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SUSTAINABLE USE OF THE WEST'S WATER

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Denver Basin Physical Characteristics

The Denver Basin, a regional geologic structure, is in east-central Colorado. The footprint of the basin is about 6,700 square miles in size and includes all or parts of Adams, Arapahoe, Douglas, Elbert, El Paso, Jefferson, Lincoln, Morgan, and Weld Counties. It is oval-shaped, extending approximately 120 miles in a north-south direction, and 70 miles in a east-west direction. The Denver metropolitan area is located on its western edge. The location of the basin and its general shape are shown in Figure 1a and 1b.

Denver Basin aquifers provide water supplies to private entities, industries, water districts, and other users that are located outside of the service areas of the major metropolitan areas. They also provide water supplies to users in an area where there is no readily available surface water supplies; in a large part of the Denver Basin area, there is no alternative water supply. As such, the Denver Basin has served and probably will continue to serve as an important source of water for the outlying regions in and around the Denver and Colorado Springs metropolitan areas.

There are four major ground water systems within the Denver Basin. They are in order of increasing depth beneath the land surface, the Dawson, Denver, Arapahoe, and Laramie-Fox Hills aquifers. The Dawson aquifer occurs at the land surface down to depths of 600 to 900 feet, depending on the location within the basin. The Laramie-Fox Hills aquifer, the deepest aquifer, is exposed at the edges of the basin and may be as deep as 2,500 to 3,000 feet near the basin axis. The Denver and Arapahoe aquifers lie between the Dawson and the Laramie-Fox Hills. Beginning in 1981[(1)], the U.S. Geological Survey began publishing a series of reports and

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[(1)]In 1981, the U.S. Geological Survey published four Hydrologic Atlases that describe the characteristics of the four aquifers. Additional reports were published later. These four Atlases are HA-643 (Dawson aquifer), HA-646 (Denver aquifer), HA-647 (Arapahoe aquifer) and HA-650 (Laramie-Fox Hills aquifer).

atlases that describe the characteristics of the four aquifers. In a 1987 report[2], the Survey concluded that there are 269 million acre-feet of recoverable ground water within the basin, distributed between the aquifers as shown in Table 1. This number has been more or less confirmed by other investigators. It is unlikely that all this water could be produced by wells.

The basin was first developed in the late 1800's, and development has continued through to the present. In the last 10 to 20 years or so, the rate of development has increased as more and more lands outside of the existing water service areas developed. In its 1987 report, the U.S. Geological Survey concluded that as of 1978, production from the Denver Basin system was 29,000 acre-feet of water per year. This production rate was not measured, instead the U.S. Geological Survey modelled the production level with a finite difference ground water model. Unfortunately, no information is available to describe the current level of use, but clearly, production from the basin has increased perhaps as much as two to four times from the 1978 level. As a result, production today from the basin could be as much as 100,000 acre-feet per year. Colorado currently allows development of the Denver Basin resource at the rate of one percent per year with an administrative life of the aquifers of 100 years. This means that potentially 2.69 million acre-feet of water per year could be produced, if the basin were developed with a "well on every square mile and in each aquifer" throughout the basin. Because production from the basin is estimated to be 100,000 acre-feet per year, presently, only about four percent of the basin potential is being realized. Considerably more work and study will be necessary to confirm this level of development, but it is obvious that much more water can be produced than currently is under Colorado law.

Unconfirmed reports by the Colorado State Engineer's Office suggest that 30 to 40 percent of the nondesignated Denver Basin ground water has been permitted and/or decreed. This means there is seven to 10 times as much water that is being produced today that can be produced simply by obtaining a well permit to construct the well, and then actually drilling the well and putting the water to use. As a result, the potential for immediate future development of the basin is significant. A large part of this permitted and/or decreed water may be dedicated to platted properties that have not yet been developed, but can be.

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[2]In 1987, the U.S. Geological Survey published a report, Professional Paper 1257, "Bedrock Aquifers in the Denver Basin, Colorado - A Quantitative Water Resource Appraisal" by Stanley Robson.

