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Water Quality Criteria: An Analysis as Applied to the Big Sioux River

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Area of study in relation to state of South Dakota.

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An Analysis as Applied to the Big Sioux River

by
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INTRODUCTION

The eastern counties of South Dakota constitute the most densely populated area in the state. It is also in this part of the state that some of the more intensive agricultural production and processing activities are conducted.

One of the main sources of water in eastern South Dakota is the Big Sioux River. The Federal Water Quality Act of 1965 required that each state establish standards of water quality for interstate streams, such as the Big Sioux, in an attempt to maintain certain regional levels of water quality. In 1967 such standards and a plan for implementing them were developed and adopted by the South Dakota Committee on Water Pollution. This study reviews these standards in reference to selected pollutants in the Big Sioux River.

Quality Standards for South Dakota Surface Waters

Surface water uses in South Dakota are in five categories. They include:

- water for irrigation;
- municipal, industrial and state water supplies;
- wildlife and fish life propagation;
- recreation; and,
- hydroelectric power production.

Water quality standards were designed to regard these uses within a larger framework of five major considerations. These include:

- Federal requirements,
- natural water quality,
- important pollutants,
- existing and potential uses, and
- enforcement problems.

In general, water quality criteria were established in the interest of protecting, preserving and enhancing all surface waters in South Dakota for their beneficial use by future generations.[1]

[1]Information on South Dakota Water Quality Standards taken from: *Water Quality Standards for the Surface Waters of South Dakota,* adopted by the South Dakota Committee on Water Pollution, February 16, 1967.

When water quality standards for South Dakota were issued in 1967, it was recognized that feedlots and farmyards could be potential sources of pollution. Since then, regulations to control pollutants from these potential sources have been adopted by the South Dakota Committee on Water Pollution.[2] These regulations establish application procedures for permits to discharge livestock wastes. The permits are to be renewed annually and are designed to foster the construction of farmyard and feedlot water pollution control measures in order to protect the health and welfare of the public, to prevent nuisance problems and to prevent the pollution of waters of South Dakota.

Big Sioux Waters Analyzed

The South Dakota Water Quality Standards stipulate the quality of water that is to be maintained for different uses in the Big Sioux River. For wildlife propagation and stock watering, a nitrate concentration of 50 milligrams per liter was set as a maximum under the sampling code. The code states: "The value specified shall be maintained at all times based on results of composite samples collected over a 24 hour sampling period. In addition, the concentration of the pollution characteristic shall not exceed 1.75 times the value specified for the material in any one grab sample collected during the sampling period."[3]

U. S. Geological Survey has water quality monitoring stations along the Big Sioux River. Most of these stations sample water on a monthly basis although some may take samples more frequently. A review of these analyses indicated that water quality standards established for nitrates were not always met in the lower reaches of the river. At the monitoring station near Brandon, S. D., east of Sioux Falls, the October 4, 1967 surface water analysis indicated a nitrate concentration of 104.3 milligrams per liter. A reading at the Akron, Ia. station, approximately 70 miles south of Sioux Falls, on February 6, 1968 indicated a nitrate concentration of 51.6 milligrams per liter. Another reading at the same station on March 11, 1969 indicated a nitrate concentration of 51.0 milligrams per liter.[4]

Basic Pollution Sources

Potential pollution sources in the river basin are identified as the agricultural, the urban, and the industrial settings. Agricultural practices in this part of South Dakota could be described as being of an intensive nature, especially along the lower reaches of the river. Most of the land is used for corn and small grain production. The use of chemical fertilizers in this region is an established practice. It is generally agreed that such fertilizer can be a source of nitrate pollution as a result of the leaching and runoff process as opposed to phosphates which tend to adhere to clay parti-

[2]See: *South Dakota Committee on Water Pollution Regulation of Livestock Enterprises for Water Quality Control.*

[3]*Water Quality Standards for the Surface Waters of South Dakota*, p. 21.

[4]Unpublished U. S. Geological Survey Data secured from Jerry L. Siegel, Manager-Treasurer, East Dakota Conservancy Sub-District, Brookings, South Dakota.

cles and reach our water supplies when soil erodes.[5] A large number of cattle and hogs are also raised in the river basin and an increasing number of these animals are being fed for market in area feedlots.

