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PROTECTING SURFACE WATER APPROPRIATIONS DOWN GRADIENT FROM GROUNDWATER PUMPAGE

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ABSTRACT: The High Plains aquifer of Tertiary age Ogallala formation and of Quaternary age sediments, supports large irrigation withdrawals in western Kansas and seven other mid-continent states. Natural discharges from this aquifer in south central Kansas feed base flows of streams. Irrigation pumping up-gradient from this discharge area depletes or eliminates base flows in the streams. The Division of Water Resources, Kansas Department of Agriculture appropriates water according to the prior appropriation doctrine. Livestock owners hold senior water rights on the streams and irrigators hold water rights in the aquifer. Additional applications for irrigation permits are pending. A hydrologic analysis of the stream and aquifer interaction in the area will define threshold pumping water levels up-gradient from affected streams that will serve as regulatory criterion for conjunctive use of this water supply. Limits may be imposed on the permits issued. Irrigation wells may be required to cease pumping or decrease pumping rates when pumping levels reach the threshold until stream flow recovers.
KEY TERMS: regional aquifer; groundwater surface water interaction; water rights.

INTRODUCTION

Regional aquifers in western and central Kansas are the primary water supply for irrigation. Irrigation development using these aquifers has resulted in depletions or has altered flow patterns significantly. Outflows from these saturated geologic formations contribute base flows to streams where the formation approaches or reaches land surface. State law in Kansas treats water as a public resource to be appropriated for beneficial use under the authority of the state. The chief engineer approves permits to divert water for beneficial use and protects the right to beneficial use according to the doctrine of prior appropriation. Under this authority, the Division of Water Resources through enforcement action may curtail or limit diversions of junior appropriations to protect more senior rights from impairment. Kansas law also recognizes the hydraulic connection of surface and groundwater. Therefore regulations of junior groundwater appropriations that disrupt or impair access to water supplies by senior surface water rights are enforceable. Surface water supplies derived from base flows sustained partially from outflows from regional aquifers were developed early in the state's history as a water source for cattle ranches. Later in time groundwater development for irrigation began and continues to the current time. Irrigation pumpage from the regional aquifer up-gradient from the ranches is depleting the base flows and limiting the water supplies to the more senior surface water rights. Ranch interests in south central Kansas have notified the chief engineer that depletions of the springs are impairing their ability to make full use of these water rights and requested that new groundwater appropriations be curtailed.

STUDY AREA

Streams draining the southern boundary of the High Plains aquifer in south central Kansas and some local precipitation recharge to alluvium near the streams provide water to cattle ranches in northwest Comanche county and adjoining areas (Figure 1). Aquifers sustaining streams are subcrop areas (Figure 2) of the Ogallala formation and saturated Quaternary Meade deposits (Waite, 1942) and underlying Lower Cretaceous rocks of the Dakota aquifer system (Macfarlane, 1989). Extensive irrigation pumping from the High Plains aquifer system including these formations up-gradient in southeastern Ford county is intercepting the regional groundwater flows to the streams depleting or drying up base flows to the streams. Water levels drop in the aquifer in response to irrigation resulting in insufficient water level gradients to sustain the stream base flow. Stream sites on Kiowa Creek and its tributaries located in Clark, Kiowa and Comanche counties provide water supply to cattle ranches in the area.

