State of North Dakota
Office of the State Engineer

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Considerations when appropriating water use from the Fox Hills aquifer

Fox Hills aquifer

The Fox Hills-Hell Creek (Fox Hills) aquifer is a shoreline sand depositional feature with lateral (and hydrologic) continuity extending throughout western North Dakota and into Montana, South Dakota, and Wyoming. Recharge to the aquifer occurs over the topographically higher landscape to the southwest, giving the aquifer a flowing pressure head in low-lying areas in west-central North Dakota where the aquifer commonly occurs between 1,000 and 2,000 feet below land surface. Use and leakage of water from the Fox Hills aquifer is causing the pressure head to decline at between about one and three feet per year in flowing-head areas, Figure 1.

Flowing-head wells

More than 500 flowing-head Fox Hills wells have been identified in western North Dakota and eastern Montana. Flowing-head wells allow ranchers to water livestock in remote pastures without the need for an electrical power supply for pumps and tank water heaters. Flowing-head Fox Hills wells were primarily installed in western North Dakota in the second half of the 20th century, mostly as stock wells. More than three-fourths of the flowing head Fox Hills wells are completed using casing two-inches or less in diameter, too small for practical installation of a submersible pump. Most ongoing water extraction from the Fox Hills aquifer in western North Dakota is from flowing-head wells.

The reason for restricting access to the Fox Hills aquifer for large-scale water use is to avoid increasing the rate of aquifer pressure head decline caused by extraction of water from the aquifer. Increasing the rate of pressure head decline shortens the time flowing-head wells will continue to flow. Because of the small diameter construction of most flowing-head Fox Hills wells, once the pressure head declines below land surface the wells will no longer be useable as a

water source. While not a water right, the flowing pressure head of Fox Hills wells in low-lying areas of western North Dakota is recognized as a valuable asset to many area ranchers.