The urban and industrial settings as a source of pollution are necessarily related since major industries in the region are located in the urban centers of Sioux Falls, Brookings and Watertown.[6] Of these, Sioux Falls is the largest with a population of approximately 75,000. The city of Sioux Falls treats nearly all of the waste from the entire metropolitan area through an activited sludge treatment plant. Substantial industrial wastes in this area originate from the livestock packing industry resulting in requirements for a sewage treatment plant larger than would usually be adequate for a city the size of Sioux Falls. The Sioux Falls plant has the capacity to treat sewage for a city of about 450,000 people and is meeting discharge standards set by the water quality standards for South Dakota surface waters.[7]

Watertown is the second largest urban center in the Big Sioux River Basin with a population of approximately 14,000. The six major industries of the city are involved primarily in manufacturing and meat processing. The city waste treatment plant is effective in reducing biochemical oxygen demand (BOD) by about 96%, suspended solids by 96%, and removal of settleable solids by 99%. The waste treatment plant is expected to be adequate for the needs of Watertown until at least 1985.[8]

The third largest urban center in the region is Brookings with a population of approximately 13,500. The largest contributor of sanitary waste is South Dakota State University. A new industry, 3M Manufacturing Plant, is expected to have a strength waste flow no greater than the domestic wastes of the city. Present waste treatment facilities are designed to serve a population equivalent of 16,000 people. Present plant capacity should not be exceeded by the increase in BOD or suspended solids anticipated in the next 5 years.[9]

Variables and Area Studied

Nitrates and other pollutants in the Big Sioux River could originate from either the agricultural, the urban or the industrial segment of the economy. These sources were studied as part of the process to determine specific origins of pollutants in a selected region of the Big Sioux River. Should the origins be more

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[5]See: Rick D. Benson, "The Quality of Surface Runoff from a Farmland Area in South Dakota during 1969," unpublished Master of Science thesis, South Dakota State University, 1970, and Terry Allen McCarl, "Quality and Quantity of Surface Runoff from a Cropland Area in South Dakota during 1970," unpublished Master of Science thesis, South Dakota State University, 1971.

[6]These urban centers are identified in Figure 1.

[7]From personal correspondence with R. N. Jorgenson, City Engineer, Sioux Falls, South Dakota.

[8]From personal correspondence with John O. Babcock, City Engineer, Watertown, South Dakota.

[9]J. T. Banner and Associates, Inc., *Preliminary Report on Existing Wastewater Facilities and Proposed Improvements for City of Brookings, South Dakota,* prepared for the Municipal Utility Board, December, 1970, pp. 2-1 to 6-3.