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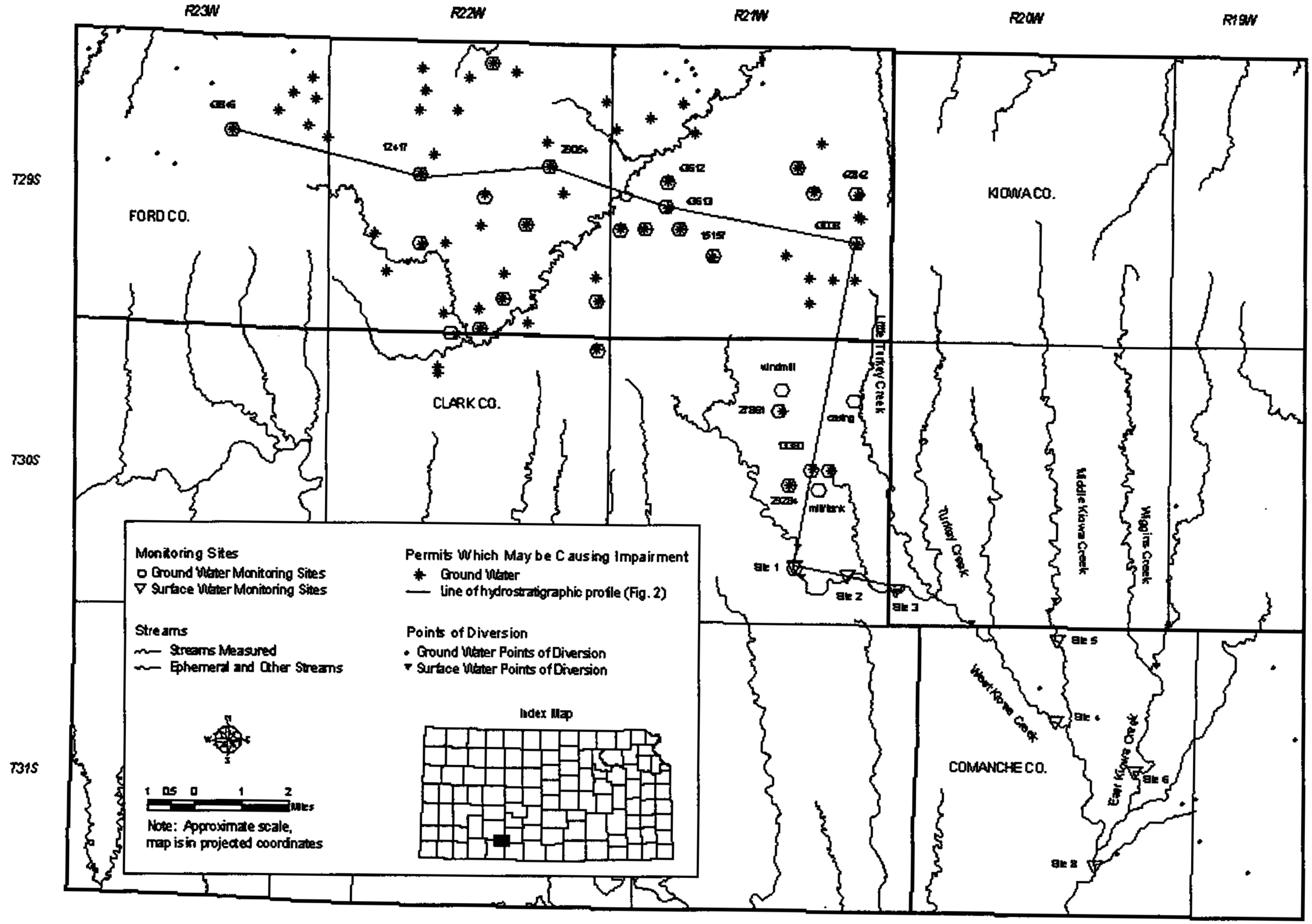

Figure 1. The Kiowa Creek study area is located in South Central Kansas.

