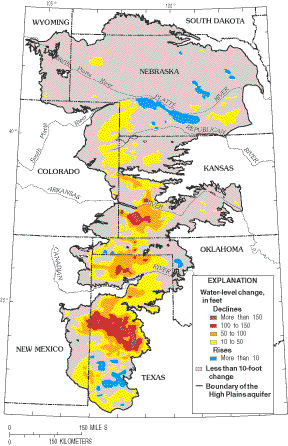
**CASE STUDY: High Plains Aquifer, Central USA**

*Prepared by Emily Keenan, University of Virginia*



***Source: Konikow, 2013.***

**General Overview**

The High Plains Aquifer was formed more than 10 million years ago by the erosive action of eastward flowing streams or rivers coming from the Rocky Mountains that carried huge deposits of sediment onto the Midwestern US plains during the Pliocene era (2-5 million years ago). Today, the American Midwest, where the aquifer is located, is characterized by its highly fertile land and massive agricultural production. The High Plains Aquifer is the life support for this agricultural system, supplying water for eight states—Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming.[[1]](#endnote-1) But, America’s “Breadbasket for the World” is in crisis. This ancient aquifer is being tapped dry from agricultural overuse, and the effects can be seen rippling through every sector of the region’s economy and beyond.

The aquifer is approximately 174,000 square miles (450,660 sq. kilometers) in extent and is the drinking water source for 2.3 million people. Though the region pumps groundwater for public, private, and industrial use, by far the largest portion of pumped water goes to irrigation. Agriculture uses as much as 95% of the aquifer’s supply.[[2]](#endnote-2) While climate and precipitation vary considerably across the region, on average the cold and semi-arid climate receives about 20.6 inches (520 mm) of precipitation annually. This precipitation is the main form of recharge for the High Plains Aquifer—the enhancement of its natural groundwater supplies.[[3]](#endnote-3) This recharge, however, is inadequate to refuel the aquifer, with more water being pumped out for irrigation than can be naturally put back into the system.

Because this aquifer crosses so many states, it provides a unique challenge to proper conservation and management. Each state provides its citizens with their own water rights—some states appropriate water while others give full ownership of groundwater to homeowners living above the aquifer. Contradictory governing of the same aquifer risks unregulated depletion. Despite the growing water scarcity felt by farmers across the region, despite crop losses in the billions of dollars, and despite years of knowledge of profound overuse, it seems as though movement toward meaningful changes in water planning and agriculture is extremely slow in coming.

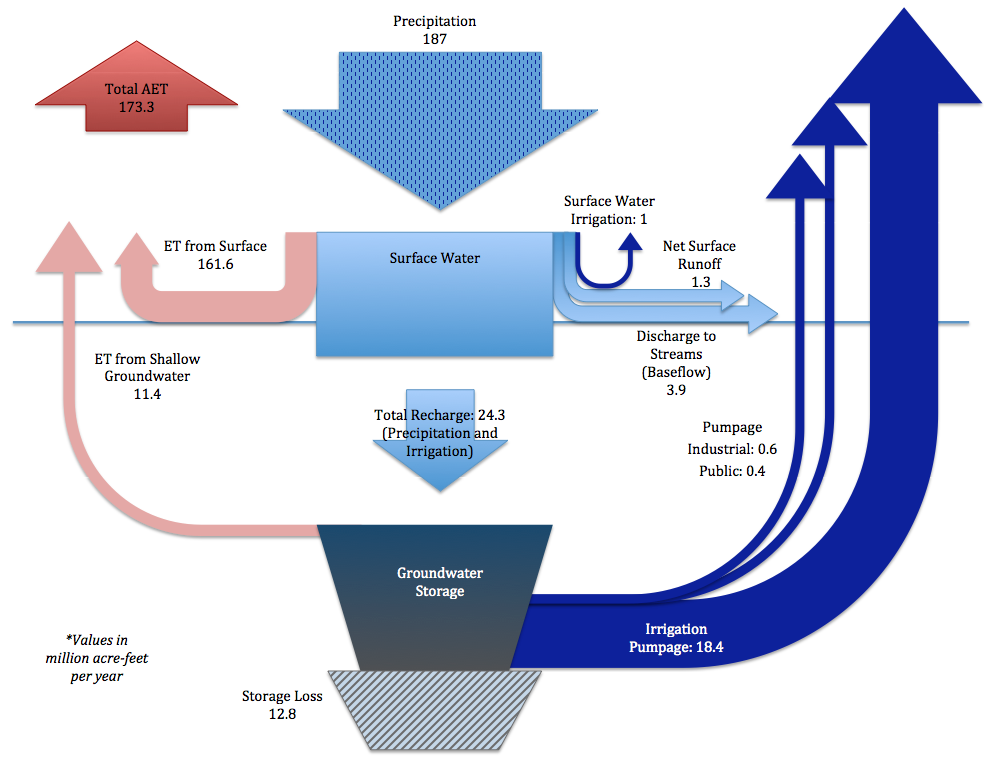
**Water Budget**

The water budget for the High Plains Aquifer illustrates the extreme imbalance between groundwater pumping and recharge of the aquifer. All data for this water budget comes from the USGS Geological Survey’s Scientific Investigation Report for the High Plains Water Budget Components, published in 2011.  
  
