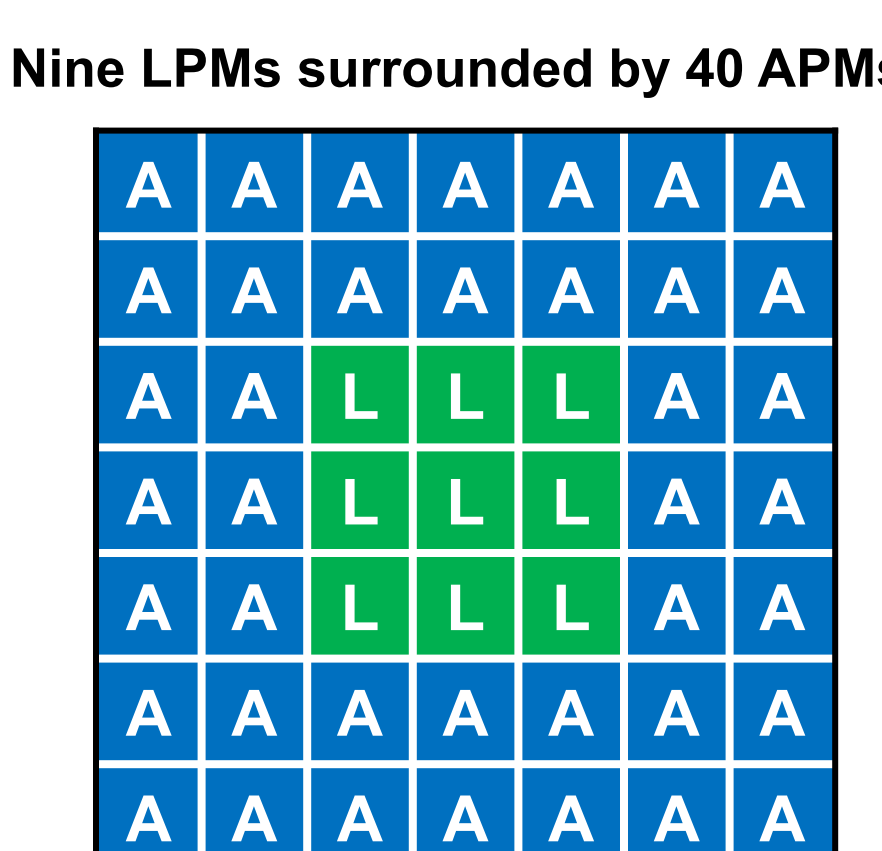
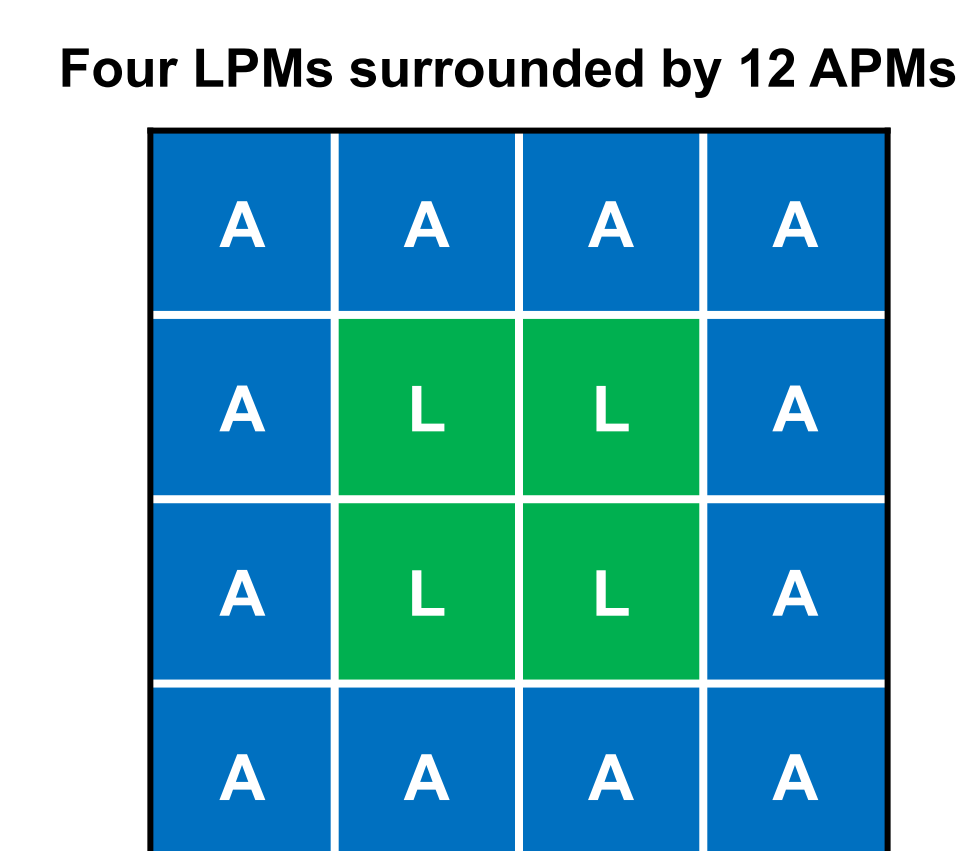
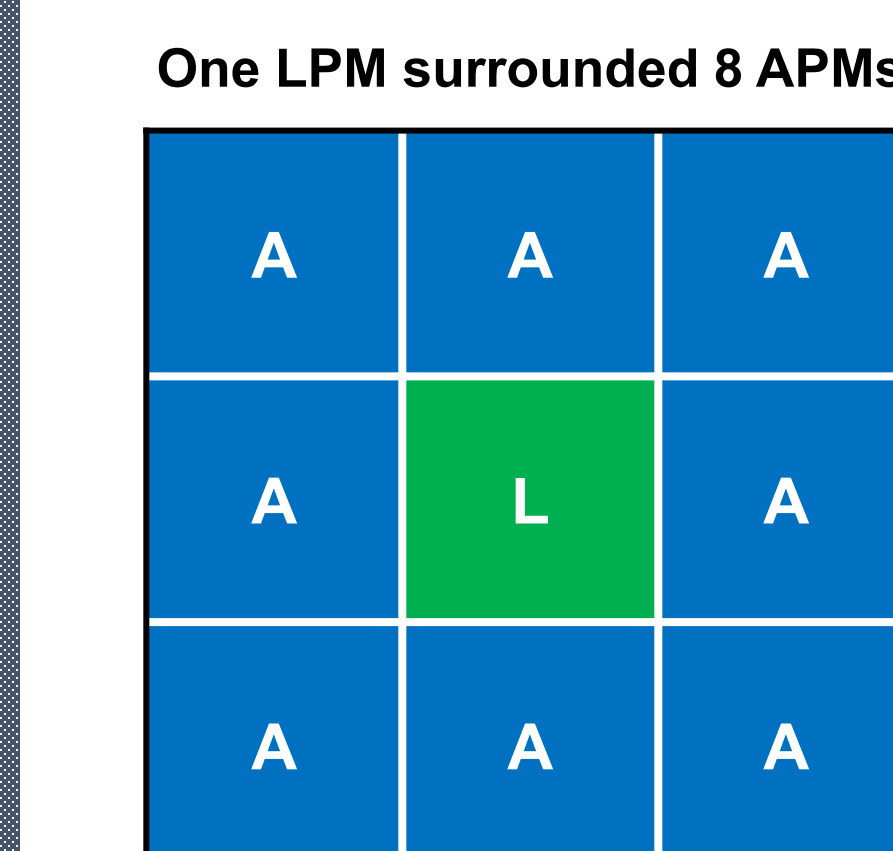