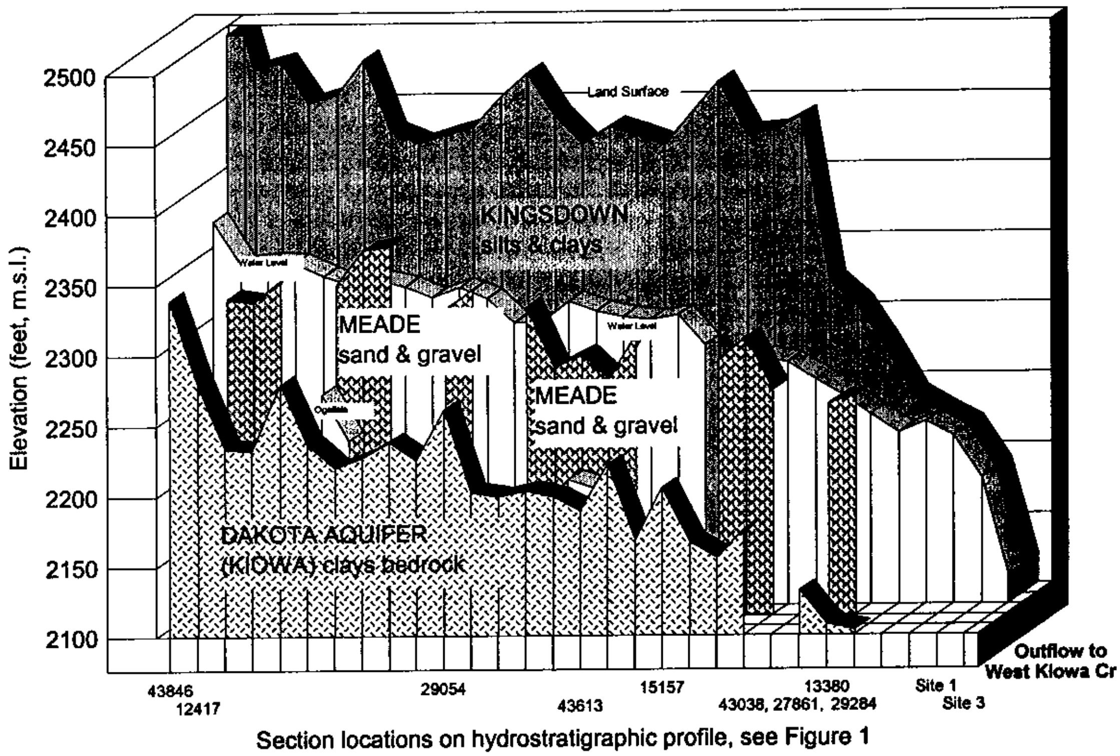

Figure 2. Profile of saturated aquifer material that sustains flows in West Kiowa Creek and other tributaries.

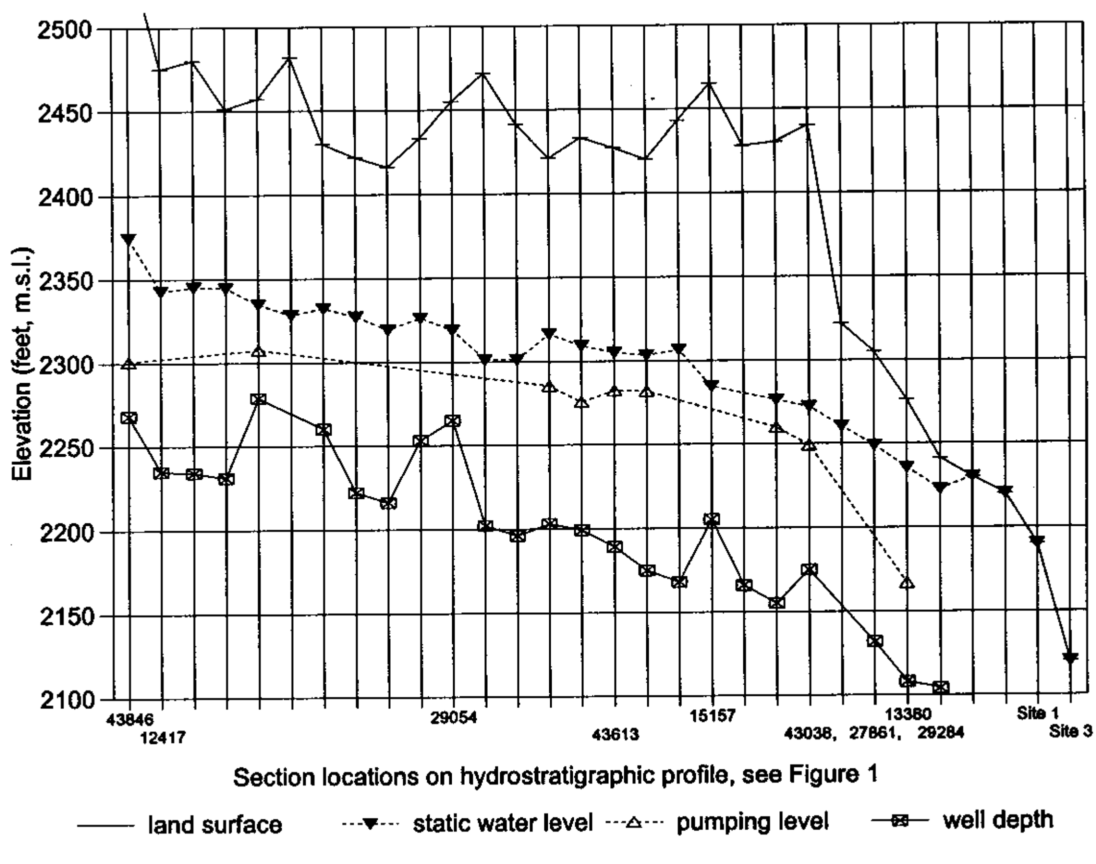

Figure 3. Measured water levels in the Kiowa Creek study area.