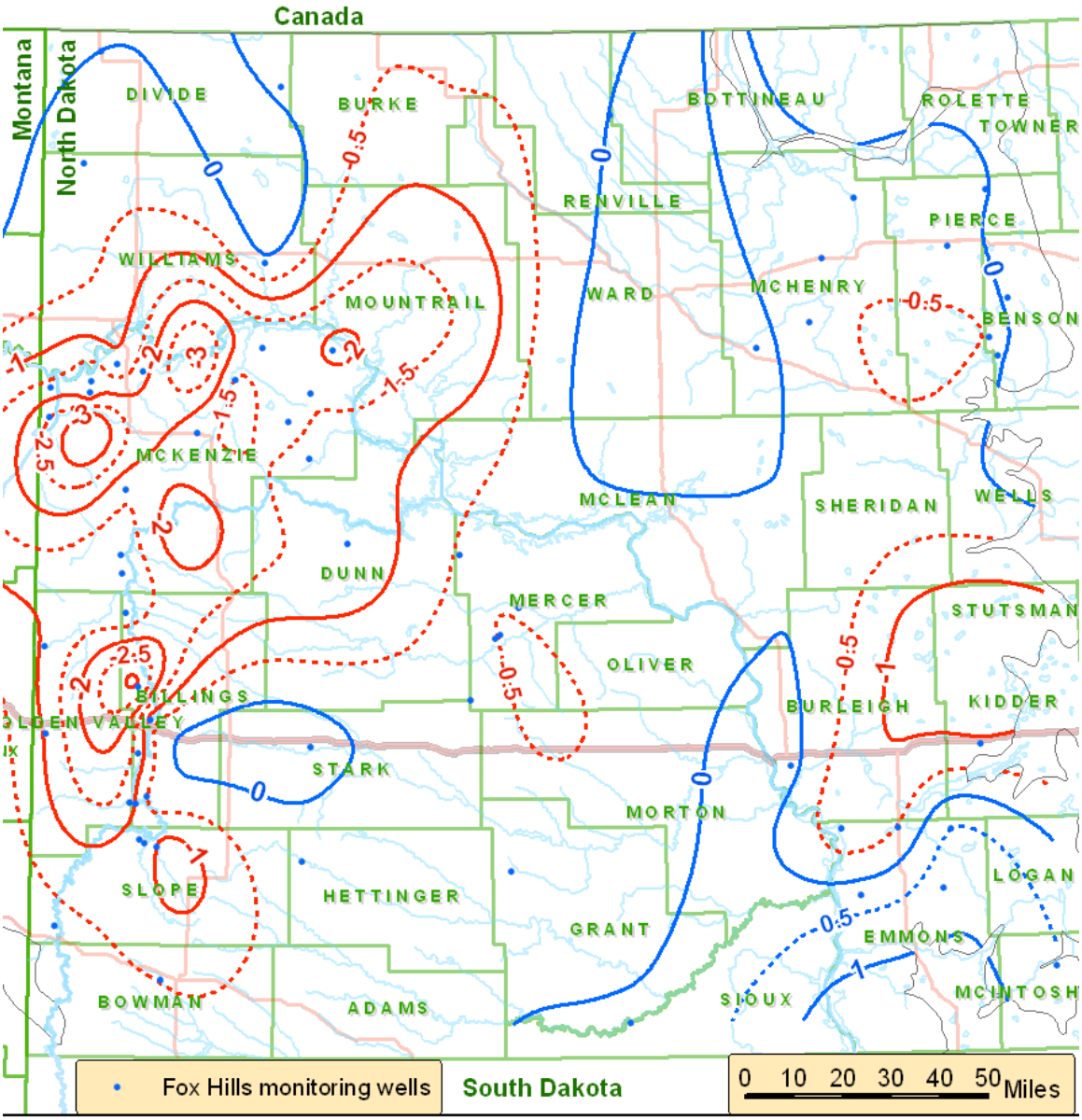

Figure 1. Annual pressure head rate of change in the Fox Hills-Hell Creek aquifer in feet per year, as measured over recent years (Wanek 2009).

Restrictions on the use of Fox Hills' water

Considerations when appropriating industrial water use from the Fox Hills aquifer was the subject of an April 5, 1984 office memo from the director of the Hydrology Division to the State

Engineer. A balanced approach of allocating water between the major users was advocated in the memo.

Since that time oil companies seeking water for dilution of brine produced with oil have been directed to install their wells in sediments overlying the Fox Hills aquifer. Water for oil field waterflooding programs have been directed to deep, non-potable water sources. Ethanol and rural water supply projects in western North Dakota were directed to use Lake Sakakawea water rather than Fox Hills water.

In addition to the availability of alternative sources, the distance to nearby flowing-head Fox Hills wells and the quantity of water requested are taken into consideration when reviewing applications where the expected water source is the Fox Hills aquifer. An extensive Fox Hills modeling effort was undertaken to better assess hydraulic properties of the Fox Hills aquifer and to predict pressure head changes with greater confidence (Fischer 2013).

Restricting permitted water use from the Fox Hills aquifer has been primarily for industrial use. An application to supply water for temporary housing using the Fox Hills aquifer may be reviewed in a more favorable light than an application to sell water for industrial use. However, away from recharge areas the quality of water in the Fox Hills aquifer makes it unattractive as a water source for human consumption.

Policy statement

It is the policy of the Office of the State Engineer, in order to preserve a flowing pressure head in low-lying areas, to restrict industrial access to the Fox Hills-Hell Creek aquifer where other suitable sources are available. The restriction is not a moratorium on future Fox Hills water use, but takes into consideration the quantity of water needed and the proximity of flowing-head wells to the proposed water use.

References

Fischer, Kimberly (2013). *Groundwater Flow Model Inversion to Assess Water Availability in the Fox Hills-Hell Creek Aquifer* (ND Water Resource Investigation No. 54. Bismarck, ND: North Dakota State Water commission. Retrieved from swc.nd.gov/4dlink9/4dcgi/GetContentPDF/PB-2246/WRI%2054.pdf

Wanek, Alan (2009). *Recommended Decision for the City of Alexander Water Permit Application No. 5990*. Office of the State Engineer, North Dakota State Water Commission, Bismarck, ND. Retrieved from Fischer (2013), above, as Appendix D, Page 131.

