In the Matter of the Order Initiating)
Proceedings to Amend the Designation) Case No. 06 WATER 4000
of the Intensive Groundwater Use Control)
Area in the Pawnee Valley)

BIG BEND GROUNDWATER MANAGEMENT DISTRICT #5
HYDROGEOLOGY STATEMENT ON HEARING ISSUES
FOR PAWNEE INTENSIVE GROUNDWATER USE CONTROL AREA DESIGNATION

In response to a request by Big Bend Groundwater Management District #5 (GMD#5) for independent information, evaluations and opinions on the subject hearing issues, the District's consulting hydrogeologist W. Peter Balleau (geologist, License No. 686) has prepared this statement based on data, publications, field inspection and interviews with water users and GMD#5 staff and officials. The statement is based upon the accompanying report "Pawnee River Basin Water Accounting for Big Bend GMD #5 Water-Management Planning," and addresses selected factual aspects of the Hearing Officer's Issues 1.a – 1.s. and 2. of December 22, 2006. Issue 1 is "*For each aquifer (alluvium, Ogallala, and Dakota) within the proposed IGUCA area, the following questions should be addressed*:" and Issue 2 is on "…*what should the boundaries be*". It is understood that the Existing Intensive Groundwater Use Control Area (IGUCA) is in GMD#5 in Pawnee County, the Area in Consideration for amendment is in parts of Hodgeman and Ness Counties as described in a June 19, 2006 order of the Chief Engineer. The entire 2700-square mile Pawnee River drainage basin is hydrologically pertinent to Issue 2.

Issues 1.a. and 1.b. Are groundwater levels in the area declining, or have they declined? If so, what is the aerial extent, magnitude and rate at which groundwater levels have declined and over what period of time?

In the alluvium of the Combined IGUCA areas in consideration, groundwater levels are not declining over time. They have declined during earlier decades of growing well development before the IGUCA was designated in 1981. After the period of growth in well withdrawal, groundwater levels decline and rise with similar frequency and magnitude, but do not display an overall declining trend.

The history of groundwater level decline and recovery is well documented in the Pawnee River alluvium, Ogallala and Dakota aquifers throughout the 2700 square-mile basin in terms of areal extent, magnitude, rate and timing. Records at 215 sites are charted in GMD#5 Exhibits 2 and 3.

In the alluvium of the Existing IGUCA Designation inside GMD#5 and the Area in Consideration combined, water levels declined overall an average 16.5 feet from 1947 to end of year 1981. Thereafter, water-level trends display symmetrical rise and decline. After 1981, water levels oscillated with several feet of rise in the late 1980's to a net 4.6 feet decline at the end of year 1992 (since 1947 a cumulative 21 feet). After 1992, water levels built up about ten feet through 1997. By the end of 2004, water levels were 3.1 feet lower than 1981, but were an average 1.5 feet above the 1992 lowest level (cumulative 19.6 feet below 1947). Various reaches of alluvium display the range of 10 to 30 feet of historic water level decline to make up the average of 19.6 feet.

In terms of the observed frequency of annual fluctuations, the Existing IGUCA and the Area in Consideration perform similarly. Annual water-level fluctuations for the 24 years from 1981 through 2004 display a balance with 80 percent of records ranging symmetrically between 2.8 feet of build-up and 2.8 feet of decline per year.

The Ogallala water level has declined throughout the Ogallala outcrop of the Pawnee drainage basin, except for wells influenced by a shallow water table near the edge of the formation generally near the southwest side of the Area in Consideration.

Dakota and undifferentiated Cretaceous wells have generally held steady or built-up water levels in the period of record since 1970.

Issues 1.c. and 1.d. What does the statutory phrase "declined excessively" used in K.S.A. 82a-1036 mean in this proposed IGUCA area? Are groundwater levels in the area declining or have they "declined excessively?

The term "*declined excessively*" has no established hydrological definition in standard glossaries.

The term is used in water planning in its conventional sense to mean declines that reasonably exceed objectives for the hydrologic system. The GMD#5 has defined a sustainable yield objective (K.A.R. 5-25-1 (l))[1] "*allowing for reasonable raising and lowering of the water table*," which is consistent with the observed trends in Pawnee alluvium. Kansas statutes make a similar provision statewide (82a-711a).[2] Historic water-level declines in the Pawnee alluvium are not excessive in terms of the sustainable yield objective.