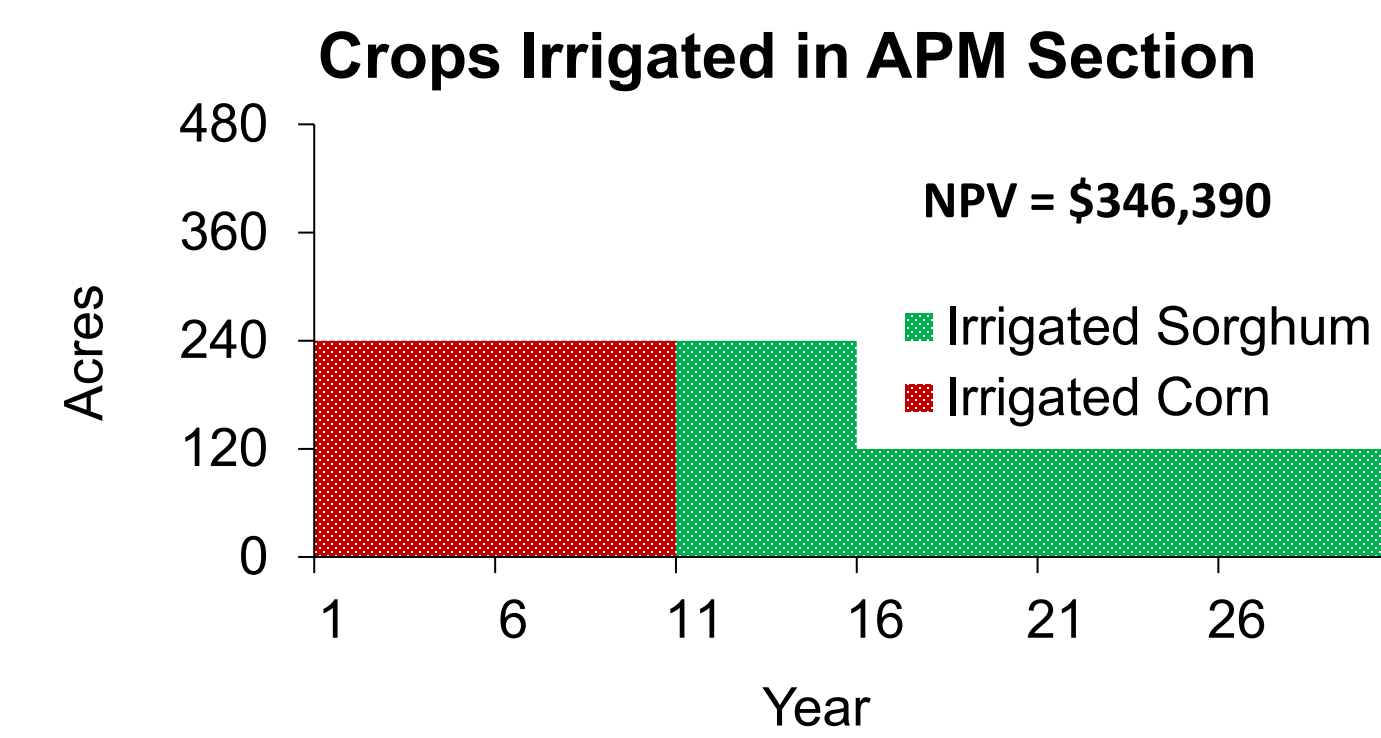
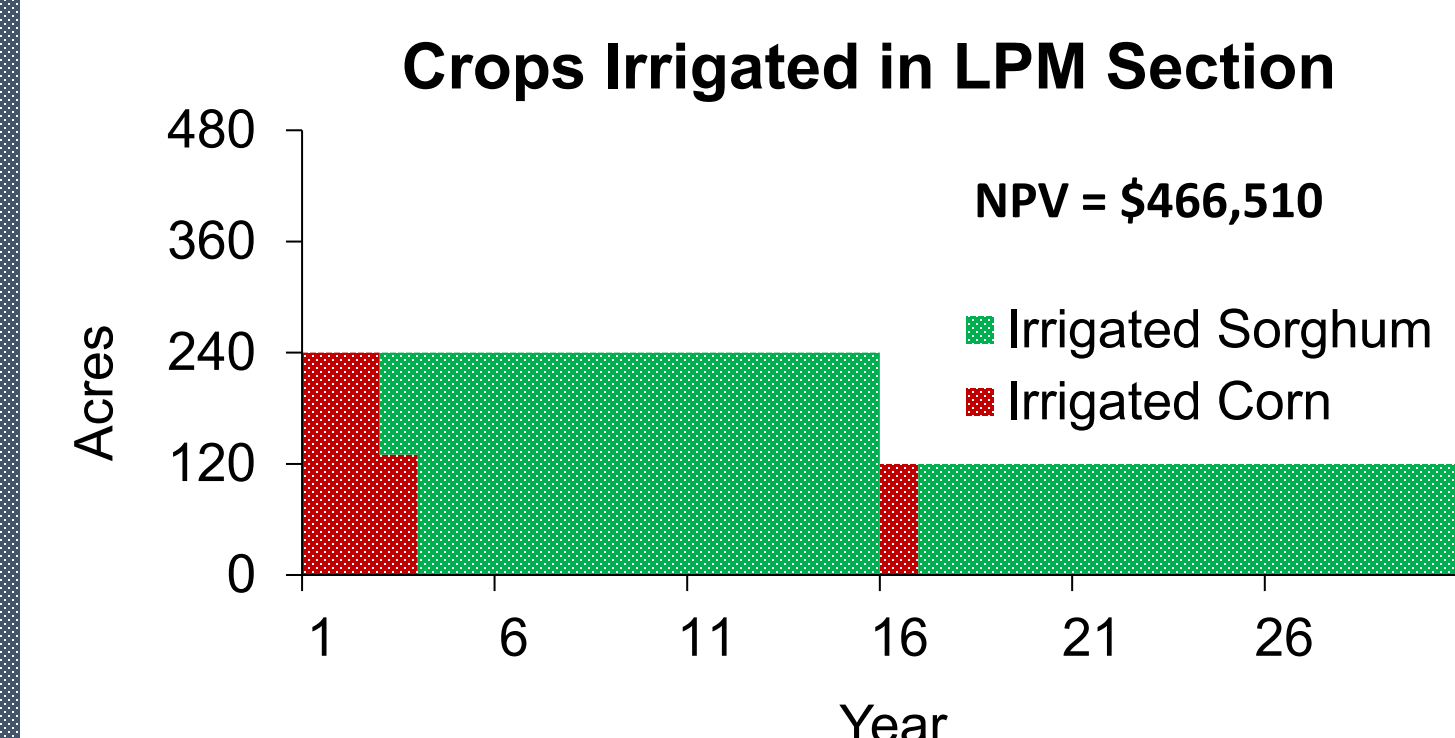