Denver Basin Status

The U.S. Geological Survey research of the Denver Basin has produced a wealth of information that describes the location and extent of the basin ground water resources. The survey reports describe the aquifer characteristics including tops and bottoms, transmissivity and storage, sand thickness and general water quality. In addition, they describe the results of an extensive computer modelling effort that resulted in estimates of current production (as of 1978) and rates of natural recharge and discharge. In the early 1980's, studies undertaken for the Systemwide Environmental Impact Statement (also known as the Two Forks study) relied on the model to study the capability of the Denver Basin system to meet future demands of the metropolitan area.

The survey model results suggest that long-term recharge to the Denver Basin is 55 cfs or about 40,000 acre-feet per year. In 1978, one could conclude that the Denver Basin, if pumping were distributed on a uniform regional basis, was not being mined and that production from the basin was less than recharge. However, by 1978, most withdrawals were concentrated in the western part of the basin extending generally from the Denver metropolitan area south to Colorado Springs, and it was likely that pumping at that time exceeded recharge to that part of the basin. If that is the case, the Denver Basin was being mined as early as 1978. Today, with Denver Basin withdrawals well in excess of 29,000 acre-feet per year and perhaps as much as 100,000 acre-feet per year, the Denver Basin definitely is being mined.

Mining a ground water resource such as that in the Denver Basin means continued withdrawal of ground water in excess of recharge. Because recharge to the Denver Basin aquifer is low and well discharge currently is high, mining of the aquifers has to occur; a necessary product of mining is lowered water levels. Throughout most of the basin water levels have declined and in places, water levels have dropped several hundred feet since records were kept. It is unlikely that development of the Denver Basin resource will increase significantly recharge to the Denver Basin aquifers. As a result, as pumping continues, water levels will continue to decline. The rate of decline will increase as new wells are brought on-line and additional water is produced.

Pumping ground water at rates in excess of recharge means there is a finite life to the resource. It is like having money in the bank, earning four percent interest annually, but withdrawing money at a rate of, say, 10 percent per year. It is obvious that within a period of time, the money supply will be exhausted. The length of time the supply will last is dependent on the size of the resource to begin with and the rate of withdrawal.

It is difficult to predict the probable life of the Denver Basin system. Water level declines in recent years have been significant, causing some to express concern regarding the adequacy of the ground water supply. However, most of the water pumped from the basin has been drawn from what is known as artesian storage or water stored under pressure within each aquifer. Water stored in the artesian part of the system is a small part of the total water in storage, usually less than one percent. As a result, when water is pumped from artesian storage, water level declines are significant. For the most part, basin development to date has not tapped into water actually in storage in the aquifer. With continued production, however, water levels will fall below the top of the aquifer and water will begin to be taken from actual aquifer storage. However, there are "hot spots" around the Denver Basin in which water stored in the artesian pressure part of the system may have been exhausted and some water already is being produced from aquifer storage.

It is unlikely that the Denver Basin system will ever be developed to 100 percent of its legal potential. Large cities that have not and will not develop Denver Basin ground water and prohibit the private development of the resource remove large tracts of land from potential development. Further, other public lands, right-of-ways, and private lands that are not and will not be developed also remove lands from future development. At the current estimated level of development of the Denver Basin, approximately four percent, a lot more water can be taken from the basin and probably will be.

Modelling of the Denver Basin

To examine the possible future life of the Denver Basin system, a parcel of land in the southern part of the Denver Basin was selected and the water available for development in each aquifer was calculated using current standards and techniques (Table 2). These water availability estimates were used as input into the Colorado State Engineer's computer model of the Denver Basin system; the model was adjusted slightly to include recharge and the artesian head. In addition, the model boundaries were changed from no-flow to head-dependent boundaries to allow lateral inflow into the model when wells within the model were operated. The computer model was then operated for 100 years with different percentages of regional development. The model was initially operated withdrawing the annual entitlements assuming there was no other pumping within the basin, and then regional pumping was increased to 25, 50, 75 and finally, 100 percent of the probable legal entitlement[3]. The results are shown in Figures 2 through 5 and indicate that even at the 100-year administrative life of the system, the actual life of the system is highly dependent on the level of regional development. At regional development levels of less than 100 percent, the model indicates the water supplies will last longer than 100 years, although with continued withdrawals and lowered water levels, many new wells will be required to maintain the current level of production. Pumping costs will also increase, probably causing some users of Denver Basin water to shift to other, adjacent supplies.