Issue 1.e. Is there a water level below which existing water rights cannot be physically satisfied in terms of either rate or quantity? If so, what is that water level and what was the basis for determining what it is?

There is no single alluvial water level depth, elevation or percentage of original thickness that comprehensively addresses the differences in the Area in Consideration and that represents a unique threshold for physically satisfying existing water requirements. A different minimum water level is required by each well construction.

The water level below which water cannot be produced from wells in authorized quantities is determined from the required water column remaining in the well. The water column is

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[1] Kansas Administrative Regulation 5-25-1 "Sustainable Yield" means the long-term yield of the source of supply, including hydraulically connected surface water or groundwater, allowing for the reasonable raising and lowering of the water table.

[2] Kansas Statute 82a-711a Chapter 82a.--WATERS AND WATERCOURSES Article 7.--APPROPRIATION OF WATER FOR BENEFICIAL USE 82a-711a. Same; express conditions of appropriations. It shall be an express condition of each appropriation of surface or ground water that the right of the appropriator shall relate to a specific quantity of water and that such right must <u>allow for a reasonable raising or lowering of the static water level and for the reasonable increase or decrease of the streamflow</u> at the appropriator's point of diversion: *Provided,* That in determining such reasonable raising or lowering of the static water level in a particular area, the chief engineer shall consider the economics of diverting or pumping water for the water uses involved; and nothing herein shall be construed to prevent the granting of permits to applicants later in time on the ground that the diversions under such proposed later appropriations may cause the water level to be raised or lowered at the point of diversion of a prior appropriator, so long as the rights of holders of existing water rights can be satisfied under such express conditions. History: L. 1957, ch. 539, § 17; June 29.

the difference between non-pumping (static) water level and the bottom of the well. Lowering of the non-pumping water level is the item of IGUCA concern. An allowance for self-induced drawdown based on specific capacity, the space for setting submersible pumps, and appropriate positive suction head is required for production at the authorized rate and volume to satisfy water rights. A properly-constructed well also provides a safety-factor for drought and regional trends of water level (Moore and others, 1995[3]; Heath, 1983[4]; and Walton 1962[5]).

The reported specific capacity for Pawnee Valley alluvial wells ranges from 6 to 66 gallons per minute per foot (gpm/ft) (Sophocleous 1980)[6]. The average specific capacity of the Ogallala where inventoried in northwest Kansas (Hecox, Macfarlane and Wilson, 2002, Table 3)[7] is 24 gpm/ft with a similar range (6.0 to 87 gpm/ft). They say (p.4) that a saturated thickness "*threshold of 30 feet has been assumed by state agencies and local users to represent an approximate value needed to support large volume water demands,*" then advise (p.17) that 40 to 50 feet may be a better number. They consider 400 gpm and 1,000 gpm to represent a low-flow and high-flow rate irrigation well. Two tests of Dakota wells in Ford and Hodgeman Counties had specific capacities of 6 to 22 gpm/ft (Lobmeyer and Weakly, 1979)[8].

Considering 400 gpm to represent a low-flow for irrigation service and assuming 20 gpm/ft to be a characteristic specific capacity for all three aquifers, and adding a ten-foot buffer for

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[3] Moore, J.E., Zaporezec, A. and Mercer, J.W., 1995, Groundwater A Primer: American Geophysical Institute AGI Environmental Awareness Series: 1. "The pump should be deep enough so that the water level does not go below the pump intake. The depth should also be sufficient to allow for drawdown caused by pumping and for natural declines in water level during periods of drought."

[4] Heath, R.C., 1983, Basic Ground-Water Hydrology: U.S. Geological Survey Water-Supply Paper 2220, p. 59. In predicting the long-term yield of a well, it is also necessary to consider changes in the static water level resulting from seasonal and long-term variations in recharge and declines due to other withdrawals from the aquifer…Records of water-level fluctuations in long-term observation wells in the area will be useful in this effort.