The annual pumping rates for all producers are entered into a MODFLOW model which is used to simulate the combined pumping on aquifer levels over a 30 year period. Various sizes of contiguous areas are tested for the LPM group. These are a single 640-acre irrigated section surrounded by eight APM sections, four 640-acre LPM producers surrounded by 12 APM sections, and a block of nine 640-acre LPM producers surrounded by 40 sections of APM producers. This continues until the block of LPM producers can retain at least 90 percent net benefits they would gain if all producers followed the LPM strategy. The LPM water-level is expected to decline at a slower rate than APM because LPM uses less water annually. Therefore, LPM water table is expected to be at a higher level than that of an adjoining APM producer as shown in Table 1.

For each size of LPM group and set of hydrology conditions, the optimal water use strategy (crop choice and water use given the current groundwater level) is determined by a multi-period (up to 60 years) Mixed Integer Programming (MIP) model and the APM optimal water use strategy is determined by Recursive Linear Programming. Following each year the amount of groundwater flow from the LPM group to the APM group is calculated. Groundwater interaction analysis are done in MODFLOW for contiguous land sizes and well locations. Drawdown effects on well interference and dewatering for a given saturated thickness are noted. The results for each size group of LPM producers with lateral flow to the APM group is compared to potential returns if all producers adopted the LPM strategy.