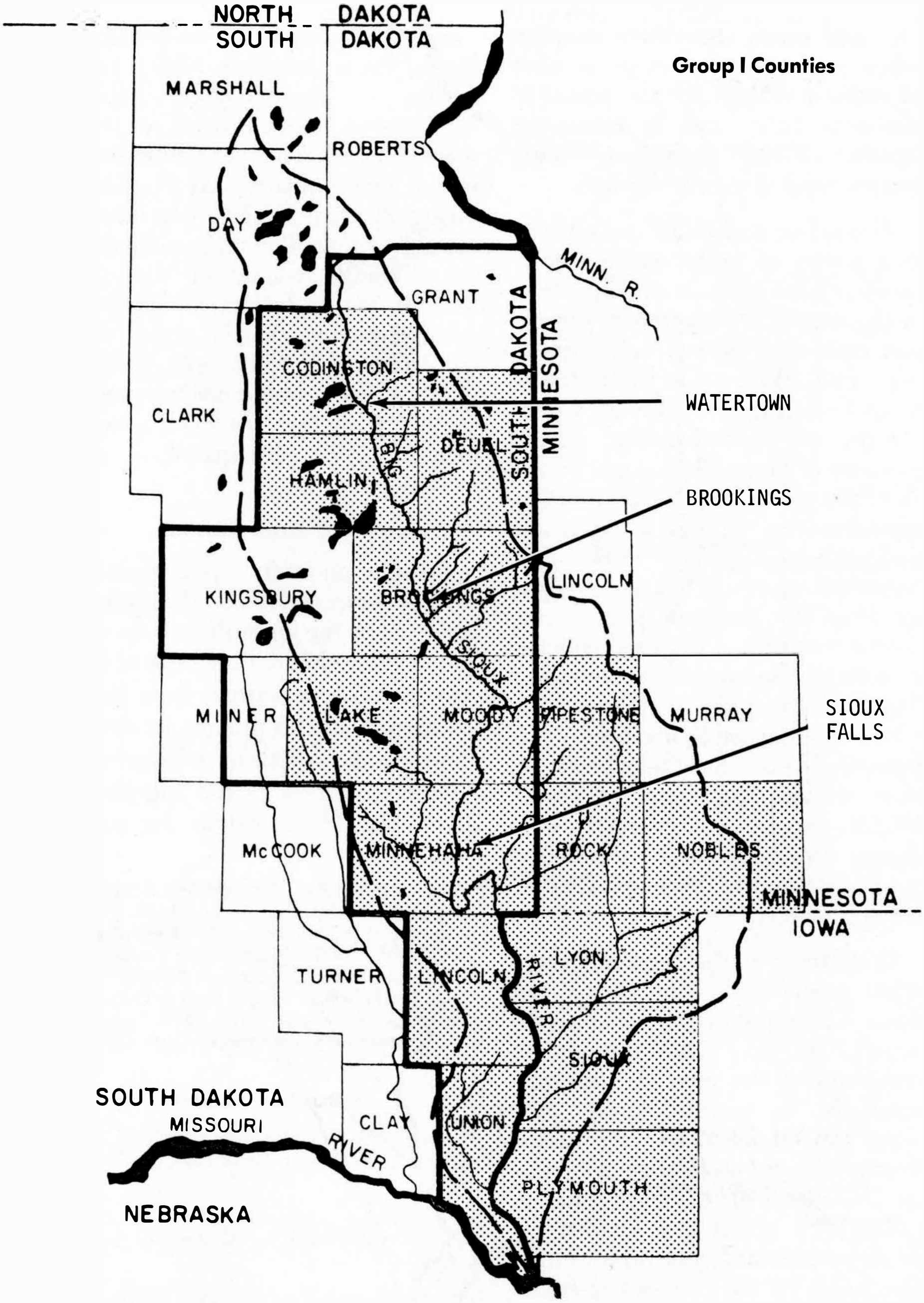
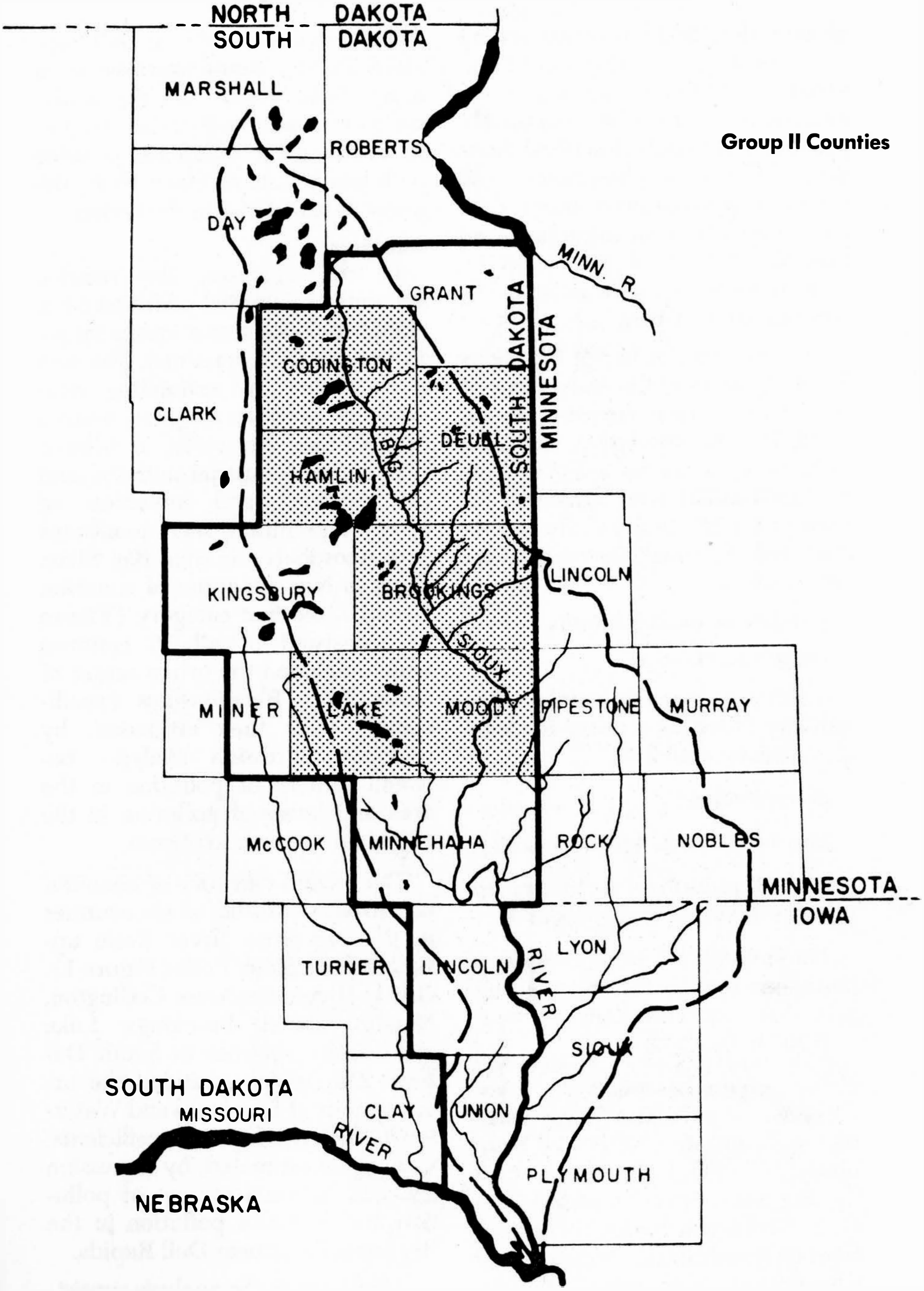