[5] Walton, W.C., 1962, Selected Analytical Methods for Well and Aquifer Evaluation: Bulletin 49, p. 66. The drawdown s in a production well has all or some of the following components, depending upon geohydrologic and well conditions: the drawdown s_a (aquifer loss) due to laminar flow of water through the aquifer towards the well; plus the drawdown s_w (well loss) due to the turbulent flow of water through the screen or well face and inside the casing to the pump intake; plus the drawdown s_p due to the partial penetration of the pumped well; plus the drawdown s_d due to dewatering a portion of an aquifer; plus the drawdown s_b due to barrier boundaries of the aquifer; minus the buildup s_r due to recharge boundaries of the aquifer. Stated as an equation: $s = s_a + s_w + s_p + s_d + s_b - s_r$.

[6] Sophocleous, M., 1980, Hydrogeologic Investigations in the Pawnee Valley, Kansas: Kansas Geological Survey Open-File Report 80-6.

[7] Hecox, G.R., Macfarlane, P.A., Wilson, B.B., 2002, Calculation of Yield for High Plains Aquifer Wells: Relationship Between Saturated Thickness and Well Yield: Kansas Geological Survey Open File Report 2002-25C, Table 3.

[8] Lobmeyer, D.H. and Weakly, E.C., 1979, Water in the Dakota Formation, Hodgeman and Northern Ford Counties, Southwestern Kansas.

suction and pump setting, then (400 gpm/20 gpm/ft) + 10 ft = 30 ft is a nominal expectation for the minimum water column to provide producible water from wells in authorized irrigation quantities. This number is a serviceable guideline for the aquifer but it cannot apply strictly to each individual well. A safety factor on the 30 feet of water column must be provided to accommodate reasonable raising and lowering. Some operators reportedly combine lower-yield supplemental wells in one irrigation pivot, thus irrigation service might be maintained at lesser specific capacities or water columns from multiple wells each producing under 400 gpm.

Data on 352 alluvial well water columns selected for review in GMD#5 Exhibit 2 illustrate that 37 of the352 wells were constructed in Pawnee alluvium with less than 30 feet of water column. Those wells have a reasonable expectation of weak service-life. The 1992 average water level was 21 feet below 1947. If 1992 levels are assumed to be 21 feet below as-built water levels, then 71 wells under 1992 conditions were added to the problematic category for characteristic well capacities. Thus 244 or 69 percent of the wells reviewed in Pawnee Valley alluvium would be expected to retain their capacity to produce authorized quantities throughout history and 31 percent are expected to have an as-built or a transient problem.

A conceptual surface 30 feet above the aquifer bottom plus the safety factor might represent a characteristic level for physical satisfaction of water rights. The well data shows under historic declines that existing shallow wells constructed with less than 50 feet of water column are sensitive to losing the nominal threshold of 30 feet at the rate of two to three alluvial wells per foot of water level decline. That relationship is reliable because it results from the pattern of variable shallow well construction.

The primary factors in evaluating Issue 1.e. are the constructed water column thickness and the associated safety factor in well performance provided by the driller or owner. Depending on safety factors, a 30- to 50-foot water column above the variable alluvial floor would be a reasonable standard for productive alluvial wells, except that many were not constructed initially to meet that standard. The alluvial edge or terrace at some land tracts does not accommodate that thickness. In some cases, a tract of land may overlie a thin or shallow alluvial unit at the margin of the valley, and have no opportunity to access large-capacity alluvial wells of a useful service life in view of operational fluctuations under a sustainable use policy. Replacement wells or other sources may be needed in that case. Also significant to the issue of water-level limitations is deeper Dakota aquifer material available for proper well construction throughout the Pawnee drainage basin.

Related guidance for proper well construction is recognized in the statute [2 above] providing that *"that the right of the appropriator shall relate to a specific quantity of water and that such right must allow for a reasonable raising or lowering of the static water level and for the reasonable increase or decrease of the streamflow".*

Wells constructed with inadequate water column to operate under historic water-levels variation are commonly a product of design discretion, rather than aquifer physical limitations. Many problems with well capacity derive from shortcomings of the well or pump, rather than from shortage of the aquifer resource available[4 above]. Where adjacent or nearby properly-constructed wells succeed in producing their water requirements, then it is likely that a well site with a particular problem is rooted in the individual well construction or maintenance.