Table 1. Annual Pumping rates of LPM and APM producers with four wells on a 640 acre for 30 years

Group	Year																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17-30
LPM (GPM/well)	287	287	200	115	115	115	115	115	135	148	148	133	130	130	130	130	65
APM (GPM/well)	287	287	287	287	284	258	252	219	219	176	128	128	128	128	128	65	65



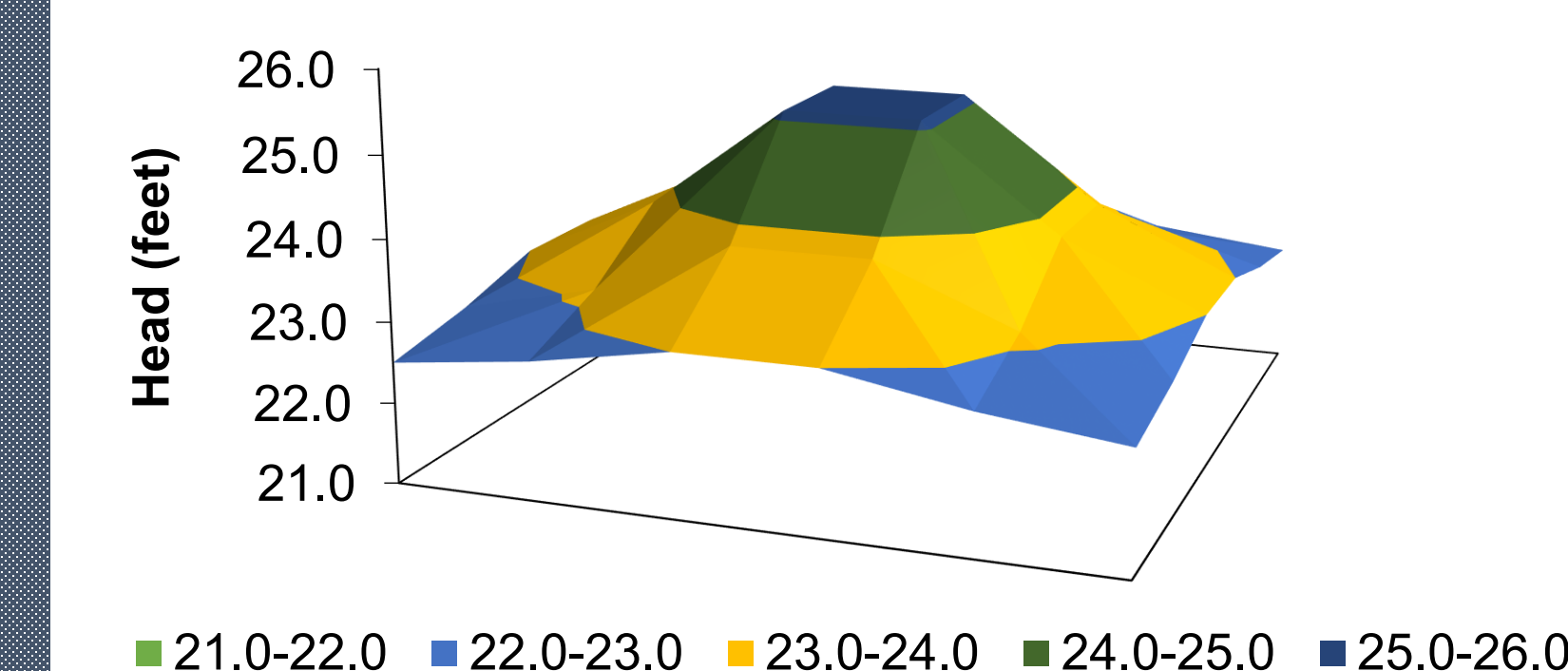
A 640-acre APM section

L 640-acre LPM section

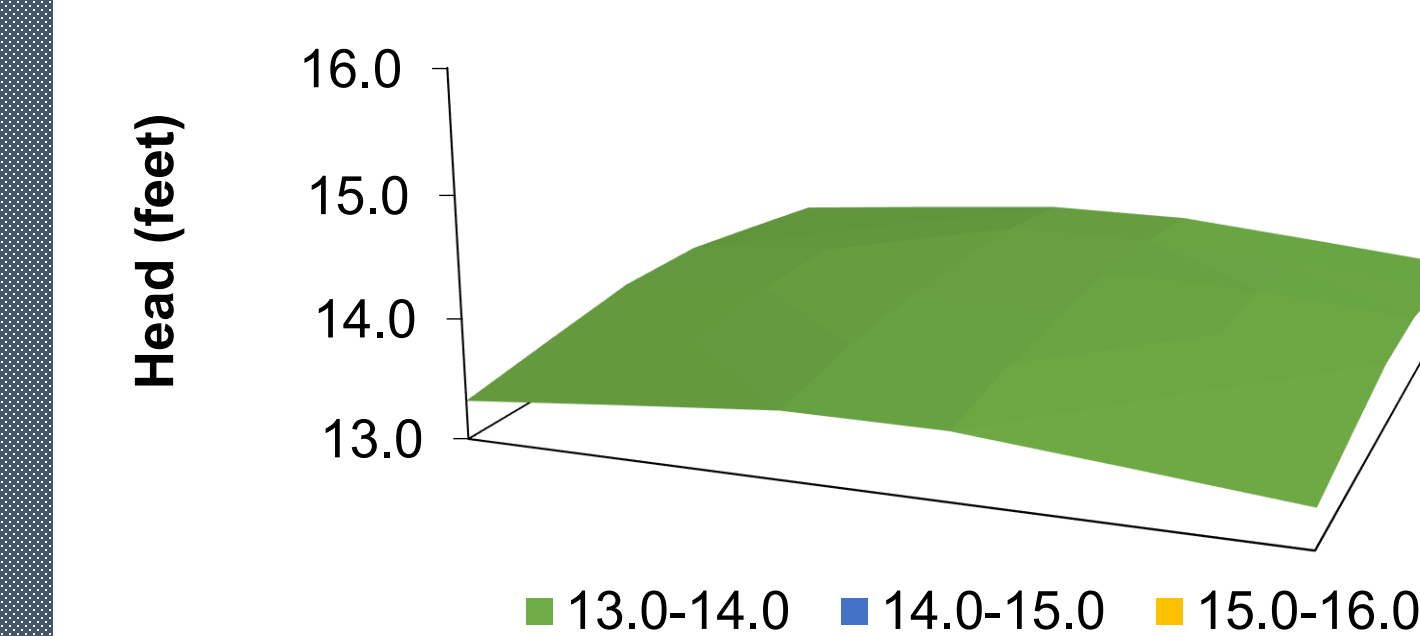
Results

Preliminary results show the effects with two CID sizes. 