Figure 1. The Big Sioux River Basin showing Group I counties (page 6) and Group II counties (page 7).



Group II Counties

clearly identified corrective actions might be suggested that would preserve or enhance the water resources in this area. This was the objective of research described here. Since nitrates and phosphates could originate from the same source, data on phosphate concentrations and possible sources of this pollutant were included to add an extra dimension to the study.

Fifteen counties in the Big Sioux River Basin were the main focus of this study. These counties are in South Dakota, Minnesota, and Iowa (Figure 1). Data for a 4-year period (1967-1970) were collected for each of the 15 counties. These data consisted of annual observations for six variables:

number of livestock units,

human population,

number of persons employed in industry (used as a proxy for level of industrial activity),

precipitation,

tons of nitrogen fertilizer, and,

tons of phosphate fertilizers applied as recorded in Appendix A.

These variables were considered potential sources of nitrate and phosphate concentrations.

Annual observations of two variables were used as indicators of levels of water pollution. These variables were nitrate (NO_3) and ortho phosphate (PO_4) concentrations in the Big Sioux River as recorded by U. S. Geological Surveys. Observations on these nitrate and phosphate concentrates were taken near Akron, Ia., at a station downstream from Sioux Falls, and near Dell Rapids, S. D., at a station upstream from Sioux Falls (Figure 1). The analyses were conducted in this manner in an attempt to isolate the possible pollution effects of Sioux Falls, the major urban center in the region.

Analyses

In the analyses, the relative amounts of potential pollution from the agricultural sector versus an urban center were examined. This was accomplished by estimating relationships between assumed sources of pollution (livestock, fertilizers, population, industrial activity, and precipitation) and indicators of levels of pollution, such as nitrates and phosphates in the Big Sioux River in two categories of counties. Group I, the first category (Figure 1), consisted of all 15 counties which included the urban center of Sioux Falls. Relationships (coefficients) were then estimated, by multiple regression analysis, between sources of pollution in the area and levels of pollution in the Big Sioux River near Akron.

The second category of counties, Group II, consisted of six counties in the Big Sioux River Basin upstream from Sioux Falls (Figure 1). Group II counties were Codington, Hamlin, Deuel, Brookings, Lake and Moody counties in South Dakota. This region included the urban centers of Brookings and Watertown. Relationships or coefficients, were again estimated, by regression analysis, between sources of pollution and levels of pollution in the Big Sioux River near Dell Rapids.

A final step in the analysis consisted of comparing, by t-test, the re-

Table 1. Regression coefficients and standard errors of variables regressed on nitrate concentration, Group I and Group II and t-values.

Independent Variable	Group I b_1	Group I ob_1	Group II b_2	Group II ob_2	t-value
Population	–2.232	5.046	–227.021	14.352	29.554xxx
Employment in industry	–1.055	0.065	1.662	0.189	–28.904xxx
	R^2=0.99		R^2=0.99		
Livestock units	0.138	0.163	–3.278	10.646	0.641
Nitrogen fertilizer	–0.296	0.004	1.009	0.650	–4.027xxx
	R^2=0.99		R^2=0.93		
Precipitation	0.011	0.002	–0.078	0.163	1.155
Nitrogen fertilizer	–0.299	0.001	0.864	0.228	–10.669xxx
	R^2=0.99		R^2=0.94		

Where: subscript 1 refers to Group I counties; subscript 2 refers to Group II counties; b=regression coefficient; ob= standard error of regression coefficients; R^2=coefficient of determination. Statistically significant probability levels indicated by: xx=5%; xxx=1%.

spective coefficients for the two groups of counties. If the coefficients differed significantly, a possible source to which the difference might be attributed was sought.