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Addendum

GARLAND ERBELE
SECRETARY AND STATE ENGINEER

NORTH DAKOTA STATE WATER COMMISSION
OFFICE MEMO

TO Vern Fahy, State Engineer
FROM Milton O Lindvig, Director, Hydrology Division
SUBJECT Considerations in Appropriating Water for Industry from the Hell Creek-Fox Hills Aquifer System - SWC #1400
DATE April 5, 1984

During the past two to three years oil companies operating in northeast McKenzie County have made increasing demands on the ground-water resources of the area The water is used to dissolve salt accumulations in the production tubing of oil wells The introduction of fresh water into the casing annulus, as oil and formation water are produced, reduces down time required for well maintenance as well as overall operational costs The result is more oil produced per unit of time, as well as extending the economic life of the well

The amount of fresh water required for each well varies with the character of the formation fluid and the amount produced Typically, the operating companies have been requesting about 3 to 10 acre-feet of water annually for each oil well Annual use reports indicate that actual use is somewhat less than the amount requested on a per well basis However, as the production from the oil well matures the amount of fresh water required may increase The producing life of the wells is estimated to be 5 to 20 years with most of the wells lasting 15 to 20 years

The following table summarizes the amount of water requested by

and/or appropriated to oil companies operating in northeast McKenzie County

Permit No	Company	Amount Request (acre-feet)	Amount Appropriated (acre-feet)	Amount in Abeyance (acre-feet)	Aquifer	Remarks
1550	Texaco	-	98 4	-	Fox Hills	To be cancelled
1769	Texaco		470	-	Fox Hills	To be reduced to 85 6 acre-feet
3183	Texaco	29	29	-	Tertiary	
3211	Texaco	22 6	22 6	-	Tertiary	
3523	Texaco	27 5	27 5	-	Tertiary	
3524	Texaco	9 7	9 7	-	Tertiary	
3566	R Olson	40	40	-	Tertiary	
3587	Texaco	188	98	90	Fox Hills	
3601	Texaco	24 2	24 2	-	Tertiary	
3608	Universal Resources	19 4	19 4	-	Fox Hills	
3610	Amerada-Hess	3 3	3 3	-	Tertiary	
3611	Texaco	24 2	24 2	-	Tertiary	
3623	Texaco	24 2	24 2	-	Tertiary	
3624	Texaco	24 2	24 2	-	Tertiary	
3631	Getty Oil Co	5 2	5 2	-	Tertiary	
3638	Texaco	24 2	24 2	-	Tertiary	
3653	Universal Resources	96 8	35	61 8	Tertiary	May request Fox Hills
3660	Amerada-Hess	6 4	6 4	-	Tertiary	
3661	Amerada-Hess	10	10	-	Tertiary	
3671	Amerada-Hess	11 7	11 7	-	Tertiary	
3672	Texaco	80 6	Under consideration			Requesting Fox Hills

To date 321 4 acre-feet of water has been appropriated from Tertiary aquifers and 203 acre-feet from the lower Hell Creek-Fox Hills aquifer system

The Tertiary aquifers are comprised of sandstone which is quite lenticular and discontinuous The occurrences of these aquifers is difficult to predict except over small distances Because of their lenticular nature the well yields are quite small and variable From existing data it appears that long term yields from individual wells completed in these aquifers seldom exceed 10 gpm In northeast McKenzie

County the Tertiary aquifers occur to depths of about 1200 feet

The lower Hell Creek-Fox Hills aquifer system is the most predictable and productive underlying the area It occurs at depths ranging from 1300 to 1700 feet Long term well yields of 50 to 100 gpm can usually be obtained, which makes it an attractive source of water for the oil companies The static water level is usually 100 to 200 feet below land surface

In the lower lying areas such as the Missouri River Valley, Tobacco Garden Creek Valley, and Little Missouri Valley many ranchers have flowing wells completed in the lower Hell Creek-Fox Hills aquifer Known pressure heads above land surface range from 35 to more than 200 feet The lower pressure heads occur in the northern part of the area These flowing wells are extremely important to the ranchers in that electric power lines do not have to be built into remote areas to service pumping equipment Also, in the winter feeding areas no heaters are needed in the water tanks