1) The first is, one LPM producer surrounded by 8 APM, and 2) the second is, four LPM producers in a CID surrounded by 12 APM producers. Results show that LPM can reduce the water migration to APM if the LPM size is increased from one to four. One LPM producer CID is expected to retain 77% and four LPM producers CID are expected to retain 82% of their conserved groundwater. The research will be extended to test larger sizes 9, 16, 25, and 36 sections (township) of LPM in effort to increase the aquifer life in OPA.

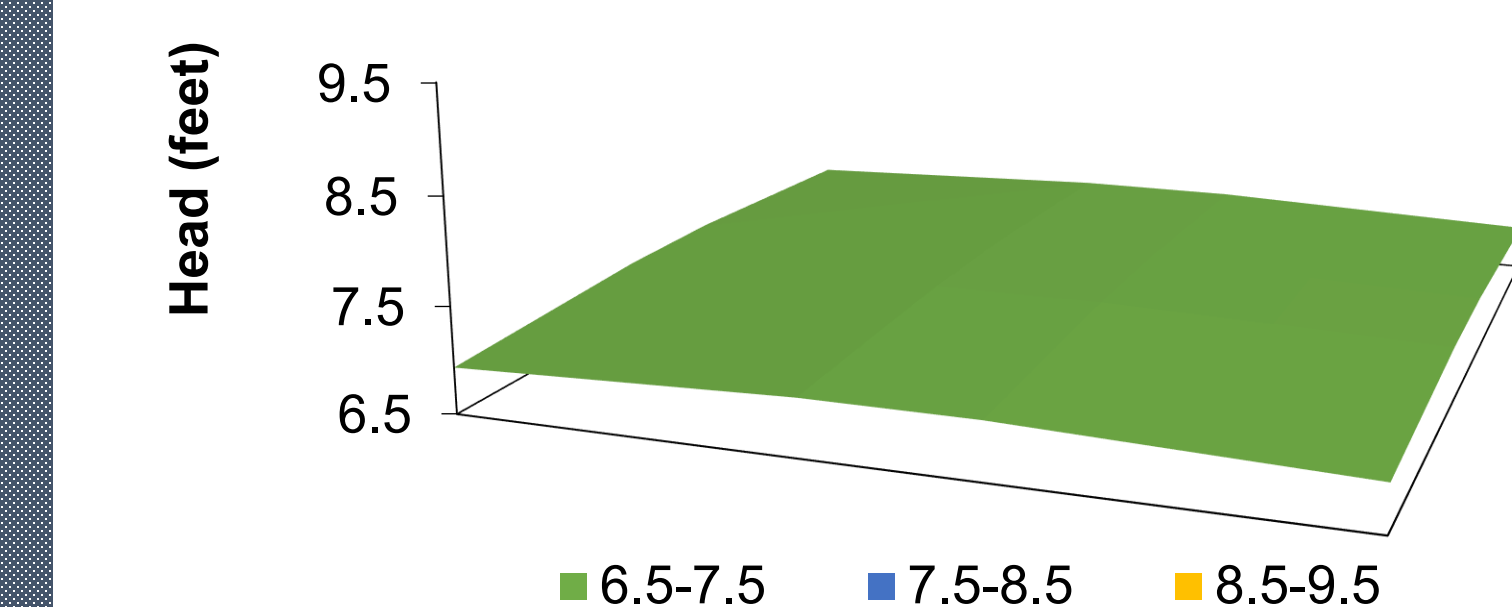
Water Table at Year 10 with One 640-acre LPM surrounded by 8 APMs