Specifically, the analysis took the form shown in Table 1. Only two independent variables were regressed on a dependent variable at one time due to data limitation imposed by observations for only 4 years. First, the two independent variables of population and number of persons employed in industry in Group I were regressed on nitrate concentrations near Akron.[10] Then the variables, number of livestock units and tons of nitrogen fertilizer for Group I were again regressed on nitrate concentrations in the Big Sioux River near Akron. In a third step the variables of nitrogen fertilizer (used again because the regression program employed required two independent variables) and annual precipitation were regressed on nitrate concentrations near Akron.

The analytical procedure was repeated for data in Group II counties with the level of nitrate concentra-

[10]The variables were analyzed in their order of importance as determined by beta-coefficients calculated in the manner described in Appendix B.

Table 2. Regression coefficients and standard errors of variables regressed on ortho phosphate concentration, Group I and Group II and t-values.

Independent Variable	Group I b_1	Group I ob_1	Group II b_2	Group II ob_2	t-value
Employment in industry	0.649	0.786	1.346	2.122	–0.616
Phosphate fertilizer	–0.542	0.421	–0.295	0.442	–0.815
	R^2=0.75		R^2=0.31		
Livestock units	6.486	3.236	–0.275	0.941	4.014xxx
Precipitation	–0.148	0.142	0.019	0.041	–2.385xx
	R^2=0.80		R^2=0.21		
Population	28.124	29.277	12.085	2.519	1.091
Precipitation	–0.012	0.204	0.025	0.009	–1.971xx
	R^2=0.48		R^2=0.96		

tion in the Big Sioux River near Dell Rapids being the dependent variable.

The respective Group I and Group II coefficients were then compared by t-test (Table 1). For example, the t-value of 29.554 indicated that there was a statistically significant difference between the coefficients of –2.232 and –227.021 which compared the relationship between nitrate concentration and population in Group I and Group II respectively.

A similar analysis was conducted using the concentration of ortho phosphates as the dependent variable. In this analysis tons of phosphate fertilizer was substituted for tons of nitrogen fertilizer (Table 2).

Results:

A summary of the analysis when nitrate concentration was the dependent variable (Table 1), shows that the coefficients for Group I and Group II counties differed significantly when population was an independent variable. This indicated that a unit change in population was associated with a 2.232 milligram per liter decrease in nitrate concentration in Group I analysis which included Sioux Falls. For Group II a unit change in population was associated with a decrease of 227.021 milligrams per liter in nitrate concentration at the Dell Rapids monitoring station. In other words, nitrate concentration at the Akron station downstream from Sioux Falls appeared to be inversely related to population in the Big Sioux River Basin. For the Dell Rapids station upstream from Sioux Falls, the inverse relationship between population and nitrate concentration was even more pronounced and nitrate concentration could not be attributed to population on the basis of the analysis.

A significant difference was also found between the coefficient for industrial activities as reflected by the number of people employed in industry. In this case a unit increase in industrial employment was associated with a decrease in nitrate concentration of 1.055 milligrams per liter for Group I counties and an increase of 1.662 milligrams per liter in Group II (Table 1). Nitrate concentration, in this case, appeared to be directly related to industrial activity upstream from Sioux Falls but not downstream from the same city.

Coefficients relating nitrogen fertilizer to nitrate concentration also differed significantly for Group I and Group II counties (Table 1). For Group I a unit increase in nitrogen fertilizer was associated with a decrease in nitrate concentration of less than one-third milligram per liter. The corresponding figure for Group II counties was an increase of approximately one milligram per liter. The analysis would suggest, therefore, that nitrate concentrations were more closely related to nitrogen fertilizer in the upper areas of the Big Sioux.