Precipitation (rain and snow) is the only source of water for the High Plains region. Some water is retained on the surface of the land where it can be held or exit as stream flow into other waterways, or used for irrigation. Greater volumes of water are available in the aquifer system, but most of that water was deposited in the aquifer millions of years ago, during the Pliocene era.

The aquifer is very slowly recharged by both precipitation and excess irrigation water application. The high rate of groundwater pumping is rapidly depleting the aquifer. Another important component of the water budget that contributes to the depletion of the aquifer is the large amount of “actual evapotranspiration” (AET) due to cropland, which makes up approximately one-third of all land cover in the region. Evapotranspiration results from both evaporation of water from soils and water transpired by plants/crops. Most of the water that is applied to crops is lost to evapotranspiration, with only a small fraction percolating back into the aquifer.

In recent decades, the aquifer volume has been declining by an average of 12.8 million acre-feet per year. The rate of depletion has increased since the 1940s, when large pumps began to be used to extract groundwater from the aquifer.[[4]](#endnote-4) As noted earlier, depletion in groundwater storage occurs when water consumption through pumpage exceeds recharge.

**High Plains Water Budget Diagram**

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**Water Budget Documentation**

McGuire, V.L., 2013, Water-level and storage changes in the High Plains aquifer, predevelopment to 2011 and 2009–11: U.S. Geological Survey Scientific Investigations Report 2012–5291, 15 p.

Stanton, J.S., Qi, S.L., Ryter, D.W., Falk, S.E., Houston, N.A., Peterson, S.M., Westenbroek, S.M., and Christenson, S.C., 2011, Selected approaches to estimate water-budget components of the High Plains, 1940 through 1949 and 2000 through 2009: U.S. Geological Survey Scientific Investigations Report 2011–5183, 79 p.

**Spatial and Temporal Variability**

The High Plains region experiences considerable climatic variability. The aquifer extends over a vast area in the Midwest, and precipitation and temperatures vary greatly across the region. Average air temperatures generally increase from north to south.[[5]](#endnote-5) Precipitation is also quite variable across the region, typically increasing from west to east. Air temperature can affect evapotranspiration rates that can then lead to increasing need for irrigation water and greater declines in aquifer storage.[[6]](#endnote-6)

Seasonal variability also affects the water budget. Precipitation, for example, generally peaks around June and then declines to its lowest amounts in December and January.[[7]](#endnote-7)

**Water Toolbox**

**Desalination** is a potential but very expensive option for increasing water supply in the High Plains region. Some portions of the High Plains Aquifer have been unusable due to high salt concentrations, particularly in parts of Kansas.[[8]](#endnote-8) Water with high concentrations of salts will adversely affect plant growth and soil properties unless the salts can be removed via desalination. However, the cost of desalination is likely unaffordable for irrigation use, and it can be quite challenging and expensive to dispose of the concentrated brine that is left over from desalination.

W**ater storage** could be a useful means of capturing some of the surface runoff in the region, but it will likely be quite inefficient due to high rates of evaporation in this area. Storage reservoirs could reduce the amount of groundwater that must be pumped, however.   
  
**Importation** of external water sources into the High Plains has been assessed for the region. In 1982, a study was done to analyze the replenishment groundwater resources through a long-distance transfer of water from Lake Superior.[[9]](#endnote-9) Such water importation would be very expensive due to the cost of the energy required to pump the water over great distance. A prohibition on exports of water from the Great Lakes, signed between 8 US states and two Canadian provinces in 2001, makes diversions from the Great Lakes virtually impossible now.  
  
**Reusing water** could help to reduce the volume of water that must be pumped from the aquifer, but it would be very challenging to capture any excess water applied to farm fields so that it could be reused. This strategy could be more easily applied in industries or other urban water uses, but those uses comprise only a very small (<5%) of all water use in the region.

**Water management** is challenging in the High Plains due to the fact that the aquifer spans multiple states. Any state regulations that might prevent unsustainable groundwater overdraft for one state will not necessarily apply to other states, unless some sort of inter-state agreement could be reached. Organizations like the High Plains Underground Water Conservation District have developed plans with specific goals to conserve, protect, and prevent waste of groundwater, and their approach can be replicated in other areas.  
  
**Water conservation** is a logical and practical tactic. The big question is whether simply using water more efficiently will be sufficient to arrest groundwater depletion. Agricultural irrigation has begun to shift toward more efficient drip-irrigation and low-pressure, full drop-line center pivot systems.

**Water Stakeholders**

**Farmers** are the most important stakeholders in this region. With more than 70% of the land area being used for agriculture, the region’s economy is heavily dependent on farming.[[10]](#endnote-10) The crops grown by these farmers literally help to feed the world, particularly for water-intensive crops such as corn, wheat, and barley.[[11]](#endnote-11) Many of their crops are fed to livestock. Farmers will be highly reluctant to cut back on their water use if it means reducing their incomes.