During the hearings on water permit applications by the oil companies, the ranchers have expressed concern that pumping from the lower Hell Creek-Fox Hills aquifer could result in a pressure decline in their wells They also emphasized the need for conserving the pressure head The grazing associations and the McKenzie County Water Resources District have also expressed similar concerns In response to these concerns the State Engineer has carefully controlled access to the aquifer

When analyzing the individual applications a general policy has been established of requiring the water appropriated to be pumped from

the Tertiary aquifers Usually, this resulted in a water well at each oil well site However, at certain sites a sufficient thickness of aquifer was not encountered in which to complete a minimum capacity water well Such was the case for Texaco water permit 3587 Attempts to complete a well in the Tertiary aquifers were not successful, thus a request was made to complete a water well in the lower Hell Creek-Fox Hills aquifer This request was approved for 98 acre-feet of water annually, with 90 acre-feet continuing to be held in abeyance pending the collection of additional water level and water use data

Conditional water permit 3587 held by Texaco, Inc has certain conditions which allows the State Engineer to modify the appropriation in the future One condition required that Texaco, Inc construct an observation well into the lower Hell Creek-Fox Hills aquifer for the purpose of water level monitoring The location and construction were approved by the State Engineer A second condition states

> "If the water level elevation in the observation well declines an amount which may result in adverse impacts on senior appropriators, the State Engineer may reduce or terminate the appropriation made under this permit "

Texaco began using water under permit 3587 in August 1983 to serve oil wells in the Blue Buttes field The water is conveyed to the individual wells by pipeline It is projected that the appropriation of 90 acre-feet of water annually over a period of 20 years will cause 5 to 10 feet of pressure decline in the flowing well areas As new oil wells are completed and the need for fresh water increases, Texaco, Inc will probably be requesting a decision on the water being held in abeyance

The demand for fresh water in this area will continue to increase as new oil wells are completed Other water permit applications will be filed and in some instances existing permit holders not now authorized to tap the Hell Creek-Fox Hills aquifer will request permission to do so The latter will occur because an adequate water supply cannot be developed from the Tertiary aquifers

Existing records indicate that the pressure head in the Hell Creek-Fox Hills aquifer system is declining at a rate of 1 5 to 2 feet per year This decline is resulting primarily from the flowing wells owned by the farmers and ranchers Appropriations of water from this aquifer for industrial purposes will cause an accelerated rate of pressure decline in the flowing well areas Therefore, the water needs of industry are in conflict with the farmers' and ranchers' need to conserve the aquifer pressure head There is a need to develop a policy which will balance these needs To accomplish this balancing process a basis must be developed for considering future water permit applications by industry and to identify conservation practices that may be implemented by owners of flowing wells

In developing an approach to appropriating water from the Hell Creek-Fox Hills aquifer certain physical factors must be recognized

1) Pressure head decline is occurring and will continue to occur, and the rate of decline will increase as the amount of water withdrawn increases
2) For all practical purposes the pressure is a one-time resource and once used recovery of the pressure will take decades or perhaps centuries

3) Even though recharge to the aquifer is negligible there is sufficient water stored in the aquifer to serve present and identifiable future needs of the area However, with time some appropriators will need to make an added effort to capture their water and for some appropriators, the economic impact of the "added effort" may preclude further utilization of some of the well locations

In light of the above factors the real issue is one of determining an acceptable rate of pressure decline while achieving maximum benefits This can be approached in two ways First, the utilization of the resource could be based on the highest use and economic benefit The agricultural industry is a continuing one and has a relatively long history of utilizing water from the Hell Creek-Fox Hills aquifer system It can be assumed that agriculture will be a viable industry in the area long after the oil is depleted Under present economic conditions it would be difficult to assign a high economic value to a unit quantity of water for these purposes

The oil industry will require given quantities of fresh water for a specific period of time Because of the relatively high economic value of the oil, a relatively high value could be assigned to a unit quantity of water for a shorter period of time This can also be considered in another way in that the alternatives of not using fresh water or hauling it to the well sites are very expensive in relation to developing a local ground-water supply