Impact of 300-Year Administrative Life of Denver Basin System

Recently, there has been some talk of legislatively increasing the administrative life of the Denver Basin system from the current 100-year standard to as much as 300 years. Presumably, the reasons for requesting this increase in administrative life are to slow down the development of the Denver Basin system and make the water supplies last longer. Increasing the administrative life of the system to 300 years would reduce the available water supply to less than one-third of the current developable supply. The impacts of this change would be to leave development in the hands of the large land holders and probably stop regional land development outside of existing water providers. Available water supplies will be reduced to less than one-third of the present amount because, in many cases, it will become very expensive to construct wells to produce a very small amount of water. As a result, the large part of the resource would probably not be developed.

Further, recall that the current level of development within the Denver Basin may be as much as 100,000 acre-feet of water per year. It is this production level that is causing the current water level declines, and this level of production will continue even if the administrative life of the aquifer is increased to 300 years. Further, as much as 30 to 40 percent of the Denver Basin ground water reportedly has been permitted and/or decreed and is simply waiting to be

[3]Because of complex stratigraphy and computer limitations, the State's model probably does not accurately reflect actual aquifer response to pumping wells. As a result, the model probably underpredicts the impacts of pumping wells.

developed. These permits and decrees may be associated with developments already on the books, but not under construction. Finally, when the word hits the street that the administrative life of the aquifer may increase to 300 years, there probably will be a rapid increase in Denver Basin filings in an effort to water rights based on 100-year life of the aquifers. Whether or not these new rights can be put to use before the law is changed is unknown.

Shown in Table 3 is a summary of the amount of water available beneath one square mile of land in the Castle Rock area. Well costs are included as are the costs per acre-foot to construct a well into the different aquifers. At the 100-year rate, it is economical to develop the resource; in fact, a large part of the Denver Basin is being developed at these costs. If the Denver Basin shifts to a 300-year administrative life, the cost triples and probably, except for extreme situations, would make constructing wells into the Laramie-Fox Hills and possibly others prohibitively expensive. This example illustrates how increasing the life of the Denver Basin system from 100 years to 300 years would reduce water supplies to less than one-third of the present amount.

A Possible Denver Basin Plan

Implementing a 300-year administrative life of the Denver Basin system would have a significant impact on the region's available water supplies and land development potential. Unfortunately, legislating a 300-year life of the system would not eliminate the current water level declines and it is likely that additional 100-year life water supplies would be brought on-line in the near future. In a way, the "horse is almost out of the barn" and increasing the life of the Denver Basin system from 100 years to 300 years probably would do little good for the current Denver Basin users. It's likely that the impacts of not having 100 year ground water available for development would be significant and probably exceed the impacts of continuing with 100-year ground water and pursuing alternative supplies.

One plan for the Denver Basin can be as follows:

1. Continue with an assumed 100-year administrative life.

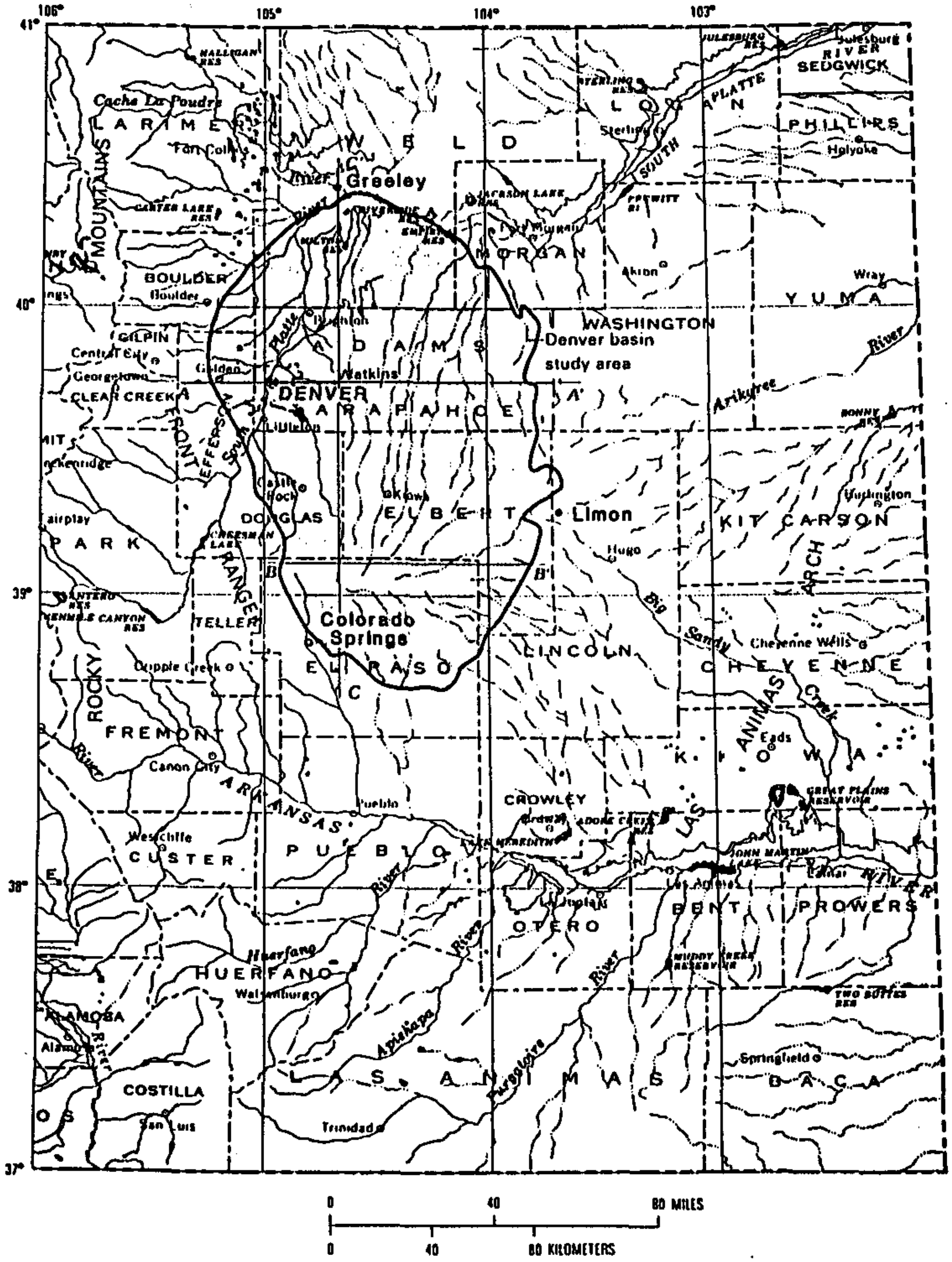
2. Recognize Denver Basin ground water as a long-term, but interim supply of ground water.

3. Start planning on a water supply alternative or alternatives. These new water supplies probably can not be made available to every Denver Basin user, but can be targeted towards centers of high Denver Basin use.

4. Encourage conjunctive use, also known as augmentation and/or recharge. Encourage construction of shallow alluvial wells and the use of Denver Basin ground water to replace consumptive use. Explore opportunities of recharge during wet years to offset Denver Basin depletions.

5. Require conservation and reuse. Every acre-foot conserved or reused means one less acre-foot pumped from the Denver Basin.

6. Understand that the solution to the Denver Basin question may be regional in nature and unlikely to be resolved by a single user.