A study of the river basin might result in the questioning of an inverse relationship between nitrate concentrations and tons of nitrogen fertilizer used in Group I counties and a direct relationship between these variables for Group II counties. This question might be posed in that Group I included counties in the lower part of the basin which raised more corn and other grains than did counties in Group II and fertilizer use would be expected to be greater for Group I counties. An explanation for the fertilizer use-nitrate concentration relationship might be that in Group I counties, an alternative source of nitrate existed. This source might contribute a nitrate concentration of a magnitude substantially greater than might be contributed by fertilizers in Group I or the region as a whole. The relationship between nitrate and fertilizer might therefore be overshadowed by the relationship between nitrate and another source. For Group II an alternative larger source might not have entered the analysis. The relationship between nitrate concentration and industrial activity described earlier might be explained similarly.

It should be noted in Table 1 that the R^2 values which indicate the degree of variability in the dependent variable of nitrate concentration accounted for by its relationship to the independent variables were high, ranging from 0.93 to 0.99.

When ortho phosphate concentration was the dependent variable, only two sets of coefficients differed significantly as seen in Table 2. In the case of the number of livestock units an increase in a unit of this variable was associated with an increase of 6.486 units of ortho phosphates for Group I counties and a decrease of 0.275 units in Group II counties. Livestock, it would therefore appear, contributed more to phosphate pollution downstream from Sioux Falls at the Akron station as compared to the upstream Dell Rapids station.

The other coefficients which differed significantly in Table 2 were those related to precipitation. For Group I counties an increase in this variable was associated with a fractional decrease in ortho phosphate concentration. The corresponding figure for Group II counties was an increase of approximately 0.02 units. Fertilizers, therefore, appeared to be a greater source of phosphate pollution in the upper parts of the Big Sioux. R^2 values in this part of the analysis ranged from 0.21 to 0.96 (Table 2).

Conclusion

Considerable variation occurs in the quality of water in South Dakota. Surface water quality standards have been set in an attempt to maintain or enhance these qualities. These standards are met with exceptions. Several tentative conclusions might assist in explaining these exceptions. It would appear that levels of pollution in the case of nitrates could be related to a relatively high density population as found in the southwestern part of the Big Sioux River Basin. Coefficients relating nitrate concentrations and population were negative for both categories of counties but the magnitude of the coefficient decreased by a factor of approximately 100 when Group II counties upsteam from the Dell Rapids station were analyzed. The exact nature of the relationship between population and nitrates would have to be determined by more refined analyses.

It would have to be concluded from this study that industry could not necessarily be held responsible for an increase in the levels of either nitrate or phosphate pollution in the Big Sioux. This conclusion should undoubtedly be subjected to further analyses before being accepted since it is recognized that major industries, especially in the Sioux Falls area, have substantial waste flows.

A final conclusion would be prompted by the positive coefficients relating fertilizers to nitrates in Group II as compared to negative coefficients in Group I. In this case, it would appear that the difference in nitrate concentrations between the Dell Rapids and Akron stations would have to be related to sources other than fertilizers. This source would again have to be determined by more refined analysis.

The Study Reconsidered

This study in part attempted to relate water quality of the Big Sioux River to possible sources of pollution. It did not attempt to determine why surface water standards are not always met. A reconsideration of the study suggests that the most important problem was probably not addressed.

Why are surface water standards not always met? There seems to be two reasons for this, the first of which centers on the natural flow of the Big Sioux River. During certain times of the year, the natural stream flow of the river is expected to be low. This was considered in the Surface Water Quality Standards by the provision of intermittent streams use category. The river reverted to this category whenever the stream flow was zero, less than the average daily waste flow or less than the average daily irrigation return flow. On the basis of historic stream flow and average waste water flows for 1962-67, the river at Sioux Falls would revert to the intermittent stream category 49% of the time during the winter months and 18% of the time during the summer months.[11]

If water quality criteria are to be met consistently, one or a combination of two alternatives could be adopted. One alternative would be to provide upstream storage facilities which could release water during critical periods to assist in maintaining quality control. The other, and less likely, alternative would be to require that waste discharged into the Big Sioux be treated to approach if not meet stream quality standards as set without honoring the intermittent stream category.

A second reason water quality standards in the Big Sioux have not been met may center on procedures required to enforce water quality criteria. U. S. Geological Survey stations can determine the general level of water in a certain part of the river. The enforcement provisions of the Water Quality Standards specify that samples shall be taken after there has been reasonable opportunity for dilution and mixture of the polluting materials

[11]Vern W. Butler, "Statement on Amendments to Water Quality Standards for the Surface Waters of South Dakota," East Dakota Conservancy Sub-District, Brookings, South Dakota, November 14, 1969.

with the receiving waters. The committee has the option to collect samples from the pollution source and meter or otherwise measure the volume of discharge from that source.[12] This option should be exercised in an attempt to determine whether the pollutant originated from multiple sources or from a single source. If they originated from a single source the alleviation of the problem should not prove difficult.