ANALYSIS METHODS AND CONCEPTS

Flows in Kiowa Creek and its tributaries are sustained by the local precipitation recharge to area alluvium and up-gradient groundwater contributions from the aquifer. Long-term groundwater levels may not be declining. However, groundwater pumping captures subsurface flows in the aquifer up-gradient from the area where groundwater discharges to the stream. Measured water levels in the aquifer across the study area shown in Figure 3 show water levels during pumping to be 10 to 70 feet lower than when wells are not pumped. It is also apparent that groundwater levels would project below the streambed further upstream during pumping, decreasing flow or drying up the stream at that point.

Long-term mean annual precipitation recharge to the area contributing to the stream will be in balance with the discharge to the stream when groundwater in storage is not intercepted and removed by pumping and seasonal riparian vegetation and surface runoff is not occurring. Stream flow measurements represent the natural base flow when up-gradient water levels have recovered from pumping and precipitation runoff is not occurring. Typically, a February stream flow measurement would represent conditions when outflows from the aquifer to the stream are in balance with the recharge to the system. Precipitation recharge in the area is estimated to be about 1.2 inches per year over the Kiowa Creek drainage area. This represents an average base flow in Kiowa Creek of 17.88 c.f.s. This computed discharge rate was confirmed by a base flow measurement (Table 1) on February 22, 2000, of 17.49 c.f.s.

Regional groundwater contribution to sustained flows in Kiowa Creek and its tributaries is a function of the water level gradients in the aquifer. At some level of pumping the gradient becomes insufficient to sustain adequate flows in the streams. Drawdowns from pumping centers up-gradient intercept groundwater flows to the streams even though long-term water levels may not be declining. Darcy's Law using estimated transmissivity, measured water level gradients, and width of the contributing area was applied to estimate the contributions of groundwater flow to the streams. The form of Darcy equation used in the estimates of regional groundwater flow is as follows: Regional flow = G x T x W, where G is the water level gradient, T is aquifer transmissivity, and W is the width of the aquifer contributing to the flow (Bouwer, 1978). Regional groundwater flow was determined for the parts of the regional aquifer as shown by the rectangles in Figure 4 and the gradients determined from the water level pairs shown in Table 1. Additional contributions from local precipitation and withdrawals by wells adjacent to the streams were considered part of the net outflow to the streams from the aquifer. Comparisons of the computations to stream flow measurements during both pumping and non-pumping conditions confirmed the approach was reasonable. Applying this approach and confirming it with flow measurements provide reasonable estimates of pumping water levels that would result in stream impairment.

Comparisons of the computations and field measurements are summarized in Table 1. Computed outflows and measured outflows are reasonably comparable for both the conditions when irrigation wells in the up-gradient pumping centers are pumping and when they are not pumping. A well pumping adjacent to the stream was found to be pumping at different rates during the June (630 gpm) and August (867 gpm), 2000, field measurements that are reflected in the outflows to Kiowa Creek. Both the computed and measured outflows show substantial decreases in the outflows to Kiowa Creek as a result of pumping. Flows at sites 1, 3, and 4 on West Kiowa Creek near diversions for surface water rights were decreased by 25% to 80% as a result of groundwater pumping.

ADMINISTRATIVE APPROACHES CONSIDERED

Water law in Kansas provides protection to senior water rights from impairment caused by actions of those rights junior to them. Stream flows for senior rights for livestock use on West Kiowa Creek are being decreased substantially from irrigation pumping up-gradient in the regional aquifer. Hydrologic analysis and field measurements confirm that decreased water level gradients in the regional aquifer caused by drawdown from pumping are decreasing stream flow. It is also apparent that a threshold water level gradient could be found that would result in no outflow or flows so small to West Kiowa Creek that surface water rights could not be satisfied. Groundwater levels recover seasonally and the long-term trends have not shown significant recent declines. Therefore the annual quantities pumped from the regional aquifer are probably not a controlling factor. The pumping water levels are reflected in the pumping rates and collective quantities withdrawn over one season.