LOCATION OF DENVER BASIN IN EASTERN COLORADO

FIGURE 1a

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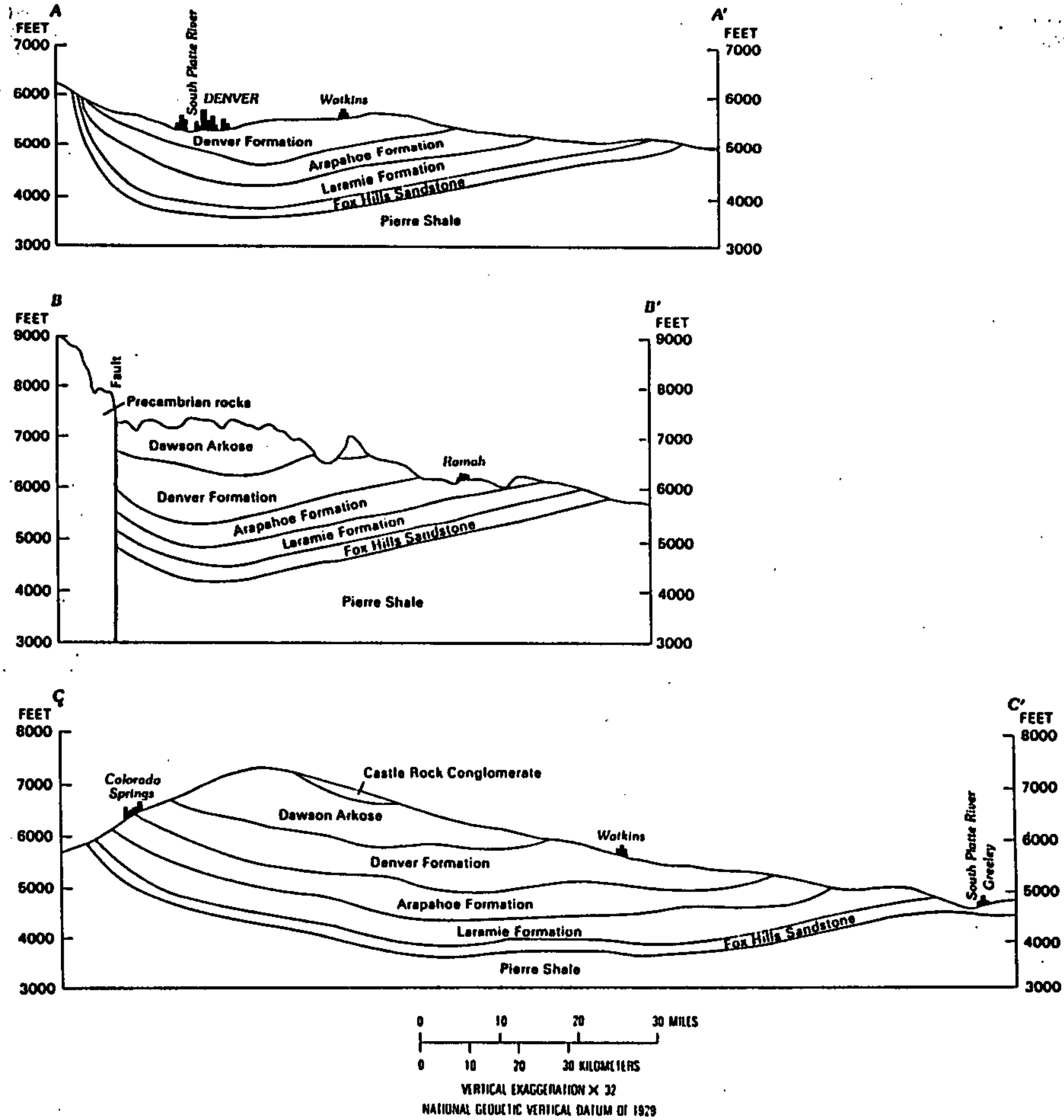

SOURCE: USGS PP1257

DENVER BASIN CROSS SECTIONS

FIGURE 1b

Bishop-Brogden Associates, Inc

TABLE 1

Recoverable Ground Water in the Denver Basin

Aquifer	Water Available
Dawson	27 MAF
Denver	42
Arapahoe	90
Laramie-Fox Hills	110
Total	269 MAF

Source: U.S. Geological Survey PP 1257.