The inconclusiveness of the results of this study prompt a final observation. This study attempted to find a relationship between pollutant and source in a selected river basin. It attempted to do so by comparing coefficients which hopefully reflected rural and urban impacts on water quality. The urban impact in the case of this study centered on Sioux Falls.

When the proposal for this study was submitted, the author anticipated that similar analyses might be conducted in which the Brookings area and possibly the Watertown area were the urban centers under study. It was expected that a similarity in the results of the analyses might exist when coefficients relating sources of pollution to pollutants were compared up and downstream from at least two and possibly three urban centers.

Insufficient data did not allow a comparison of this nature. Yet, statistically significant results were found despite the small sample size. These results should therefore be considered as being of practical importance. But the author would question whether a similar study at a future date when more data would be available would be necessarily meaningful. This study dealt with aggregate data and it would appear that if we are to answer the question of what or who the major sources of water pollution are in either the rural or urban setting, we should possibly concentrate on research at the level of the firm or the plant. If then there is a desire to have the pollution source bear a portion of the cost of removing the pollutants, for which they are responsible, a combination of alternatives could be considered to improve the environmental quality. This could include but not necessarily consist entirely of governmental regulations as presently applied.[13]

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[12] *Water Quality Standards for the Surface Waters of South Dakota*, p. 10.

[13] For information on such alternatives see: U. S. Congress, *The Analysis and Evaluation of Public Expenditures: The PPB System*, Volume 1, 91st Congress, 1st Session, 1969, pp. 67-86; James E. Krier (ed.) *Environmental Law and Policy* (New York: The Bobbs-Merrill Company, Inc., 1971), pp. 422-435, and Steve H. Hanke and John J. Boland, "Thermal Discharges and Public Policy Development," *Water Resources Bulletin*, Volume 8, No. 3 (June 1972), pp. 446-458; A. Myrick Freeman III and Robert H. Haveman, "Residual Charges for Pollution Control: A Policy Evaluation," *Science*, July 28, 1972, Volume 177, No. 4046, pp. 322-329.

APPENDIX A
Data Used in the Study

Year	Nitrate MG/L*	Ortho* Phosphate MG/L	Livestock† Units	Population‡	Industrial§ Activity	Precip- itation‖ (Inches)	Nitrogen** Fertilizer (Tons)	Phos- phate** Fertilizer (Tons)
				GROUP I				
1967	20.05	3.19	1,579,000	306,600	53,969	18.92	43,678	32,075
1968	17.38	3.64	1,607,789	306,700	56,481	29.33	52,998	36,697
1969	16.25	0.93	1,563,143	303,300	57,751	25.87	56,597	41,289
1970	14.32	2.06	1,592,291	300,400	59,493	25.12	63,060	41,037
				GROUP II				
1967	2.02	0.60	453,833	72,800	9,125	17.89	10,186	7,077
1968	3.05	0.82	458,313	72,700	9,557	27.19	12,426	9,278
1969	5.90	0.39	465,153	70,000	9,601	23.73	14,071	9,956
1970	7.00	0.59	491,313	71,200	9,910	22.97	16,707	10,663

*Average figures calculated from U. S. Geological Survey data, courtesy Jerry L. Siegel, East Dakota Conservancy Sub-District, Brookings.

†Source: *South Dakota Agriculture, 1967-1970,* South Dakota Crop and Livestock Reporting Service, Pierre, S. Dak.

Minnesota Agriculture Statistics, 1967-1970, State-Federal Crop and Livestock Reporting Service, St. Paul, Minnesota.

Iowa Annual Farm Census, 1967-1970, Iowa Crop and Livestock Reporting Service, Des Moines, Iowa.

Formula used to calculate livestock units:

Livestock = ½ (Grain Fed Cattle Mktd.) + milk cows (1.2) + Beef Cows (1.2) = ____________

$$\frac{\dfrac{\text{Sheep} = \tfrac{1}{2}\ (\text{Grain Fed Lambs Mktd.}) + \text{Lambs born}}{1.05}}{5} = \_\_\_\_\_\_\_\_\_\_$$

$$\text{Hogs} = \frac{\tfrac{1}{2}\ (\text{Hogs mktd.}) + \text{Sows fall farrowing} + \text{Sows spring farrowing}}{3} = \_\_\_\_\_\_\_\_\_\_$$

Total livestock units=____________

Note: Data for livestock for Iowa for 1970 were not available at time of study. Data used for 1970 were 1969 data minus 1% of 1969 figures.