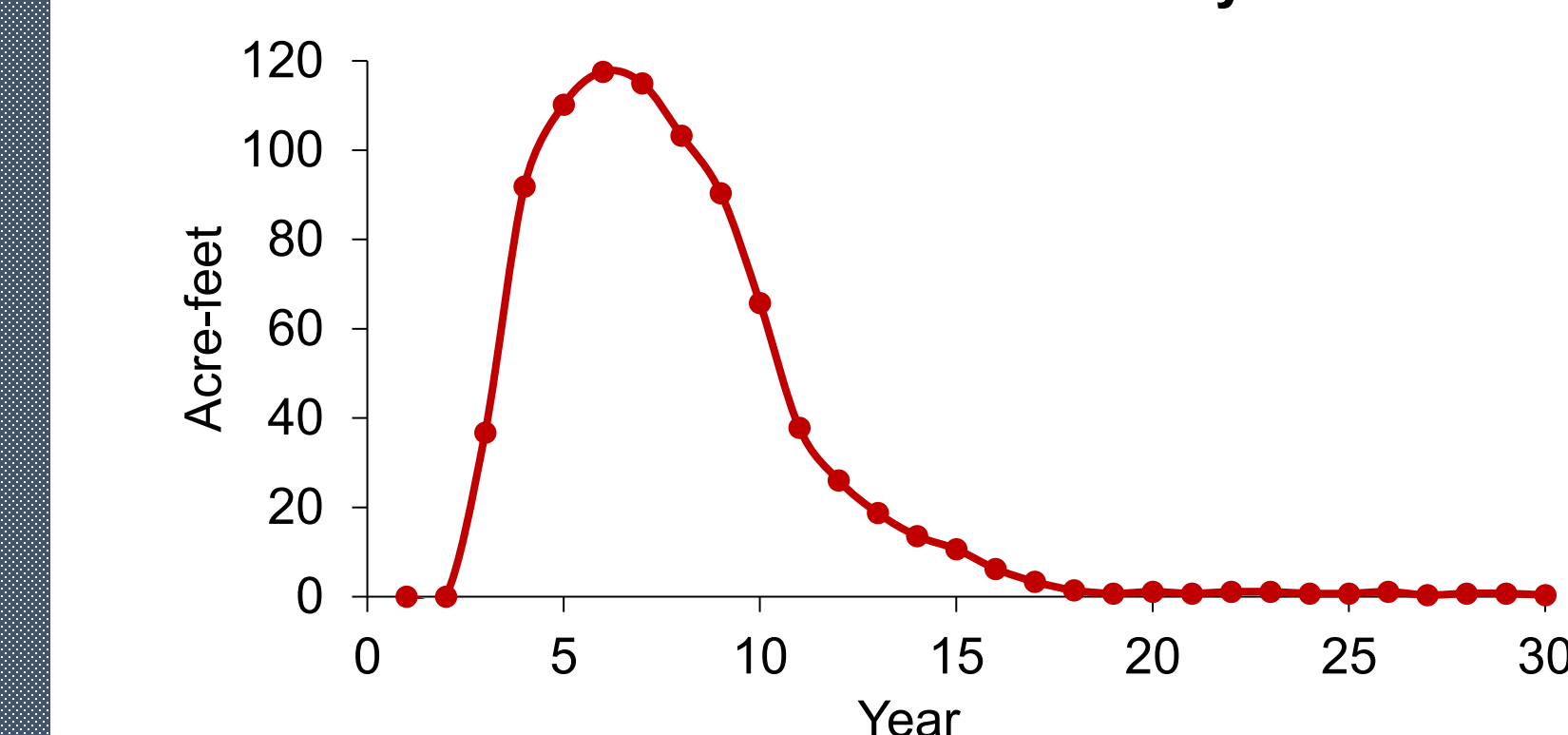
Water Table at Year 20 with One 640-acre LPM surrounded by 8 APMs



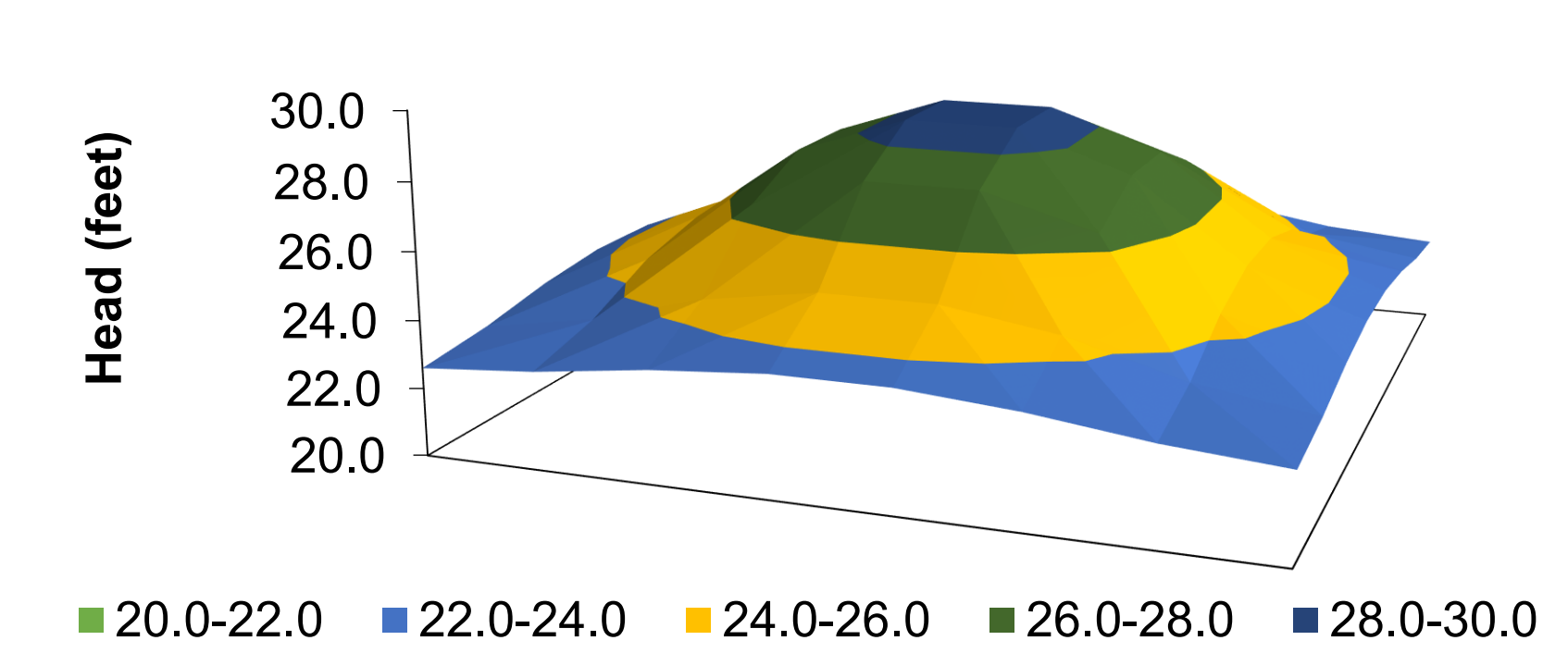
Water Table at Year 30 with One 640-acre LPM surrounded by 8 APMs