MAF - million acre-feet

TABLE 2

Water Available Beneath a Parcel of Land,
Southern Denver Basin

Aquifer	Water Available
Dawson	160 af/yr
Denver	825
Arapahoe	831
Laramie-Fox Hills	287

TABLE 3

Water Available Beneath a Section of Land, Castle Rock Area

Aquifer	100-Year Life Supply	300-Year Life Supply
Upper Dawson	192 af/yr	64 af/yr
Lower Dawson	192	64
Denver	435	145
Arapahoe	283	94
Laramie-Fox Hills	168	56
	1,270 af/yr	423 af/yr

TABLE 4

Cost of Water Development, Castle Rock Area

Aquifer	Well Cost	100-Yr Life Cost/AF	300-Yr Life Cost/AF
Upper Dawson	$ 41,300	$ 270	650
Lower Dawson	76,500	400	1,200
Denver	209,000	480	1,450
Arapahoe	216,000	760	2,300
Laramie-Fox Hills	319,000	1,896	5,700

Figure 2.

Heads in the Dawson Aquifer

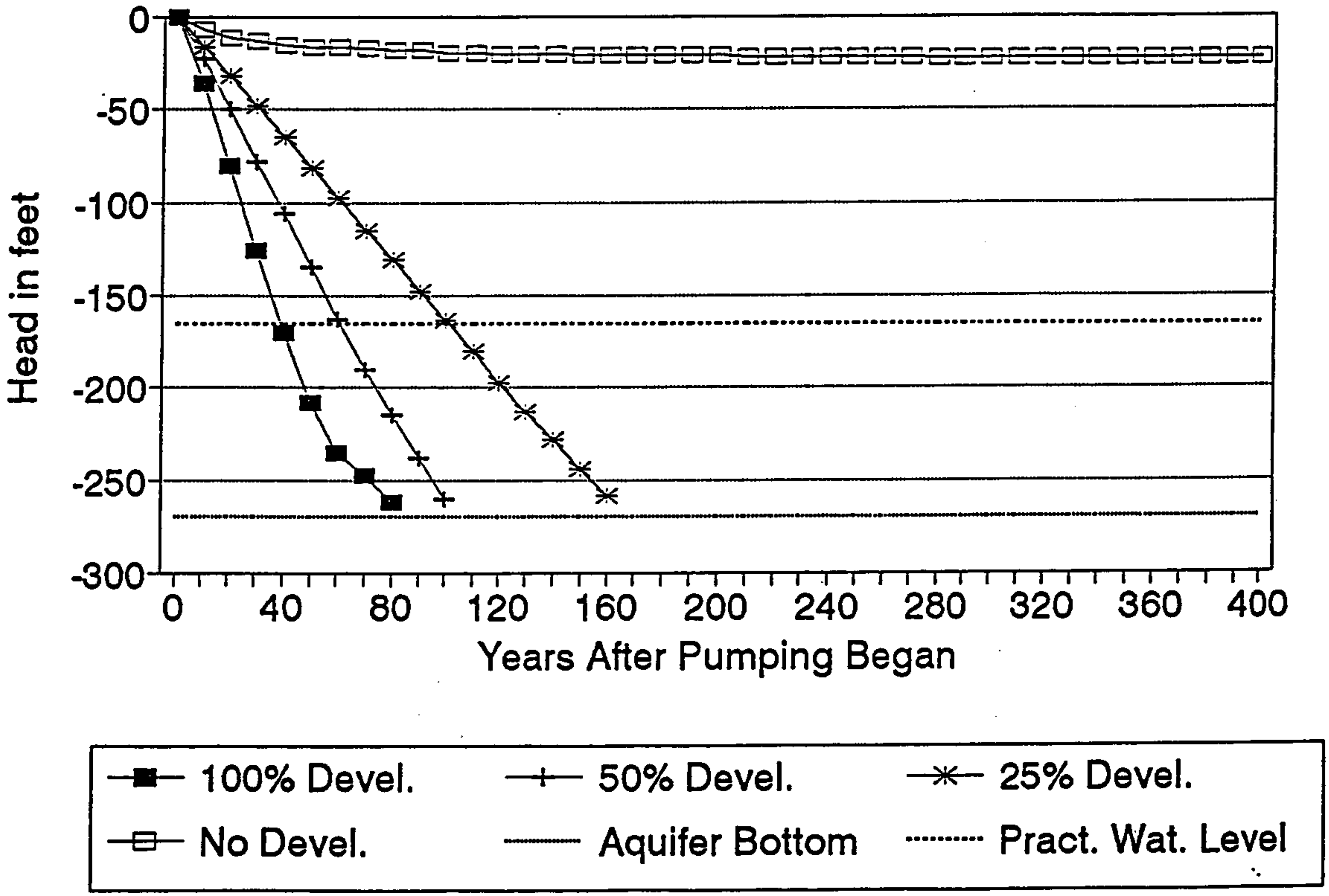

Figure 3.
Heads in the Denver Aquifer

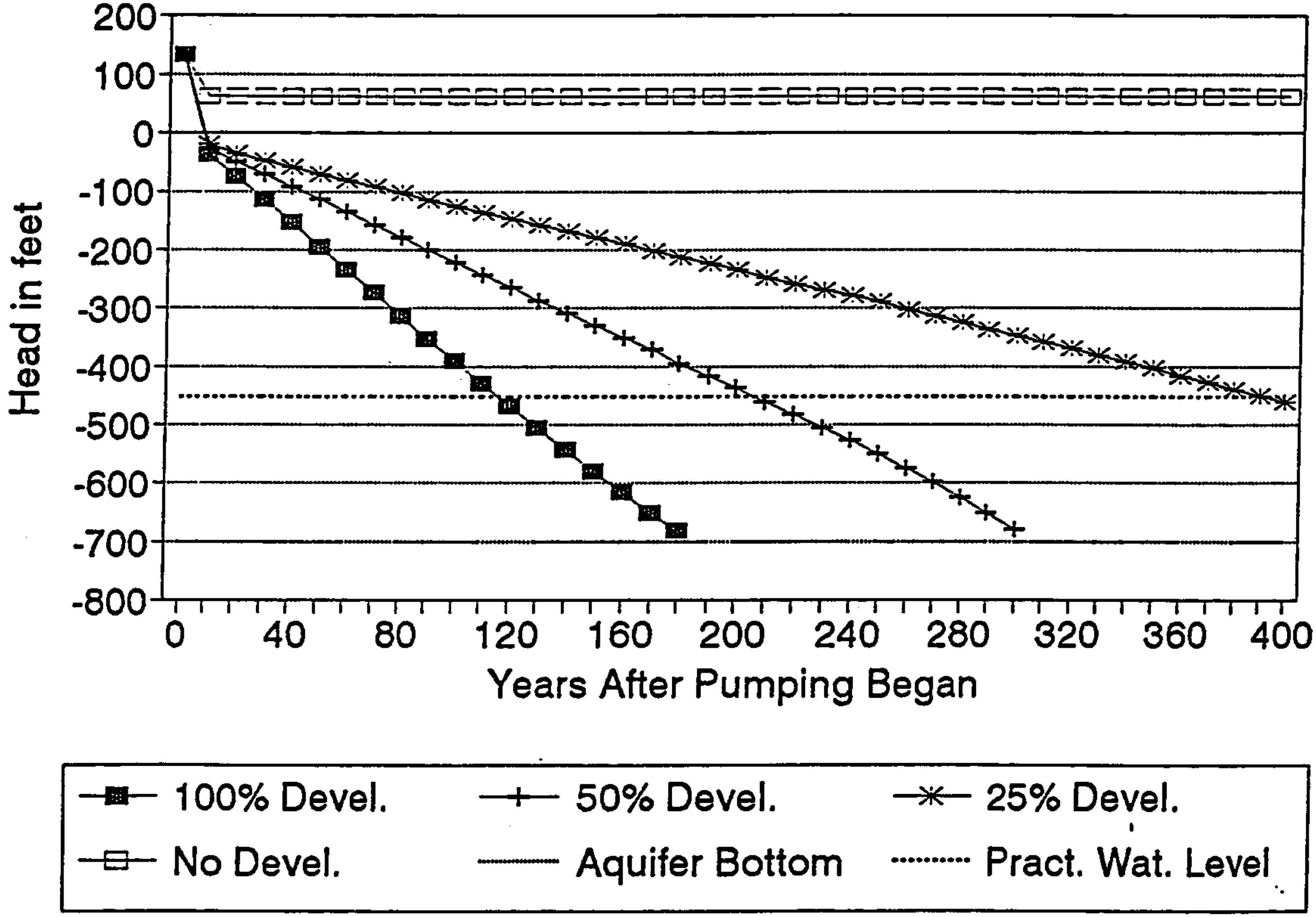

Figure 4.
Heads in the Arapahoe Aquifer

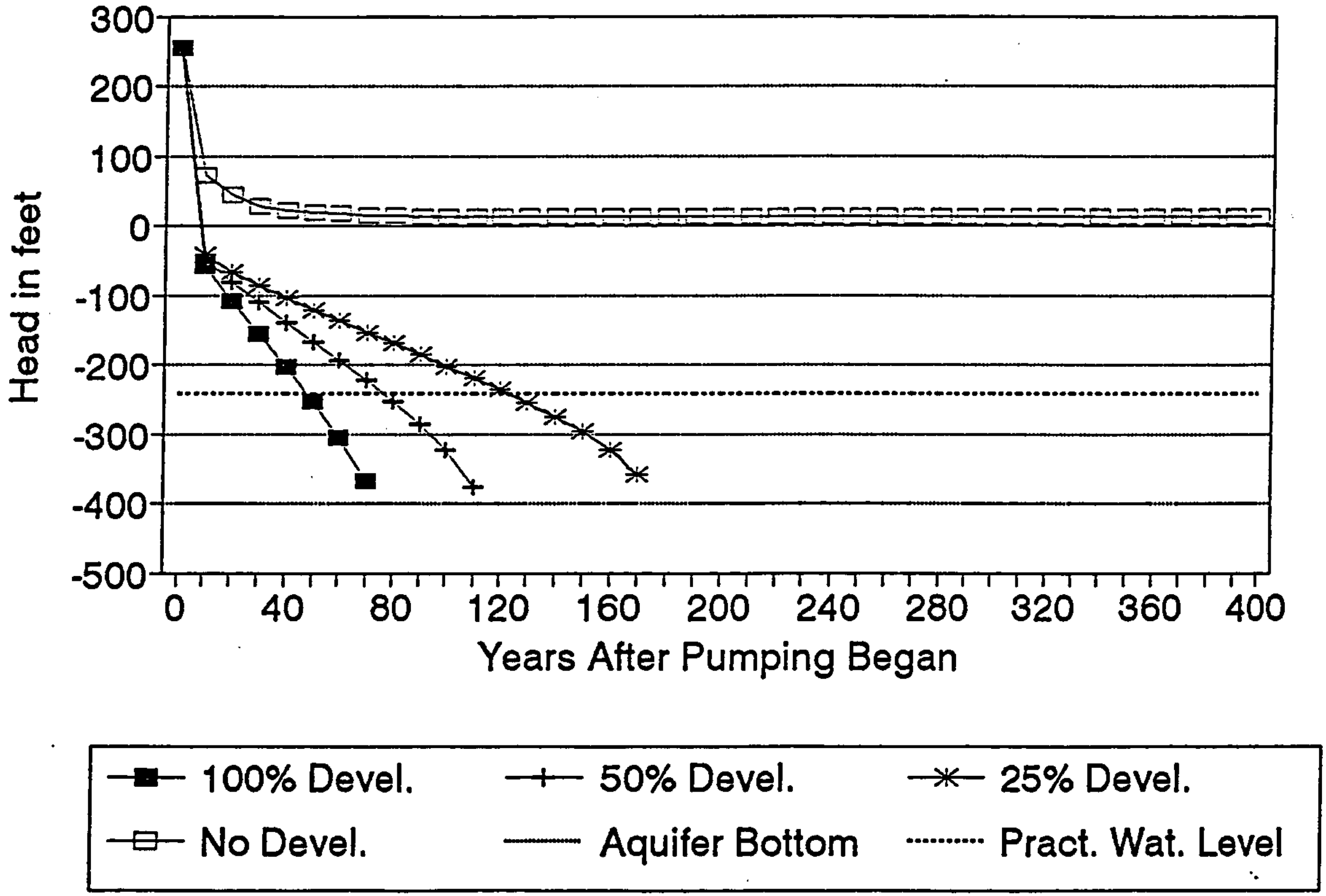

Figure 5

Heads in the Laramie-Fox Hills Aquifer