In direct comparison there is a significant and fundamental difference in assigning a value to a unit of water used by agriculture versus that used by industry The value of water for agriculture will be relatively small while being utilized over a very long period of time However, with industry the value of water will be relatively high while being used over a much shorter period of time Considering that conservation of aquifer pressure is the primary purpose of this exercise, it will be difficult to determine values for the various economic benefits, because the effects of the pressure decline will vary widely between water users In most instances the negative impacts of the pressure decline in the flowing well areas will be 10 or more years into the future, which may hold a significantly different set of economic values for water Therefore, it appears that applying economic criteria as an approach to achieving a balance between agricultural and industrial use of water is quite impractical

A second approach to allocating the resource could be based on some reasonable or acceptable rate of decline in the flowing well area The rate or amount of total estimated decline could be divided between the competing uses and the water allocations to the oil industry made on that basis

The following illustrates how this approach could be applied It is determined that an acceptable average rate of pressure decline is 4 feet per year The current rate of decline is 1 5 to 2 feet per year, which leaves 2 to 2 5 feet of annual rate on which additional

appropriations could be based The annual rate of decline would be based on the average of a 20 year projection Applications for industrial water that would cause the average annual rate of decline to exceed 4 feet per year would not be approved

It is my opinion that the latter approach represents the most practical and conservative alternative Water levels will be monitored to determine the actual decline and conditions can be attached to the permits that will allow for future adjustments A conservative aspect will be incorporated based on the premise that the decline projections will be calculated on the total annual appropriation being used each year of the 20 year period However, in actual practice several years may elapse before the total annual appropriation is utilized

The selection of an acceptable or reasonable rate of decline becomes, for the most part, a judgement call However, it seems that the emphasis should be placed on preserving the flow from the largest number of wells for a reasonable period of time If the average rate of decline is held to three feet per year most of the wells will continue to flow for at least 20 to 30 years By further restricting the flow from the stock wells, the pressure head will continue above land surface for a longer period

Water level records show that water levels in the Hell Creek-Fox Hills aquifer system are declining at a rate of 1 5 to 2 feet per year A limit of 3 feet of decline per year will allow industry to appropriate a quantity of water that will cause 1 to 1 5 feet of annual decline

Selection of a larger acceptable rate would mean that more ranchers would be affected sooner, and that may not allow adequate time to make the necessary changes in their operation to cope with reduced pressures Even though the determination of this rate may seem somewhat arbitrary it does protect the senior appropriators and the public interest It will also provide a basis for restricting access to the Hell Creek-Fox Hills aquifer and requiring applicants for industrial water to seek alternative sources

Based on the foregoing the following actions are recommended

1) Cancel Texaco, Inc water permit 1550 in the amount of 98 4 acre-feet This permit is unused and allows the utilization of the Hell Creek-Fox Hills aquifer

2) Continue Texaco, Inc water permit 1769 for an annual appropriation of 85 6 acre-feet of water from the Hell Creek-Fox Hills aquifer to serve 9 oil wells Cancel the remaining 384 4 acre-feet

3) Continue to hold 90 acre-feet of water in abeyance under Texaco, Inc water permit 3587 It must be recognized that this may eventually be granted The appropriation of 98 acre-feet is from the Hell Creek-Fox Hills aquifer

4) Continue to hold 61 8 acre-feet of water in abeyance under Universal Resources permit 3653 Thirty-five acre-feet are currently appropriated under this permit, however access to

the Hell Creek-Fox Hills aquifer is restricted Universal Resources may request a waiver of this restriction because an adequate supply cannot be developed from the shallower Tertiary aquifers

5) Evaluate the long term impact of approving Texaco, Inc water permit application 3672 for 80 6 acre-feet of water annually from the Hell Creek-Fox Hills aquifer

6) Require all industrial water permit applicants in northeast McKenzie County to develop their water supplies from the shallower Tertiary aquifers, and approve access to the Hell Creek-Fox Hills aquifer only when the shallower aquifers prove inadequate

7) Continue to monitor water levels in observation wells completed in the Tertiary aquifers as well as the Hell Creek-Fox Hills aquifer Frequency of measurements will be determined by the staff of the State Engineer, however they will probably range from monthly to quarterly

8) Construct additional observation wells on an as needed basis to monitor water level changes due to development Industry may be required to construct some of these wells

9) Work with the owners of flowing wells to better manage and reduce the discharge from them in an effort to reduce the rate of pressure head decline

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