Absent long-term declining trends, curtailing water use globally to accommodate water levels at marginal well sites is not an effective way to satisfy existing rights. In the Pawnee Valley alluvium, more rights would be curtailed than protected. As an alternative, marginal wells may be reconstructed, or their rights served from other sources in the Dakota or off-site.

Issues 1.f., 1.g. and 1.h. What has been the rate of recharge to the area in question and has it changed over time? If so, how has it changed? What has been the rate and amount of withdrawal of groundwater within the area in question over time and in each area of the proposed IGUCA? Has the rate of withdrawal of groundwater exceeded the rate of recharge over time within the area in question?

The rate of recharge to the alluvium in the Combined Area in Consideration has varied from little or none to over 100,000 acre feet per year (AFY) since 1981. It has changed with land use and aquifer development from a regime of recharge going to support baseflow, to one of induced recharge in the form of streamflow capture going to support well withdrawals. Withdrawal of groundwater has varied from 18,000 to 79,000 AFY in the same area and time period. Low withdrawals, however, are associated with high recharge years. Net withdrawal has not exceeded net recharge over time. For example, the cumulative alluvial aquifer recharge has been 105 percent of cumulative withdrawals since 1991 (608,000 AF). Recharge has added 29,000 AF more than withdrawn in that period.

The DWR Exhibit B derives a reasonable estimate of average natural recharge for the alluvial valley of about 13,000 AF (18 cfs), and for the DWR Ogallala subunit a rate of 3,400 AFY, which is a small part of 49,000 AFY recharge by SWRMP methods on the larger Ogallala outcrop area in the drainage basin. Chloride ion ratios indicate that natural recharge on the 2700 square mile Pawnee Basin is about 58,000 AFY. The Dakota recharge is indicated by the Lobmeyer and Weakly (1979)[8 above] value of natural discharges from the Dakota Formation in Hodgeman and Ford Counties as over 1,100 AFY from recharge in an uncertain area to the southwest. These values represent natural accretion to the aquifer compatible with K.A.R. 5-1-1 (ggg)[9]. Natural recharge has no direct hydrologic relationship to the groundwater-level decline caused by well withdrawals. Bredehoeft (2002) says succinctly "*Capture is independent of the recharge*."[10]

Natural recharge goes to natural discharge as baseflow, sometimes called base recharge, which is added to riparian evapotranspiration (ET) from the water table to make up total recharge. Natural recharge, however, is a baseline feature of the basin water balance and does not enter the water account to balance withdrawals. Only the changes from the baseline can be credited as hydrologic sources of water to balance withdrawals (Lohman, 1979)[11].

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[9] Kansas Administrative Regulation 5-1-1 (ggg) "Recharge" means the natural infiltration of surface water or rainfall into an aquifer from its catchment area.

[10] Bredehoeft, J.D., 2002, The Water Budget Myth Revisited: Why Hydrogeologists Model: Groundwater Vol. 40, No. 4, p. 340-345.

[11] Lohman, S.W., 1979, Ground-Water Hydraulics: Geological Survey Professional Paper 708. *"…a new state of dynamic equilibrium cannot be reached until there is no further loss from storage. This can only be accomplished by: 1. Increase in recharge (natural or artificial). 2. Decrease in natural discharge. 3. A combination of 1 and 2".*

Where isolated from artificial effects, the natural recharge rates in Kansas have not altered appreciably over time[12]. Induced recharge and capture of discharge constitute the artificial change in natural recharge and discharge. These changes in response to development are used in the water account to balance withdrawals for development.

In response to development, the Pawnee River alluvium has established an observed pattern of cyclical equilibrium with water induced from the Pawnee River sources (captured baseflow, induced direct flow and salvaged riparian ET), plus water induced from Dakota Formation bedrock where gradients toward alluvium have been increased by alluvial drawdown, and the offset of withdrawals by return flow from irrigation and other water operations. The alluvial induced recharge varies annually depending on river flow and stage from little or none in the driest years to over 100,000 AF in wet years as shown in GMD #5 Exhibit 2. Induced river recharge is the primary source of water balancing well withdrawals in Pawnee Valley alluvium. Groundwater level decline is a minor source of about five percent of the 1,269,000 AF volume withdrawn since 1981. In contrast, recharge has provided 105 percent of the 608,000 AF volume withdrawn while levels built up after 1991. The dominance of river recharge over aquifer storage as a source is demonstrated by 138 percent of the year 1981 alluvial aquifer content (921,000 AF) being withdrawn by wells (1,269,000 AF) to year 2004. The aquifer would be dry without river recharge. Accordingly, curtailing withdrawals will be relatively ineffective at raising water levels in terms of volume of withdrawal foregone relative to restored aquifer volume.