Administrative criteria should be set that limit the pumping water levels to a threshold level in the regional aquifer that will provide adequate base flow to the stream to satisfy senior rights. These limitations on the irrigation pumping within the pumping center should be considered when new applications for permits are processed. Pumping water levels that decrease the gradient beyond the threshold levels would result in legal notices to junior water right holders to cease diversions or to decrease pumping rates to maintain pumping levels above the threshold. It is apparent that local precipitation recharge contributes to the stream flow. Therefore climatic conditions will influence the need for regulatory controls on pumping rates from year to year. It is a relatively simple approach to monitor water level gradients to determine the appropriate time and conditions for water administration once the thresholds are established. However, retrospective and reactionary management approaches to regulation of irrigation pumping are problematic. It frequently results in curtailing irrigation diversions in mid-season when investments have been made. It is more useful to use a prospective approach by limiting the authorized pumping rates through controls on permits at the time of approval based on typical climatic conditions. It is also useful to be able to project hydrologic conditions and provide some probability of the need for administration before the irrigation season begins in the case of a dry climatic year. Threshold water level gradients would provide information for that projection.

Table 1. Comparison of computed and measured stream flows for selected groundwater level gradients in Kiowa Creek and Kiowa Creek tributaries and southeastern Ford County, Kansas.

			Flow Comparisons in cubic feet per second (c.f.s.)						
Site no.	Groundwater Elevation (feet, m.s.l.)	Flow Measurement condition	Upper West Kiowa Cr. near origin		mid and lower West Kiowa Cr.		Middle Kiowa Cr.	East Kiowa Cr.	Kiowa Cr.
			Date	Site 1	Site 3	Site 4	Site 5	Site 6	Site 8
42842 windmill	2276.19 2260.30	Non-pumping Static site	Dec. 21,'99	1.91	3.04	5.46	3.57	3.75	16.43
*27861 mill/tank	2235.3 2229.77	Non-pumping Static site	Jan. 20, '00	1.84	2.84	6.22	3.22	3.44	15.53
43,612 casing	2303.28 2244.54	Non-pumping Static site	Feb. 22, '00	1.86	3.14	4.92	3.35	3.12	17.49
**Computed non-pumping outflow				1.91	2.95	6.21	3.02	3.48	17.9
42842 windmill	2259.97 2260.30	Pumping site Static site							
*27861 mill/tank	2190.55 2225.87	Pumping630gpm Static site	Jul. 20, '00	1.56	2.09	3.41	1.97	2.39	
43612 casing	2282.02 2242.41	Pumping site Static site	Aug. 23, '00	1.37	1.72	2.08	1.88	1.47	7.62
**Computed June pumping outflow				1.44	1.68	1.21	1.25	1.32	5.95
42842 windmill	2259.97 2260.30	Pumping site Static site.							
*27861 mill/tank	2166.91 2225.87	Pumping867gpm Static site	Aug. 23, '00	1.17	1.18	0.43	1.15	0.97	3.39
43612 casing	2282.02 2242.41	Pumping site Static site	Sep. 27, '00	1.21	1.51	1.7	1.66	1.42	4.84
**Computed August pumping outflow				1.17	1.23	0.45	1.16	1.12	4.73

*Site numbers 27861 and 13380 represent the same gradient; measured at site 13380.
**Computed outflow includes precipitation recharge, regional groundwater determined from water level gradients and withdrawals from wells adjacent to the stream.

CONCLUSIONS

Regional groundwater withdrawals upgradient from Kiowa Creek significantly deplete the stream. Senior water rights to surface water from Kiowa Creek and tributaries have insufficient supplies to meet their needs for livestock water and irrigation when groundwater pumping occurs. Analysis and field measurements indicate that draw down from pumping wells decreases the water level gradient and the outflows of groundwater to the stream. Darcy's law can be used to compute an estimate of the amount of regional groundwater outflow to the streams. The application of Darcy's law could also be used to determine the groundwater level gradients that would cause impairment to the surface water rights. State administrative procedures should consider limitations on pumpage at the time of approval of permits. Monitoring groundwater levels to determine times to begin regulatory controls are important to protect supplies of senior surface water rights. It is more practical to project the need for regulatory controls before the irrigation season commences based on climatic conditions.