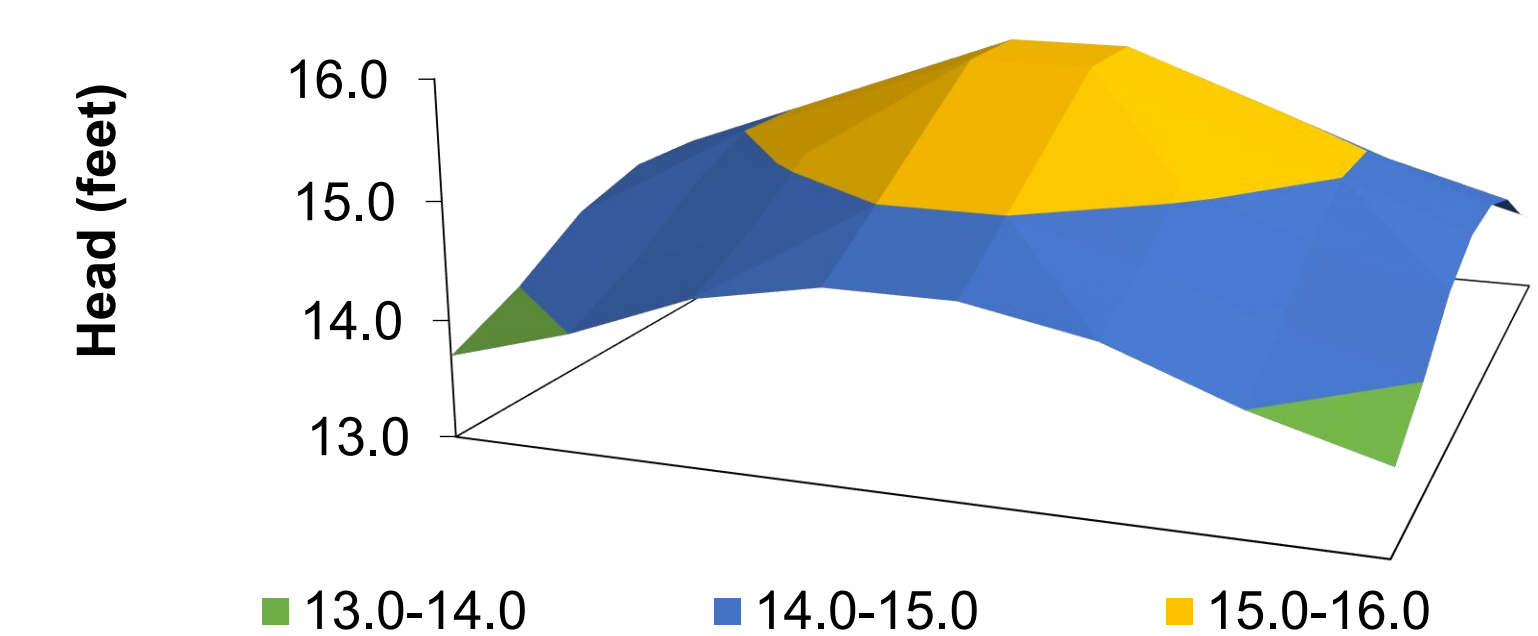
One LPM Surrounded by 8 APM: Estimated Annual Water Loss by each LPM



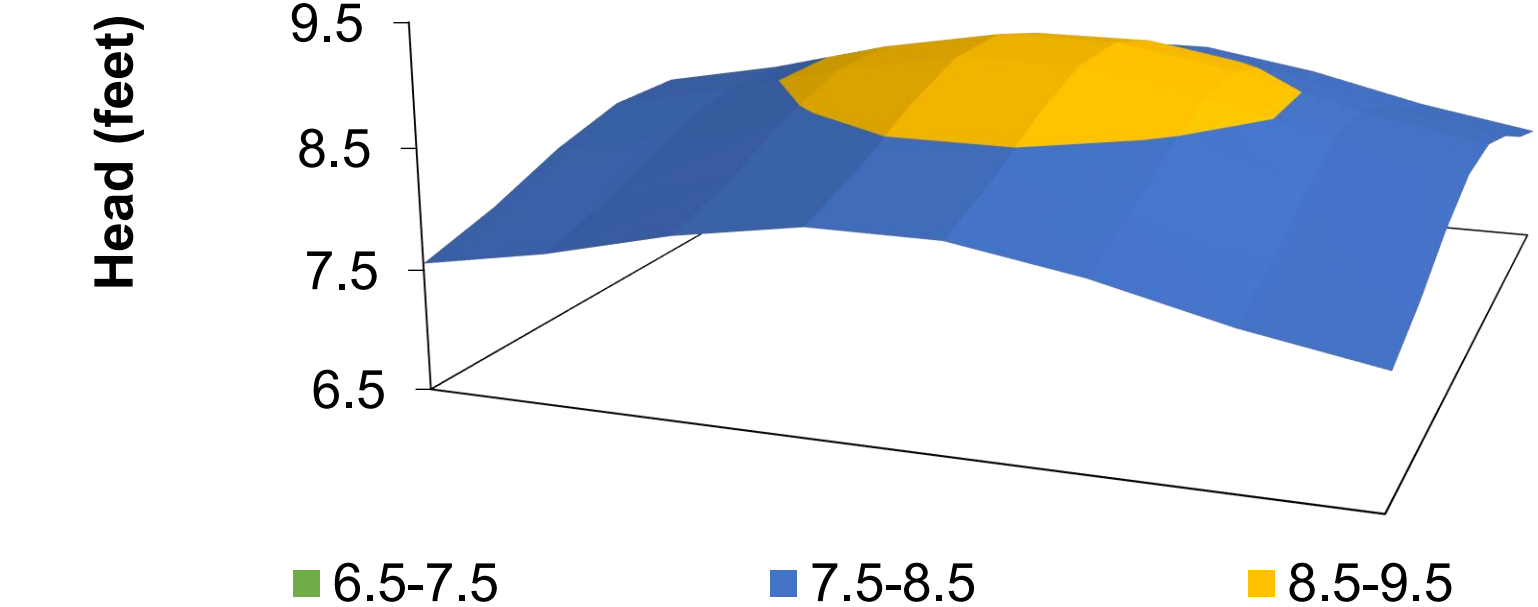
Water Table at Year 10 with Four 640-acre LPM surrounded by 12 APMs