The Dakota Formation and Ogallala have induced additional recharge from interrelated streams, wetlands, and riparian zones inside the radius of influence of certain wells, but the aquifers have not reached a final equilibrium in that long-term process. Leakage across formations is a presumptive source of stability in Dakota wells.

If the amount of water added to the aquifer as a response to the stress of development is disregarded, then the rate of withdrawal in Pawnee drainage basin has exceeded the isolated rate of natural recharge in each aquifer and each SWRMP subunit of the Area in Consideration. Induced recharge, however, has periodically exceeded the rate of

[12] Koelliker, J.K., 1998, Effects of Agriculture on Water Yield in Kansas, *in* Kansas Geological Survey Bulletin 239.

withdrawal in the alluvial aquifer to bring the alluvial system back to balance. The Ogallala and Dakota aquifer balance in the Pawnee drainage basin has not been studied quantitatively, but reasonably approaches balance only where surface water sources are within the few-miles radius of influence of certain wells.

Issue 1.i. How has each aquifer responded to changes in pumping and other factors over time?

The alluvial aquifer in the GMD#5 IGUCA and in the Area in Consideration has responded to pumping and other factors during the period 1981 to the end of 2004 by drawing on the several sources of water (river depletion, riparian salvage, capture of return flow, Dakota drainage and aquifer storage) to various degrees to retain a water balance. In the alluvium, aquifer storage is secondary to river depletion as a balancing source of water. The annual volumes from each source to the alluvium are calculated in GMD#5 Exhibit 2.

The Dakota and Ogallala draw on the same types of sources but the degree of weight to each source is undetermined and needs further quantitative work to respond to the issue.

Issue 1.j. How have the existing water rights in the area in question been impacted by changes in water level over time in general, and as follows?

One general impact to water rights over the Area in Consideration caused by water-level change has been periodically to raise and lower the energy cost of water. Up to five feet of water level fluctuation in annual rise and fall since 1981 would add or subtract about $100 to annual pumping cost at a typical well producing 120 AFY.

An additional general impact is that in the period 1981 to 2004 about five percent of 352 alluvial wells periodically would gain or lose their capacity to produce low-levels (400 gpm) of irrigation water requirement, based on the ratio of 2 to 3 wells impacted per foot of water level change.

The specific impact on individual water rights is not in the available data, but that information reasonably could be obtained by interview with the irrigation managers and operators.

Issues 1.j. (A), (B) and (C). Have pumping rates changed? If so, how? Have diversions of water changed? If so, have they been caused by water level changes in the aquifer? Have the number of acres irrigated been affected; and if so, by how much?

Pumping rates at 337 wells with 225 water rights in the GMD#5 IGUCA have varied from 10,000 AFY to 40,000 AFY in a pattern that corresponds to high and low precipitation. In the separate Area in Consideration 483 wells with 351 water rights have varied from 10,000 AFY to 38,000 AFY in a similar pattern. In the total Pawnee drainage basin 844 wells with 1,136 water rights have varied in exercise from 32,000 AFY to 169,000 AFY in a similar pattern of response to precipitation.

Reported diversions are inversely related to water level. The degree to which some variation has been caused by water level change in the aquifer is obscured by the overriding opposite relationship to precipitation variations. The greatest pumping and diversion is in years of low water level, and the least pumping and diversion is in years of high water level in the aquifer.

The pattern of irrigated acreage has varied alongside withdrawals as described above.

Issue 1.j. (D) Have irrigators been able to satisfy the beneficial consumptive use of their crops? If not, what has been the deficit, and the cause of the deficit, over time?