REFERENCES

Bouwer, H. 1978. Groundwater Hydrology. McGraw-Hill Series in Water Resources and Environmental Engineering, pp. 48.
Macfarlane, P.A., et. al., 1989. The Dakota Aquifer Program: Annual Report, FY 89. Kansas Geological Survey Open-file Report 90-27a, University of Kansas Publications, Lawrence, Kansas.
Waite, H.A., 1942. Geology and Groundwater Resources of Ford County, Kansas. Kansas Geological Survey Bulletin 43, University of Kansas Publications, Lawrence, Kansas.

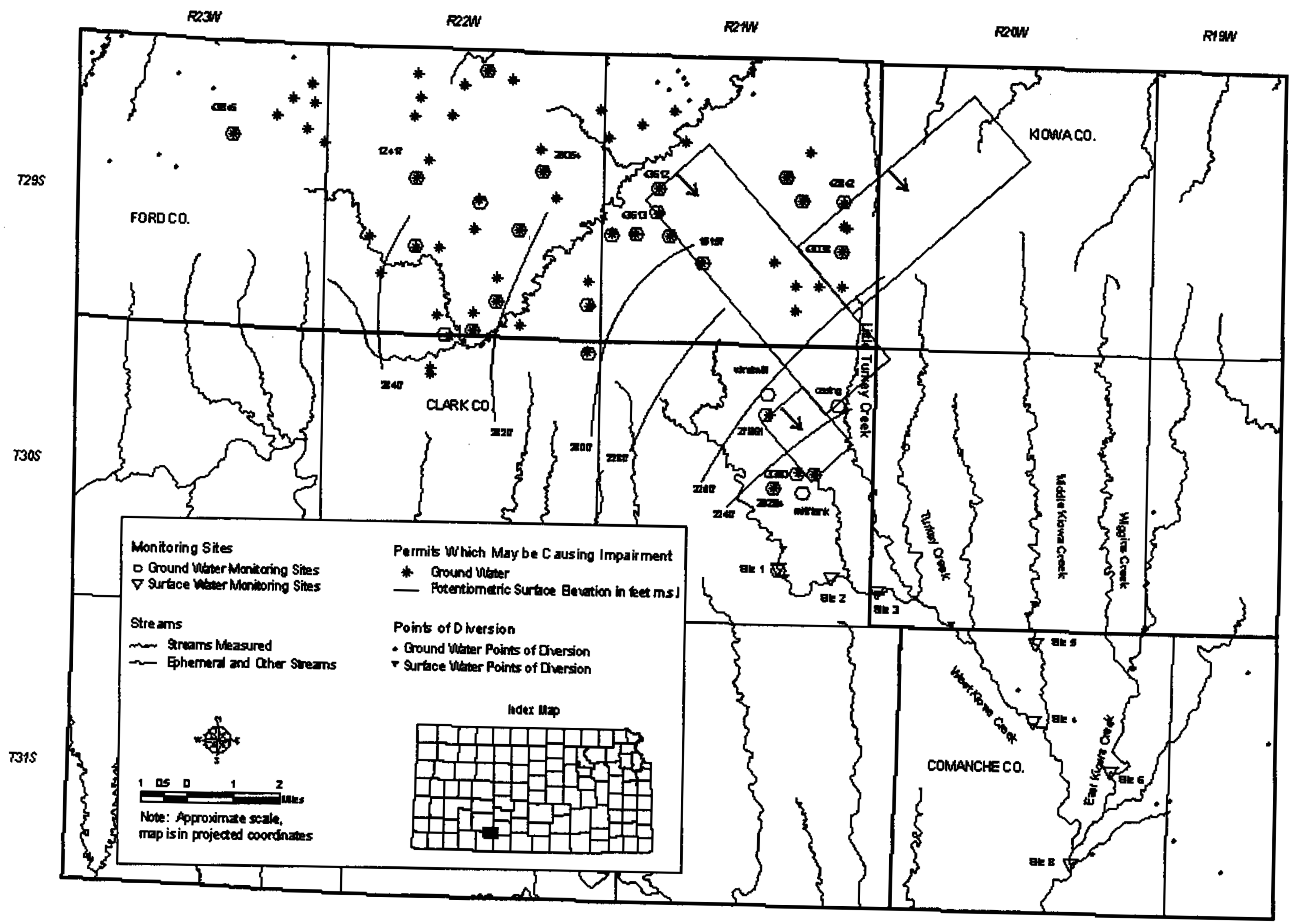

Figure 4. Computational areas of ground water flow using water level gradients and Darcy's law.