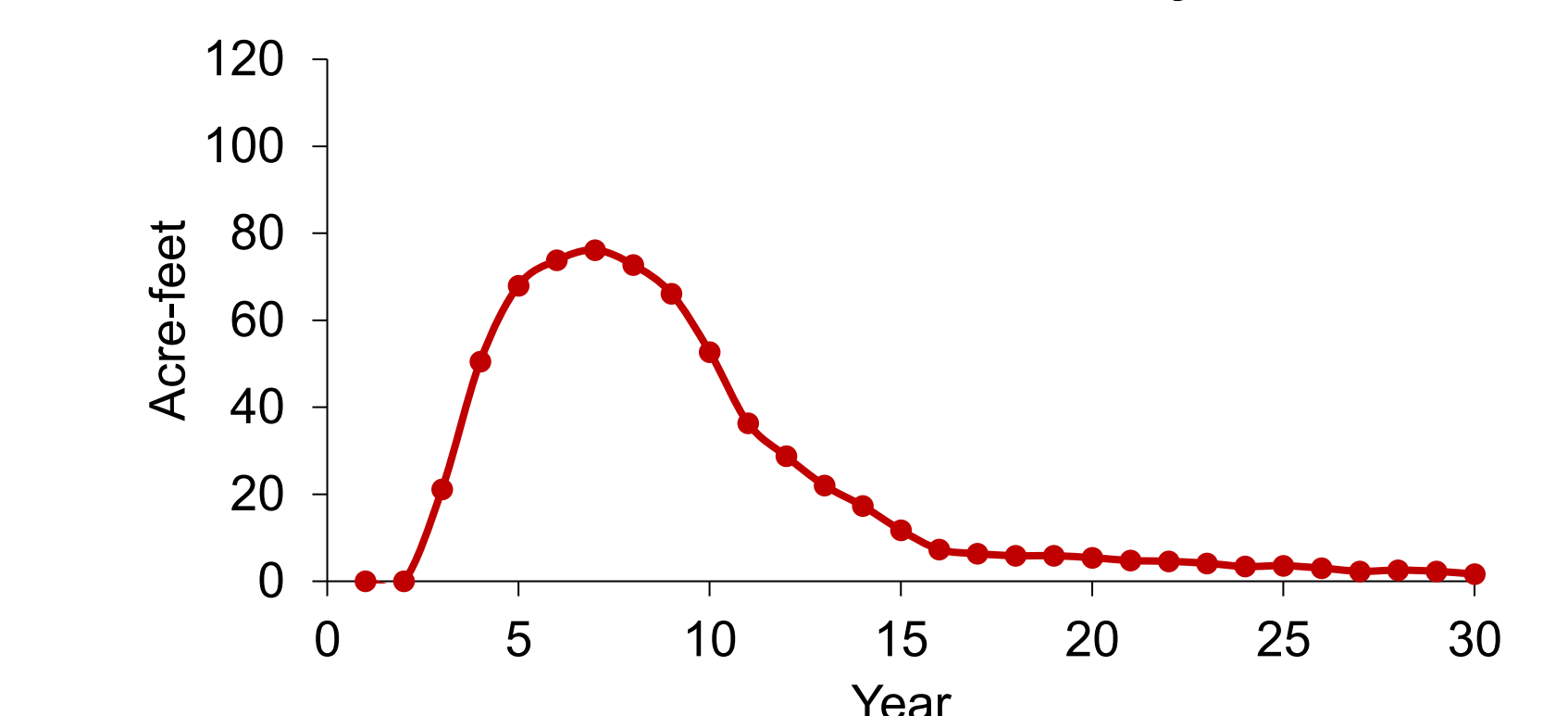
Water Table at Year 20 with Four 640-acre LPM surrounded by 12 APMs



Water Table at Year 30 with Four 640-acre LPM surrounded by 12 APMs



Four LPM Surrounded by 12 APM: Estimated Annual Water Loss by each LPM



References: Ramaswamy, K., A. Stoecker, R. Jones, J. Warren, and S. Taghvaeian. 2017. "Choice of Irrigated Corn or Grain Sorghum and Center Pivot or Subsurface Drip Systems in the High Plains of Oklahoma" AAEE 2017 Annual Meeting Proceedings, July 30-August 1, Chicago, IL.

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