‡*Sales Management Survey of Buying Power* for years 1968-1971 inclusive. Philadelphia: Bill Brothers Publishing Corporation.

§*County Business Patterns,* 1967-1970. U. S. Department of Commerce, Bureau of the Census. Washington: U. S. Government Printing Office.

‖*Climatological Record,* 1967-1970.

**To calculate the tons of nitrate and phosphate fertilizers used in the 15 counties, the 1964 county percentages of total fertilizers used were recorded from the 1964 Census of Agriculture. It was then assumed these percentages would apply to the period under study. Thus the 1967-70 figures on fertilizers used were tabulated by applying the 1964 percentages to annual amounts of fertilizers and by states as recorded in *Fertilizer Summary Data, 1968 and 1970.* Muscle Shoals, Alabama: Tennessee Valley Authority.

APPENDIX B
Data Used to Calculate Beta-Coefficents

Year	Change in Nitrate Concen- tration (MG/L)	Change in Phos- phate Con- centration (MG/L)	Livestock Units	Population	Industrial Activity	Precip- itation (Inches)	Nitrogen Fertilizer (Tons)	Phosphate Fertilizer (Tons)
Brookings-Dell Rapids Stations								
1967	–0.28	–0.19	197135.82	31910	4828.32	18.92	4837.66	3509.64
1968	1.69	0.01	179088.57	31668	5087.01	28.54	5941.57	4484.75
1969	4.09	–0.26	181974.99	30839	5248.98	24.98	6835.45	4926.56
1970	1.83	0.01	191171.06	30311	5439.67	23.96	7894.92	5111.86
Dell Rapids-Akron Stations								
1967	18.03	2.59	706601.01	165445	34431.80	18.93	19750.75	15104.86
1968	14.33	2.82	659014.69	165620	35947.65	30.66	24097.23	16759.20
1969	10.35	0.54	696182.24	165125	37000.30	27.30	26002.30	19333.60
1970	7.32	1.47	696648.19	161580	38148.65	26.37	29474.43	18548.35

In setting up the data to calculate beta-coefficients the basic question asked was: If there is a change in either nitrate or phosphate concentration between two monitoring stations, what portion of the variables to which this change could be associated is located in a geographic region that is drained by the Big Sioux River between the two stations? In other words, assume there is an increase in nitrate concentration at the Dell Rapids station as compared to the Brookings station (limited data on nitrate and phosphate concentrations were available for the Brookings station). If this is the case, how many livestock units, population, level of industrial activity, precipitation, tons of nitrogen fertilizer and tons of phosphate fertilizer could be attributed to this change between the two stations.

To calculate these proportions of variables that might affect the concentrations of nitrates and phosphates in the Big Sioux River, it was assumed that only that area that was drained and the portion of variables in that area could be related to possible changes in pollutants between monitoring stations. For example, the Brookings monitoring station reflects approximately one-third of the area of the state that would drain into the Big Sioux River below the station. Only one-third of the variables recorded for Brookings County in Appendix A were therefore considered to be related to either the nitrate or phosphate concentrations between the Brookings and Dell Rapids stations.

Variables for other counties were calculated in a similar manner. The portions of counties and the variables thereof that were assumed to be related to changes in nitrate and phosphate concentrations between monitoring stations by virtue of drainage to this common area were estimated as recorded in Table 3.

Beta-coefficients were calculated after standard deviations and regression coefficients were analyzed with the variables arranged in the order of:

Change in nitrate concentrations between stations = f (livestock units, population, industrial activity, precipitation, nitrogen fertilizer).

Change in phosphate concentrations between stations = f(livestock units, population, industrial activity, precipitation, phosphate fertilizer).

Table 3. Portions of counties drained between monitoring stations.

Monitoring Stations	County	Portion of County
Brookings-Dell Rapids		
	Brookings	.33
	Lake	.25
	Moody	1.00
	Pipestone	.25
	Minnehaha	.10
Dell Rapids-Akron		
	Minnehaha	.90
	Pipestone	.75
	Rock	1.00
	Nobles	.50
	Lincoln	.50
	Lyon	1.00
	Sioux	.50
	Union	.25
	Plymouth	.10
	Lake	.50

1.5M—4-73—4981