Records suggest that the typical water operation meets requirements but a significant fraction do not. Between 25 and 40 percent of 6,603 diversion records (1956 to 2004) apply less than the NIR for corn, sorghum or soy beans. A similar fraction is seen in post-1989 and post-1995 data. The median diversion record delivers 16 percent more than the NIR for corn. Shortfalls in NIR may be part of farm planning and the cause reasonably could be found by interview with irrigation managers and operators. Because of the uniformity of this pattern of water delivery through the years, the deficits in meeting NIR are not reasonably due to periodic lack of resource availability in the aquifer.

Issue 1.j. (E) Have domestic, industrial, irrigation, municipal, stockwatering, and any other water users been able to divert whatever water has been needed within the limits of their water rights permits?

No specific information has been examined regarding purposes of use other than agriculture. The largest fraction of irrigation uses have been satisfied, with about one-third not delivering their NIR for unknown reasons, but not reasonably related to ability to divert.

Issues 1.k. – 1.n. and 1.q. Is "preventable waste" of water occurring in the area in question? What does the statutory phrase "preventable waste" used in K.S.A. 82a-1036 mean within this proposed IGUCA area? What kind or kinds of "preventable waste" are occurring? What is the magnitude of each type of "preventable waste" that is occurring? Whether "preventable waste" may occur within the proposed IGUCA area?

One concept of "*preventable waste*" is linked to the idea of excess water lost to the atmosphere and removed from that available in the drainage basin for rediversion or use downstream. The best-managed water operations minimize their wetted footprint and the non-beneficial incidental consumptive uses. The degree to which those losses could be prevented by better management is not indicated in the available records.

Issues 1.o., 1.p., 1.r. and 1.s. Are there conditions in the area in question that require regulation in the public interest? If so, what are those conditions, and why do they require regulation in the public interest? What does the statutory phase "regulation in the public interest" used in K.S.A.82a-1036 mean? What factors should the chief engineer consider in determining what the public interest is and how can it best be protected?

The hydrologic conditions reasonably projected for a future similar to the past 24 years do not indicate a hydrologic need for regulatory intervention in water-management operations. The hydrologic conditions in the Area in Consideration are sensitive primarily to any increase in the authorized quantity of water use. That factor appears to be adequately controlled in the baseline for the future.

The correlation of withdrawals and water-level change shows an expectation of balance at 51,880 AFY, compatible with historic performance. The 444,000 AF of depleted alluvial storage since 1947 need not be fully restored to create managed conditions of improved water levels and baseflow. For example, baseflow at Rozel apparently was restored for two years by the prevailing 1997 and 1998 aquifer condition.

The 23,000 AFY average annual water gaged at Rozel since IGUCA controls were established in 1981 and representing discharge to the Arkansas River at the mouth of Pawnee River illustrates that the drainage basin yield generates a long-term surplus above actual consumptive use. The GMD#5 sustainable use policy provides for multi-year drawdown and restoration of the resource stored in the aquifer.

Issue 2. If the Chief Engineer determines that the designation of the IGUCA in the Pawnee Valley should be amended, what should the boundaries be?

The boundaries to be designated should include the entire 2,700-square miles because the upper basin is hydrologically related to the conditions of concern. Alternatively, the entire basin should be modeled quantitatively in advance of amending the boundaries to establish that certain areas can be excluded from designation for lack of a causal relationship to the IGUCA issues.

The boundaries of an expanded IGUCA depend on the objectives to be attained and the functional relationships of changes in water operations to the objectives. I understand that the objectives for which GMD#3 areas are managed differ from those for the Pawnee Area in Consideration. If the IGUCA designation is found to be justified, then more study of the basin's interconnections between upstream and downstream water operations will be needed. The causal relationship of the location of regulated water operations basin-wide and the response in terms of IGUCA conditions of concern is not known. That relationship is the proper focus for comprehensively addressing the differences in the entire 2,700-square mile Pawnee River Basin rather than a focus on clustering of aquifer thickness, water right density or places of use. Hydraulic gradients, stream reach connections, and areas of shallow water table connection are sufficient to show that the upper basin is hydraulically connected in some degree to the area under consideration and to the Existing IGUCA in GMD#5. Quantification of those relationships, including interactions of land use, surface dams and wells remains to be identified. Any future boundaries and corrective controls are best focused on the particular basin-wide water operations that cause the conditions of concern.

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