**Conservation and groundwater management groups** have been working to institute more efficient farming practices and have tried to encourage those practices through incentive programs. These initiatives include efficient drip and center pivot irrigation methods.[[12]](#endnote-12) These groups also promote water conservation practices outside of agriculture, specifically in the domestic sector of water use. They advocate for better home water utilization. In a number of states, groundwater management districts have been established that bring together water users to conduct joint planning for future conditions of groundwater.[[13]](#endnote-13)

S**tate governments** play an important role in determining how surface water is apportioned within their state, and state laws also determine who owns or controls groundwater use. In some states, landowners own the groundwater beneath their land, making it very difficult to regulate or control. However, groundwater is owned by the state in other cases, which could provide an opportunity for controlling its use.

**Homeowners** More than 2 million people draw their drinking water from the aquifer. As the volume of the aquifer is depleted it places this drinking water supply at great risk.

**Corporations** rely heavily upon the agricultural production of the High Plains region. They are the major buyers of these crops and therefore contribute greatly to the national production of crops and food. This means that C**orporations** that depend on these goods so too depend on the water that grows their products. They are economically quite influential in the production methods and quantity demand. If the aquifer goes dry, more than $20 billion worth of food and fiber will vanish from the world's markets.[[14]](#endnote-14)

**Water Budget Sources**  
  
*Given:*   
**Net Surface Runoff** (Figure 25) – 1.3  
**Net Groundwater Discharge** (Figure 25) – 3.9   
  
**Actual Evapotranspiration** (all sources)  
*Calculated* by averaging methods  
NWS – 193

SSEB – 173

SWB – 154

Average – 173.3   
  
\*\*Evapotranspiration from shallow groundwater   
Calculated by averaging methods  
NWS – 12.6  
SSEB – 12

SWB – 9.6

Average – 11.4

**Pumpage**  
*Calculated* from given information (page 12 and 52 – Irrigation 95%, industry 3%, public 2%)

18.4 for irrigation 🡪 total pumpage is 19.37  
Public = ~0.4  
Industry = ~0.6  
  
**Irrigation supply from surface water**  
(page 52) – 1   
  
**Reduction in Groundwater**   
Given from USGS Study 2000-2009 (Figure 25) – 10   
Given from USGS Study 2009-2011 of water-level and storage changes – (Table 3) another 2.8

* This summation was for the most up to date storage loss
* 2000-2011 data was used for the budget because the other component of the budget were from 2000-2009 data as opposed to the 1940-1949 data

**Total out of the system calculated by addition**  
211.7 MGD

**Precipitation (Table 3)**  
Averaged by methods  
PRISM – 185  
NWS – 199   
IDW – 190  
Average – ~187  
  
**Recharge (Table 6)**  
Calculated by averaging methods  
SOWAT – 35   
SWB – 15.9   
  
**Total in to the system calculated by addition**   
~212 MGD

*\*Unless Specified, all of this data came from the USGS Geological Survey of High Plains water budget components from 1940 to 1949 and 2000 to 2009:*

*Stanton, J.S., Qi, S.L., Ryter, D.W., Falk, S.E., Houston, N.A., Peterson, S.M., Westenbroek, S.M., and Christenson, S.C., 2011, Selected approaches to estimate water-budget components of the High*

*Plains, 1940 through 1949 and 2000 through 2009: U.S. Geological Survey Scientific*

1. http://pubs.usgs.gov/ha/ha730/ch\_c/C-text5.html [↑](#endnote-ref-1)
2. http://pubs.usgs.gov/sir/2011/5183/pdf/sir2011-5183.pdf [↑](#endnote-ref-2)
3. http://www.epa.gov/climatechange/impacts-adaptation/greatplains.html [↑](#endnote-ref-3)
4. http://ca.water.usgs.gov/pubs/ScanlonEtAl.pdf [↑](#endnote-ref-4)
5. <http://pubs.usgs.gov/sir/2011/5183/pdf/sir2011-5183.pdf> [↑](#endnote-ref-5)
6. http://pubs.usgs.gov/sir/2011/5183/pdf/sir2011-5183.pdf [↑](#endnote-ref-6)
7. http://www.beg.utexas.edu/staffinfo/Scanlon\_pdf/Strassberg\_et\_al\_GRL\_07.pdf [↑](#endnote-ref-7)
8. <http://pubs.usgs.gov/ha/ha730/ch_d/D-text2.html> [↑](#endnote-ref-8)
9. http://deepblue.lib.umich.edu/bitstream/handle/2027.42/24926/0000353.pdf?sequence=1 [↑](#endnote-ref-9)
10. http://www.epa.gov/climatechange/impacts-adaptation/greatplains.html [↑](#endnote-ref-10)
11. http://www.epa.gov/climatechange/impacts-adaptation/greatplains.html [↑](#endnote-ref-11)
12. http://www.ext.colostate.edu/pubs/garden/04702.html [↑](#endnote-ref-12)
13. http://www.hpwd.com/aquifers/groundwater-management-area-2 [↑](#endnote-ref-13)
14. http://site.xavier.edu/Blairb/sustainable-agriculture-2/student-led-1---ogallala/little-ogalla-2009.pdf [↑](#endnote-ref-14)